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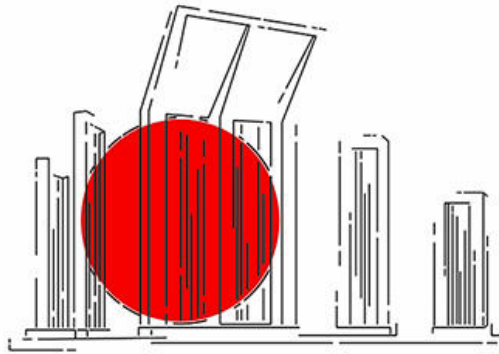
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This Volume of
Journal of Natural Science and Textile Technology
is dedicated in honor of the Martyrs of International Mother Language Day
of 21st February 2022

MESSAGE FROM THE CHIEF PATRON

I am delighted to learn that Department of Textile Engineering of Northern University Bangladesh is going to launch its own journal recognized by ISSN authority. The Journal of Natural Science and Textile Technology will create an opportunity for the researchers to share their work and achievement in words. It is dignified to be a part of this journal that contains authentic researches in the field of textile sector. It is a milestone in the academic development of the university where NUB has become one of the most reputed institutions of higher education that provides promised quality education by skilled and qualified faculties of the university. A very dynamic administrative staff is here to ensure positive environment in the campus. The effort of writing scholarly articles by the faculties will enhance their wisdom and expertise. This journal will represent collective thinking of innovative ideas will enrich research field and also promote quality education of NUB. Department of Textile Engineering of Northern University Bangladesh will certainly move one step forward by publishing this journal. The combined efforts for the successful implementation of this journal is appreciated and prayed the gradual development of this journal in the coming days.

Prof. Dr. Abu Yousuf Md Abdullah
Chairman, NUBT

MESSAGE FROM THE CHIEF ADVISOR

It is with great pride, enthusiasm, and anticipation that I invite you to read the inaugural issue of the very first Journal of Textile Engineering Department titled “Journal of Natural Science and Textile Technology”.

The motto of this publication is to provide a space for the generation of knowledge, critique, and collaboration among all faculties. The immediacy of the publication makes it possible for us all to be fully connected to each other and to developments in our field and to be directly involved in ongoing knowledge creation. The vision of the journal is to create a high-quality publication that will be relevant, challenging, thought-provoking, and inclusive of a diverse range of voices and perspectives, researchers and scholars. Every year, the faculties publish numerous research articles in renowned journals all over the world. Northern University Bangladesh is also preparing to host an international conference in liaison with other universities from home and abroad. NUB has formed collaboration with Wuhan University, China and DKTE’s Textile and Engineering Institute. We are extremely pleased that our inaugural journal of “Journal of Natural Science and Textile Technology (JNSTT)” will help the faculty members keeping themselves up to date with latest advancements in their respective fields.

I wish to express my appreciation to the journal committee.

Prof. Dr. Anwar Hossain

Vice Chancellor, Northern University Bangladesh

MESSAGE FROM EDITORIAL BOARD MEMBER

I am honored to be a part of the journal of “Journal of Natural Science and Textile Technology” that published by Northern University Bangladesh and NUB research center. Research in textiles sector is very essential because during several years the garment industries specially in Bangladesh have evolved in terms of safety, industrial relations and transparency with export earnings crossing US\$37 billion with new markets beckoning possibilities where compliance being placed as the highest priority with sustainability being considered as crucial. Challenges around the industry have become multi fold like the synchronization between wage and skill, new market expansion, efficiency and resource optimization, innovation requirements, challenges of 4.0 industrial revolution, capacity analysis, and of course, research and design continue being is the utmost priority. So, it is expected that this journal will encourage scholars to be more engaged in researches in various value chain of textile for future leading in textiles around the world. This Research Journal based on textiles will introduce new concepts, innovative technologies and processes, chemistry and sustainable systems. Also it will include research on polymers, fibers, composites, textile process improvement, smart textiles, and sustainable approach in textile sector. The efforts for publishing this journal are appreciable and will steer Northern University Bangladesh ahead to a new height of glory to ensure quality education with research for the students and publication.

Prof. Dr. Engr. Md. Zulhash Uddin

Ex-Dean, Faculty of Textile Chemical Engineering, Bangladesh University of Textiles
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CHIEF EDITOR'S NOTE

Journal of Natural Science and Textile Technology (JNSTT) is a new peer reviewed journal published by Department of Textile Engineering of Northern University Bangladesh and NUB Research Center. JNSTT provides an opportunity to recognize research articles related to the fields of fiber technology, yarn and fabric technology, dyeing and finishing technology, green environment technology and so on. The objective of JNSTT is to publish high-quality and original research papers alongside relevant and insightful reviews of Textile. Papers that are submitted, either individually or collaboratively, are much appreciated or will make a substantial contribution to the early development and success of the journal. In the 1st volume and 1st issue of this journal, there are different research articles of textile discipline. One article is based on garment solid waste where researchers (Sraboni Ahmed, et.al.) tried to provide an overall idea about the types and amount of solid waste generated each year from various factories and the finding was that proper waste management can ensure maximum utilization of the solid waste with potential recyclable materials. Some articles are based on different dyeing technology with synthetic dye and natural dyes. Md. Tofazzal Hossain, et.al. showed the impact of liquor ratio on different properties dyed cotton fabric with reactive dye and found, the color strength, fixation, and exhaustion were higher at liquor ratio where the fastness was better at a higher liquor ratio expect light fastness shows better results at lower liquor ratio. Researcher Nusrat Jahan and her team worked on sustainable dyeing technique of jute fabric with natural dye sources. Impact of Sewing thread Count on Seam Strength was another research where researchers (Md. Mazharul Islam, et.al.) found that finer count in indirect system sewing thread gives higher seam strength and the seam produced with chain stitch has the higher seam strength than seam produced by lock stitch seam. Colorimetric analysis and fastness rating of natural Yellow color Dyes on cotton fabric is another research article researched by Jannatul Ferdush, et.al that observed color-coordinate value and fastness properties of dyed samples with natural dyes using different mordants. One review article of G.M Faysal presented the green composite material production process by using the high melting point natural fibers. Another research of Nasif Chowdhury, et.al. is based on antimicrobial finishing and current developments in antimicrobial finishing, covered to minimize the risks associated with the application of organic and inorganic antimicrobial finishes and plant-based antimicrobial finishes. Thank in advance to all researchers for the contribution to the Journal of Natural Science and Textile Technology.

Md. Tanjim Hossain

Assistant Professor and Head Department of Textile Engineering, NUB

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Impact of Liquor Ratio on Color Uptake and Fastness Properties of Reactive Dyed Cotton Fabric

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Abstract

This study shows the impact of liquor ratio on color strength, exhaustion, fixation, and various fastness properties of reactive dyed cotton fabric. Here, two reactive dye such as Reactive Yellow 145 and Reactive Blue 250 was used to dye cotton fabric at various liquor ratios (1:4, 1:6, 1:8, 1:10, 1:12, and 1:14). Then the color fastness was assessed against washing, rubbing, perspiration and light. It was found that the color strength, fixation, and exhaustion were higher at liquor ratio 1:6 for Reactive Yellow 145 and 1:8 for Reactive Blue 250. In most cases, the washing fastness, rubbing fastness, and perspiration fastness were better at a higher liquor ratio for lower dye adsorption. In the case of light fastness, a lower liquor ratio shows better results than a higher liquor ratio.

Keywords: Liquor ratio, Color strength, Reactive dye, Color fastness, Exhaustion, and Fixation

1. Introduction

Textile dyeing is based on a mixture of various dyes used in different percentages. Thus desired shades can be obtained by mixing them with specific proportions with water. Dyes that can react chemically, forming a covalent bond with the textile substrate are known as reactive dye. Reactive dyes are becoming increasingly popular for dyeing cellulosic fibers because of their wide range of shades, brilliant color, ease of application, and excellent wash fastness properties due to strong covalent bonds. In textile industries, reactive dyes are extensively used in the dyeing process because of their availability, affordability, a wide variety of colors, and high color fastness [1]. These are the most common type of dye used for cotton fiber dyeing. This dye can react with the hydroxyl group of cellulose to form a covalent bond [2]. It happens due to the specific addition or substitution reactions within the reactive groups of reactive dyes and the hydroxyl groups of cellulose fibers. Therefore, the dye can quickly fix with cellulosic fibers and gives superior fastness properties to other dyes [3]. The dyeing of reactive dyes is influenced by a number of factors, including the alkali, electrolyte, temperature, and liquor ratio [4]. The reactivity of dyes, salt concentration, dyeing time, and material to liquid ratio influence reactive dyes exhaustion and fixation percentages. A highly reactive dye has a more significant likelihood of reacting with fiber, but it also has a higher risk of hydrolyzing. However, to acquire the best results from the procedure, the behavior of dyestuff in various constraints should be investigated.

Many researchers have been studied the effect of various parameters during the dyeing of cotton fabric using reactive dyes [5]. Haque investigated the fixing of reactive colors into cotton fabric by varying the temperature and changing the alkali concentration [6]. Rahman et al. [7] studied the effect of color percentages on different factors such as CPI, GSM, WPI colorfastness properties of reactive dyed cotton fabric. Another researcher analyzed the influence of soda on the fastness properties of reactive dyed cotton fabric [8]. However, these investigations have described the impact of dyeing of cotton fabric with one reactive dye.

In this research, the impact of material to liquor ratio on different reactive dyed cotton fabric qualities, such as color strength, exhaustion, fixation, and various color fastness features, such as color fastness to washing, rubbing, and perspiration, and light fastness, was investigated.

2. Materials and Methods

2.1 Materials

100% cotton knitted fabric of 160GSM was used for the experiment. C.I. Reactive Yellow 145 (RY 145) and C.I. Reactive Blue 250 (RB 250) dyes (Fig. 1 and Fig.2, respectively) in the commercial grade were collected from Colorchem Ltd. Bangladesh. Other chemicals such as Soda ash (Na_2CO_3), Caustic Soda (NaOH), Hydrogen peroxide (H_2O_2), Stabilizer, Glauber Salt anhydrous (Na_2SO_4), Leveling Agent, wetting agent, Sequestering Agent, Anti-creasing agent were purchased from a local market and used in this investigation without any further purification.

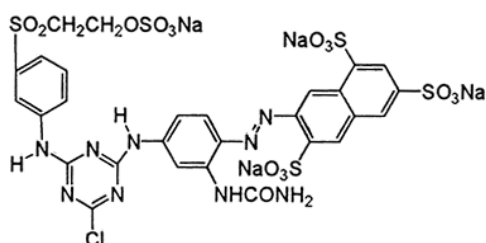


Figure 1. Chemical structure of C.I. Reactive Yellow 145

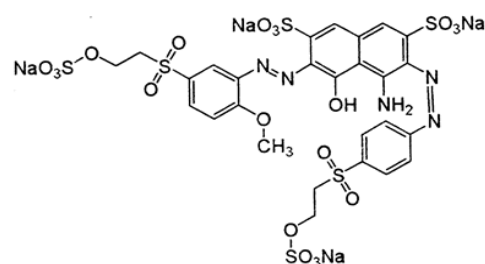


Figure 2. Chemical structure of C.I. Reactive Blue 250

2.2 Scouring and bleaching of cotton fabric

Table 1. Scouring and bleaching Recipe for cotton fabric

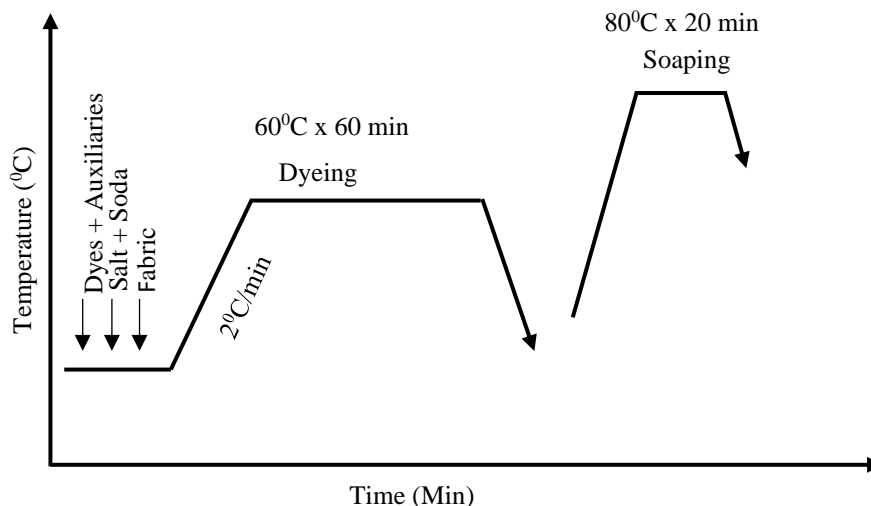
Chemicals	amount
Wetting agent	1.0 g/L
Sequestering agent	0.7 g/L
Anti-creasing agent	0.8 g/L
Stabilizer	0.3 g/L
Hydrogen peroxide	2.5 g/L
Caustic soda	2.25 g/L
Temperature	95°C
Time	50 min

The cotton fabric was Scoured and bleached at high-temperature exhaust method. 2.5 g/L hydrogen peroxide was used for bleaching (to remove natural color/grey color), and 2.25 g/L Caustic was used for scouring (to remove fat, oil, and wax) in this study. Other chemicals were used as per recipe amount, which has given in table 1. High temperature (95°C) was used for 50min to scour and bleach the fabric. Finally, neutralized the material, washed, and dried in a dryer [9].

