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Research article

Effect of natural thickener on printing performance over cotton woven fabric

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ABSTRACT

Execution of natural thickener (wild taro corm) over pretreated cotton woven fabric with reactive dye has been explored in this research work. Taro root was collected from Sherpur in Bangladesh and made into a fine powder using a grinder. Thickener pastes were prepared by using different concentrations of taro powder, then their viscosity was measured to find out the difference with sodium alginate thickener, which is traditionally used for reactive printing. A suitable thickener stock paste concentration was selected from a number of trials and depending on the result of visual sharpness of the printed samples. A suitable reactive printing method was selected between all in (1 step) and 2 step methods of reactive printing and finally the amount of thickener on the printing recipe was optimized. The color fastness to wash, color fastness to rubbing, bending length, K/S value, levelness, penetration%, print paste adds on and visual sharpness were measured to assess the printing quality. The findings indicate that when Taro corm powder is combined with boiled water, it produces a solution with higher viscosity. Additionally, a mixture of 15 % taro and boiled water yields the most distinct print outline. Comparatively, the 2-step reactive printing method offers a superior outline compared to the 1-step (all in one) method. Moreover, using 50 to 60 gm of taro corm thickening paste for every 100 g of print paste results in a higher K/S value. The results revealed that the wild taro corm could be used successfully as thickener for reactive printing. Finally, the cost was also calculated, and it was found economical as well compared to sodium alginate.

1. Introduction

Printing on textile is the process of applying dye on fabric surface to predefine design area. A lot of printing processes are running nowadays, like screen printing, transfer printing, block printing, direct printing, discharge printing, resist printing, glitters printing and so on. And also, several types of dyes and color are used in printing [1,2]. Reactive printing is one of the popular forms of printing and two types of reactive dyes out of three are used for this printing. One of medium brand reactive dyes which contain bifunctional

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reactive group and good fastness property like vinylsulphone dye and other is hot brand reactive dyes which is reacted at high temperature like 60 to 65 °C, such as 2,4,6-trichloropyrimidine.

In screen printing mesh fabric is used to transfer ink onto a substrate, except in areas made impermeable to the ink by a blocking stencil. Screen printing with reactive dye is the mostly used method for printing of cotton woven fabric where reactive dye forms covalent bonds with fibre polymer and thus attaches itself with fibre [3,4].

As printing is a localized coloration technique, print paste needs to be viscous to stay at a selected area. So, an ingredient is needed to provide viscosity of print paste. Thickener is used for printing to give the required viscosity to the print paste and also to prevent premature reactions between the chemicals contained in print paste and hold the ingredients of print paste on the defined area on the fabric. Thickener imparts stickiness and plasticity of the print paste so that it may be applied on the fabric surface without bleeding and be capable of maintaining the design outlines [5,6]. Traditionally, synthetic thickeners have been used in this process. Nowadays environmentally friendly ingredients with good color fastness are highly recommended and researchers have focused on it. The widely used thickener like sodium alginate has high cost, limited availability and environmental concern [7,8]. On the other hand, natural thickener like wild taro corm is compatible with reactive printing, and it will be a good alternative [9,10]. The wild taro corm contains high levels of starch, which makes it an excellent thickening agent. The starch is extracted from the corm by grinding it into a fine powder and then mixing it with water to form a paste-like consistency. This paste can be added to the dye solution used in reactive printing to enhance its viscosity and improve color retention on the fabric. One of the key advantages of using wild taro corm as a natural thickener is its biodegradability. Unlike synthetic thickeners that can be harmful to the environment, wild taro corm is derived from a renewable plant source and breaks down naturally over time. This makes it an ideal choice for those seeking sustainable alternatives in textile production. Charoon et al. [10] have researched eco-printing on cotton fabric with natural indigo dye using wild taro corms as a new thickening agent. They revealed that the printing paste comprising the thickening agent prepared from modified starch of wild taro corms can be applied and the color fastness to light and rubbing was mostly good and fair respectively. Rattanaphol et al. [11] have also researched about wild taro corm in textile printing and used it as a new resist agent for reactive printing on cotton fabric. The result revealed the impressive color fastness of the printed fabric. Klaichoi et al. [12] have used wild taro corm as resist paste for batik on cotton fabric using pigment dyes and the pattern formed from the cotton batik fabrics as their highest resistant areas still shows sharpness and the color fastness to washing and rubbing test were resulted good to very good level.

Some research works dedicated to natural thickeners on textiles materials can be found in scientific sources [10,11,13–16]. However, there is a lack of investigation in the field of wild taro corm as a natural thickener on reactive printing over cotton woven fabric published in the literature. The well-documentation of effectiveness, stability, and impact on print quality is not found for wild taro corm as a thickener.

The objective of this study is to prepare an environmentally friendly and economical natural thickener from "Wild Taro Corm" and use it on reactive printing over cotton woven fabric. The reactive printing performances were evaluated in terms of color fastness to wash, color fastness to rubbing, color strength (K/S) value, bending length and visual sharpness evaluation. The appropriate ratio of wild taro corm was also determined.

2. Material and method

2.1. Materials and chemicals

A two-dimensional 3/1-S twill weave 100 % cotton woven fabric having an areal density of 260 g/m^2 (grams per square meter) was utilized as the substrate. The ends per inch (EPI) and picks per inch (PPI) were recorded as 120 and 60 respectively. Moreover, the warp and weft count were 16 and 10 Ne respectively.

