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Herbal Pretreatment of Natural Fabrics for Digital Printing with Ecological Inks

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ABSTRACT

Solvents and humectants are utilized in vast amounts in the textile digital print industry. This poses dire consequences to the environment and human health. The instigated study experimented with eco-friendly pre-treatment to prepare wool and cotton fabrics for digital printing with herbal inks. A factorial experiment was designed to study the quality of printing affected by various factors (variables). The one-way analysis of variance (ANOVA) was used to determine whether there were any significant differences among the variables. Contradictory to the hypothesis the herbal pre-treatment with guar gum was deducted to be more substantial than guar gum-glycerol pre-treatment for both wool and cotton fabrics on digital printing with herbal inks. The commercially pre-treated fabric was implemented as a reference. The ANOVA one-way test reported a p-value of 0.014 indicating the effect of pre-treatment on the color values gained as statistically significant. Also, the Standard Deviation of 1.12 was manifested with Herbal pre-treated fabrics and an SD of 1.02 was noted with Commercial pre-treated fabrics, implying that the estimated data is trustworthy. Before herbal pre-treatment, the plasma surface modification is recommended for future work as it would impel the subsequent herbal pre-treatment & resultant fabric properties required for digital printing.

摘要

在纺织数字印刷工业中大量使用溶剂和保湿剂. 这对环境和人类健康造成了可怕的后果. 这项发起的研究试验了生态友好的预处理, 以制备羊毛和棉织物, 用于使用草药油墨进行数字印刷. 设计了一个析因实验来研究各种因素 (变量) 对印刷质量的影响. 采用单向方差分析 (ANOVA) 确定变量之间是否存在显著差异. 与假设相反, 在使用草药油墨进行数字印刷时, 用瓜尔胶对羊毛和棉织物进行的草药预处理比瓜尔胶甘油预处理更为重要. 将商业预处理的织物用作参考. 方差分析单向检验报告p值为0.014, 表明预处理对获得的颜色值的影响具有统计学意义. 此外, 草药预处理织物的标准偏差为1.12, 商用预处理织品的标准差为1.02, 这意味着估计数据是可信的. 在草药预处理之前, 建议对未来的工作进行等离子体表面改性, 因为它将推动后续草药预处理, 并产生数字印刷所需的织物性能.

KEYWORDS

Plant-Based biomaterials; wool; cotton; digital printing; herbal ink; herbal pre-treatment

关键词

基于植物的生物材料; 羊毛; 棉; 数字印刷; 草药墨水; 草药预处理

Introduction

The global market of digitally printed textiles anticipates £4.90 billion of growth by 2023, the equivalent of the Compound Annual Growth Rate (CAGR) of 11.6% (Smithers 2021). Likewise, the market for digital textile printing ink is predicted to expand at a remarkable CAGR of 17.5% for the period from 2018 to 2023 (Stratview Research 2019). The European green deal aims at neutralizing greenhouse gases by 2050. EU supports industrial transformation to be sustainable by investing in digital innovations (European Commission n.d.). It is noted that fabric preparation is the first step and would affect the quality of the resultant inkjet printed fabrics. Parallelly, the volatile organic

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compounds are implemented in enormous amounts in the textile digital printing industry in the form of solvents such as polyethene glycol, ethanol, methanol, toluene, and others. Also, humectants such as urea are applied during pretreatment, ink formulation, and subsequent processes. Consequently, greenhouse gas effect, ozone depletion, and diseases in humans such as DNA mutation are increasing issues. Hence, it is imperative to investigate circular materials and devise methods that are low on energy demands and can promulgate the implementation of environmental technologies such as plasma surface modification and waterless inkjet print technology as it would enable mitigating the climate crisis arising due to emission and effluents from the textile coloration units (OEcotextiles n.d.) (Christie, Mather, and Wardman 2000; Christina 2015). The impeccable fabric pre-treatment acquired is crucial to subsequently accomplish desirable inkjet printed fabrics. The criteria to achieve advantageous pre-treatment are listed below.