2.3 Dyeing of cotton fabric

Table 2. Recipe of dyeing cotton fabric

C.I. Reactive Yellow 145		C.I. Reactive Blue 250	
Chemicals	Amount	Chemicals	Amount
Wetting agent	0.8 gm/L	Wetting agent	0.8 gm/L
Sequestering	0.5 gm/L	Sequestering	0.5 gm/L
Anti-creasing	0.5 gm/L	Anti-creasing	0.5 gm/L
C.I. Reactive Yellow 145	1.0%	C.I. Reactive Blue 250	3.0%
Leveling agent	1.0 gm/L	Leveling agent	1.0 gm/L
Glauber Salt	40.0 gm/L	Glauber Salt	70.0 gm/L
Soda ash	10.0 gm/L	Soda ash	15.0 gm/L
Temp.	60°C	Temp.	60°C
Time	60min	Time	60min

**Figure 3.** Dyeing process curve

Cotton fabric was dyed in a rotary infrared laboratory dyeing machine at 60°C for 60 minutes with two different reactive dyes (CI Reactive Yellow 145 and C.I. Reactive Blue 250) at various liquor ratios (1:4, 1:6, 1:8, 1:10, 1:12, and 1:14). After dyeing, the fabric was neutralized, washed with soaping agent in a shaker bath at 80rpm on 80°C for 20 minutes, and thoroughly rinsed in tap water. Finally, the dyed fabric was dried in a hot air oven dryer.

2.4 Measurement of Color strength, exhaustion and fixation percentages

The reactive dyed cotton fabric's color strength (K/S) was determined using a Datacolor 650 reflectance spectrophotometer (USA). The experiments were carried out on a machine using a D₆₅ light source and a 10° viewing geometry [10]. The reflectance of each specimen was taken in the 400–700 nm range by folding it twice, and by using the Kubelka–Munk equation, the reflectance (R) at the wavelength of maximum absorption (λ_{max}) was measured (Eqn. (1)) [11]. Three measurements were taken for each sample [12, 13].

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

Where K and S are absorption and scattering coefficients of the dyed fiber. R is the reflectance of the dyed fabric at λ_{\max} .

After every dyeing, the exhaustion rate E(%) was measured by the following equation Eqn.(2)

$$E (\%) = \frac{A_0 - A_1}{A_0} \times 100 \quad (2)$$

and the fixation rate F(%) was calculated by the following equation Eqn.(3)

$$F (\%) = \frac{A_0 - A_1 - A_2}{A_0} \times 100 \quad (3)$$

Where A_0 is the initial dye bath concentration, A_1 is dye concentration in the dye bath after dyeing, and A_2 is concentration of dye in the finish baths (mgL^{-1}).

2.5 Assessment of color fastness

Color fastness was evaluated using a variety of established testing procedures. According to ISO 105-C03 (2010), color fastness to washing was measured using the Atlas LEF Lander-Omitter (Atlas, USA). Color Fastness to Perspiration (Acid, Alkali) was investigated using an AATCC Perspirometer (Atlas, USA) in accordance with ISO 105 E04 (2013). To assess staining, a multifiber was attached to each sample in the case of their wash, perspiration fastness. The color fastness to rubbing was tested using an AATCC Crockmeter (Atlas, USA) following ISO 105-X12 (2016). Atlas-150S+ was used to test color fastness to light by ISO 105-B02 (2013) standards (Atlas, USA). For all color fastness tests without light, shade change and staining were evaluated using greyscale ratings from 1 to 5, where 5 implies no shade change. Whereas the light fastness ratings are from 1 to 8 [14].

3. Results and Discussions

3.1 Impact of liquor ratio on color strength

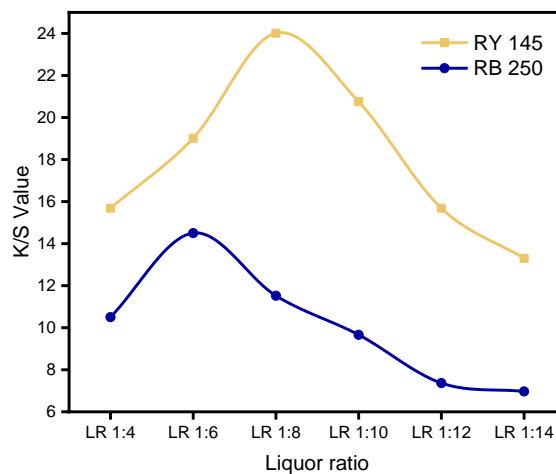


Figure 4. Impact of Liquor ratio on color strength

Color strength is the ratio of the co-efficient of absorption and co-efficient of scattering measured by a color matching system. Fig.4 represented that the color strength value increased with increasing the liquor ratio up to 1:6 and 1:8 respectively for RY 145 and RB 250. After that, it decreases gradually with a higher liquor ratio and the highest MLR 1:14 it explicit the K/S value is 8 and 13 for RY 145 and RB 250. In lower liquor ratio means higher concentration dyes become aggregate and unable to diffuse into the fiber. As a result, after soaping the unbonded dyes are removed from the fiber surface and it yields a lower color strength value. Reversely with a higher liquor ratio means a lower concentration of

dye molecule in bath, there is a chance of hydrolysis and lack of absorption due to the higher distance of each dye molecule [15]. In this investigation, 1:6 and 1:8 is the effective concentration for RY 145 and RB 250 dyes.

3.2 Impact of liquor ratio on exhaustion and fixation of dye

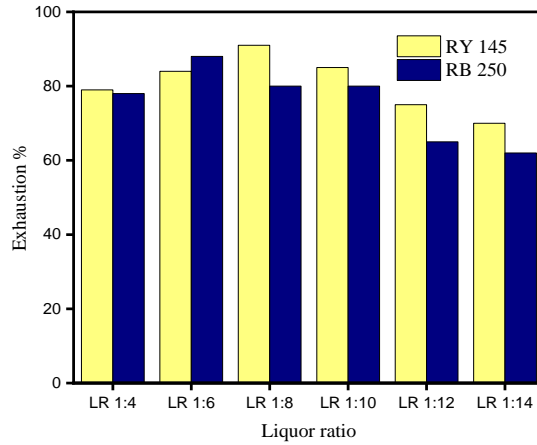


Figure 5. Liquor's impact on Reactive Dye Exhaustion in Cotton Fabric

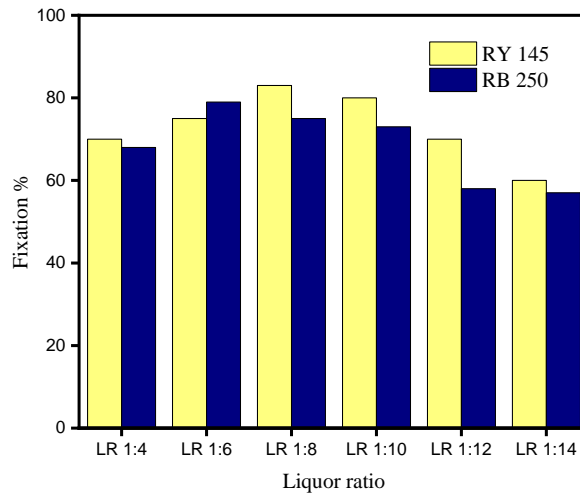


Figure 6. Liquor's impact on Reactive Dye Fixation in Cotton Fabric

Dye exhaustion indicates the amount of dye molecules transferred dye bath to the materials while fixation refers to the amount of dye bonded with the fiber. The exhausted dyes are not caused 100% fixation. Both are affected by different dyeing parameters like time, temperature, pH, material to liquor ratio, and auxiliary chemicals. Regarding this exhaustion and fixation liquor ratio is a crucial factor in dyeing. This investigation concludes that for RY 145 and RB 250 two reactive dyes liquor ratios 1:6 and 1:8 yield the best result. In the same conditions, RB 250 showed better exhaustion (90%) and fixation (80%) than RY 145 (exhaustion 85% and fixation 77%) due to their inherent properties. This result indicates that at lower liquor ratio dye exhaustion is hindered due to the high concentration of dyes and their self-attraction results aggregation. Also, the solubilization of huge amounts of dyes and auxiliary chemicals affects exhaustion. This hampered exhaustion causes a lower fixation of dyes. After effective concentration, the higher liquor ratio also showed poor exhaustion and fixation for both RY

145 and RB 250 dyes. In the higher liquor ratio, the space between dye molecules is increased and causes lower exhaustion. It happened more for low-affinity dye. Besides this, the higher liquor ratio causes hydrolysis of reactive dye and this greatly affects exhaustion and fixation of dyes [15, 16].

3.3 Impact of liquor ratio on color fastness to washing

Table 4. Color fastness to washing

Dyes		Liquor Ratio					
		1 : 4	1 : 6	1 : 8	1 : 10	1 : 12	1 : 14
C.I. Reactive Yellow 145	Change in color	4	4	4	4	4-5	4-5
	Staining	3-4	4	4	4	4	4
C.I. Reactive Blue 250	Change in color	4	3-4	3-4	4	4	4
	Color Staining	3-4	3-4	3	3-4	4	4

The fastness properties of dyed materials depend on the dye fiber bond formation. Regarding this physical theory of dyeing state that stronger bonds have higher fastness properties will exhibit. Also, the larger size and lesser the solubility of dye yields better fastness. According to Table 4, the consequence of all fabric's color staining and color change value is nearly the same but the values of a higher liquor ratio showed a slightly better result than liquor ratio 1:6 or 1:8. This happened due to there is not enough dye to be stained or reduced in lighter shade yields at higher liquor ratio.

3.4 Impact of liquor ratio on color fastness to rubbing

Table 5 shows that the color staining and color change values of all textiles are approximately similar for colorfastness to the rubbing test. Dye molecules that are adhered to the fabric surface with a less strong bond or without chemical bond cause staining. At a lower liquor ratio dyes molecule become aggregated and adhere to the surface of the fabric without proper bonding. Aggregated dye molecules are unable to diffuse into the fiber which leads to poor rubbing fastness. But higher liquor ratios give better results both for dry and wet rubbing fastness because the dyed surface contains fewer dye particles.