Reactive dyes (Novacron medium brand; Red) were collected from the Huntsman Corporation, USA. Wild taro collected from natural source and sodium alginate ($C_6H_6NaO_7$) from the Sisco Research Laboratories Pvt. Ltd. India. were used to give required viscosity to the print paste and Sodium bi carbonate ($NaHCO_3$), hygroscopic agent (Urea) [$CO(NH_2)_2$], Sodium meta-nitrobenzene sulphonate ($C_6H_5NNaO_5S$), sodium carbonate anhydrous ($Na_2CO_310H_2O$), sodium perborate ($NaBO_3\ _nH_2O$) were collected from the Merck specialties private limited, India. Soaping agent collected from Jintex Corporation Ltd., Taiwan. ECE detergent collected from James H. Heal, UK and common salt (NaCl) collected from local markets.

2.2. Mercerization of cotton woven fabric

Mercerization is a process that enhances the smoothness and luster of cotton fibres, while also improving the fabric's absorbency. This treatment involves opening up the cotton fibres, allowing dyes to penetrate more effectively. As a result, when dyed, the colors appear brighter, more vibrant, and longer-lasting, which is particularly beneficial for printed or colored cotton fabrics. To carry out this treatment, a 20 % sodium hydroxide (NaOH) solution was used at room temperature for a duration of 2 min. The fabric was fully submerged in the solution to ensure uniform treatment and maintained under uniform tension to minimize any distortion during the process. After the treatment, the fabric was removed from the alkali solution and thoroughly rinsed with water to remove any excess alkali. Finally, it was immersed in a dilute acid bath (acetic acid) to neutralize any residual alkali present in the fabric.

2.3. Preparation of natural thickener from wild taro corm

Wild taro corms were separated from the taro plant (*Colocasia hassanii*) and washed. Fresh taro corms were cut into pieces using cutlass and then sliced. Then all the slices were dried under sunlight for around two weeks. After drying all the pieces were grinded by a grinder (mixer grinder miyako crusher, 750 W) to make powder. The larger particles were removed from the taro powder by passing it through a fine-mesh sieve. Particle size was 10–50 mic and it was measured by a sieve shaker (Bionics Scientific Technologies Private Limited). For making different concentrated thickener paste, a calculated amount of water was mixed with a certain amount of wild taro corm powder. Then, a mechanical stirrer was used at constant RPM for 10 min for stirring. A wild taro plant and its different parts along with corm powder are indicated in Fig. 1. Fig. 2 indicates the stepwise representation for obtaining corm powder.

2.4. Work plan

The work plan is important to organize the study effectively, ensure the project stays on track and delivers meaningful results. The work was executed according to the plan mentioned in Fig. 3. The wild taro corms were first separated from the taro plant and thoroughly washed. The fresh taro corms were then cut into pieces using a cutlass and sliced. Once all the pieces were dried, they were ground into a powder using a grinder. Next, a taro corm thickener was prepared with various concentrations, and the appropriate concentration was selected based on its viscosity. During thickener preparation, the dispersion mixture was vigorously stirred for 20 min at room temperature, followed by streaming the dispersion at 90 °C for 1 h. Following this, the best printing method for the taro corm thickener was chosen between the 1-step and 2-step reactive printing methods. Finally, a suitable amount of thickener from five different concentrations was selected and tested for its printing performance.

2.5. Measurement of thickener viscosity

The viscosity of thickener paste was measured by determining the velocity of flow through a capillary tube or Ostwald viscometer commonly known as U-tube viscometer where viscosity can be calculated through kinematic viscosity measurement equation [17].

Viscosity of thickener, $\eta_y = \eta_w \times \frac{d_y \times t_y}{d_w \times t_w}$.

Here, η_y: Viscosity of tested liquid, η_w: viscosity of water, d_w: density of water, d_y: density of tested liquid, t_w: timing of runoff of water, t_y: timing of runoff of tested liquid.

2.6. Print paste add on percentages

To determine print paste, add on percentage, initial weight of the fabric before printing and final weight after printing was noted. Then using the following formula add on percentage can be measured [18].

Paste adds on percentage $= \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100\ \%$