(1) Selection of a neutral and eco-friendly thickener, and likewise other auxiliaries.
(2) Selection of preshrunk fabric with a correct grain (Cie 2015).
(3) Preparation of pretreatment paste to correct viscosity, and application of paste onto fabric and dried thoroughly (Cie 2015).

The pretreatment appears invisible; however, it is of prime importance to achieve optimum digital prints on fabrics. Traditionally natural gums such as gum tragacanth, gum Arabic, guar gum, maize, wheat, alginates, sago, potatoes, arrowroot, cherry gum, agar, and others were utilized for pre-treatment of textiles before digital printing (Neddo 2015) (Bibhudutta, Divyadarshan, and Tejas n.d.) (Sabnani n.d). Commercially it is normally performed with a thickening solution of anionic nature. It is a colorless clear viscous liquid miscible in water and has a pH value of 6 ± 1. The thickening solution is required to be stable and non-reactive (Sarex 2018). A typical pre-treatment composition for protein-based fabrics to be subsequently printed with acidic inks is illustrated in Table 1. It is usually applied by the pad-dry method. The pre-treated proteinic fabric was then inkjet printed with acid inks, then steamed at 102–103°C for 30–40 minutes before being further washed and dried (Sarex 2018).

Figure 1(a,b) remarkedly indicate the increased clarity and brightness of digital print acquired with pre-treated fabric in contrast to the one without (Splashjet Inkjet Ink Private Limited 2020). In other words, correct pre-treatment acquired for digital printing is half battle won (Cie 2015).

Sodium alginate, polyacrylic acid, polyacrylamide, and others were similarly implemented as thickeners on varied fabric substrates (Faisal et al. 2020). However, an ecological approach would be to overlook fossil-based raw materials. VOC emitting solvents were recommended to be ignored (Marrion 1994). Sodium alginate is a natural thickener; however, it is sometimes unavailable, difficult to acquire and expensive (Christie, Mather, and Wardman 2000). Alternative renewable and biodegradable thickeners such as guar gum, gum arabic, and others could be experimented with. It motivates the initiated research. Also, urea (humectant) was implemented in substantial proportion in fabric pre-treatment for digital printing; however, severe restrictions were placed on the nitrogen matter of aqueous effluents. Therefore, it is essential to replace or reduce the use of urea for printing (Christie, Mather, and Wardman 2000). The ultra-flexible hydrogel was constituted from a combination of guar gum-glycerol that exhibited ultrafast self-healing ability, self-adhesive property,

Table 1. A typical commercial pre-treatment composition for proteinic fabrics (Sarex 2018).

Ingredient	Quantity
Solvent	60–80 g/l
Thickener	1–3 g/l
Urea	80–100 g/l
Ammonium sulfate (25%)	10–20 g/l
Salt	10–20 g/l

Figure 1. The difference in print quality in-between (a) Pre-treated fabric and (b) No pre-treated fabric after inkjet printing (Splashjet Inkjet Ink Private Limited 2020).

Table 2. Wool and cotton fabric specifications.

Fabric	Weave structure	Fibre type	Yarn count, tex warp	Yarn count, tex weft	Density Warp, ends/5cm	Density Weft, picks/5cm	Fabric weight, g/m^2
Wool	Plain weave	100%	26	26	65	50	115
Calico	Plain weave	100%	30	30	60	60	140

and strain sensitivity (Xiaofeng et al. 2018). The idea is analogous which is to pre-treat fabrics and add functionality before digital printing. Furthermore, glycerol is readily eco-friendly and reusable (Safaei et al. 2012). Ding et al. examined cotton and PET fabrics pre-treated with two reagents DP-300 and DP-302 that consist of metal salts and are used to coagulate the inks. The acrylic resin was used to hold the ink onto the substrate. It was observed that the wettability of PET and cotton fabrics was improved by 87% and 33% respectively. The wet and dry crock fastness properties in both warp and weft directions for the pre-treated fabrics were found lower than the untreated fabrics (Ding et al. 2018). The Time of Flight-Ion Mass Spectroscopy (ToF-SIMS) test was conducted to characterize the printed fabrics. The surface analysis confirmed that the low crock fastness of the pre-treated fabrics arises from higher pigment levels on the surface of the pre-treated fabric. Furthermore, the use of eco-friendly metal salts-free pre-treatment was recommended (Christie, Mather, and Wardman 2000; Cie 2015). ToF-SIMS results could provide more information about moieties and peak intensities that were overlooked in the research paper. Also, there was no account of wash fastness in the study. Pigment inks are complex, expensive, and generate high carbon footprints as compared to water-based inks from natural materials. Thus far, the research paper has argued that eco-friendly pre-treatment by taking a green route is a crucial step for digital printing of textiles.