Table 5. Color fastness to Rubbing

Dyes		Liquor Ratio					
		1 : 4	1 : 6	1 : 8	1 : 10	1 : 12	1 : 14
C.I. Reactive Yellow 145	Dry	4-5	4-5	4-5	4-5	4-5	4-5
	Wet	3-4	3-4	3-4	3-4	4	4
C.I. Reactive Blue 250	Dry	4-5	4-5	4-5	4-5	4-5	4-5
	Wet	2-3	2-3	2-3	2-3	3	3

3.5 Impact of liquor ratio on color fastness to perspiration

Table 6. Color fastness to perspiration (Acid and Alkali)

Dyes	LR ratio	Acid		Alkali	
		Color change	Color staining	Color change	Color staining
C.I. Reactive Yellow 145	1:4	4	3	4	3
	1:6	4-5	3-4	4-5	3-4
	1:8	4-5	3-4	4-5	3-4
	1:10	4-5	3-4	4-5	3-4
	1:12	4-5	3-4	4-5	3-4
	1:14	4-5	3-4	4-5	3-4
C.I. Reactive Blue 250	1:4	3-4	3	3-4	3
	1:6	3-4	3	3-4	3
	1:8	3-4	3	3	2-3
	1:10	4	3-4	4	3-4
	1:12	4	3-4	4	3-4
	1:14	4	3-4	4	3-4

The perspiration fastness of both acids and alkalis for RY 145 and RB 250 are almost the same except 1:4 of RY 145. Additionally, Table 6 provides a micro indication of lower value of color change and staining at lower liquor ratio due to higher exhaustion than higher liquor ratio. In the case of both dyes, RB 250 showed perspiration fastness to acid and alkali lower than C.I Reactive Yellow 145 due to the higher shade percentage of RB 250. More dye in the fabric surface with less strong bond has the possibility of poor perspiration fastness.

3.6 Impact of liquor ratio on color fastness to light

Color fastness to light depends on the structure of the dye. The unsaturated loosely held electron in the dye molecule causes poor results. But regarding liquor ratio, the strong bond yields better results. Also, the higher exhaustion and fixation comparatively lower liquor ratio without aggregation produce deeper shade and the lighter fading seems negligible while the little change in the light shade has great impact. In this study liquor ratios, 1:6 and 1:8 for RY 145 and RB 250 showed better results. Between them, the light fastness of RY 145 was higher than that of RB 250, as seen in Fig. 7 RY 145 provides the best light fastness at a liquor ratio of 1:6, whereas RB had a light fastness of 6 at a liquor ratio of 1:8.

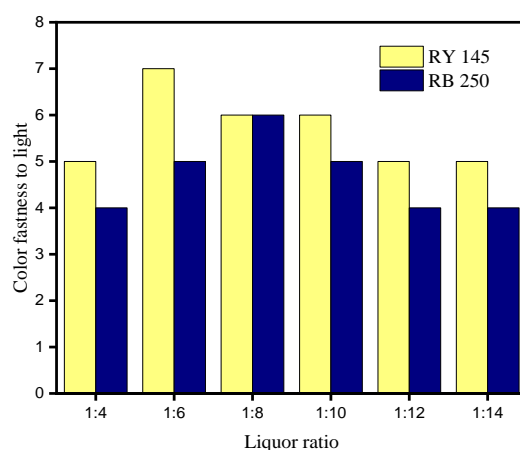


Figure 7. Impact of liquor ratio on light fastness

Color fastness to light depends on the structure of the dye. The unsaturated loosely held electron in the dye molecule causes poor results. But regarding liquor ratio, the strong bond yields better results. Also, the higher exhaustion and fixation comparatively lower liquor ratio without aggregation produce deeper shade and the lighter fading seems negligible while the little change in the light shade has great impact. In this study liquor ratios, 1:6 and 1:8 for RY 145 and RB 250 showed better results. Between them, the light fastness of RY 145 was higher than that of RB 250, as seen in Fig. 7. RY 145 provides the best light fastness at a liquor ratio of 1:6, whereas RB 250 had a light fastness result is 6 at liquor ratio of 1:8.

4. Conclusions

This research investigates the impact of liquor ratio on two reactive dyes (C.I. Reactive Yellow 145, C.I. Reactive Blue 250) dyed cotton fabric. The optimal liquor ratio has been determined according to the color strength and different fastness properties. Color strength, exhaustion, and fixation were increased with increasing liquor ratio 1:6 for C.I. Reactive Yellow 145 and 1:8 for C.I. Reactive Blue 250. The improvement of the color strength can explain this phenomenon at a high liquor ratio and the adsorption of dyes in the fabric. The color fastness to washing, rubbing, and perspiration better resulted in a nearly higher liquor ratio. The color fastness to light was the best result at a lower liquor ratio than a higher liquor ratio.

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Conflict of interest

All authors are confirming that there is no conflict of interest of this work

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A Survey on Solid Waste Management in Garments Industry of Bangladesh

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Abstract

Management of solid wastes produced in the garments industry by reducing, recycling, and disposal is a significant matter of concern. Garment industries will continue to produce a large number of solid wastes each year. With increasing solid garment wastes the cost of management is increasing with the depletion of available disposal facilities. This remaining residue is a burden unless it is disposed of properly. In this study, we aimed to identify the present situation associated with the management of solid wastes generated from garment industries. The efficiency of solid waste management is dependent on proper management, recycling, available resources for disposal and the willingness of concerned authority. With location, seasons, and industry type solid wastes generation varies. Regardless of those facts recycled wastes possess economic value if they can be collected and reused correctly. The existing barriers to collecting, recycling, reuse and disposal of different wastes include costing, proper planning for reusing of recycled materials, suitable technology and awareness.

Keywords: Textile Industry, Solid Garment Waste, Solid Waste management, Recycling and Disposal, Environment.

1. Introduction

Management of waste depends on social and technological advancement. Depending on the amount and type of wastes, available facilities and disposal capacity wastes management may vary. Minimizing waste generation and environmental protection can be achieved by technological advancement. Before discharging to the environment the effluents and other wastes must be treated as per requirements using the suitable technology.

Clothing demand has grown by 30 times since the 1950s as reported [1]. With this growing demand, solid waste production is also growing. Waste generation is growing with increasing consumption of textile products worldwide. The majority amount of textile waste can be recycled if proper measures are taken. According to the source, textile wastes can be classified as post-consumer waste and pre-consumer waste. Unlike underdeveloped countries, the developed countries have effectively created environmental awareness, social responsibilities in waste management practices being more efficient. The burying of recyclable waste has been prohibited in European Parliament [2].

In most cases, management considers landfilling as a means of waste disposal rather than available and effective waste management systems. Turkey has set an example of recycling 84% of total textile waste as a part of effective waste management as reported in 2008, while in Lithuania 71% ended up in landfills [3]. This ineffective management was due to the lack of equipment and technology. Being a cheaper way of disposal landfilling also did not trigger the authority to find new disposal solutions [4]. The textile and clothing industry is the backbone of Bangladesh's economy for a long time. Due to low labor cost, minimum skill requirements of labor, and relatively available technology garments industry in Bangladesh has grown for over decades [5].

The solid waste significantly impacts on the environment. The responsibility of the industry is to minimize the impacts on the environment caused by their production processes. The majority of

solid wastes are produced during the garment manufacturing stage and the higher the production, the greater the amount of waste. From the economic point of view, apparel industries have a significant contribution to the economy of Bangladesh. Solid waste directly impacts on the environment and social life due to improper disposal system. Solid wastes from apparel industry have potential application if it is recycled properly. Solid waste generation can be increased depending on manufacturing operations. The Knit apparel industry itself requires a minimum disposal area of 3.155 km of which only 40% of cleanliness capacity is available in the industry [6].

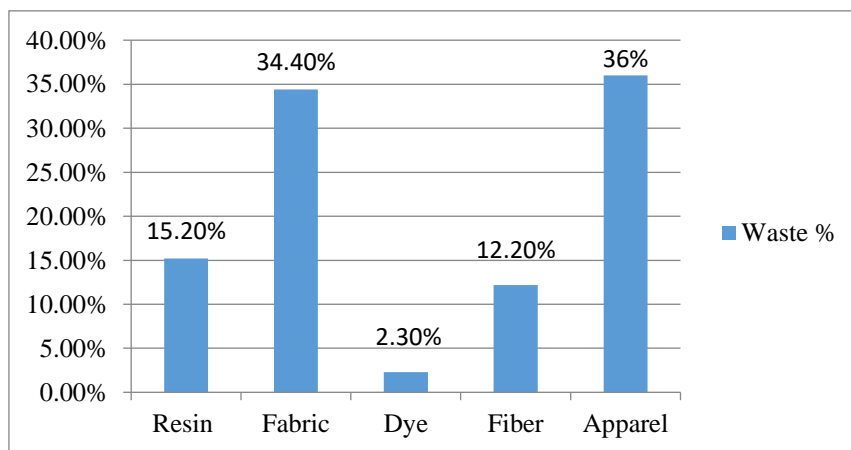


Figure 1. Maximum solid waste generation stages [7]

Land being filled and water bodies were polluted due to just throwing away the solid waste around the factory area. Solid wastes are not collected completely. A significant amount of wastes are disposed of by dumping which causes pollution and environmental hazard^[7]. Bangladesh is dependent on importing from overseas to run garment industries. Instead of throwing away if the solid waste processed properly it can provide as a source of raw material and save money and materials.

This survey aimed to find out the present statistics and existing management regarding solid waste disposal and its utilization in the textile industry of Bangladesh.

1. Finding out the current status of the solid waste management system.
2. Finding out the impact of recyclable solid waste as a source of starting materials for final product.
3. Finding out the impact of solid waste management regarding environmental issues and solid waste disposal.

2. Research strategy

This survey is based on selected questionnaires asked to the different garments factories in Bangladesh.

2.1 Research Design

In our current survey, we have directly collected information from various industries regarding solid waste and used it as primary source of information. As a secondary source, supporting information has collected from different journals and research articles regarding solid waste management.

2.2 Target Population and Sample Size

About 50 factories were targeted from various areas in Bangladesh to study and analyze the present condition of solid waste management.

2.3 Data Investigation Procedure

Information collected from different factories was investigated and analyzed using regular computer software and represented as a bar diagram.

$$Frequency\% = \frac{frequency}{population} \times 100 \tag{1}$$

3. Results and Discussions

Five parameters were taken to analyze and represent survey results using a bar diagram.

3.1. Waste Disposal Practices

Most of the manufacturers were unaware of proper waste management practices. Now a day, manufacturers recycle their waste and make yarn from the recycled fiber. Our study shows that around 50% of the garment manufacturers recycle their solid waste and the rest of the wastes are either sold or disposed of by stockpiling, landfilling and incineration.

Table 1. Details about Waste Disposal Practices

What does your company prefer in case of waste processing?		
Response	Frequency	Percentage
Landfilling	9	18%
Incineration	5	10%
Recycling	7	14%
Stockpiling	2	4%
Selling to Buyers	25	50%
Others	2	4%

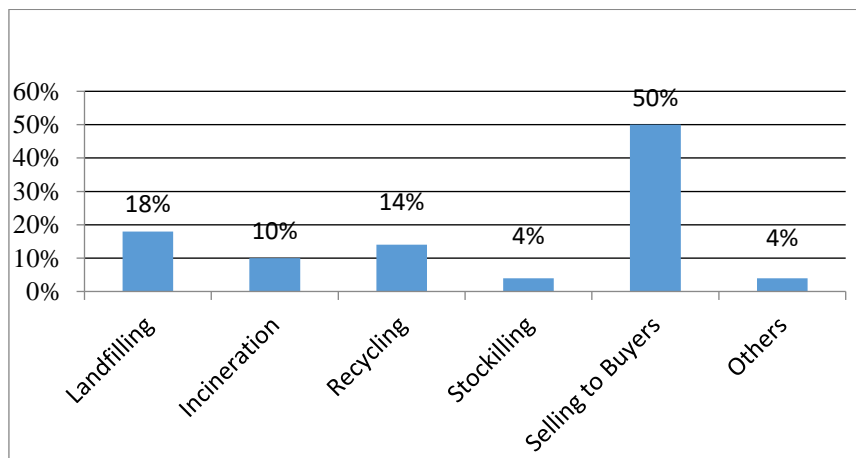


Figure 2. Waste Disposal Practices

3.2 Barriers to Recycling

Despite being potential raw materials solid wastes are not recycled effectively in most factories due to some existing barriers namely shortage of technology and equipment, skilled manpower, lack of awareness about the impact of wastes material on environment. Suitable technology was the main barrier to recycling and accounted for 42% as indicated by the management. Similarly, shortage of tools, consumer awareness, materials, production costs were accounted for 26%, 16%, 10%, and 6% respectively.

