

Journal of Textiles, Coloration and Polymer Science https://jtcps.journals.ekb.eg/



Alternatives Binder in Printing Using Colored Pigments on Cotton Fabrics

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Abstract

rganic pigments with non-polar groups cannot be applied directly because they cannot be dissolved in water or the majority of organic solvents. Moreover, binders must be added to the printing paste since textiles and pigments do not adhere to one another, giving printed fabrics a stiff hand feel and poor rubbing fastness. In this research, we will discuss alternatives to the use of binder during printing with pigment, as well as digital printing on cotton fabrics, whether they are treated or using polymers that act as adhesives that do not cause a rough feeling on the surface of the fibers.

Keywords: pigments, binder, cotton fabrics, digital printing.

Introduction

An ancient art form that has been practiced for thousands of years is textile printing.[1, 2] It is among the most interesting and important ways to incorporate colors and patterns into textile materials.[3-7] It also involves blending a design idea, one or more colors, and a substrate (often textiles) with a natural or artificial thickening while using a method to apply the colors properly.[4]

Textile printing is a controlled process that uses specialized printing methods and equipment to color cloth in predetermined patterns or motifs. It also refers to the technique of painting or sketching a pattern in color on textiles. In properly printed fibers, the color is linked to the fiber to resist washing and crocking. Textile printing is often referred to as localized dyeing. Contrary to dyeing, printing allows the dye to reach particular areas of the substrate. **[8, 9]**

Classification of printing techniques

In general, there is a distinction between printing methods and printing aesthetics. Direct printing and indirect printing are the two categories into which traditional textile printing techniques may be divided.[10-23]

Direct printing

The most often used way to include a color pattern is by direct printing. It can be applied to previously colored fabric or white fabric, in which case it is known as over-printing.[5] It is sometimes referred to as "print-on," and in the current textile business, it is the most popular and simple method of printing on materials.

The word "direct" originally meant that there had been no prior mordanting or dyeing.[4] In this scenario, [7, 24] printing pastes come into direct contact with the fabric surface without undergoing any extra processing modifications, and it is theoretically possible to employ the same dyes that were used to dye fiber for both dyeing and printing on it.[10]

However, pigment is the most widely used colorant in textile direct printing and accounts for about 75-80% of the total printing processes because it is a straightforward and affordable method that requires little equipment, does not call for washing, and generates only a small amount of waste.[2, 4, 8]

Direct printing encompasses a wide range of processes, including the following. Block printing, Screen printing (Flat-screen printing, Rotary screen printing), Burn-out printing, Digital printing(Inkjet printing, Transfer printing)

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Indirect printing

Direct printing and indirect printing are distinct from one another. Indirect printing techniques include resist and discharge printing. Since the beginning, these methods have been used in textile printing.[4] These styles will always be significant since the outcomes are frequently unique and visually superior, even though contemporary technology has enabled the use of direct printing possible for many more designs and reduced the need to employ them in recent years.[6]

There are several incredible indirect printing methods like Resist printing, Discharge printing.

Cotton fabric

The natural fiber of vegetable origin is cotton. It is regarded as the king of textile fibers. The main ingredient is cellulose. Each fiber is constructed of 20–30 layers of cellulose that have been neatly wound around several natural springs. The arrangement of the cellulose provides cotton fibers their great strength, resilience, and absorbency.

One of the primary components of cotton fiber is cellulose. In the natural world, plants use CO2 that is present in the air, water, and soil to build up compounds that include C, H, and O when sunshine is available. Photosynthesis is the name of this process. One of the products produced in this manner is glucose.



Fig.4 Chemical structure of the Glucose, Cellobiose, Cellulose fiber

Cellobiose is created when two glucose molecules interact, while large cellulose molecules are created when many cellobiose molecules combine. These cellobiose molecules were thus joined longitudinally by a strong oxygen bridge. Additionally, by relatively weaker sideways forces, crystalline regions are formed where these forces are active, and amorphous regions are formed where they are not.

Different processor types:

Herbal Pretreatment of Cotton Fabrics for Digital Printing with Ecological Inks

For the blue, red, and yellow hues, respectively, the herbal inks were made from plant extracts of bio indigo, quebracho red, and the flame of the forest herb.

