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Calorimetric Analysis and Fastness Properties of Banana fibre dyed with Basic dye.

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Abstract
This work focuses on the properties of banana fibre dyed with basic dyes preceded by scouring and bleaching. The raw banana fibre was pretreated with caustic soda, sodium silicate and hydrogen peroxide which is later been dyed with 5% of Basic dye (Maxilon basic dye) using the hot thermosol method. Data accumulation is carried out by quantitative research methodology and experimental work for the investigation. 6% Hydrogen peroxide, 8% Sodium silicate and 0.7% Sodium Hydroxide treated Banana fibre was dyed with a 5% concentration of Basic dye. Testing was carried out to access the colour and its fastness properties of the fibre. Colour measurement was conducted using a spectrophotometer where the K/S value was used to determine the colour strength. The fastness properties of the fibre have also been analyzed and it has been observed that the colour fastness to light and rubbing was very promising and the perspiration fastness was fairly satisfactory but the wash fastness rating of the Basic dye treated fibre was really poor. The fibre strength was also determined which shows that the fibre strength has gradually decreased with the application of further chemical treatment.

Keyword: *Banana fibre, colour properties, dyeing, Basic dye, Colour fastness, fibre strength.*

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I. Introduction:

Banana plants are cultivated in over 130 countries, along the tropics and sub-tropic of Capricorn. Two wild species, Musa acuminata and Musa balbisiana are thought to have given rise to existing edible bananas [3]. Banana fibre at present is a waste product of banana cultivation and either not properly utilized or done partially. So fibre production or its end product is not yet emerged as a profitable business in global or local market. Therefore, the use of banana fibre for textiles and other purposes as a natural material is not known to all [4].

Banana is a bast fibre that has excellent mechanical properties like high strength, moisture absorption, higher density and biodegradability [5-6]. It therefore has a huge potential to become the raw materials for sustainable Textiles leading to green technology [7]. For its application, some modification on the fibre has been done. Natural fibre being sustainable and biodegradable has higher values for the Textile and apparel manufacturer as well as to the consumers [1]. Among the natural fibres, Bast fibre of cellulosic origin has been used for thousands of years as a common textile material [2].

Raw untreated Banana fibre has natural yellowish colour [3]. To increase the dyeing performance of the fibre it is necessary to remove its original colour. Colour deterioration symbolizes the processing performance of fibre and affects the ability of fibres to absorb and hold dyes and for final finishing [9].Banana fibre is a lingo-cellulosic fibre. Lignin is a complex composed of complicated phenyl propane units nonlinearly and randomly linked; three main monomers are coumaryl alcohol, coniferyl alcohol, and sinapyl alcohol [3]. Basic dye is utilized for the dyeing of the cellulosic part of the fibre. Cellulosic fibres like banana develop negative surface charge (zeta potential) in contact with an aqueous dye bath. Basic dyes possess a strong affinity for different animal fibre, such as wool, silk, leather etc. because they seem to hold some acidic properties of their own [10]. Vegetable substrates like cotton, linen, paper have impurities like vegetable acids, gum etc which need to be removed because they have no affinity at all even to the most powerful basic dyes. Basic dye having an affinity to the negative hemicellulose bast fibre e.g. banana fibre and thus can be suitable for this purposes [11-15].

Banana fibre has been taken into consideration to dye with synthetic dyes like reactive dye [16]. However there is no significant investigation on the dyeing behaviour of banana fibre with basic dye. This experiment aims to determine the colour strength, its fastness properties and the strength of the fibre after the process has been carried out.

II. Material And Methods

2.1Material
2.1.1 Banana Fibre:

The banana plant is collected from the Rampura, Ulon of Dhaka city fig(1).For the selection of the Banana fibre well -grown matured plant were preferred.

Figure 1: Banana Plant

The collected plants are then separated into layers of Lamina which are later taken for processing into fibre extracting machine fig(2)The fibre extracting machine, also known as a mechanical decorticator, is consisted of a pair of feed rollers and a beater. The slices were fed to the beater in between the squeezing roller and the scrapper roller. Thus the pulp gets separated and fibres are extracted. After sun drying, a bunch of fibres are mounted or clamped on a stick to facilitate segregation. Each fibre is separated individually according to fibre length and is grouped accordingly [17]. The approximate length of the fibre was 0.9-1 meter; the fibre strength 26 gm/Tex and the diameter of the fibre were about 0.20-0.25 mm