Materials

The research adheres to sustainable fabrics that are wool, and cotton as specified in Table 2, also including two commercially pre-treated wool and cotton fabric samples for comparison purposes. All fabric samples were sourced from Whaley's Bradford Limited, UK. Before inkjet printing of the wool and cotton fabrics with herbal inks, the herbal pre-treatment was performed with guar gum (GG) and guar gum-glycerol (GGG) on wool and cotton fabrics, respectively. The analytical-grade reagent Glycerol (CAS – 56-81-5) was acquired from Fisher Scientific, UK. Guar gum (CAS – 9000-30-0) was gained from Special Ingredients, UK.

Methods

Herbal pre-treatment

Figure 2 demonstrates the herbal pre-treatment process performed on wool and cotton fabric samples. Guar gum was weighted and gradually added to 50°C distilled water and stirred continuously to avoid lump formation. The required viscosity was acquired with 1 g per 100 ml of proportion for guar gum and distilled water, respectively. A semi-transparent viscous solution of pH between 6 and 7 was obtained. The wool and cotton fabric samples were soaked in the solution for 1 h, keeping the material-to-liquor ratio at 1:10. The treated wool and cotton fabric samples were then flat-dry. In the parametric study guar gum (1%)-glycerol (1%), variation was performed in the same way as per the guar gum pre-treatment method. The commercially pre-treated wool and cotton fabric samples were utilized to study the effect of conventional processing on digital printing with herbal inks for comparison purposes.

Inkjet printing of wool and cotton fabrics

The herbal pre-treated and commercial pre-treated wool and cotton fabrics were inkjets printed with the herbal inks. For **filling the cartridges** BD Discardit II syringes of 20 ml and BD Microlance # 3 (needles) were utilized. The empty syringe fitted with a needle was applied to draw up the herbal ink stored in the tightly lidded glass bottles. The bigger pink knob at the top of the empty cartridge was opened to let the herbal ink fill in the empty cartridge. Thereafter, **priming** aka processing the cartridges for setting into the printer was done from the opposite side of the filling area with the priming adapter provided along with the empty set of cartridges. It involves drawing out 1–2 ml of herbal ink to discard as indicated in Figure 3a. The priming step propels the flow of ink from the cartridges to the ink capillaries and tubes that further connect to the print head responsible for printing the wool and cotton fabric samples as shown in Figure 3b. Materials utilized in the herbal ink composition, the plausible chemistry, and the colors of herbal inks are provided in the SM in Table 12 (Cardon 2007; Just Ingredients Limited 2021), Figures 8 (PubChem n.d.) (PubChem n.d.) (Oberoi and Ledwani 2010) and 9 in the SM, respectively. Moreover, scientific research investigations accomplished on natural colors from plants indicate no possible health treatment or toxicity to humans and

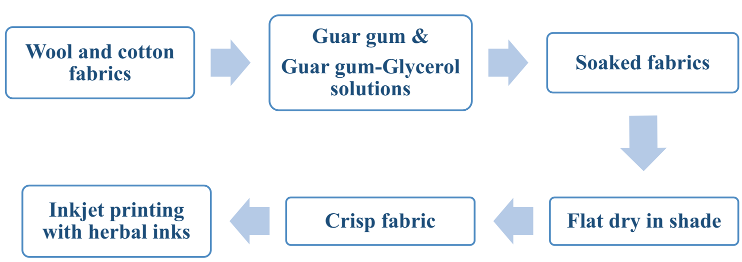

Figure 2. Herbal pre-treatment process illustrated.