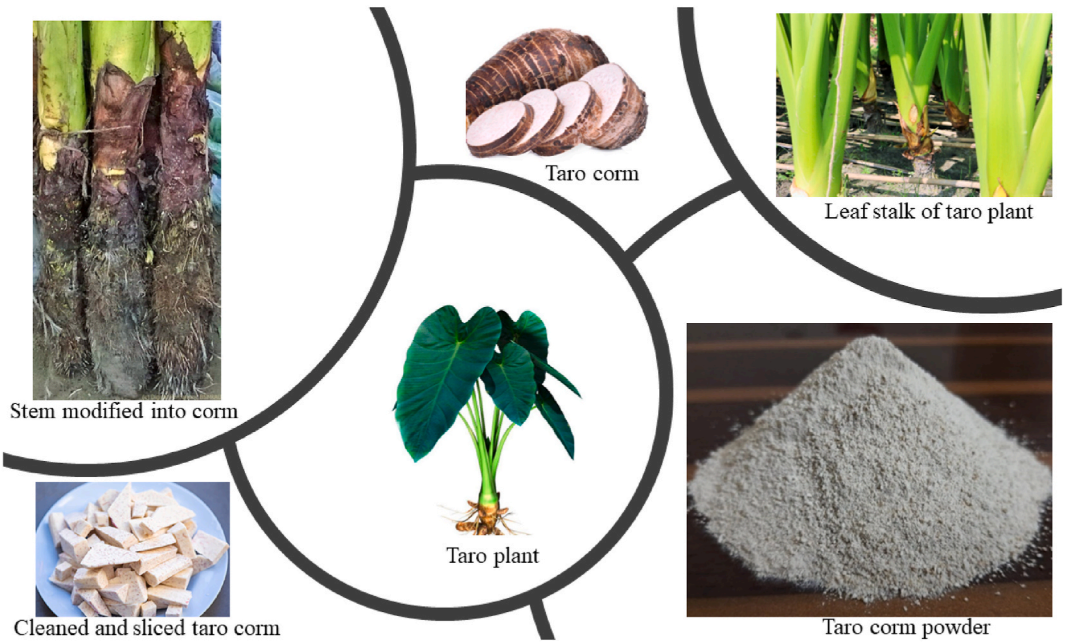


Fig. 1. A wild taro plant and its different parts along with corm powder.

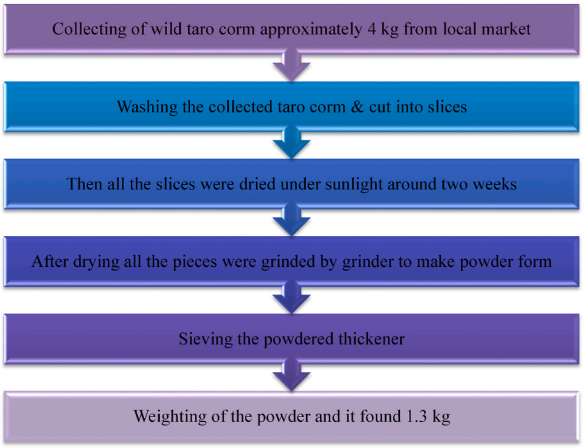


Fig. 2. Stepwise representation for obtaining corm powder.

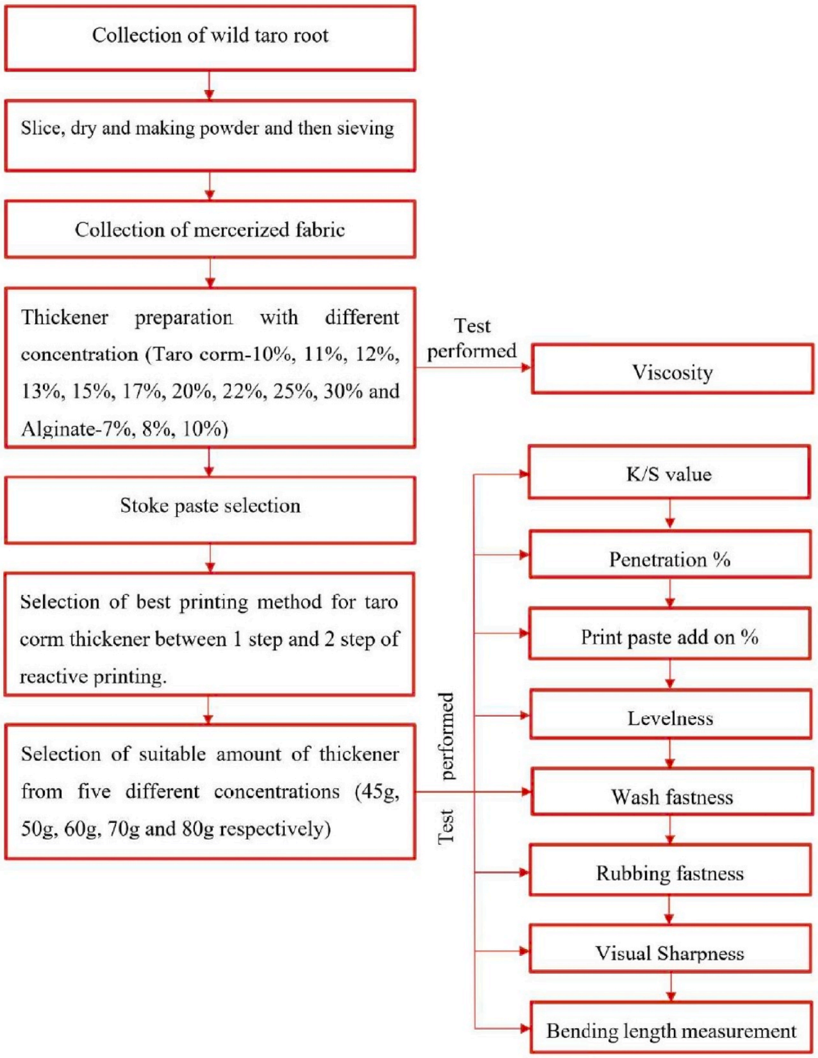


Fig. 3. Schematic representation of work plan.

2.7. Visual sharpness evaluation

The sharpness of the printed sample was evaluated through visual inspection. The rating was denoted by the following number: 1 for poor, 2 for average and 3 for good respectively and assessed the uniformity of print samples [19].