The fundamental hues bio indigo, quebracho red, and the flame of the wild plant were combined to create the black herbal ink. Table 2 lists the herbal inks' rheological characteristics.

Herbal inks

When making plant-based ink, the plant extract, distilled water, and glycerol were all measured by weight. The purchased plant extracts were ballmilled and professionally extracted using the Soxhlet device, usually using distilled water as the solvent. Even though the plant extracts may be dissolved in water, the grinding was done by hand with a pestle and mortar. It was done to make it easier for the powdered plant extract to dissolve in the distilled water. The distilled water was progressively mixed with the milled plant extract while being swirled for two minutes at a high speed on a magnetic stirrer.[25]

For one hour, the agitated mixture was left still to allow the additional plant extract particles to settle.

To get a pure color solution, the liquid was filtered and strained using a 70-mm Whatman glass fiber filter. To get rid of the resulting sludge, the filter was replaced in between. To achieve a homogenised solution, the weigh-up quantity of glycerol was swirled into the filtered color solution using a magnetic stirrer for 2 min at a high speed.

To guarantee complete filtration and homogenization of the colloidal solutions of plantbased inks, the resultant solution was filtered once more via a microfilter (MF) — Millipore, 0.22 m membrane (MCE) microfilter. The sterile microfilters were hydrophilic nano filters measuring 47 mm.[26]

The double-filtered ink was then put into an airtight, sterile bottle and marked suitably, as shown in Figure 5.[25]



Fig. 5. Double-filtered plant-based inks in cyan, light cyan, magenta, light magenta, yellow, black, light black, and light, light black colors are shown in order from left to right.

To get eight inks based on the printer's C, M, Y, and K color models, the same process was repeated. The bigger kind of vacuum filtrations method

was disregarded while working with tiny amounts of

ink for percolation to reduce the possibility of ink waste. Additionally, the use of vacuum filtrations would be hindered by the formation of sludge during purification. Additional rheological testing was done on each of the synthetic inks.[26]

The residual moistened plant components known as "sludge," or "marc", are left idle because they have reached saturation and their greater particle size prevents them from passing through the filter. To avoid inkjet blockage, it is crucial to remove the sludge and double-filter the colloidal plant-based ink solution. In other terms, sludge is a recyclable and biodegradable organic by-product of the filtration process. Table 1 provides a summary of the rheological characteristics of the composed plant-based inks.**[25]**

Table 1. Physical	l properties of herbal ink
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Herbal ink colour	Relative density	Viscosity (cP)	Surface tension (mN/m)	Conductivity (mS/cm)	pH
Distilled water	1	4.07	74	00.0	6.34
Bio indigo, C	1.06	7.67	58	09.6	7.69
Quebracho red, M	1.06	8.16	54	02.5	5.21
Sacred tree, Y	1.06	9.66	49	04.2	5.47
Bio indigo + quebracho red + sacred tree, K	1.06	9.46	59	10.3	5.88

Colours: C is cyan colour, M is Magenta, Y is yellow, and K is black

Methods

The source of all fabric samples was Whaley's Bradford Limited in the UK. Guar gum (GG) and guar gum-glycerol (GGG) were used to execute a herbal pre-treatment on cotton fabrics before inkjet printing wool and cotton fabrics with herbal inks.

Herbal pre-treatment:

The herbal pre-treatment method used on samples of cotton fabric is shown in Figure 6.

To prevent lump formation, guar gum was weighed out and introduced gradually to distilled water at 50° C while being constantly agitated. Guar gum and distilled water were both used in proportions of 1 g per 100 ml to achieve the requisite viscosity. The result was a viscous, semi-transparent solution with a pH range of 6 to 7. The wool and cotton fabric samples were immersed in the mixture for one hour, maintaining a material-to-alcohol ratio of one to ten. The samples of treated cotton cloth were subsequently flat-dried. Variation was carried out in the same manner as the guar gum pre-treatment procedure in the parametric investigation using guar gum (1%) and glycerol (1%). **[27, 28]**



Fig. 6. The herbal pre-treatment process illustrated

Inkjet printing of cotton fabrics:

The herbal inks were used to print on cotton garments that had been commercially and herbally pre-treated. 20 ml BD Discardit II syringes and BD Microlance # 3 (needles) were used to fill the cartridges. The herbal ink kept in the tightly-lidded glass vials was drawn up using the empty syringe with a needle attached. To allow the herbal ink to fill the empty cartridge, the larger pink knob at the top of the cartridge was opened. After that, using the priming adapter that was included with the empty set of cartridges, processing the cartridges for placement into the printer was done from the other side of the filling area. **[28, 29]**

Color fixation and herbal washing-of

examples of cotton fabrics Herbal inkjet prints underwent color fixing in an industrial steamer for ten minutes. Then, fabric samples were removed using one of two methods:

- (1) To remove the herbal wash, a variety of herbal soaps, including shikakai and a reetha nut, were purchased from Sheetal Ayurved in India. For the saponins to progressively extract, 50 grams of each plant were steeped in 1000 ml of distilled water at 70°C for a whole night. Individual fabric samples were immersed in the herbal soaping mixture for 30 minutes before being gently rubbed and squeezed. They were then cleaned in water that was 40°C and dried in the shade.
- (2) Using nonionic soap Synperonic BD 100, commercial washing-off was done on cotton textiles with digital printing using the traditional technique.[29]

Color values

When the cotton fabric is inkjet printed with specially developed herbal inks, the color achieved on guar gum-pretreated cotton fabric is more visible than the color obtained on guar gum-glycerol-pretreated cotton fabric.[29]

Conclusions

The cotton fabrics were pre-treated with natural biomaterials for inkjet printing, and the following conclusions can be drawn.

- Low material-to-liquor ratio and low temperature were used for the herbal pretreatment on natural textile substrates, which resulted in lower water and energy usage and was more environmentally friendly. The materials used can decompose. For the cotton textiles, the guar gum pre-treatment worked better than the guar gum-glycerol pre-treatment.
- Guar gum pre-treated cotton cloth inkjet printed with herbal inks showed a color difference of 10.35 as opposed to 6.07 when pre-treated with guar gum-glycerol. All of the materials had very good to outstanding wash, stain, rub, and light fastness. Cotton textiles that had previously been pre-treated with guar gum-glycerol had low wash fastness against color change. The pre-treated cotton textiles with guar gum had high wash fastness to color change.[29]

Using a covalently linked, very durable polymer colorant to print cotton that has been treated with citric acid without using a binder

A unique polymer colorant (PGMA-NH-X-3B) with great stability and reactivity was created, and it

was then used to print pigments without a binder on cotton fabric that had been treated with citric acid.

A three-step process was used to create a particular new type of polymer colorant. First, emulsion polymerization was used to create microspheres of polyglycidyl methacrylate (PGMA). To prepare the amination of PGMA (PGMA-NH2) microspheres, the branching polyethylenimine (PEI) was added to the PGMA microspheres through the opening of the epoxy group. To create the polymer colorant (PGMA-NH-X-3B), the reactive dye X-3B was lastly attached to the surface of PGMA-NH2 microspheres by a reactive dyeing technique.[30]

Materials

Cotton fabric, Glycidyl methacrylate (GMA), Branched polyethyleneimine (PEI), Reactive dye X-3B (C.I. Reactive Red 2, its chemical structure was shown in figure 7), Pigment Red 112 (common pigment), Polyvinylpyrrolidone (PVP), ammonium persulfate(APS), citric acid (CA), sodium dihydrogen phosphate (SHP), Ammonium polyacrylate thickener, polyacrylate binder.[**30**]



Fig.7. The chemical structure of reactive dye X-3B (C.I. Reactive Red 2)

PGMA and PGMA-NH2 microsphere preparation:

To create an aqueous phase, 100 g of distilled water was used to dissolve 8 g of PVP. Then, GMA (20 g) was gradually added while being mechanically stirred for 30 minutes at 600 rpm using an RW20N, IKA. With the aid of a stirrer, the liquid was poured into a flask with four necks.[30]

After 20 minutes of complete N2 charging, the flask's temperature was increased to 75 C. After being dissolved in 5 mL of water, the initiator APS was added to the flask and kept there for 5 hours. The dispersion was then cooled to ambient temperature and centrifuged for one hour at 10,000 rpm.