Table 2. Details about Barriers to Recycling

What are the barriers to recycling?		
Response	Answer Given	Percentage
Lack of equipment	13	26%
Lack of Technology	21	42%
Lack of material	5	10%
Lack of consumer awareness	8	16%
Production costs	3	6%

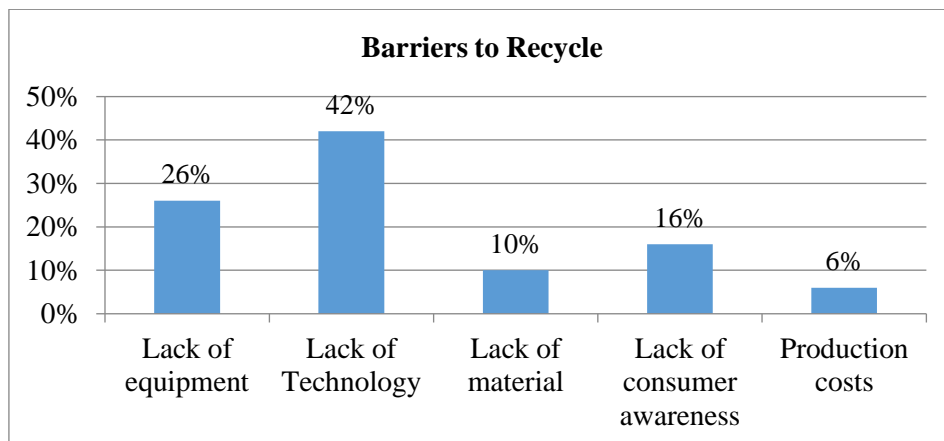


Figure 3. Barriers to Recycle

3.3 Pricing Strategies

The pricing of recycled materials must be compatible with product quality to sustain the market. Due to high production costs, the prices of recycled goods remain high. The opinions about pricing from the various organizations represented below.

Table 3. Details about recycled product compared to product from new raw materials

What would be the price of recycled product compared to product from new raw materials?		
Response	Frequency	Percentage
Low end	7	14%
Low to moderate	21	42%
Moderate	16	32%
Moderate to high	4	8%
High	2	4%

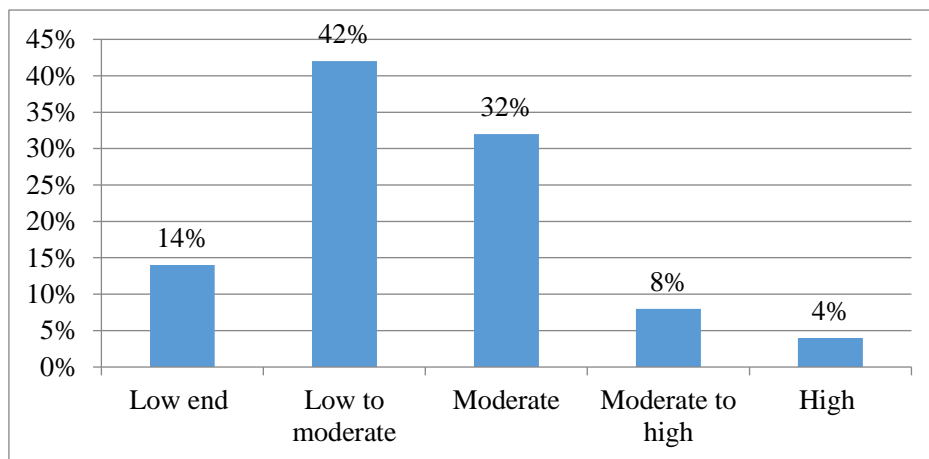


Figure 4. Price of Recycled Product Compare to Product from New Raw Materials

3.4 Promotional Strategy

About 38% were agreed about similar costs regarding promotion; while slightly less and slightly more costing was recommended by 26% and 18% respectively to compensate profit margin. About 12% of the respondent thought that the promotional cost would be significantly less whereas 6% of the respondent thought that the promotional cost would be significantly more than the product from new raw materials.

Table 4. Promotion Cost of Recycled Product Compared to Product from New Raw Materials

What would be the promotion cost of recycled product compared to product from new raw materials?		
Responses	Frequency	Percentage
Significantly less	6	12%
Slightly less	13	26%

About the same	19	38%
Slightly more	9	18%
Significantly more	3	6%

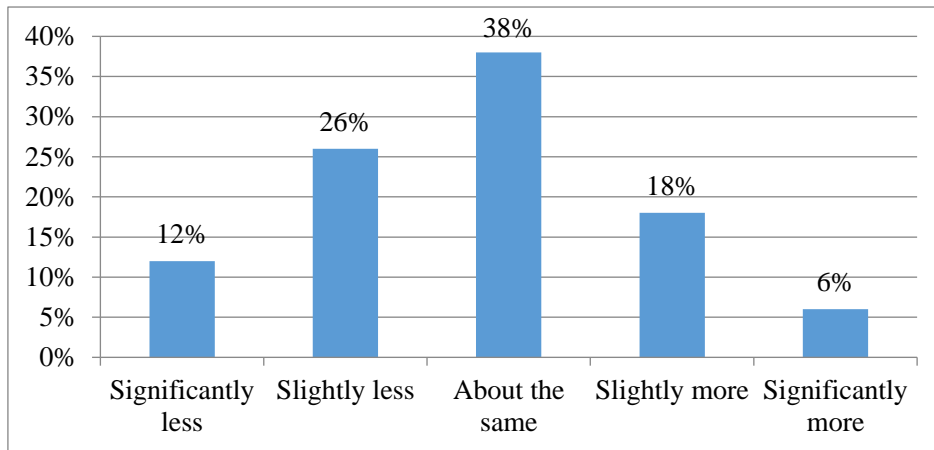


Figure 5. Promotion Cost of Recycled Product Compared for Product from New Raw Materials

3.5 Environmental Issues of Solid Waste Disposal

The material to which we call solid waste among them fabric pieces, jhuts, and paper bags are important. Cotton-based fabrics are usually biodegradable and others made of non-biodegradable materials sustain on the earth for many years that cause soil pollution. Such non-biodegradable materials are polythene, polyester etc. can sustain for more than 500 years in the soil and highly detrimental to the fertility of land. The paper bags which are used for packing the garments are biodegradable. Nearly 10% were positive regarding thus case of environmental issues while 22% think it’s not much detrimental. But almost (44%) respondents claimed it as harmful. But only a few (6%) were more cynical that they declared it as highly harmful to environment. Among these problems some shows us hope that the solid waste can be bio degradable and their number is about 18%.

Table 5. Details about environmental issues of solid waste

How much extent it is harmful if it is thrown away in the environment?		
Response	Frequency	Percentage
Degradable	9	18%
Less harmful	5	10%
Moderately harmful	11	22%
Harmful	22	44%
Hazardous	3	6%

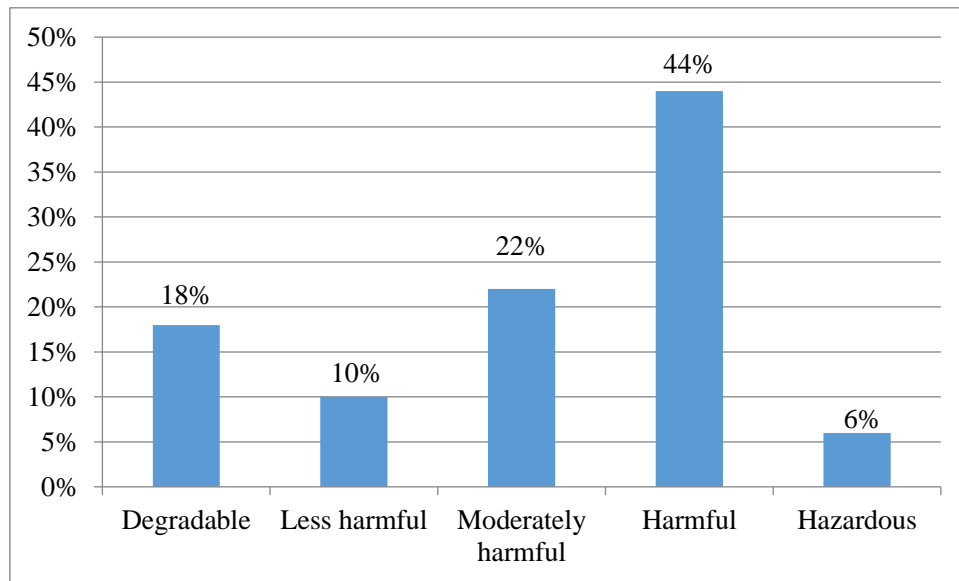


Figure 6. Environmental Issues of Solid Waste

4. Conclusions

Management of wastes becomes an essential part of the garments factory. With the growing production of finished products, solid wastes are generating in significant quantity with the potential to pollute the environment. For maximum utilization of wastes, an ideal waste management system must be practiced to make this sector beneficial. Large scale and efficient recycling needed to be practiced so as to meet the increasing solid wastes. An efficient recycling method will provide opportunities to maximum wastes recycling and utilization.

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All the data regarding the solid waste management was collected from various factories. Specially would like to acknowledge the personnel from Masco group who helped me very cordially.

Conflict of interest

All authors are confirming that there is no conflict of interest of this work.

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Impact of Sewing Thread Count on Seam Strength

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Abstract

In a garment the strength of seam assembly is termed as Seam strength. Among some other factors, Seam strength is basically functioned by the strength of the thread, type of fabric used for the seam and type of seam in a garment. Breaking of sewing thread or tearing of the fabric at the seam or excessive slippage of yarn to the adjacent stitches or a combination of the aforementioned conditions can cause the failure of seam. The objective of this study is to find out the effect of different sewing thread count on the strength of seam. For this experiment, a fabric having construction (EPI: 75, PPI: 42, Warp count: 10 Ne and Weft count: 8 Ne) has been selected. Then, the samples have been prepared according to ISO 13935-2:1999 method. After that, seam strength of all the samples have been tested using seam strength tester. For this experiment, different stitch like lock stitch 301, chain stitch 401 and different sewing thread count 20/2 Ne, 20/3 Ne & 40/2 Ne have been selected. Finally, the seam strength reports are collected from the machine. From the result, it can be said that if finer count in indirect system sewing thread is used for sewing, higher will be the seam strength. Moreover, the seam produced with chain stitch has the higher seam strength than seam produced by lock stitch seam.