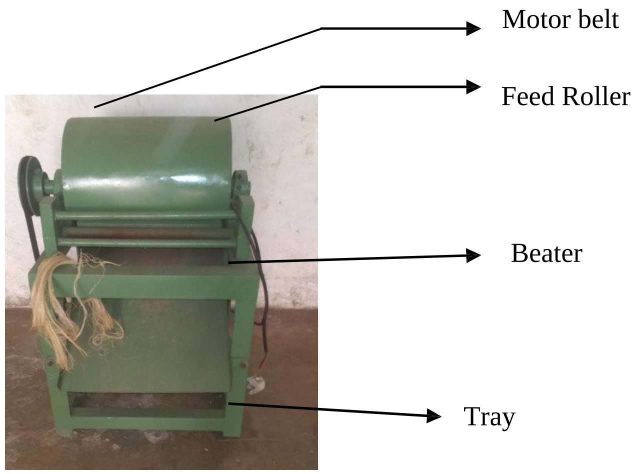

Figure 2: Mechanical Decorticator

2.1.2Chemicals and auxiliaries:
The dye and the other auxiliaries and chemicals used in this experiment were collected from the local market of the
Dhaka, Hatkhola. For scouring and bleaching Sodium Hydroxide and Hydrogen peroxide were used. Maxillon Basic red GRL 46 fig (3) was used for dyeing. Acetic acid was used for dye exhaustion. Wetting and Levelling agents were also used for dye levelling and fixing. For washing nonionic detergent was taken into considerations.

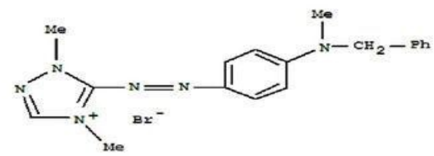

Figure 3: Maxilon Basic Red GRL 46

2.2 Methods:

Extraction of fibre from the plant:

A mechanical decorticator has been used for fibre extraction. Dyeing has been carried out in an open bath and the colour characterization is done by Spectrophotometer. For fastness properties assessment Greyscale and Blue scale have been used. Fibre strength is determined by using Stelometer. All the experiments were carried out in the Wet Process Engineering Laboratory of the Bangladesh University of Textiles.

2.2.1Pretreatment:

Scouring and bleaching of the fibre was done by using Hydrogen Peroxide= 6% o.w.f Sodium Silicate= 8% o.w.f, Sodium Hydroxide= 0.7%, Detergent= 1 g/L, Sequestering Agent= 1 g/L and Peroxide Stabilizer= 3 g/L. The fibre was later washed with Hydrogen Peroxide Killer= 1g/L and Acetic Acid=1% o.w.f. The scoured bleached fibre was later dried and prepared for dyeing process.

2.2.2Dyeing:

For Basic dyeing hot thermosol process was used [5].Basic dye= 5% o.w.f was taken along with Acetic Acid= 1 g/L , Leveling Agent= 1 g/L Sequestering Agent= 1 g/L and Lubricant= 1 g/L. Temperature has been raised to 90*C (and run)for 60 minutes. Later it was drained and washed with Alkali= 1 g/L and Non-ionic detergent= 1 g/L [11]. Figure 4 shows the step way process of dyeing taken place in the experiment.