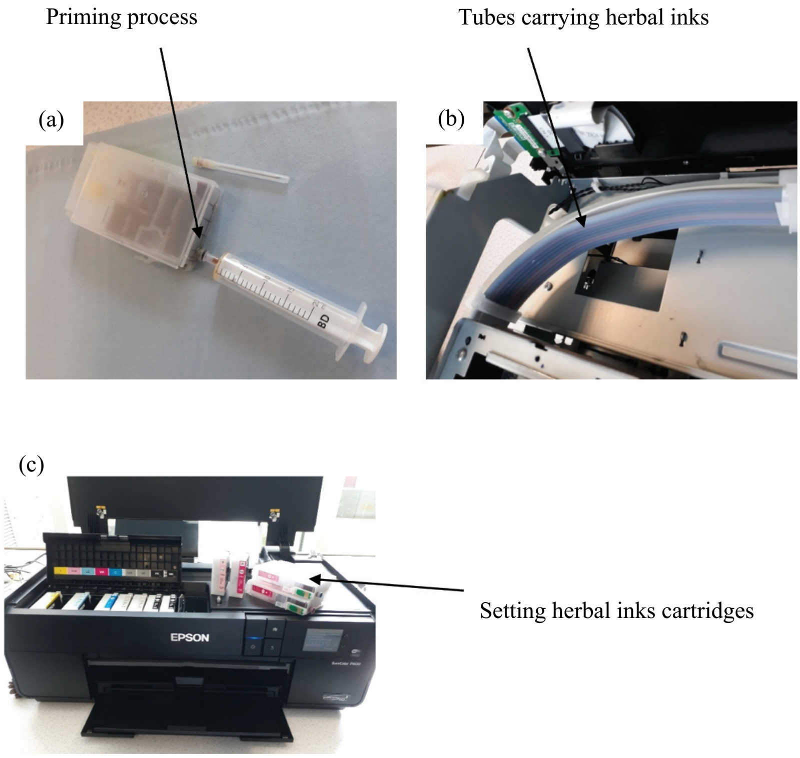

Figure 3. Illustration of (a) Priming, (b) Tubes carrying herbal inks to print head, & (c) Setting herbal inks cartridges in Epson SureColour PC-600 print system.

animals alike (Vankar and Shukla 2019). They are predominantly synthesized from natural fruits, flowers, stems, leaves, bark, grasses, seeds, roots, trees, and berries. The molecules of natural origin are biodegradable, whereas synthetic chemicals lack biodegradability, and they remain in the environment releasing toxic fumes (Sharma, Singh, and Dighe 2018).

For **inkjet printing**, the Epson SureColor 600 inkjet printer was implemented. It is attuned to the C, M, Y, & K color models. It consists of nine cartridges filled with synthetic inks. The original cartridge set in the printer from left to the right direction corresponds to different colors – yellow (Y), vivid light magenta r (VLM), light cyan (LC), vivid magenta (VM), cyan (C), light, light, black (LLK), light black (LK), black (PK, photo black color), black (MK, matte black color). The original set of color cartridges was removed, and the corresponding set of herbal ink-filled cartridges was set into the printer as shown in Figure 3c. The pre-treated wool and cotton fabrics of A5 sample size were arranged on the paper feed of the printer, ready to print. The herbal ink levels were noted for the filled cartridges. The Epson SureColor 600 printer accepted the new herbal ink-filled cartridges and reflected full levels of herbal inks on the computer system for each of the colors. The print command was given for the design to print from the computer connected to the printer. The pretreated wool and cotton fabric samples were printed and collected on a paper output tray. It was conducive to feed in one/few fabric samples at a time for printing with herbal inks to avoid printer jam. **Print quality analysis** was performed with a USB Digital Microscope. The VMS-004 Universal Serial Bus (USB) microscope with micro-capture camera was applied for examination of the print quality of the wool and cotton fabric samples inkjet-printed with the herbal inks. The inkjet-printed line and the solid area were measured in millimeters (mm) at 20x.