1. Introduction

Stitches and seams are basic constituent of a quality garment. These are responsible to give the apparel a shape for wear by joining different components of apparel [1]. The overall performance of any garments in use are basically rely on the seam quality especially strength of seam [2]. A process of transforming two-dimensional fabric into three-dimensional clothing by assemble two or more pieces together is defined as Seam [3]. Sewing is the joining of two or more fabric pieces by using sewing machines, sewing threads and various types of stitching methods [4]. The main raw-materials of garment is sewing thread and fabric. The quality of seam in a garment is influenced by the properties of raw material and the quality of fabric does not fulfil all the criteria alone for preparing high quality garments [5, 6]. So, selection of proper raw material not only provides comfort to the wearer but also it helps in smooth functioning of manufacturing process and finally lead to fault free product [7]. In apparel industry, the quality of seam is evaluated by means of its elongation, efficiency, bending, strength of seam, stiffness, resistance to abrasion, and damage of seam. A good seam having different aesthetic and functional requirements and the functional performance of seam is evaluated by efficiency, elongation, bending stiffness, and resistance to washing and resistance to abrasion of seam. The durability of Seam depends on strength and seam efficiency along with the appearance of the seam [8]. Seam strength is the strength of seam assembly in apparel which is functioned by the strength of the thread, type of fabric used for the seam and type of seam assembly in apparel. It is essential to select the appropriate type of Sewing thread, seam and sewing conditions for getting a quality product [9]. Some research work has been performed on seam strength analysis. Researchers found that fabric tensile strength, density, thickness, rigidity to bend, rigidity to shear and extensibility have great impact on seam quality [10]. In other study, researcher observed that, the seam strength and efficiency increase when the stitch density increases [11]. Researcher Nasif found that, the seam strength, seam efficiency and seam elongation decrease with the increase of needle size. In the study, approximately 5% tensile strength of seam is reduced with the increase of needle size from 12 to 16[12]. Some researcher analyzing the seam strength considering the characteristics of PES-PTFE air-jet-textured sewing

threads. Seam breaking force for the PES-PTFE threads depends directly on the manufacturing parameters and maximum breaking force is obtained using core threads overfeed and mean air pressure [13]. The existing studies about seam strength does not consider the thread count. Specific seams are suitable for particular fabrics because each fabric has its own unique properties. As fiber content and thread count play a role in seam strength and hence garment quality. So, this study is planned to investigate the effect of sewing thread count on the seam strength.

2. Methodology

The analysis of seam strength was carried out on a woven fabric having construction of EPI: 75, PPI: 42, Warp count: 10 Ne and Weft count: 8 Ne. Then, the samples have been prepared according to ISO 13935-2:1999 method. The fabrics were sewn by using two types of stitch namely lock stitch 301, chain stitch 401 using three types of sewing thread (Count:20/2 Ne, 20/3 Ne & 40/2 Ne). After that, seam strength of all the samples have been tested using seam strength tester. Finally, the seam strength reports are collected from the machine.

3. Results & Discussions

In this research work, seam strength of a superimposed seam having different sewing thread count has been measured. The results are summarized below:

Table 1. Comparative study on seam strength based on seam & stitch type.

Stitch types	Sewing thread count	Observations	Seam strength of Warp (N)	Avg. seam strength Warp (N)	Observations	Seam strength of Weft (N)	Avg. seam strength Weft (N)
301	20/2 Ne	1	150.63	130.75±15.17	1	114.42	125.07±15.77
		2	133.41		2	122.78	
		3	124.39		3	116.90	
		4	119.09		4	124.69	
		5	126.22		5	146.55	
	20/3 Ne	1	415.54	400.39±16.19	1	123.30	130.79±12.58
		2	387.61		2	118.59	
		3	396.69		3	139.63	
		4	389.33		4	142.13	
		5	412.78		5	130.29	
	40/2 Ne	1	143.48	144.2±8.22	1	104.03	119.06±16.67
		2	145.85		2	118.06	
		3	133.19		3	107.92	
		4	149.42		4	133.79	
		5	149.11		5	131.52	
401	20/2 Ne	1	144.67	138.14±13.14	1	113.09	117.52±16.03
		2	140.74		2	118.41	
		3	126.89		3	130.17	
		4	150.85		4	127.90	
		5	127.56		5	98.01	
	20/3 Ne	1	400.29	350.34±71.19	1	163.91	148.92±20.43
		2	371.14		2	123.83	

	3	389.75		3	150.19	
	4	258.92		4	163.12	
	5	331.60		5	143.53	
40/2	1	275.25	296.51±	1	142.23	145.03±
Ne	2	311.08	49.82	2	120.94	20.82
	3	265.60		3	155.33	
	4	269.86		4	141.16	
	5	360.78		5	165.49	

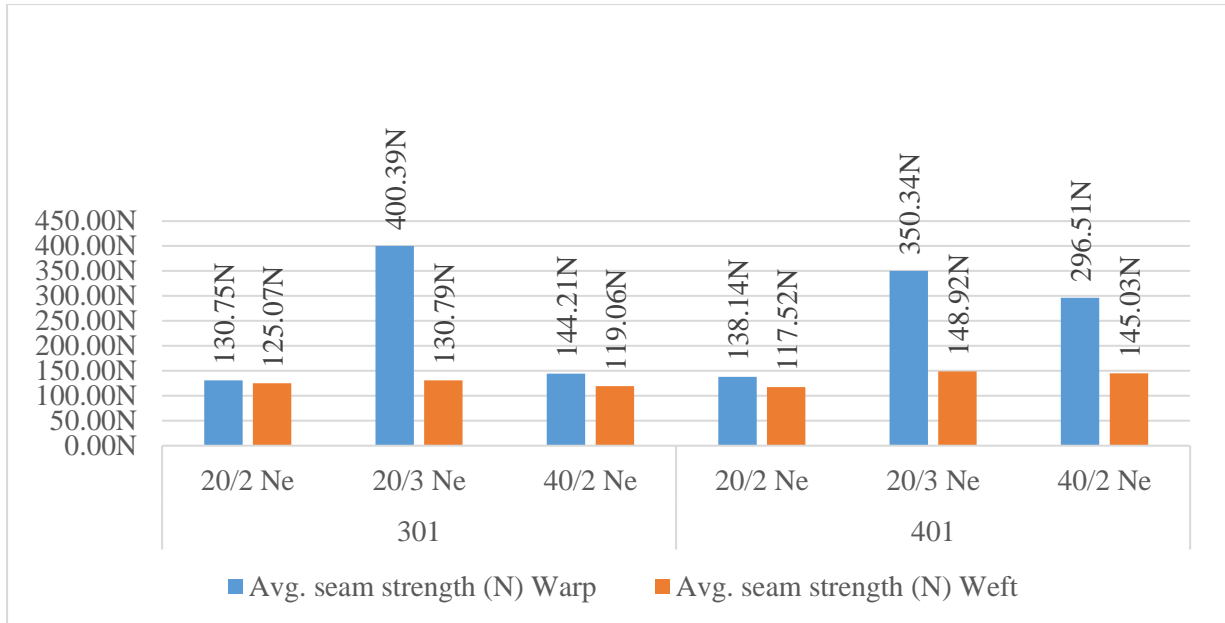


Figure 1. Comparative study on seam strength based on sewing thread count & stitch type.

Table 1 & figure 1 illustrate a comparative study on seam strength based on seam & stitch type. Average seam strength value of warp in case of single needle lock stitch stood at 130.75N for 20/2 Ne sewing thread. Which increased significantly to 400.39N in case of 20/3 Ne lock stitch, followed by the lowest value 144.21N for 40/2Ne lock stitch seam. On the other hand, average seam strength value of weft in case of single needle lock stitch stood at 125.07N for 20/2 Ne sewing thread. Which increased steadily to 130.79N in case of 20/3 Ne lock stitch, followed by the lowest value 119.06N for 40/2Ne lock stitch seam.

However, for chain stitch; the seam strength value stood at 138.14N and it dramatically increased to 350.4N. Finally, it fell steadily to 296.5N for 40/2Ne chain stitch seam. But for weft seam, the seam strength value stood at 117.52N and it dramatically increased to 148.92N. Finally, it slightly decreased to 145.03N.

Overall, 20/3 Ne sewing thread has the highest value of seam strength for both lock & chain stitch and also for warp & weft seam. So, it can be said that if finer count in indirect system sewing thread is used for sewing, higher will be the seam strength. Moreover, the seam produced with chain stitch has the higher seam strength than seam produced by lock stitch seam.

4. Conclusions

From the results, it is concluded that sewing threads of various count and stitch will show different results on seam strength. Sewing thread of finer count will show higher seam strength and chain stitch

will show higher seam strength than seam produced by lock stitch. As stitch types and selection of sewing thread has a great impact on the strength of seam, so suitable sewing thread and stitch must be chosen to ensure better quality garment or end product. In addition, the seam strength should be tested to assure that it meet the ISO/ASTM standards before entering the global market to enable customers to choose the garment as per their desired quality.

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Conflict of interest

All authors are confirming that there is no conflict of interest of this work.

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Sustainable Dyeing of Jute fabric with Natural Dye Sources by Cold Pad Batch Technique

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Abstract

Jute is popularly known as perishable, reusable and ecological friendly fiber having golden & silky shine appearance; therefore termed as the Golden fibre in Bangladesh. Jute is budget friendly vegetable fiber procure from the bast or skin of the plant's stem and most important fiber after cellulosic cotton fibre in terms of variation in usage, universal consumption generation & availability. Natural dyestuffs are popular now days for sustainable issues in textiles industries. This research was focused on environment friendly natural dyeing technique on jute fabric with natural dye sources through cold pad batch (CPB) dyeing technique. Java plum fruit, kadamba flower & malbar spinach vegetable were selected as natural dye sources and extracted dye liquors using methanol solvent. Evaluated dyed samples by color co-ordinate values by spectrophotometer where lighter to darker shades were achieved on dyed Jute samples with the dye extracts and K/S value was analysis to assess color strength among dyed samples. Different Color fastness test was done to find better dyeing performance on jute where sample dyed with malbar spinach vegetable extract showed better performance compared to other dye extracts. Moreover, the research was intended to observe dyeing possibilities of jute fabric with natural sources without focusing on mordant for opening a new export area of sustainable dyed jute goods maintaining sustainable textile processing.

Keywords: Jute fiber, Natural dye, Extraction, Cold pad batch dyeing, Sustainable.

1. Introduction

Jute is ecofriendly as well as being one of the most affordable bast fiber like flax and hemp fiber; jute plants are easy to grow and high production per acre need less amount of pesticides and fertilizers unlike cotton fiber. Implementation of natural bio sources have been getting importance due to sustainability issues in 21 century [1]. The application of fiber & dye from natural sources in textile sectors is now a concerning issue of many countries & organizations to avoid the toxic and health hazard problems associated with synthetic dyes which are mostly used in textiles to save our environment [2]. To save our upcoming generations we should find sustainable ways to minimize hazardous dyes & chemicals as well as synthetic fibers usages. Therefore, Little research was done on jute fabric dyeing with natural dyes[[3][4][5]] specially there is no work on cold pad bath jute dyeing technique using natural dyes and also the application of dyed jute fabric is very limited. This research have taken an attempt to research natural dyes applications on jute fiber where dyes were extracted from three natural sources like java plum fruit, kadamba flower & malbar spinach vegetable and used cold pad batch technique for dyeing without using mordant.

2. Experimental

2.1 Materials

2.2.1 Fabric

A raw plain weave jute fabric was used in the experiment. Jute fabric was sourced from a manufacturing plant named Hasan Fabric Limited, madhabdi, Narshindi, Bangladesh. Table 1 presented the fabric specification. Prior to dyeing collected jute fabric was pretreated using following recipe displayed in

Table 2 where H₂O₂ and NaOH are not sustainable chemical yet so further research can be possible to use sustainable chemical for pretreatment of jute fabric. In this research, only dyes are used from sustainable sources.

Table 1. Specification of Jute fabric

Fabric	EPI	PPI	Count (Ne)	GSM
Jute	12	12	2	311

Table 2. Recipe of pretreatment of raw jute fabric

Parameter	Amount
Hydrogen peroxide	15 g/l
Sodium Hydroxide	10 g/l
Stabilizer	2 g/l
Sequestering Agent	5 g/l
Wetting Agent	1 g/l
Detergent	3 g/l
Time	90 Minutes
Temperature	98 °C
pH	10
M:L	1:10

2.2.2 Dyes

- Java plum fruit,
- Kadamba flower
- Malbar Spinach vegetable

2.3 Methods

2.3.1 Extractions

The color components of java plum fruit, kadamba flower and malbar spinach vegetable were extracted using solvent (methanol) extraction method. At first, java plum fruit, kadamba flower and malbar spinach vegetable were collected, thoroughly washed and cleaned. Then dried by sunlight for a week and grinded into fine powdered. Then weighting 50 g of dried powdered materials and dissolved with 500 ml of methanol maintaining 1:10 material liquor ratio in a conical flask separately and covered the open end slightly and let them simmer for seven days for extraction facilitation. After seven days, extracted dye liquors of java plum fruit, kadamba flower and malbar Spinach vegetable were filtered and collected. Then the extractions were heated to evaluate the remaining solvent.