2.8. Color difference (ΔE)

The measurement of each dyed sample is conducted using a spectrophotometer (Datacolor 650, dual beam reflectance, USA). The spectrophotometer is set to D65 illuminant and 10° observer settings. The first reading, referred to as reading-1, is considered the standard, while the remaining nine readings are treated as sample batches. Data for each batch are analyzed with respect to color difference, ΔE value. ΔE is a single value that takes into account the differences between the L*, a* and b* values of the sample and standard in the CIE L*a*b* color system. Eq. (1) was used to calculate the ΔE [20].

Color difference, $\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$.

Here, $\Delta L = L_1 - L_2$, Difference in lightness/darkness value.

$\Delta a = a_1 - a_2$, Difference on red/green axis: +ve represents redder and -ve represents greener.
$\Delta b = b_1 - b_2$, Difference on yellow/blue axis: +ve represents yellower and -ve represents bluer.

Accepted range of ΔE,

$\Delta E \leq 1$, Color match
$\Delta E \geq 1$, Color does not match.

The degree of levelness was described according to ΔE values [21] as shown in Table 1.

2.9. Determination of color strength (K/S)

The color strength (K/S) value of the dyed samples was measured by a data color spectrophotometer based on Kubelka Munk theory which gives the relationship (equation (1)) between K/S and R as mentioned below [22].

$$\frac{K}{S} = \frac{(1-R)^2}{2R} \tag{1}$$

Where, R is reflectance of an incident light from the dyed material, K and S is absorption and scattering coefficient of the dyed fabric respectively.

2.10. Determination of penetration percentage

To determine penetration percentage, K/S value for both face and back side was noted and then by following the formula penetration percentage was measured [18].

$$\text{Penetration percentage} = \frac{100\left(\frac{K}{S}\right)_b}{0.5\left[\left(\frac{K}{S}\right)_f - \left(\frac{K}{S}\right)_b\right]}.$$

Where, $\left(\frac{K}{S}\right)_f$ is the K/S value for face and $\left(\frac{K}{S}\right)_b$ is the K/S value for the back side of printed fabric.

2.11. Testing of color fastness and bending length

Evaluating various color fastness properties of the selected dyed fabric, standard methods were employed. Color fastness to wash and rubbing (dry and wet) were accessed by using grey scale of color change and staining according to ISO 105-C06 (C2S):2010 [23]

Table 1
Suggested interpretation of ΔE values.

ΔE values	Visual appearance of levelness	Extent of unlevelness
≤0.20	Excellent levelness	Unlevelness not detectable
0.21–0.50	Good levelness	Unlevelness noticeable under close examination
0.51–1.0	Poor levelness	Apparent unlevelness
>1.0	Bad levelness	Conspicuous unlevelness

and ISO 105-X12:2016 [24]. The bending length was determined by BS 3356:1990 [25]. To conduct the wash fastness test, the specimen was cut into dimensions of 10 cm × 4 cm. A piece of multifiber fabric of the same size as the specimen was also cut and sewn together on one small side. The composite specimen was then placed in a wash pot along with 25 steel balls and a wash liquor. The wash pot was operated for 30 min at a temperature of 60 °C. Afterward, the specimen was removed, rinsed, and dried. The color change and staining were assessed using grey scales. The recipe used for the wash fastness test included the following ingredients: ECE detergent (4 g/L), Sodium perborate (1 g/L), Liquor (50 ml), and pH level maintained at 10.5 ± 1. Buffer solution was used to control the pH level.

To measure rubbing fastness, the specimen is positioned under the finger in the crock meter. The size of the specimen is 14cm × 5 cm. It is then rubbed using a 5cm × 5 cm dry crocking cloth for dry rubbing fastness, and a 5cm × 5 cm wet (100 % pick up) crocking cloth. A total of 10 strokes are performed within a span of 10 s. Afterward, the crocking cloth is evaluated using a grey scale to determine any staining.

To measure the bending length, a specimen measuring 25mm × 200 mm was cut and marked at both the head and tail on both the face and back sides. The sample was then placed over the fixed position of the Shirly stiffness tester. The bend position was fixed using a mirror, and the scale reading was obtained. Four readings were taken for each sample and the average was recorded.

2.12. Process flow-chart of printing method

The reactive printing process can be done using either a one-step method or a two-step method followed by hand screen printing technique. Fig. 4 indicates the flowchart of the printing method for all in one (1 step) method and 2 step method. The effective printing method will be chosen depending on the results of various tests.

2.13. Print paste recipe

Reactive printing recipe and recipe for development bath (for 2 step) is mentioned in Table 2.

2.14. Standard atmosphere

All experiments were carried out under a standard atmosphere (20 °C ± 2 °C temperature and 65 % ± 4 % humidity) according to the standard LST EN ISO 139:2005 [26]. Each data has been taken a minimum three times and average results have been presented.