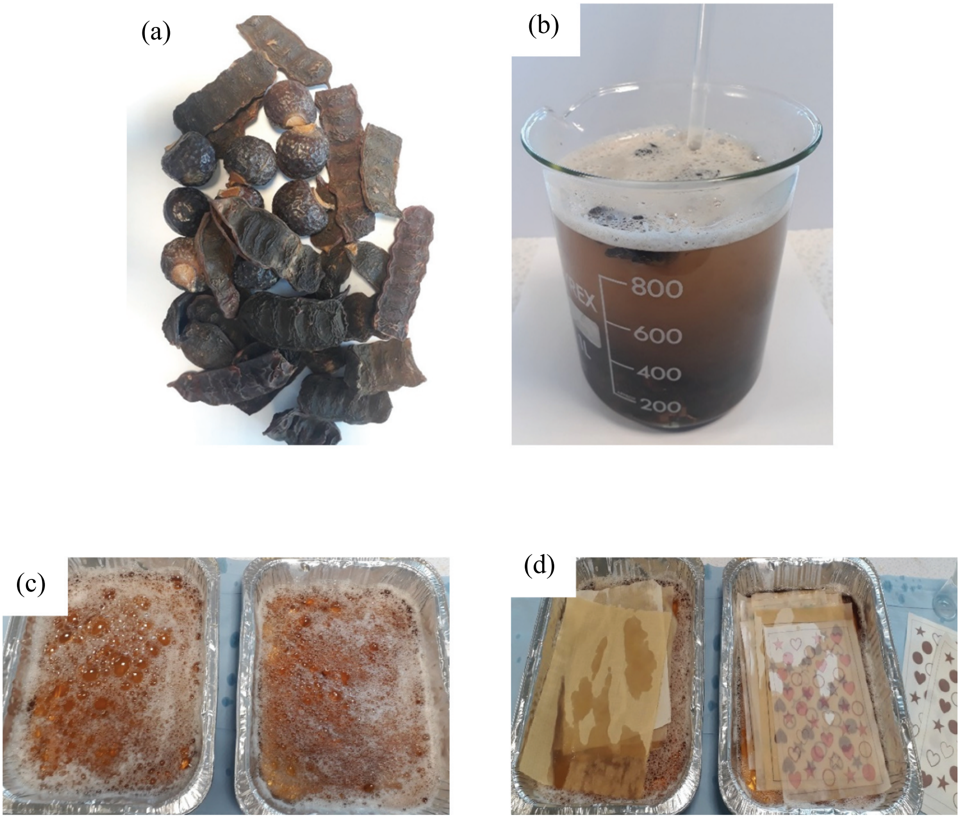

Figure 4. Herbal washing-off, (a) Raw areetha nut and shikakai, (b) Soaking of herbs for saponin extraction, (c) Saponin solution with foam, & (d) Herbal cleansing of wool and cotton fabrics inkjet printed with Herbal inks.

Color fixation and herbal washing-off

For Color fixation, the herbal pre-treated (HPT) and commercially pre-treated (CPT) wool and cotton fabric samples inkjet-printed with herbal inks were undergone color fixation in an industrial steamer for 10 min. Fabric samples were then washed off in either of the two ways: (1) **Herbal washing off** was done with a mixture of herbal soaps, namely, areetha nut herb and shikakai herb, acquired from the Sheetal Ayurved, India. Fifty grams of each herb were taken and soaked in 1000 ml of distilled water at 70°C and left overnight for the saponins to extract gradually as demonstrated in Figure 4(a,b). The fabric samples were soaked individually in the herbal soaping solution for 30 min, gently rubbed and squeezed as indicated in Figure 4(c,d). Thereafter, they were washed in 40°C water and dried in

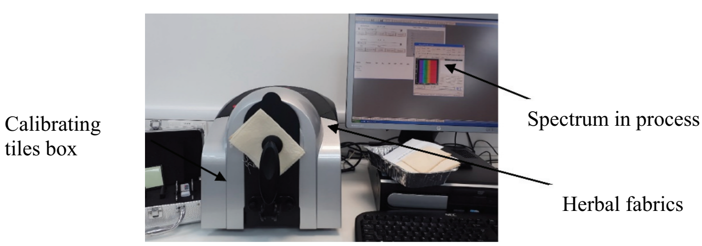

Figure 5. Datacolor 600 is in process for the determination of color values of herbal fabrics.

shade. (2) **Commercial washing-off** was executed on digitally printed wool and cotton fabrics utilizing nonionic soap Synperonic BD 100 following the conventional method.