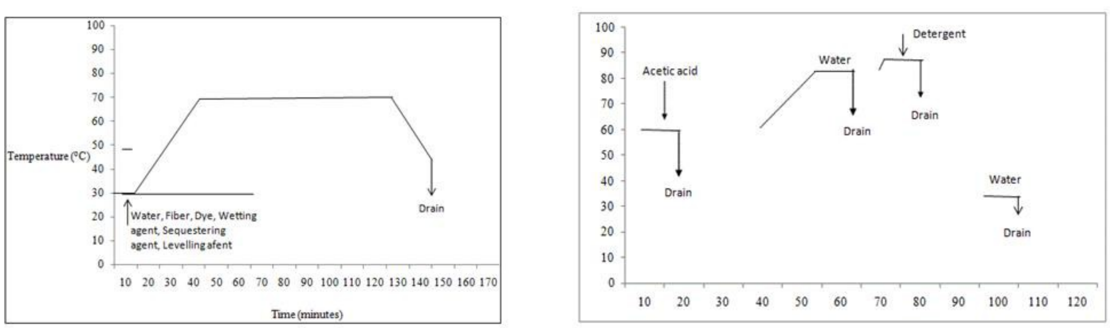

Figure 4 :Dyeing Curve

2.3 Characterization:

2.3.1 Color strength:

The spectrophotometer is used to measure the colour values of the Basic dye.ΔE* value is obtained by CIELab (L*, a*,b* and h) colour system[18]. The lightness— L* and the chromaticity coordinate a*—green/red, b*—blue/yellow, C*—chroma, and h—hue angle colour parameters were assessed. According to the American Association of Textile Chemists and Colourists (AATCC) test method, the colour value was evaluated as 173-2006 in illuminant D65, large area view, and International Commission on Illumination (CIE) 10° standard observer[19]. ΔE* indicates the total colour differences. If spectrophotometer expressed $\Delta E^* < 1$, the value of colour differences could be accepted in overall test specimens. ΔL* negative value shows that the colour of the samples is darker than the standard samples. ΔL* positive value describes that the colour of the samples is lighter than the standard samples. Δa* positive value results in a surplus of the red nuance and negative value of Δa* results in a surplus of the green nuance. Δb* positive value explained that the yellow subtlety is much and Δb* negative value symbolizes that the blue subtlety is great. The fibre strands were wound on a holder and the measurement is carried out. The *K/S* value was assessed using the spectrophotometer to observe the colour strength of different reactive dyes, which works on the Kubelka-Munk equation 1.

$K/S = (1-R^2)/2R$ ………………… (i)

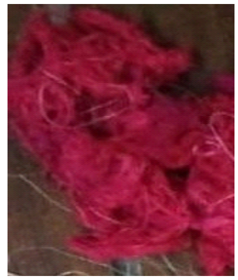

Figure 5 : Basic dye treated Banana fibre

2.3.2 Wash fastness:
The ISO 105 C06 1989 method was applied to measure the wash colour fastness properties of the dyed sample. In this method, a dyed fabric (10 cm × 4 cm) is attached to a multi-fibre fabric and an undyed fabric like a sandwich and the sample was treated with standard detergent, sodium carbonate at 60 °C for 30 minutes in a washing machine where M:L was 1:50. Then, colour fastness to wash was assessed in respect to colour change (ISO 105 A02) and colour staining (ISO 105 A03) by matching with standard grey scales.

2.3.3 Rubbing fastness
Colour Fastness to Rubbing is measured using International Organization for standardization ISO 105-X12:2016. Dyed samples of 14 cm × 5 cm were mounted on a crock meter and the finger of the crock meter covered with a 5 cm × 5 cm crocking cloth at the pressure of 9 ± 2 N. The samples were rubbed with the finger at 10 turns within 10 seconds. But for the wet rubbing test, this process is followed after soaking the crocking cloth in water at a 100% pickup.

2.3.4 Perspiration fastness
Colour Fastness to Perspiration is measured using International Organization for standardization ISO 105-E04:2013. Colour fastness to perspiration of all dyed samples was measured in media like acid and alkali following the ISO 105 E04 testing method. Like the samples (10 cm × 4 cm) for the wash and water fastness, a multifibre fabric and undyed fabric were further soaked in an alkali and acid solution. Alkali and acid solutions were prepared by using 0.5 g/l l-histidine monohydrochloride monohydrate, 5 g/l sodium chloride, disodium hydrogen orthophosphate dehydrate/ sodium dihydrogen orthophosphate dehydrate and definite pH for acid and alkali. Two composite specimens are thoroughly wetted out in two different artificial perspiration solutions at a liquor ratio of 1:50 for 30 min at room temperature and are placed between two glass plates, pressed with a force or weight of 4.5 kg for 4 h at 37 ± 2°C (body temperature). Specimens are removed, dried at or below 60°C and change in colour as well as the degree of staining on white are compared with respective grey scales.

2.3.5 Light fastness
Colour Fastness to Artificial Light: Xenon Arc Fading Lamp Test is measured using ISO 105-B02:2014.The samples were placed in the lightbox and exposed to the light source for about 24 hours. Later the fastness is measured using greyscale of lightfastness.