2.3.2 Cold pad batch dyeing

Cold pad batch (CPB) lab dyeing machine (figure 1) was used for the experiment. Padder pressure was set before dyeing as minimum pressure was set to achieve maximum pick up percentage. Then dyeing solutions were prepared according to following recipe presented in table 3 individually and padded and squeezed fabric for 5 times to achieve shade on fabric. Usually in cold pad batch dyeing technique follows low liquor ratio but here considered 1:10 liquor ratio in the experiment for developing shade properly during dyeing. Then dyed samples were cold washed and dried for 100 °C temperature for 5 minutes. Table 4 represent labeling of jute samples

Table 3. Recipe for cold pad batch dyeing

Parameter	Quantity
Sample size	(3x3) inch
Extractions (java plum fruit,kadamba flower and malbar spinach vegetable)	50g/l
padder pressure	0.12 Mpa
pick up (%)	80
Padding cycle	5 times
MLR	1:10

**Figure 1.** Cold pad batch lab dyeing machine**Table 4.** Labeling of Samples

Sample identification	Sample description
JR	jute sample in raw condition
JT	Treated jute fabric
J1	Dyed jute fabric with java plum fruit
J2	Dyed jute fabric with kadamba flower
J3	Dyed jute fabric with malbar spinach vegetable

2.2.3 Characterization of dyed samples

Dyed samples were characterized by color co-ordinate values and color strength results using spectrophotometer where kubelka-Munk equation (equ.1) is followed to find k/s value of dyed samples.

$$\frac{k}{s} = \frac{(1-R)^2}{2R} \quad (1)$$





Different color fastness (C/F) test method like C/F to wash (ISO 105 C06), C/F to water (ISO 105 E01), C/F to perspiration (ISO 105 E04), C/F to light (ISO 105 B02) and C/F to rubbing (ISO-105-X12) were done for evaluating fastness properties of dyed samples.

3. Results and Discussions

3.1 Visual Assessment of dyed samples

The pictorial view of treated and dyed jute fabric was exhibited on table 4. It was observed that dyed sample with java plum fruit gave better color yield than dyed sample of kadamba flower and malbar spinach vegetable. The chromophoric group of java plum fruit extract yield light purple in hue where kadamba flower extract gave light yellow color and malbar spinach extract gave light green hue. Mordant was not used during dyeing that why yield color on dye extracts produced lighter shade on jute fabric. Table 5 presented pictorial view of jute samples where effects are not properly visualized due to electric scan.

Table 5. Pictorial view of jute samples dyed with java plum fruit, kadamba flower and malbar spinach vegetable extract.

Serial no.	Samples	Pictorial view
1	JR	
2	JT	
3	J1	
4	J2	



3.2 Colorimetric value

Table 6 plotted the color co-ordinate value of dyed jute samples that are characterized by CIE L* a* b* Under D65 artificial light source d/2 viewing geometry. It was observed that scoured and bleached samples gave highest lightness value, whereas lightness value all dyed samples was decreased compared to bleached sample. Moreover, J1 has -24.32 blueness and 6.24 redness in tone where J2 give 16.52 yellowish and 2.92 redness. Again, J3 has -7.15 greenish and 11.43 yellowish in tone. It is clearly observed that samples dyed with java plum fruit extract gave darker shade yield compared to other extractions.

Table 6. Colorimetric value of dyed jute fabric

sample	D65				
	L*	a*	b*	C	H
JT	67.02	5.19	17.91	19.71	70.32
J1	58.03	6.24	-24.32	20.62	60.12
J2	61.15	2.92	16.52	15.18	55.17
J3	62.02	-7.15	11.43	12.06	59.01

3.3 Color strength analysis

Color strength value is related to reflectance value. Darker shade of samples have high reflectance value and high k/s value. Figure 2 plotted color strength value of tested samples. Dyed jute fabric with Java plum fruit extraction (J1) gave darker shade among other dyed samples that's why it has high color strength value compared to other dyed samples.

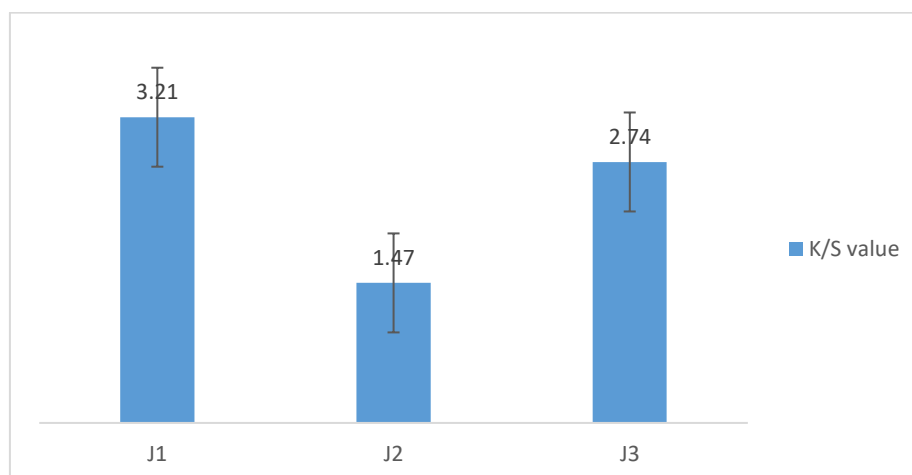


Figure 2. Comparison among dyed samples by color strength value

3.4 Analysis of different color fastness test results

Dyed jute sample with malbar spinach extract (J3) has very excellent color fastness to wash results against color staining to multifiber fabric and color change (grey scale rating 5 and 4/5) where dyed jute sample with kadamba extract (J2) showed 4 and 4/5 grey scale rating against multifiber fabric and dyed jute sample with java plum extract gave satisfactory color fastness to wash rating (grey scale rating 2/3, 3,4) plotted in the figure 3. Again, dyed jute samples showed satisfactory color fastness to light test result whereas jute sample dyed with java plum extract (J1) showed very poor blue scale test rating (figure 4). Therefore, J3 and J2 samples have better acid and alkali perspiration and color fastness to water test result compared to J1 samples displayed in the figure 5 and figure 6. Moreover, dry rubbing of all dyed samples showed better performance compared to wet rubbing (figure 7).

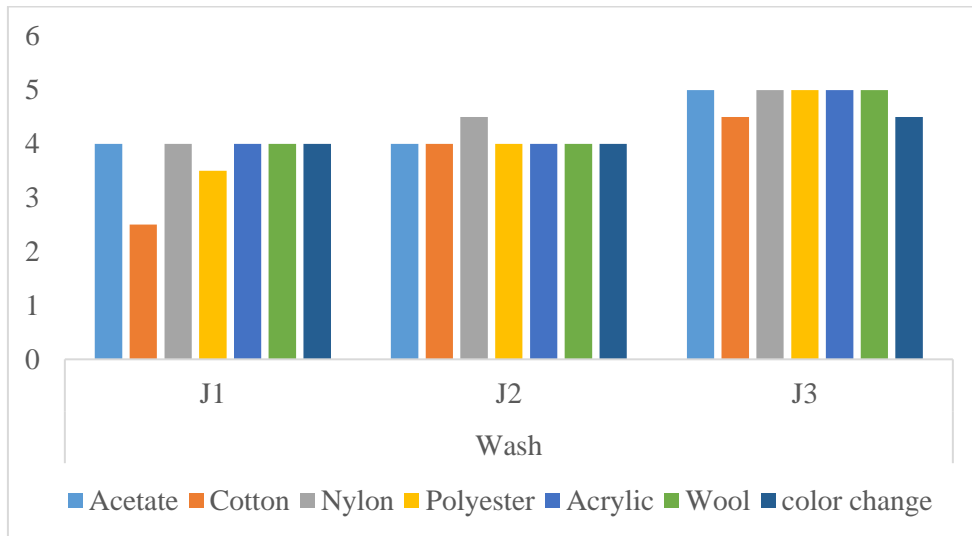


Figure 3. Comparison of color fastness to wash test results among dyed jute samples

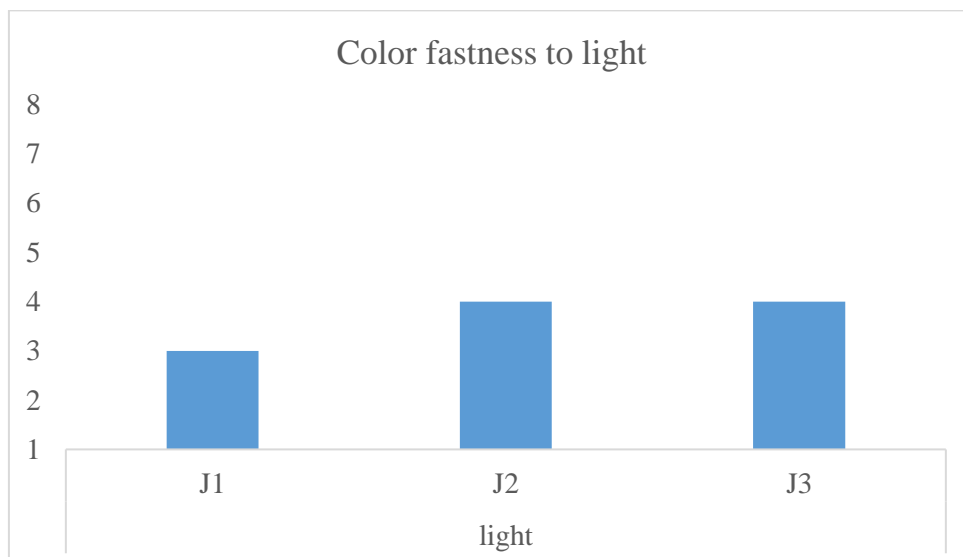


Figure 4. Comparison of color fastness to light test results among dyed jute samples

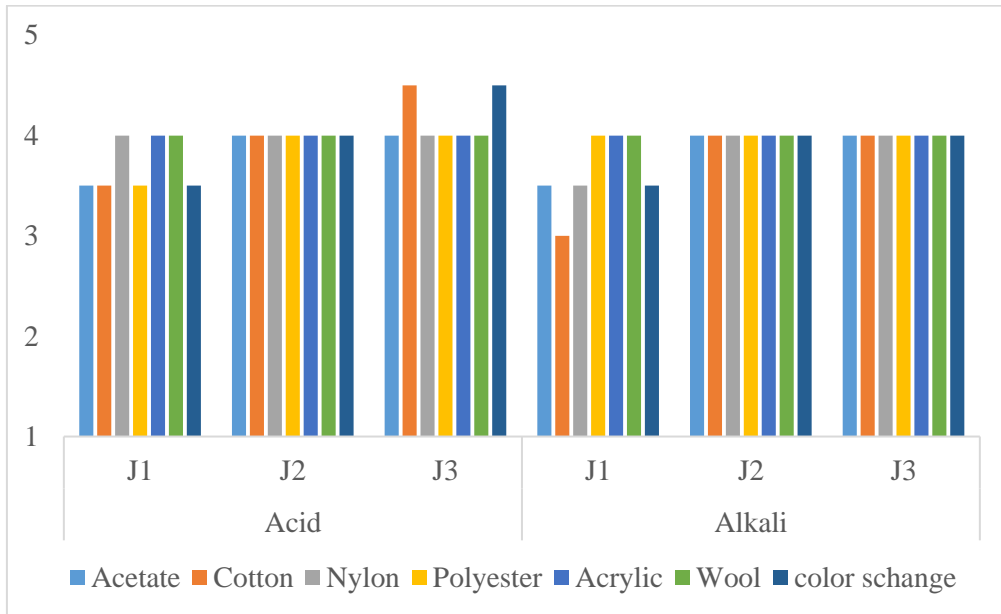


Figure 5. Comparison of color fastness to perspiration test results among dyed jute samples