Measuring colour values

Datacolor 600, a dual-beam spectrometer, was utilized for color measurement. The device has an SP2000 monochromator with dual 256 LEDs and a high-resolution holographic grid. The light source is D65; it covers the spectral range from 360 to 700 nm and has a photometric range of 0 to 200% (Technical Color Solution 2012–2013). The Datacolor tools version of 1.2.0 spectrum, 1994–2007 was utilized for color measurement of inkjet-printed wool and cotton fabrics as visible in Figure 5. The device was calibrated with black, white, and green reference tiles with Datacolor tools software. The untreated wool and cotton fabric samples were used as references. Each of the herbal fabrics was double folded for noting the color values as indicated in Figure 5. The Datacolor match pigment version 1.2.0 displayed the numeric values of K/S, L, a*, b* & ΔE (color difference) that were applied for data analysis (Technical Color Solution 2012–2013).

Color difference

As defined by the Commission Internationale de l'Eclairage (CIE), the L*a*b* color space was developed after an opposite-color concept stating that two colors cannot be red and green at the same time or yellow and blue at the same time. Hence, L* indicates lightness, a* is the red/green coordinate, and b* is the yellow/blue coordinate. Deltas for L* (ΔL*), a* (Δa*) and b* (Δb*) may be positive (+) or negative (-). The total color difference of two colors ΔE*, however, is always positive, and it is calculated by Equation (1) (Louris et al. 2018; Minolta 2006–2020; X-Rite Pantone 2016).

$$E_a b^* = \sqrt{\left((L_2^* - L_1^*)^2 + (a_2^* - a_1)^2 + \left(b_2^* - b_1^*\right)^2\right)} \tag{1}$$

Delta E (ΔE) is measured on a scale from 0 to 100, where 0 indicates no color difference and 100 indicates complete distortion. More detailed information is organized in Table 9 of the Supplementary Materials (SM) (ViewSonic Library 2021).

Fastness tests

Wash fastness, light fastness, and rub fastness tests were performed on the wool and cotton fabric samples inkjet-printed with herbal inks. The **wash fastness test** was performed on SDL-ATLAS, M229 Rotawash as per the British Standards Institution (BSI) ISO 105 C06-A2S test. The **lightfastness test** was conducted on Turfade, serial number 200/18/1053 as per BSI ISO 105 B02 test standard. The **rub fastness test** was conducted using James H. Heal & Co. Ltd, manual crock meter, Model number 680 according to BS EN ISO 105-X12:2016 test standard (The British Standards Institution 2010, 2014, 2016).

Table 3. Physical properties of herbal inks.

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

Table 4. Color values as obtained on cotton fabrics.

FN	PT	HC	L*	a*	b*	K/S	ΔE
OCF	-	–	**96.71**	**3.71**	**−15.75**	**1.6074**	-
D1, GG	HPT	M	81.36	6.30	−10.61	2.0058	16.39
D2, GG	HPT	M	69.54	7.26	−2.59	2.4838	30.39
D3, GG	HPT	K	81.92	10.49	−16.29	2.0854	16.28
D4, GG	HPT	Y	80.22	6.39	−11.83	2.2765	17.16
D5	CPT	C	83.17	4.24	−18.44	2.0602	13.81
D6	CPT	K	89.93	8.31	−12.02	2.0966	9.00
D7	CPT	Y	78.64	5.91	−9.70	2.4142	19.17
D8	CPT	M	77.14	6.68	−10.83	2.0624	20.40
D9, GG	HPT	Y	78.76	5.47	−8.97	2.3797	19.27
D10	CPT	Y	94.32	2.71	−9.06	2.0849	7.17
D11, GG	HPT	Y	93.15	2.05	−6.17	1.5741	10.35
D12, GGG	HPT	Y	93.56	3.36	−10.58	1.6032	6.07

Note: OCF is original cotton fabric.