To get rid of the unreacted chemicals, the sediment was washed three times with ethanol before being rinsed with deionized water. After the sediment had been freeze-dried, PGMA microspheres were produced.

To create the PGMA dispersion, 10 g of the purified PGMA microspheres were dissolved in 100 mL of distilled water.

The PEI (3 g) was dissolved in 10 mL of distilled water before being added to the PGMA dispersion. The reaction was carried out with a 250 rpm agitator at 80 C for 6 hours. After that, the dispersion was cooled to ambient temperature and centrifuged for 30 minutes at 12,000 rpm. To eliminate the unreacted PEI, the silt was washed three times with water. The silt was finally freeze-dried to produce the PGMA-NH2 microspheres.[**30**]

Preparation of PGMA-NH-X-3B microspheres:

To be more precise, 10 g of PGMA-NH2 microspheres were dispersed in 100 mL of distilled water while being continuously stirred at 250 rpm. The resulting dispersion was then placed into a 250 mL three-necked flask that was fitted with a digital agitator and a reflux condenser. The reactive dye X-3B solution (3 g reactive dye X-3B and 100 mL distilled water) was poured into a flask and swirled for 30 minutes. With the help of sodium carbonate (NaCO3), the pH of the reaction solution was raised to 9 to 10 before being heated for two hours at 40 C.**[30]**

The mixture was then cooled to room temperature, and centrifuged for 10 minutes at 10,000 rpm to remove the unreacted dyes, and the sediment was washed three times with deionized water. To create the PGMA-NH-X-3B microspheres, the sediment was finally freeze-dried. figure 8



Fig. 8. Preparation process of the PGMA-NH-X-3B microspheres



Fig. 9. The colorant is covalently bonded to the cotton material without a binder

Modification of cotton fabric:

Modified cotton textiles were used. In a specially designed laboratory curing oven, samples

were then dried at 80 C for 5 min and cured at 160 C for 4 min.[**31**]

For 2 minutes at room temperature, the cotton textiles were submerged in aqueous solutions containing CA and SHP in a 2:1 molar ratio. Following this, the cotton fabrics were padded with a 100 2% wet pick-up. To create the cotton textiles treated with citric acid (CA), the fabrics were then dried at 80 C for 5 min and cured at 160 C for 4 min. Carboxyl groups were added to the cotton fabric's surface after CA was modified.[32]

which can be printed by reacting through a thermal amidation reaction with the amino groups on the surface of PGMA-NH-X-3B microspheres. The heat amidation reaction between the carboxyl groups on the modified cotton fabric and the amino groups on the surface of the PGMA-NH-X-3B microspheres was aided by the curing process.[32]

it is shown how curing temperature and time affect the color strength (K/S) of the PGMA-NH-X-3B printed textiles. The optimal curing temperature and duration were 160-170 C and 4-5 min, respectively. It can be shown that raising the temperature and lengthening the curing time will assist raise the K/S value of the printing. This behavior can be explained by the quicker thermalization reaction between the carboxylic groups of the modified cotton fabric and the surface of PGMA-NH-X-3B amino groups the microspheres. [30]



Printing:

The printing on cotton cloth was done using a screen-printing process. The cotton textiles printed with PGMA-NH-X-3B were dried at 80 C and then cured at 160 C for 4 min. Cotton textiles printed with Pigment Red 112 were produced by drying at 80 C and curing at 160 C for 4 minutes.

The printing pastes were made following the directions in Table 2, and deionized water was added to the leftover portion. Before usage, the DM-5221 was diluted five times with deionized water.[30]

Pigment (g/k

Conventional printing paste		20
Conclusions		
A reactive dye wa	as used as	the basis for the
three-step preparation	of the ex	tremely stable an

20

Table 2 Recipe for printing paste Paste type PGMA-NH-X-3B (g/kg)

PGMA-NH-X-3B printing

ıe d covalently bonded polymer colorant (PGMA-NH-X-3B), which was effectively characterized by FT-IR, EDS, SEM, DSC, TG, and XRD. With centrifugal, thermal, and storage stability readings of 92.53%, 90.00%, and 96.20%, respectively, the results of the stability testing demonstrated that it has outstanding

dispersion stability. It's significant to note that after a 10-minute powders ultrasound. PGMA-NH-X-3B mav effectively disperse in water, and the new dispersion can last for 30 days. The PGMA-NH-X-3B microspheres were then used to print on cotton fabric that had been treated with citric acid.