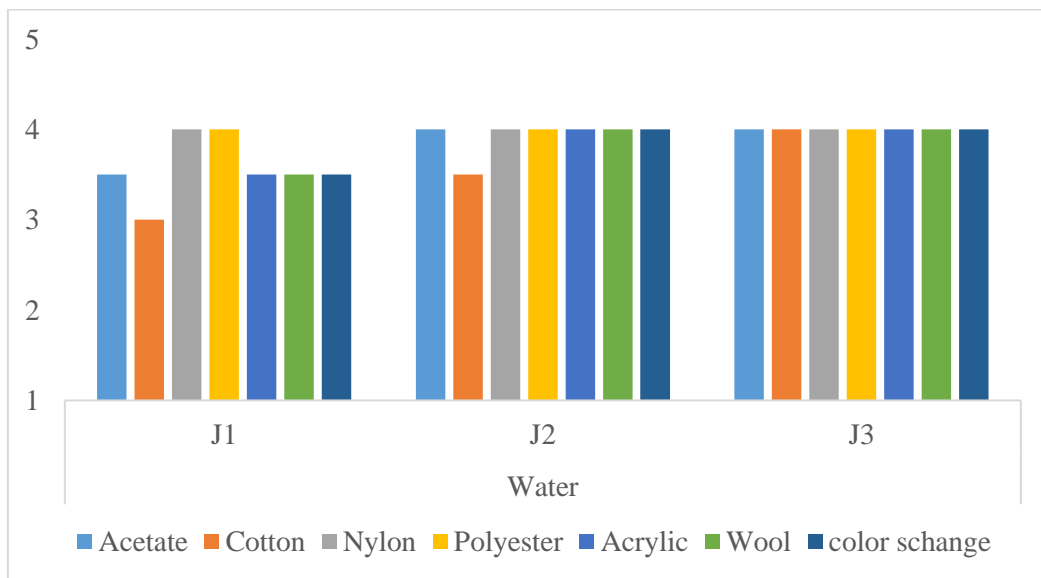


Figure 6. Comparison of color fastness to water test results among dyed jute samples

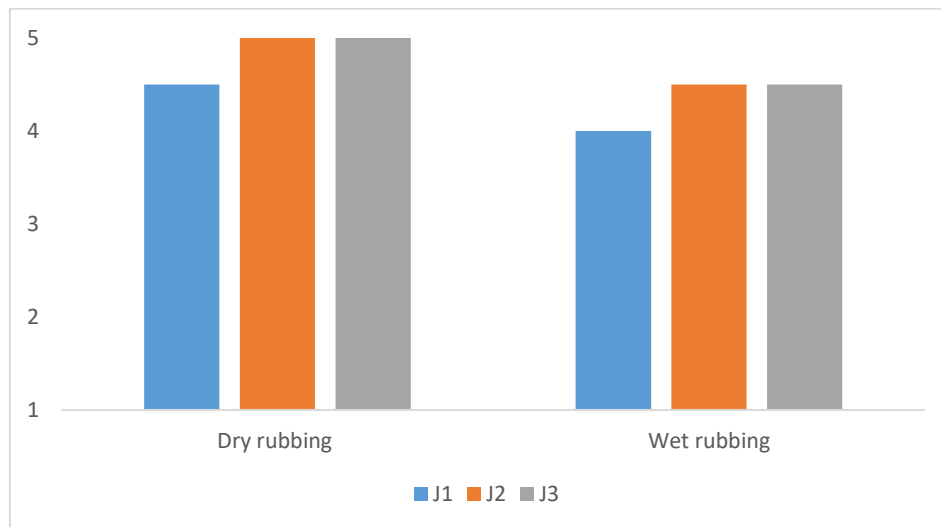


Figure 7. Comparison of color fastness to rubbing test results among dyed jute samples

4. Conclusions

Jute is one of the most affordable natural fibers and is the second after cotton fiber in amount of production and variety of uses. This research have showed pad batch natural dyeing technique on jute fabric with three different types of natural dye sources and characterized and evaluated samples by colorimetric value and fastness properties where Jute samples dyed with malbar spinach leave extract showed better natural dyeing performance compared to other samples. In a conclusion it can be said that all the extracts can be good substitute of synthetic dyes for sustainable jute dyeing in future prospect. The limitation of this research is that levelness of dyeing was not achieved properly due to less substantively of jute fiber with these dye sources and used of non-sustainable chemical in pretreatment process. In this research, no finishing treatment was done of the samples for color retention for a long period. So further research work is need to study its after finishing behaviors & color longevity and levelness with different natural dye sources on jute fabric.

Acknowledgements

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Conflict of interest

All authors are confirming that there is no conflict of interest of this work

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Applications of High Melting Point Natural Fiber and Green Composite Materials: A Review

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Abstract

Natural fibers and green composites may compete with conventional materials in the structural and transportation sectors. We currently know and utilize natural fiber-reinforced polymer matrix composites (NPMCs). These composites have been studied extensively in the literature, and new findings are being made. They pose an unwelcome threat of flammability in the majority of applications. Fire-resistant natural fiber and green composite materials have newly gained attention from researchers. This article focuses on natural fiber and green composite flammability, which provides an overview of recent developments. The mechanism for fire retardancy has been described. All factors that affect fire retardancy and how to measure it have been entirely covered. Fire retardants have been shown to affect composite's other properties.

Keywords: Fiber, fiber-reinforced polymer, Green Composite Materials, Flammability, Fire retardants

1. Introduction

Renewable, cost-effective, and environmentally friendly materials have emerged in response to environmental concerns and the increasing cost and diminishing supply of conventional synthetic materials. Most non-biodegradable and toxic inorganic waste materials are inorganic wastes [1]. On the other hand, biodegradable materials include natural fibers, green polymers, and fillers, all of which decompose[2]. Natural fiber-reinforced composite materials are widely used in automobiles and construction because of their lightweight and low cost[3]. On the other hand, composites have several drawbacks, such as their tendency to burn quickly [4]. Research on the flammability of natural fibers and green composites is few at this time. They may be used in the automotive, aerospace, marine, construction, and electronics sectors if more research is done[5]. An in-depth look at current developments in the flammability of natural fibers and green composites is provided in this article. Fire retardant methods, fillers, and other factors that affect the flammability of composites are summarized in this paper.

Engineered techniques, less flammable polymers, and fire retardant (FR) additives are utilized to boost the fire resistance of polymer composites[6]. Despite being the cheapest, engineering is not considered safe. A durable polymer made of low-flammability polymers costs a lot. Compounds containing FR additives are the most widely used and well-accepted technique. Nano or micro powder fillers are often used in FR additives, which work in various ways to inhibit the spread of fire[7].

Wood flour/polypropylene composites containing zinc borate (ZB), montmorillonite, manganese dioxide (MnO₂), and stannic oxide (SnO₂) were developed[8]. FR additions had a positive synergistic effect on the composites' fire resistance. According to the researchers, Flame retardant epoxy resin composites using hemp fibers are being developed[9]. FR additives based on phosphorus were used to enhance the flammability of hemp/epoxy composites. Fire retardant, thermal, and mechanical properties of sisal/polypropylene composites may be improved by adding ammonium polyphosphate, magnesium hydroxide, and ZB[10]. Shah et al. improved a polypropylene matrix's fire resistance and thermal properties by adding oyster shell powder as an organic filler[11]. APP, MPP, and aluminum hydroxide (AlHx) were used by Umemura et al. to reduce the flammability of wood-plastic composites[12]. In the recent literature, further study on natural fiber reinforced composites (NFRC) is included in Table 1. In order to include FR materials into composites, the production process has to be altered. The most crucial

factor is to ensure that the additive particles are well incorporated into the other components of the composite. Improper distribution of flame retardant (FR) additives leads to unsatisfactory mechanical and water absorption properties[12]. There are several techniques to mitigate the negative consequences of FR additions[13].

2. Characteristics of Polymers

Composites rely on polymeric matrices, which look good and serve an important function. The polymeric matrix and manufacturing procedure greatly influence composite properties. It is possible to see the most common polymers and their physical characteristics in Table 2. Our everyday lives revolve around polymeric materials because of their unique properties. As a result, both natural and artificial polymers are highly flammable because of carbon's fundamental component. Polymer matrix (polymer) protects reinforcements in composites against fire propagation and heat loads. However, this is not always the case[14]. Several papers have dealt with polymers and polymer composites[15]. Polymer flammability may be described using characteristics such as LOI and HRR. Table 2 provides information on the flammability of some of the most commonly used polymers.

3. Characteristics of Natural Fibers

Figure 1 illustrates the classification of natural fibers based on how they were taken from plants, animals, and minerals. For example, natural fibers are flammable because of their chemical composition. Plant fibers include cellulose, hemicellulose, and lignin, while animal fibers are mainly composed of protein[16]. Plant fibers have long been used as significant reinforcing fibers over the globe, although animal and mineral fibers are less well-known[17]. The flammability of plant-based natural fibers is the primary focus of this review paper. Seed, leaf, bast, fruit, and stalk are all sources of plant-derived natural fibers. The lignin, pectin, and wax combination give these fibers their structure. Natural fibers are flammable because of their chemical composition. Table 03 explains the role of fiber components in a product's qualities, as shown. The cellulose content of natural fibers determines their mechanical properties[18]. Hemicellulose was aids in the absorption of water and microbial and thermal degradation[19]. Hemicellulose is the flammable element of natural fibers, whereas lignin is the char-forming part[19].

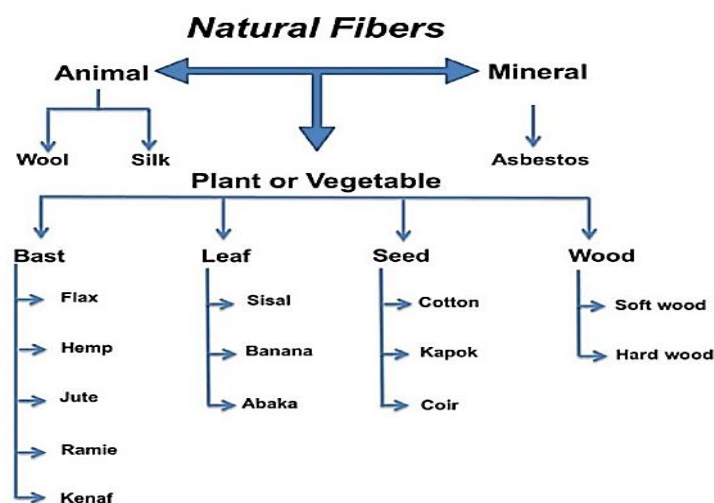


Figure 1: Natural fiber classification according to their source of extraction
Source: National Natural Science Foundation of China[20]

Table 1: List of newly published work on natural fibers or polymer matrix composites with FR additives

Natural fibers	FR additives	fibers/polymer matrix	References
Rice husk & sawdust	Sodium metasilicate & zinc borate	High-density polyethylene	[21]
Cellulose, Hemp, Flax, Sugar cane, and bamboo	Ammonium polyphosphate	Poly butylene succinate	[22]
wood flour	Zinc borate	Polyvinyl chloride	[23]
Jute	Halloysite nanotubes	Soy protein concentrate	[24]
Coconut & jute	Di-Ammonium phosphates	Polylactic-Acid & Polypropylene	[20]
Flax	Phosphorous compounds	Poly butylene succinate	[25]
Banana	Nano-Clays	Polypropylene	[26]

Table 2: Polymer physical and flammability characteristics[27].