Results & discussion

The herbal pre-treated (HPT) and commercially pre-treated (CPT) wool and cotton fabric samples were inkjet-printed with herbal inks. The rheology of the formulated herbal inks is summarized in Table 3 for each C, M, Y, & K color. The parametric study is diagrammatically presented in Figure 1 of the supplementary materials (SM).

Color values

The color values gained on digitally printed wool and cotton fabric samples are organized in Table 5 & Table 4 respectively. It is evident that the guar gum pre-treated wool exhibited a slightly higher ΔE value of 6.91 than the guar gum-glycerol pre-treated wool with a ΔE value of 6.44. Correspondingly, as per the ΔE values, the color obtained on guar gum pre-treated wool fabric is more perceptible than the color obtained on guar gum-glycerol pre-treated wool fabric inkjet-printed with the formulated herbal inks. In the same vein, the higher b* value of 18.15 was obtained on GG pre-treated wool fabric as compared to the b* value of 17.69 gained on GGG pre-treated wool fabrics digitally printed with herbal inks. The color trend obtained is of a light-yellow hue. This implies guar gum pre-treatment to be better quality than guar gum-glycerol pre-treatment.

Table 4 illustrates the data gained for the analysis of herbal pre-treatment variations on cotton fabrics. It indicates that ΔE achieved on guar gum pre-treated cotton fabric is 10.35, whereas a ΔE of 6.07 is for the guar gum-glycerol pre-treated cotton fabric digitally printed with Y color herbal ink. Correspondingly, as per the ΔE scale, the color obtained on guar gum pre-treated cotton fabric is more perceptible than the color obtained on guar gum-glycerol pre-treated cotton fabric inkjet printed with the formulated herbal inks. In the same vein, a higher a* value of 2.71 was obtained on GG pre-treated wool fabric as compared to the a* value of 2.05 gained on GGG pre-treated wool fabrics digitally printed with herbal inks. The color style obtained is a light-red shade. Contrary to expectations, guar gum pre-treatment outperforms guar gum-glycerol pre-treatment on cotton fabrics.

Data given in Tables 5 & 4 indicate HPT fairing equally as CPT on cotton fabric than on wool fabric. Eventually, the statistical analysis was performed for herbal pre-treatment parameters as organized in the conclusion. The ANOVA one-way test reported a p-value of 0.014. Also, the Standard Deviation (SD) of 1.12 was manifested with HPT and an SD of 1.02 was noted with CPT. Hence, the estimated data is reliable. The results and discussion of the evaluation of print colors obtained on HPT and CPT wool and cotton fabrics inkjet printed with herbal inks are illustrated in Figures 6 and 7 of the SM.

Table 5. Color values as obtained on wool fabrics.

FN	PT	HC	L*	a*	b*	K/S	ΔE
OWF	-	-	**86.26**	**−0.45**	**11.27**	**0.5079**	-
C1, GG	HPT	M	68.20	3.75	3.71	0.9455	20.03
C2	CPT	K	67.10	12.09	18.29	2.4447	23.95
C3, GG	HPT	K	77.28	5.47	4.18	0.6515	12.88
C4	CPT	K	67.60	7.02	7.59	1.4055	20.43
C5, GG	HPT	K	82.43	7.05	7.49	0.4945	9.23
C6	CPT	Y	72.60	4.60	25.21	2.5027	20.16
C7, GG	HPT	Y	86.84	−0.57	18.15	0.7250	6.91
C8, GGG	HPT	Y	85.97	−0.12	17.69	0.7337	6.44

Note: FN is fabric number, PT is pre-treatment, HC is herbal color, OWF is original wool fabric and ΔE is delta E that is a color difference..

Fastness properties

Wash fastness

The wash fastness test result obtained for wool fabric inkjet printed with herbal ink represents consistently excellent wash fastness ratings of 5 to multifibre fabric staining. On the other hand, the wash fastness to color change was poor with ratings of 1 and 2 for fabric numbers C3, C7, & C8 as illustrated in Table 1 of the supplementary materials (SM). These results are likely to be related to the uneven and mild nature of herbal pre-treatment.