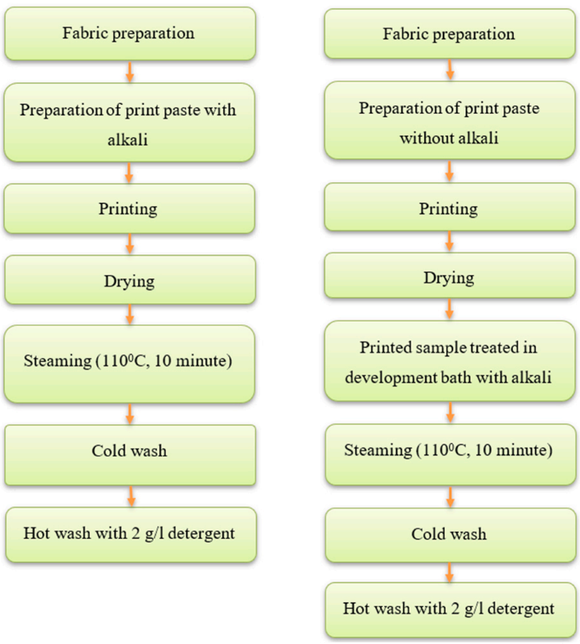


Fig. 4. Flowchart of printing method: one step method (left side) and two step method (right side).

Table 2
Reactive printing recipe for 100 g print paste.

Ingredient	Amount for 1 step	Amount for 2 step	Recipe for development bath (for 2 step)	
			Sodium carbonate	Common salt
Medium brand reactive dye	3 g	3 g	10 g	10 g
Thickener	60 g	60 g		
Resist salt	1 g	1 g		
Urea	3.5 g	3.5 g		
Sodium bicarbonate	3	–		
water	rest	rest		
Total	100 g	100 g		

3. Result and discussion

3.1. Selection of thickener stock paste for printing

Viscosity control is crucial to ensure that the taro corm thickener is of the right consistency for the printing process. A consistent viscosity is essential for uniform application of the thickener to the fabric, which, in turn, impacts the quality and consistency of the print. The viscosity of the thickener also affects the overall viscosity of the dye paste and the sharpness of the print. The right viscosity can enhance color penetration and saturation.

When 10 % taro corm powder was mixed with normal water, it cannot give the proper viscosity by which fabric can be printed. So, the concentration was increased to find proper print ability. Thickener which mixed with normal water, started to show print ability above 17 % concentration. On the other hand, thickeners mixed with boiled water started to show print ability above 13 %. From the given data in Table 3, it is observed that with the increasing of thickener stock paste concentration, viscosity of paste increases and paste prepared with boiled water gives a pretty high viscosity than paste prepared with normal water.

8 % sodium alginate thickener provided the best print ability (Viscosity: 21040 cP). 10 % percent was more viscous to pass through the screen under a suitable pressure (Viscosity: 30080 cP). 7 % can't maintain the sharp outline (Viscosity: 7680 cP). A series of trials was carried out to find out the best stock paste concentration. Depending on the results of visual sharpness, 15 % stock paste prepared with boiled water of taro corm proved to give sharp printing out line. This optimization can lead to reduced material wastage and improved production throughput.

3.2. Printing method selection

Following the recipe given in Table 2, reactive printing (with 15 % stock paste) is carried out in both 1 step (all in method) and 2 step method. The procedures of printing given in Fig. 3. Table 4 shows different test results, depending on which best printing method was selected.

High penetration percentage was a major drawback at the 1 step printing process by taro corm. Though change in shade is better at 1 step, the K/S value was extremely low. The visual sharpness drastically falls in 1 step. High print paste add on (%) makes the fabric stiffer as it was found in the bending length result. Bleached cotton staining was better for both steps which ensured to provide a white background. K/S value and visual sharpness strongly stand for 2 step printing, that is why two step printing was selected for further work procedure.

Table 3
Viscosity of taro corm thickener (mixed with normal and boil water).

Material	Concentration	Mixed with normal water		Mixed with boil water	
		Viscosity (cP)	Visual sharpness	Viscosity (cP)	Visual sharpness
Taro corm	10 %	7200	Poor	16000	Poor
	11 %	9700	Poor	36900	Poor
	12 %	13000	Poor	42060	Average
	13 %	18000	Poor	48140	Average
	15 %	27000	Poor	**62370**	**Good**
	17 %	42150	Average	80870	Good
	19 %	70782	Good	102320	Average
	20 %	94000	Good	–	–
	22 %	116400	Average	–	–
	25 %	139200	Average	–	–
	27 %	144000	Average	–	–
	30 %	235600	Average	–	–

Table 4
Effects of printing methods on printing performance and methods optimization.

Parameters		1 step	2 step
K/S value		6.84	16.63
Penetration%		42.75	12.30
Add on %		18.83	9.01
Wash fastness	Change in shade	4/5	3/4
	Staining in bleached cotton	4	4
Bending length (cm)		3.41	3.21
Obtained color			
Visual sharpness		Below average	Excellent

3.3. Selection of appropriate amount of thickener in printing recipe

Five different recipes were produced for the final sample where only the variation from thickener amount, otherwise all the ingredients present with the same amount. The recipe of reactive printing is stated in Table 5.

3.4. Color strength (K/S value) and levelness of printed area

Evaluation of printed fabrics is performed by measuring color strength values (K/S) obtained using a spectrophotometer. K/S (Absorption coefficient (K) and scattering coefficient (S)) is a value used to determine the depth of color of a printed fabric. K/S values are used in textile applications to control the color process parameters of fabrics. The effects of wild taro corm on color strength and color levelness are presented in Table 6.