2.3.6. Fibre strength assessment
Fibre strength of the fibre is measured by using Stelometer value at zero gauge length using gm/Tex. In this case, fibre is combed and straightens. Fibre is collected using a twizer. Fibre is later transferred to sample holder Pressley jaws. The clamed was tightened and even pressure was maintained. It was clamed and positioned in Stelometer. The reading was taken when the fibre broke. The following equation was used to determine fibre bundle strength.

$$\textbf{Tenacity of the fibre in gm/Tex} = \frac{\text{Breaking load in kg x Length of sample in mm}}{\text{Mass of the fibre in mg}}$$

III. Result And Discussion:

3.1: Colour Strength: The dyeing behaviour of the fibre is shown in table 1. The spectrophotometric analysis has been done for 5% shade. The reflectance of the dye (R%) is 61.54. It has been observed that colour strength of the basic dye (k/S) is 29.55. This indicates that the dye uptake for dye is satisfactory. The lower L*value shows the depth of the shade is quite higher due to higher dye absorptions. The higher positive value of a* shows the colour of the shade was reddish. The CMC DE shows the fibre tends to attract dye molecules inside its interface because of its higher absorption and amorphous nature.

D65 Illuminant (750)	Sample					
	S-1	S-2	S-3	S-4	S-5	Avg
L^*	26.5	27.3	25.55	26.1	26.45	26.38
a^*	42.81	43.14	41.2	43.12	43.66	42.786
b^*	1.09	1.11	1.21	0.93	1.11	1.09
C^*	42.83	41.44	43.3	41.67	43.32	42.512
DL^*	-43.29	-42.32	-41.34	-43.76	-43.27	-42.796
Da^*	37.68	35.76	38.95	36.73	37.83	37.39
Db^*	-16.55	-16.54	-16.12	-16.34	-16.75	-16.46
DC^*	24.45	23.65	24.76	25.67	26.48	25.002
DH^*	-33.1	-32.76	-34.66	-32.13	-32.83	-33.096
CMC DE	48.2	47.9	48.35	47.93	48.67	48.21
R%	61.46	60.5	62.66	62.45	60.64	61.542
K/S	29.74	30.3	28.86	29.87	28.96	29.546

Table 1: Spectrophotometric analysis for Basic dye

3.2. Colour Fastness to Wash

The wash fastness was accessed using ISO 105 process. For rating of the colourfastness Grayscale was used using the 5-1 rating system. Where Class 5 is the best,4-good,3-fair,2-poor and 1-very poor is being used. Besides half rating system also being considered like 4-3, 3-2 and 2-1.For determining the staining on the fibre multifibre were also used. The multifibre being taken are as follow DA= Diacetate, CO= Cotton, PA= Polyamide, PET= Polyester, AC= Acrylic and WL= Wool.

From table 2 the colour fastness for the washing is visualized. The wash fastness of the fibre is moderate. The staining is however is very good for PET fibre. Other multifibre show lower staining rating. The wash fastness rating signifies that the Basic dye treated banana fibre is not preferable to use where subsequent washing is involved.

Dye	Sample	Shade Change	Degree of Staining					
			DA	CO	PA	PET	AC	WL
Basic	B-1	2-3	1-2	2-3	1-2	3-4	2-3	1-2
	B-2	3	2	2-3	2	4	3	2
	B-3	2-3	2	3	2	4	2-3	2
	B-4	2-3	2-3	2	1-2	3	3	2
	B-5	3	1-2	3	1-2	3-4	2	1-2

Table: 2 Colour Fastness to Wash

3.3 Colour Fastness to perspiration

In this experiment, ISO 105-E04:2013 is used for determining the resistance of the colour of textiles of all kinds and in all forms to the action of human perspiration. Both the Acidic and Alkali media is taken into consideration in deterring the degree of the perspirations. The dyed fibre is rated using the 1-5 scale rating system of the Greyscale. Multifibre is used for assessing the staining where the term DA= Diacetate, CO= Cotton, PA= Polyamide, PET= Polyester, AC= Acrylic, WL= Wool was used. The staining is graded using the
1-5 scale rating system using the Grayscale of colour staining where 5 being used as excellent with no staining and 1 being very poor with higher perspiration fastness.

From table: 3 the colour fastness of the Basic dye can be assessed. It can be visible that the colour fastness of the dye is not good for both acidic and basic medium. Although staining on the multifibre can be improved further using mordent. Considering the colour fastness values of perspiration test results it can be summarized that basic dye is not suitable for textile application for basic dye prior to perspiration. But it is cheaper which can be used for dyeing in the fabric not applicable in direct skin contact or perspirations.