The PGMA-NH-X-3B printed fabric has a smoother hand feel and greater rubbing and washing fastness compared to standard pigment-printed textiles.[33]

The created PGMA-NH-X3B presents an idea to prepare a self-dispersing polymer colorant for tackling the two main difficulties (stiff hand-feel and poor rubbing fastness) of pigment printing, despite the disadvantages of the lengthy procedure and high manufacturing costs. This research expands the possible uses of self-dispersing polymer colorants in binder-free printing by presenting a design methodology.[33]

Synthesis of reactive self-adhesive branched polyurethane dispersant for textile pigment printing.

A multipurpose branching polyurethane with self-adhesive and dispersion properties was created. The A2 monomer (with two isocyanate groups) from the polyurethane prepolymer was employed, and the B3 monomer (with three hydroxyl groups) from TMP was used to create the branched polyurethane. The epoxy group was then grafted as a crosslinking group and 3 morpholinopropan-1amine was added as an anchoring group to create a kind of reactive branching polyurethane dispersion. These dispersants have a strong self-adhesive action and dispersing stability. Without the need for a binder, the reactive branching polyurethane dispersant-based pigment paste may adhere the color to the cloth.[34]

Materials

Isophorone diisocyanate (IPDI), Polyethylene glycol 400, dibutyltin dilaurate (DBTDL), and 2,2dihydroxypropionic acid (DMPA). Polyethylene glycol 400. Tetrahydrofuran(THF), 3-Morpholino propan -1-amine(AMP) and Glycidol(GLD). Trimethylolpropane (TMP).

Triethylamine as a neutralizing reagent. Phthalocyanine blue. Thickener (TF-311). the isocyanate crosslinking agent. [34]



Fig.11. structure of PU

Synthesis of branched polyurethane:

Following was the method used to create BPUs. IPDI was first introduced to a three-neck flask that included a condenser tube and an electric stirrer. PEG400 was added to the flask and heated to 70C for 2 hours before reacting with IPDI. Following the addition of the DMPA as a chain extender, the reaction was continued for a further two hours at 70C with the addition of 34 drops of DBTDL as a catalyst. The system's solvent, THF, was employed to lower the system's viscosity throughout the synthesis process. The system was then elevated to 80C, TMP was dissolved in THF and added dropwise to three flasks. Thereafter, a branching reaction was then carried out for 4 hours.[34]

After cooling the branched polyurethane solution to 60C, the necessary quantity of APM was added, and the mixture was allowed to react for 2 hours. Then, for a further two hours, glycidol was added at 60C. By adding TEA and allowing the reaction to take place at 40°C for 40 minutes, carboxylic acid was completely neutralized.[34]

Preparation of pigment dispersion:

Following the procedures listed below, many homogenous aqueous pigment dispersions were created. To make 75 g of dispersion emulsion, 6.25 g of polyurethane dispersant was dissolved in water and swirled uniformly at 1000 rpm. To avoid foaming throughout the appeals procedure, around 0.3 g of defoamer was used.

The fundamental pigment ingredient, 25 g of phthalocyanine blue 15:3, was then added to the system and well mixed into the dispersion. The pigment dispersions were ball milled at 4000 rpm for 3 hours with the addition of 200 g of zirconium beads.[34]

paste

Printing with pigment paste:

With 3% pigment dispersion, 1% thickening agent, and 5% blocked isocyanate crosslinking agent, the homogenous color paste was made by stirring. It was then further printed on cotton textiles and initially dried at 80C before curing for 3 minutes at 150C.[34]



Fig.12. Schematic diagram of the dispersion and adhesion

Color properties and fastness

As a result of its exceptional flexibility, chemical stability, softness, and environmental protection, polyurethane was a good choice for printing adhesives.[35, 36]

Additionally, as a binder, epoxy-modified polyurethane had more dazzling adhesion qualities than regular polyurethane. [37]40 BPU, an epoxymodified branched polyurethane, showed excellent dispersibility and reasonable adhesion after being grafted with epoxy groups on unbranched end groups. Cotton textiles were printed using pigment pastes made with BPUs and small-molecule dispersants, and the color fastness of printing was evaluated. Printed textiles treated with polyurethane dispersants had washing fastness of about 4 grades, which was 1-2 grades better than that of the control group. It was amply demonstrated that printing with BPU paste had a sizable impact on washing colorfastness. The BPU molecule has a carboxyl group, and its breakdown in water will encourage the epoxy group's ring opening.