It is evident from Table 6 that the K/S increased with the decrease of thickener amount at a certain level. K/S value gradually increased from 80 gm to 50 gm thickener amount and then decreased. Solid particles increased in print past with increasing thickener amount which created difficulties for dye to react with fabric. So that 80 gm and 70 gm provide a little bit lower than 50 gm to 60 gm. The print paste containing 50 gm thickener provides the best result from them. Below 50 gm thickener, K/S value started to decrease again.

Levelness is dependent on the print paste proper mixing and constant angle and pressure of the squeezer. These parameters were tried to maintain properly but as the system was manual, it could not handle precisely. Table 6 expresses the effect of concentration variation of natural thickener like wild taro corm on the degree of color levelness value. The wild taro corm has both positive and negative effects on the degree of color levelness. Lowest ΔE value i.e., excellent levelness was yielded for TRP1. Though, there was a difference in average color difference value, but most of the samples showed good color levelness. The continuing upturn of concentration of wild taro corm promotes easier add-on into the interior of the fibre homogeneously which conceivably leads to a positive impact on color levelness and vice versa.

3.5. Penetration percentage and print paste add on percentage

It is a challenge for printers to print a fabric having a minimum penetration% and a lower paste add-on%. A lower paste add-on onto

Table 5
Recipe for reactive printing.

Sample No	Thickener (15 %) (g)	Dye (g)	Urea (g)	Resist salt (g)	Water (ml)	Development bath (for 100 ml)	
						Sodium carbonate (g)	**NaCl (g)**
TRP1	80	3	3.5	1	12.5	10	10
TRP2	70	3	3.5	1	22.5	10	10
TRP3	60	3	3.5	1	32.5	10	10
TRP4	50	3	3.5	1	42.5	10	10
TRP5	45	3	3.5	1	47.5	10	10

Table 6
K/S value and Levelness value for different concentrations of thickener.

Sample code	K/S value at λ_{max} = 530 nm	Levelness value		
		ΔE (Left)	ΔE (Middle)	ΔE (Right)
TRP1	15.31 ± 0.01	0.31 ± 0.01	0.35 ± 0.02	0.33 ± 0.01
TRP2	15.32 ± 0.02	1.09 ± 0.02	1.13 ± 0.02	1.11 ± 0.02
TRP3	16.63 ± 0.01	1.88 ± 0.02	1.96 ± 0.01	1.92 ± 0.01
TRP4	16.88 ± 0.01	2.33 ± 0.02	2.09 ± 0.02	1.89 ± 0.02
TRP5	14.06 ± 0.01	2.41 ± 0.02	2.55 ± 0.02	2.48 ± 0.04

the substrate is possible when the printing paste shows shear thinning behaviour at a higher shear rate. And after releasing the squeeze pressure, the onset of lower stresses hinders the passage of the printing paste through the fabric openings, resulting in a lower percentage of penetration into the fabric [27]. Fig. 5 indicates the effect of taro corm thickener on penetration percentage (%) of printed fabric and Fig. 6 indicates the effect of wild taro corm thickener on paste add-on%. It was found that 50 gm to 60 gm would be the range for lowest penetration percentage. Below 50 gm the penetration starts to increase extremely with a thickener amount decrease. Paste add on parentage is directly proportional to hand feel. With an increasing amount of thickener in the printing recipe increases print paste add on%.

3.6. Color fastness

Color fastness is one of the important parameters for assessing the quality of printed fabric in terms of serviceability, which also indicates the fixity of the dye-fibre system. Shade change to wash and staining on diacetate, bleached cotton, polyamide, polyester, acrylic and wool are represented in Table 7. Shade change for all the samples were not less than 4 which is good and staining on all the fibres of multifibre fabric also found very slight to no staining with few exceptions. Images of samples after wash fastness and rubbing are stated in Table 8.

3.7. Bending length

Fig. 7 Illustrates the effect of wild taro corm thickeners on the bending length of printed fabric. With increasing amount of thickener in printing recipe increases bending length (with few exceptions) which indicates higher the thickener in printing recipe stiffer the fabric. The bending length of the fabric is 3.04 cm before printing.

The stiffness or bending length was decreased with the decrease of wild taro thickener in the print paste. The bending length of the printed fabric was found 3.1 cm for TRP1 and 2.9 cm for TRP5.

3.8. Measurement of sharpness of the print

The sharpness of the printed samples with natural wild taro corm thickener is shown in Table 9. Sharpness of the printed fabrics was assessed out of maximum grade 3. The result of sharpness depends on the thickener. Good sharpness was found for the samples of TRP3

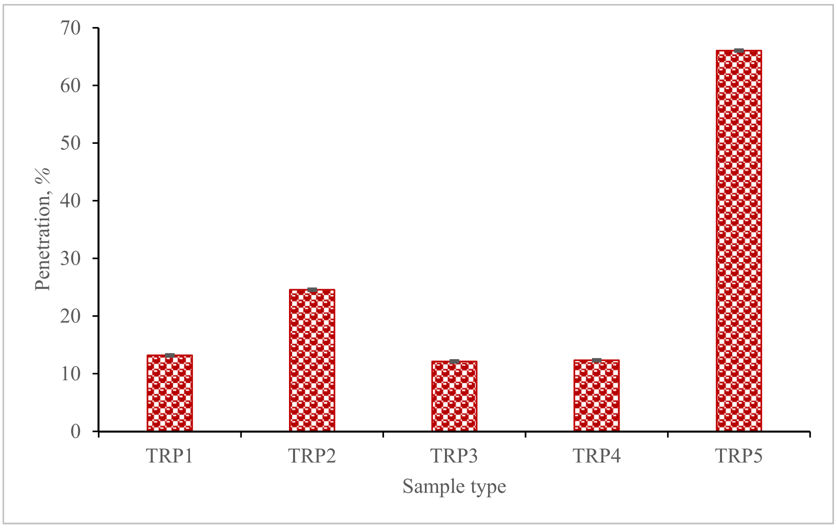


Fig. 5. Effect of wild taro corm on print paste penetration percentage.