Dye	Sample	Perspiration Type	Shade Change	Degree of Staining					
				DA	CO	PA	PET	AC	WL
Basic	B-1	Acidic	3	2	2-3	2-3	4-5	1-2	1-2
		Alkaline	2-3	2	3	1-2	3-4	1-2	1-2
	B-2	Acidic	2-3	2-3	2	3	4	2	2
		Alkaline	3	2-3	2-3	2	4	2	2
	B-3	Acidic	3	3	2-3	3	4-5	2	2
		Alkaline	2-3	2-3	3	2-3	3	1-2	1-2
	B-4	Acidic	3	2-3	3	3	4	1-2	2
		Alkaline	3	3	3	2-3	4	2	2
	B-5	Acidic	2-3	2-3	2	2-3	4-5	2	1-2
		Alkaline	2-3	3	2-3	2	3-4	1-2	1-2

Table: 3 Colour Fastness to perspiration

3.4 Colour Fastness to rubbing

ISO 105-X12:2016 method has been used for determining the colour fastness to rubbing in this experiment. Both of the dyed fibre is taken into consideration in case of dry and wet conditions. The dyed fibre is rated in a 5 scale rating system. The staining is graded using the 1-5 scale rating system using the Grayscale of colour staining where 5 being used as excellent with no staining and 1 being very poor with higher rubbing fastness.

From table 4 the colour fastness to perspiration can be summarized. The table clearly shows that the rubbing fastness is moderate to good for the dry condition but fails in wet condition. The staining is also high especially for the PA, PET and AC fibres in wet condition. Due to having a higher dry rubbing rating and comparatively lower wet rubbing the fibre can be utilized in the domestic upholstery, carpet or curtain fabric being infused with other cellulosic fibre like cotton or jute.

Dye	Sample	Rubbing Condition	Shade Change
Basic	B-1	Dry	5-4
		Wet	3-2
	B-2	Dry	5-4
		Wet	3
	B-3	Dry	4
		Wet	3-2
	B-4	Dry	5-4
		Wet	3
	B-5	Dry	5
		Wet	3

Table: 4 Colour Fastness to rubbing:

3.5 Colour Fastness to Light

ISO 105-B02:2014 has been utilized for determining the lightfastness rating. The lightfastness rating has been done using the 1-8 scale rating using the greyscale. The rating 8 indicates outstanding, 7 indicates excellent, 6 indicates very good, 5 indicates good, 4 indicates fair, 3 indicates moderate,2 indicates poor and 1 being very poor.

Table 5 shows the excellent to very good lightfastness rating of the basic dye. The blue scale rating also represents that the basic dye on the banana can withstand UV radiation. Due to this excellent lightfastness rating, its use in domestic fabric like drapes and curtain is very suitable. Being cheaper and available with the excellent properties of Banana fibre this dye poses a huge potential in this field.

Dye	Sample	Blue Scale Rating	Average
	D-5	7-8	
Basic	B-1	7-8	7-8
	B-2	7-8	
	B-3	8	
	B-4	7-8	

Table 5: Colour Fastness to Light

3.6 Fibre strength assessment

Fibre strength is the strength of the individual fibre. The Banana fibre used in this experiment has been gone through a series of wet processing methods which have affected its bundle strength. Due to this the fibre strength has been determined in terms of gram/Tex. Stelometer has been utilized for this purpose.

From table 6 it has been determined that the fibre strength has gradually decreased due to the fibre treatment. Scouring and bleaching reduce the fibre strength to a greater extent whereas dyeing has reduced the fibre strength to a lesser extent.

Material	Breaking load	Weight in Bundle (mg)				Strength in zero gauge (gm/Tex)			
		S-1	S-2	S-3	Avg	S-1	S-2	S-3	Avg
Raw	4	1.81	1.77	1.83	1.8	25.38	25.8	26.67	26.243
Scoured Bleached	4	2.41	2.46	2.45	2.43	19.51	19.92	19.845	19.68
Basic	4	2.48	2.53	2.46	2.5	18.61	19.1	18.573	18.88

Table 6: Fibre strength

IV. Conclusion:

Banana fibre having hemicellulose property supposed to show a good colour absorbency and depth in the shade. The dye uptake of the fibre is quite satisfactory and thus the shade obtained is very vivid. In this study, a clear picture has been drawn to determine its fastness properties against washing, rubbing, perspiration and light. The lightfastness of the dye for the banana is quite satisfactory while a poor fastness rating has been found both in the case of wash, perspiration and rubbing. The use of the Basic dye-infused fibre is applicable in the area where lower washing and perspiration fastness is involved. But for improving the wash fastness treatment of the fibre mordanting or coupling can be suggested.

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