The wash fastness test results obtained for cotton fabric inkjet printed with herbal ink signify regular excellent wash fastness ratings of five to multifibre fabric staining. In contrast, the wash fastness to color change was poor with ratings of 1, 1–2 & 2–3 for fabric numbers D1, D3, D4, D6 & D12 as illustrated in Table 2 of the supplementary materials (SM). Again, these results are likely to be related to the uneven and mild nature of herbal pre-treatment except for fabric number D3 as it is a commercially pre-treated fabric. Therefore, Plasma Surface Modification is recommended for future work as it could potentially enhance the uniformity of HPT and would enable achieving greater color values and fastness properties on the final wool and cotton fabrics digitally printed with herbal inks.

Lightfastness

The data points in Table 3 of the SM state the guar gum pre-treated fabric sample C7 to have a fair light fatness rating in contrast to the poor light fastness value of guar gum-glycerol pre-treated wool fabric sample C8.

The records from Table 5 of the SM denote that the cotton fabric samples have steadily gained good light fastness values. Together with information in Tables 3 & 5 of the SM same trends are observed in lightfastness ratings acquired for wool and cotton fabrics, respectively. The lightfastness ratings achieved on cotton fabrics are greater than that of wool fabrics. Also, it is common knowledge in the field of coloration with plant extracts that shade drying is advocated for the finished garments so that possible fading on exposure to sunlight is evaded.

Rub fastness

Overall, it can be seen from Table 4 of the SM that wet and dry rub fastness ratings are very good for all the HPT and CPT wool fabric samples digitally printed with herbal ink. As can be seen from Table 6 of the SM both wet and dry rub fastness ratings are very good for all the HPT and CPT cotton fabric samples inkjet printed with herbal ink.

Statistical analysis of pre-treatment variance & K/S response

The parametric study designed on the pre-treatment of natural fabrics for digital printing was statistically analyzed and concluded. The data utilized for the ANOVA one-way test analysis of pre-treatment variance on K/S response is illustrated in Table 7 of the SM. The descriptive statics as organized in Table 8 of the SM and the means comparison analysis with the Bonferroni test yield promising results as displayed in the diagrams of Figures 2(a-c) of the SM. The probability value of 0.014 and Sig equals 1 represent that at the 0.05 level, the means of the population are significantly different. The Standard Deviation (SD) of CPT is slightly lower than that of HPT. However, the SE of HPT is lower than the SE of CPT. The actual power of 0.70 implies that the experiential data is 70% trustworthy. Overall, it is concluded that herbal pre-treatments, herbal wash-off and herbal inks are efficient and promising for digital printing of wool and cotton fabrics. The big picture is that this study impels sustainability in the field of textiles and adheres to Sustainable Development Goals.

Conclusions

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

(1) The herbal pre-treatment was applied on the natural textile substrates applying low material-to -liquor ratio and low temperature, hence low water and energy demand and more sustainable. The materials utilized are biodegradable. The guar gum pre-treatment outperformed guar gum-glycerol pre-treatment for both the wool and the cotton fabrics.
(2) A color difference of 10.35 was acquired on guar gum pre-treated cotton fabric inkjet printed with herbal inks in contrast to 6.07 pre-treated by guar gum-glycerol. The wash fastness to staining, rub, and light fastness were very good to excellent for all the fabrics. The wash fastness to color change was poor for both wool and cotton fabrics pre-treated with guar gum-glycerol. The wash fastness to color change was good for the cotton fabrics pre-treated with guar gum.
(3) According to statistical analysis, the actual power of 0.70 implies that the experiential data is 70% trustworthy. The results attained could be further improved by achieving more uniform herbal pre-treatment. The herbal pre-treatment is equally competitive with commercial pre-treatment.
(4) This research adheres to the following Sustainable Developmental Goals, as displayed in Figure 3 of SM. To end, the study productively establishes the possibilities of application of natural biomaterials for preparing the natural fabrics for inkjet printing with plant-based inks.

Future work

A natural progression of the research is to perform a Life cycle analysis of the herbal formulations. Applying plasma surface modification technology could enable achieving uniform herbal pre-treatment therefore suggested for future work. It is vital to propagate circular materials to propel sustainability in the field of textiles.

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