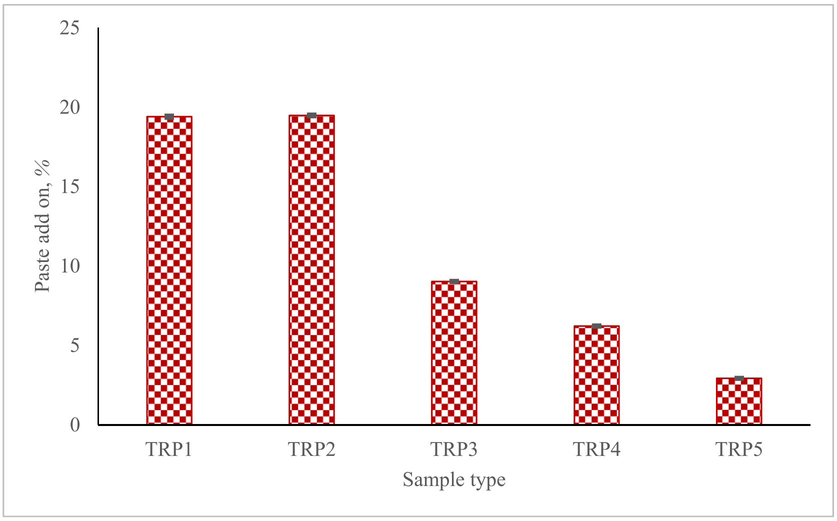


Fig. 6. Effect of wild taro corm on print paste add-on percentage (%).

Table 7
Color fastness to wash and rubbing of printed samples.

Fastness	Grading		Sample code				
			TRP1	TRP2	TRP3	TRP4	TRP5
Wash	Color change		4	4	4	4	4/5
	Color staining	Diacetate	3	3/4	4	3/4	4
		Bleached cotton	4	4	4/5	4	4
		Polyamide	3/4	3/4	4	3/4	4
		Polyester	4/5	4/5	4/5	4	4/5
		Acrylic	4	4/5	4/5	4/5	4/5
		Wool	3/4	3/4	4	4	4
Rubbing	Dry		4	4/5	4	4	4/5
	Wet		3	3/4	3/4	3	3/4

The results of the wet and dry rubbing fastness tests are presented in Table 7. Generally rubbing fastness is increased with the decrease of thickener concentration. It reflects the best result for 45 and 70 gm.

and TRP4. The sample treated with 45 gm wild taro thickener showed poor sharpness. Additionally, average sharpness was found for the samples of TRP1 and TRP2. The digital photographs of the printed sample (front and back side) are also presented in Table 9.

3.9. Cost analysis

Wild taro corm root was bought from the local market of Sherpur in Bangladesh and cost is found as follows.
1 kg wild taro corm root = 50 BDT (≈$ 0.47)
1.3 kg taro powder was produced from 4 kg taro corm root.
So, 1 kg or 1000 gm wild taro powder cost $= \frac{50\times4\times1}{1.3} = 153.85$ BDT (≈$ 1.45)

On the other hand, 1 kg Sodium Alginate powder was bought from a local authorized dealer for 400 BDT (≈$ 3.78). So, it's clear that the cost of wild taro powder is less than sodium alginate powder. Table 10 indicates the thickener and print paste cost calculation per 100 g.

If it could be bought from rural areas, it would have a lower price. It is extremely affordable in rural areas or in small cities. There will, however, be labor and transportation costs associated with making powder from taro root.

Based on the viscosity and visual clarity, a 15 % stock paste prepared using boiled water from taro corm was found to produce distinct printing profiles. The K/S value and visual clarity strongly support the efficacy of two-step printing, prompting its selection for further experimentation. TRP1 exhibited the lowest ΔE value, indicating excellent color uniformity. While there were variations in average color difference values, most samples demonstrated satisfactory color consistency. Increasing the concentration of wild taro corm facilitated better penetration into the fibers, potentially improving color consistency. An optimal range of 50–60 gm was identified to minimize penetration percentage, with levels below 50 gm resulting in excessive penetration with decreased thickener amounts. Paste application percentage directly correlated with fabric hand feel. Rubbing fastness improved with decreased thickener concentration, with optimal results observed at 45 and 70 gm. Higher thickener concentrations in the printing recipe generally resulted in stiffer fabric, indicated by increased bending length. TRP3 and TRP4 samples exhibited good sharpness, while TRP1 and TRP2

Table 8
Images of samples after wash fastness and rubbing.