The COOH on BPU's molecular chain would catalyze the ring opening of the epoxy group when BPU was dissolved in water. Hot water acts as a moderate Bronsted acid catalyst in epoxide ring opening reactions throughout the drying process.[**38**] At 150°C, inhibited isocyanate crosslinking was released to create free NCO, which would then interact with the hydroxyl groups on cellulose and those created by ring opening.[39]

In this manner, the cross-linked network structure fixes the pigment particles to the fiber. Additionally, under the catalysis of TEA (150C), certain unopened epoxy groups would engage with isocyanate groups.[40]

Conclusions

It was successful to create the self-adhesive branched polyurethane dispersion. To create branched polyurethane, TMP was added as a branching unit to the polyurethane segment. The polyurethane was terminated by adding APM and glycidol as anchor and reactive groups, respectively. The reactive branching polyurethane was successfully synthesized, according to FTIR spectra, and DSC and TG verified its excellent thermodynamic characteristics.

The generated pigment dispersions had particle sizes that were all under 200 nm, and SEM examination revealed exceptional dispersion homogeneity. The pigment paste most notably showed extraordinary stability.[34]

All five of the dispersion pigment pastes had centrifugal stability over 90% at 3000 rpm. BPU3, which remained at 92.1%, has the highest centrifugal stability of all of them. The topflight storage stability was similarly BPU3, which is consistent with centrifugal stability, and the particle size altered within 20 nm after being held at 50C for five days. BPU demonstrated a more preferred adhesion property and outstanding dispersion stability in comparison to pure dispersant. The wet and dry rubbing ratings for printed materials were in the range of 3 and 2-3, respectively, while the washing fastness was at level 4.

It offered a brand-new polyurethane dispersion design that showed great promise as a self-adhesive dispersant.[34]

Summary

Many of the previous treatments that were developed in the field of textiles to serve environmentally friendly printing without any pollutants or waste, by using pigment as a colorant sometimes to be attached to the raw material without using a binder or by exploiting natural resources to extract environmentally friendly ink and finally exploiting the branched polyethylene polymer to make an adhesive that is used in pigment prints.

Conflicts of interest

There are no conflicts to declare

Funding sources

There is no fund to declare

Acknowledgments

The authors are gratefully-grateful to acknowledge the Faculty of Applied Arts, Benha University. Furthermore, the authors are gratefully grateful to acknowledge the Central Labs Services (CLS) and Centre of Excellence for Innovative Textiles Technology (CEITT) in Textile Research and Technology Institute (TRTI), National Research Centre (NRC) for the facilities provided.

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بدائل البيندر فى الطباعة باستخدام أصباغ ملونة على الأقمشة القطنية

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الملخص

لا يمكن تطبيق الأصباغ العضوية ذات المجموعات غير القطبية مباشرة لأنه لا يمكن إذابتها في الماء أو غالبية المذيبات العضوية. علاوة على ذلك ، يجب إضافة المجلدات إلى معجون الطباعة لأن المنسوجات والأصباغ لا تلتصق ببعضها البعض ، مما يمنح الأقمشة المطبوعة إحساسا صلبا باليد وضعف ثبات الفرك. سنناقش في هذا البحث بدائل استخدام مادة رابطة أثناء الطباعة بالصبغة، وكذلك الطباعة الرقمية على الأقمشة القطنية، سواء كانت معالجة أو باستخدام بوليمرات تعمل كمواد لاصقة لا تسبب شعورا خشنا على سطح الألياف.

الكلمات المفتاحية: أصباغ ، مادة رابطة ، أقمشة قطنية ، طباعة رقمية