Fastness	TRP1	TRP2	TRP3	TRP4	TRP5
Wash (Color change)					
Dry rubbing					
Wet rubbing					

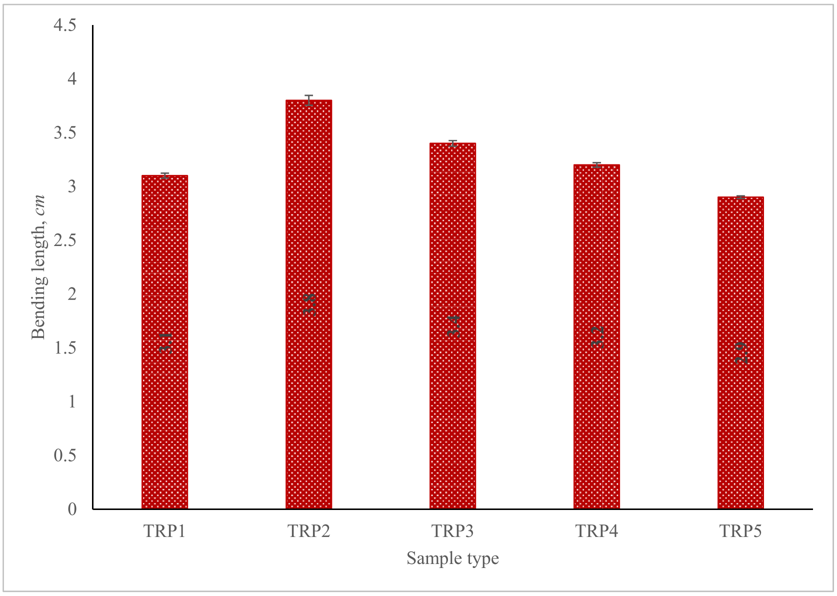


Fig. 7. Effects of wild taro corm on bending length of printed fabric.

Table 9
Visual sharpness of the design printed fabric.

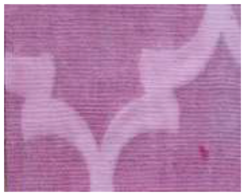
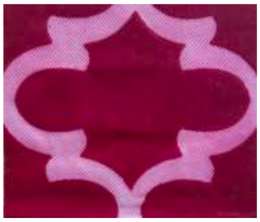
Sample code	Visual sharpness		Obtained color	
	Grade (Out of 3)	Observation	Front side	Back side
TRP1	2	Average		
TRP2	2	Average		
TRP3	3	Good		
TRP4	3	Good		
TRP5	1	Poor		

Table 10
Thickener and print paste cost calculation per 100 g.

Thickener type	Required amount	Thickener cost, BDT (≈$)	Print paste cost (100 gm), BDT (≈$)
Sodium alginate	8 %; 60 gm	1.92 (≈$ 0.018)	4.50 (≈$ 0.042)
Wild taro corm powder	15 %; 80 gm	1.84 (≈$ 0.017)	4.42 (≈$ 0.042)
Wild taro corm powder	15 %; 70 gm	1.61 (≈$ 0.015)	4.19 (≈$ 0.040)
Wild taro corm powder	15 %; 60 gm	1.38 (≈$ 0.013)	3.96 (≈$ 0.037)
Wild taro corm powder	15 %; 50 gm	1.15 (≈$ 0.011)	3.73 (≈$ 0.035)

displayed average sharpness.

4. Conclusion

Environmentally friendly products are currently one of the major concerns in the textile printing industry. This exploration shows that wild taro corm can be used as a natural thickener like sodium alginate in reactive printing. Though sodium alginate is also a natural thickener, but its collection from its source is pretty difficult, and it is costly as well. Wild taro corm grows on wet ground near the sewer spontaneously without any fertilization process. So, there is no need to pave soil and pesticides for the cultivation of taro corm. Any uncultivated land is useful for wild taro cultivation. As the scenario of the demand of arable land increases day by day, there are no shortages of uncultivated land. Those lands would be used for wild taro cultivation, where taro will put its impact on food and to produce environment friendly thickener. Taro corm powder provides a more viscous solution, when it is mixed with boiled water and 15 % taro mixed boil water provides the best print outline (viscosity 62370 cP). The two-step reactive printing method provides a better result than the 1 step (all in one) method. 50 to 60 gm taro corm thickening paste for 100 g print paste provides better K/S value (16.88). Moreover, 60 gm taro corm thickening paste provides a better white background. Higher stiffness (3.8 cm) and high add on% (19.48) were found for applying higher concentrate thickener. Some errors were found due to the manual procedure, defective padding mangle and improper printing screen. Considering printing performance, it seems to be possible to use taro corm as a natural thickener in the reactive printing process. Further studies can be carried out to optimize processing parameters including concentration, temperature, and processing time to achieve the best printing results. Long-term studies should be conducted to evaluate the durability and wash fastness of prints made with wild taro corm thickener on different fabrics.

Ethical approval

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Consent to participate

Not applicable.

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CRediT authorship contribution statement

Shaima Islam: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nasrin Akter:** Writing – review & editing, Visualization, Resources, Methodology, Investigation, Conceptualization. **Md. Reazuddin Repon:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Methodology, Formal analysis, Conceptualization. **Md Abdullah Al Mamun:** Writing – review & editing, Visualization, Resources, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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