Polymer	Density (g/cm ³)	Tensile strength (MPa)	Tensile modulus (GPa)	Tm (°C)	Thermal conductivity (w/m ° k)	Total HR (kJ/g)	LOI (%)
PE	0.925	15	0.08	105-115	0.33-0.51	41.6	18
PP	0.920	40	1.9	130	0.1-0.22	41.4	17
PAN	1.184	57	2.7	300	1.0	13.3	27
PC	1.2	70	2.6	157	0.19	20.3	26
PS	1.04	40	3	240	0.03	38.8	18
PMMA	1.18	47	2.2	130	0.20	24.3	17
PVC	1.4	51	2.4	160	0.19	11.3	45
PVA	1.19	40	1.7	200	0.31	21.6	20.5
PLA	1.2-1.4	50	3.5	150-160	1.13	14.2	21.7
PET	1.38	55	2.7	260	0.15	15.3	21

Table 3: Shows the different types of fibers and their characteristics

Components	Properties
Cellulose	Mechanical properties
Hemicellulose	Moisture absorption, Thermal stability, Biodegradation, Flammability
Lignin	Char formation

4. Composites Flammability

The matrix of polymer rapidly degrades [28]. The thermal stability of polymer composites may be improved by adding fiber reinforcement at high temperatures. Natural fibers are much more susceptible than synthetic fibers[29]. As illustrated in Figure 2, the thermal breakdown of polymer composites in the presence of combustion is a multistage process. A composite is broken down into various gases and

char during a fire. In the presence of oxygen, flammable gases may be more easily ignited. Gases released as a result of combustion include CO, CO₂, and smoke. The breakdown process is aided by the heat generated during combustion, and the burning cycle is self-sustaining. The flammability of polymer composites may be affected by tampering with the combustion process at any point. Burning char layers are often used to stop heat transfer in contemporary fire retardant methods[30].

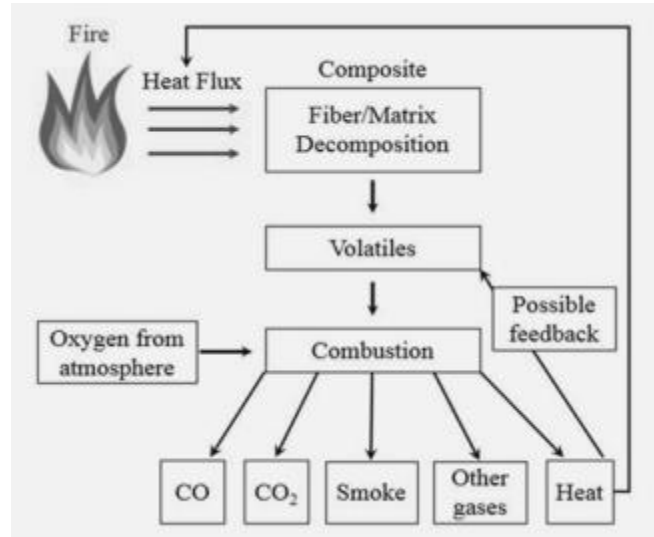


Figure 2: Polymer composite thermal degradation (32).

5. NFRC Properties Affected by FR Additives

There is a focus on FR additives-based fire retardant technologies in this review paper. Additives for fire retardancy (FR) may increase the fire resistance of composites, but it is essential to know how they impact other properties. The mechanical, water absorption, and thermal properties of NFRC are examined in this work due to the addition of FR.

5.1 Mechanical Properties Effects

A strong interfacial connection improves mechanical properties when the FR additions are chemically compatible with the matrix and natural fibers. In contrast, most FR additions do not interact with composite components chemically and instead function physically. Fire-retardant additives to NFRC may increase fire resistance while decreasing NFRC's mechanical properties. Mechanical strength is reduced by debonding, stress concentration, and the buildup of filler powder in composites. As a result of the high rigidity of the composite materials with FR additives, the elastic modulus may increase.

Polypropylene (PP)/wood-fiber composites were tested for the effects of ammonium polyphosphate (APP) and silica on their mechanical properties and flammability[4].

The mechanical properties of PP/wood composites were reduced with fillers. Tensile strength increased slightly for smaller silica loadings, but this effect disappeared as silica loadings increased. Experts say experts reduced mechanical properties due to incompatibilities between FR additives and the matrix. Aluminum trihydroxide (ATH) was employed as an FR additive in Flax/PP[31]. Grades 32, 40, and 60 CD of Apyral were used in the experimentation. Tensile and impact strength were decreased, despite a gain in fire resistance and thermal stability.

Composites' stiffness was measured by the elastic modulus, which rose. It was found that the APP filler had a significant impact on the biocomposites made from ramie fibers and polylactic acid (PLA)[32]. At lower filler loadings, the APP increased the fire resistance of ramie/PLA biocomposites without

compromising their mechanical properties. However, the mechanical properties of the composites were observed to decrease with higher filler loadings substantially. The polymer/filler contact was hindered by the presence of APP, resulting in a decrease in mechanical properties. Flax fiber-reinforced PLA/TPS biocomposites were studied by Bocz et al., and one of the FR additives they used was APP, which has a wide range of applications[33]. APP decreased the HRR rate of the composites in order to increase fire retardancy. However, this came at the sacrifice of tensile and flexural strength. As an inorganic filler, Shah et al. employed OSP (oyster shell powder) with PP at various doses (FR additives)[11].

The inclusion of OSP led to an improvement in PP's fire resistance but a decrease in its tensile strength. With a decreased tensile strength, burning time is increasing. The poor interfacial bonding between the FR additives and matrix resulted from the incompatibility between OSP and PP. FR additives and the matrix may sometimes be made to work better together via a compatibilizer. Filler dispersion and chemical bonding between filler and matrix may increase mechanical properties. There are a few reported cases of FR additives being used to increase the fire resistance and mechanical properties of NFRC. According to Biswal et al., the nano-clay/banana fiber/PP fire retardant composite demonstrated better tensile and flexural capabilities[26]. The scientists used maleic anhydride grafted polypropylene (MAPP) as a compatibilizer, which helped bind the nano-clay to the PP matrix.

Polymer chains were inserted into silicate clay layers to enhance the surface area of contact between silicate clay layers and the polymer matrix to improve mechanical properties. Using Cloister 30B (C30B) nanoclays as FR additives, Paluvai et al. studied the properties of unsaturated polyester (UP) toughened epoxy nanocomposites reinforced with sisal fibers in their study[34]. Epoxy/tensile, UP's flexural, and impact properties improved with the addition of C30B- and alkali-silane-treated sisal fibers. Chemical bonding between alkali silane-treated sisal fiber and the epoxy/UP system was claimed to improve the material's mechanical properties.

5.2 Water Absorption Effects

FR additives boost the NFRC's water absorption capability since natural fibers are often hydrophilic. Since the filler particles have uneven shapes and poor interfacial interactions with the matrix and natural fibers, some micro-gaps and fractures occur at the composite interfaces. These flaws allow water to seep into the structure. The impact of FR additives on NFRC's water absorption has been studied in the literature.

Composites made of wood flour and expanded polystyrene waste were tested for diammonium phosphate (DAP)[35]. Fire resistance was improved while the DAP modification increased water absorption. Hydrogen interaction between water molecules and free OH groups in the DAP structure and possible diffusion of water molecules into the composites were cited by scientists as the mechanism for water absorption. CaCO₃- and DAP-filled PP/kenaf composites were studied for their properties[36]. The PP/kenaf composites' water absorption improved by adding FR additives. Calcium carbonate, according to experts, absorbs water, causing the composite to grow in weight as a result.

The water resistance of nanocomposites containing FR additives may be improved by taking specific measures. FR additives boron and phosphate compounds were used to study wood/PP composite materials[26]. The composites employed MAPP as a coupling agent. The water absorption parameters of MAPP and without MAPP were compared. A team of researchers found that FR additives to composites without utilizing MAPP lowered their water resistance, but that after applying MAPP, the water resistance increased. Coupling agents improve interfaces by sealing and reducing water infiltration into the composites' interior flaws and fractures. Nano-clay-filled cellulose fiber/vinyl ester nanocomposites were tested for water absorption[37]. A reduction in water absorption was seen after adding nanoclay to the composite materials. In the water molecules pathway, the high aspect ratio of nano-clay platelets is to blame.

5.3 Thermal Stability Effects

The FR additives often form a char deposit when burned at high temperatures. The char layer acts as a heat-resistant medium on the composite surfaces. It is also worth noting that, as opposed to the FR additions in the polymer matrix, FR additions are more prone to crystallization and melting. During burning, the char layer protects the fibers since the breakdown temperature of cellulosic fibers is very low. According to the literature, the thermal stability of composites may be improved by including FR compounds. Sisal fiber/PP composites were tested for the impacts of APP, magnesium hydroxide, and ZB on their performance[10]. When heated to 500 degrees Celsius, polypropylene completely degrades, losing all of its weight. The decomposition temperature of sisal fiber is lower than that of polypropylene (PP).

Despite the author's FR additions, char residues were formed in the sisal/PP composites to increase their heat stability. Thermal barrier properties of PBS/BF biocomposites may be improved by employing microencapsulated ammonium polyphosphate (MCAPP) as an FR addition, and the char residue serves as a barrier at high temperatures[38]. When PBS was reinforced with BF, it lost some of its thermal stability; however, adding MCAPP to the PBS/BF composites restored that stability. Composites made with MCPAP are more thermally stable than those made with non-MCAPP components. Wood/PP composites containing melamine, ZB, APP, ATH, natural flake graphite, and expandable graphite were studied for their reactivity to fire[39]. When the composite specimen was exposed to high temperatures, the authors calculated the mass-loss rates of the composite specimen. To their surprise, they found that char residues in the wood/PP composites with FR additions are higher than those in the typical wood/PP specimen. In terms of mass loss, flame retardant-based wood/PP composites had a lower rate than non-flame retardant-based wood/PP composites. The wood/PP composite filled with APP and expandable graphite was determined to be the most stable in terms of thermal stability. Nano silicon dioxide (APP) and wood fiber/polyethylene composites were studied[40]. Thermogravimetric analysis (TGA) and derivative thermogravimetry (DTG) were employed to measure the weight loss of composites at high temperatures (DTG). The composite's thermal degradation was minimized when APP and nano-SiO₂ were added.

Both FRs resulted in a char deposit on the surface and increased heat resistance. *Spartium junceum* L. short fibers reinforced PLA biocomposites were tested for the effects of montmorillonite nanoclay[41]. According to the researchers, the thermal stability of nano clay-treated biocomposites was superior to that of untreated composites and pure PLA. Using nano clay as a "charring agent" reduced the rate of weight loss at higher temperatures. There was a paper on the properties of OSP-filled PP composites[11]. An FR additive, OSP, was used to enhance the heat stability of composites. When OSP is added, the thermal stability of pure PP is believed to increase significantly. Airborne TGA thermograms of composites made of OSP and PP (as a medium). Findings show that PP declined in a single step, whereas OSP/PP composites degraded in two phases.

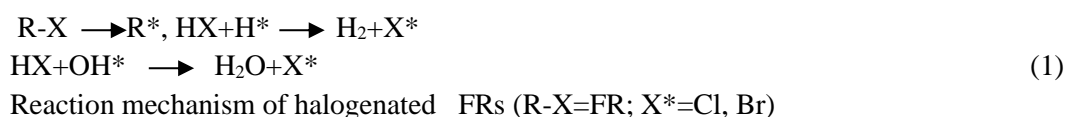
6. Flame Retardant (FR) Additives Types

The use of additives for flame retardant coatings, plastics, thermoplastics, thermosets, rubbers, and textiles. These FR additives may be used to prevent, reduce, suppress, or halt the combustion process of materials. Polymer flames may be extinguished or reduced in various ways using these devices. In 2012, a market study found that [42], Four years ago, FR retardant usage was at its lowest level ever.

6.1 FR Additives with Halogens

This class of FR additives is mainly used in producing everyday items that we all rely on. Depending on the ratio of halogen to carbon and the bond energy of the carbon-halogen bond, they are excellent in capturing free radicals and releasing them. Consequently, they may be able to stop or slow the spread

of fire[43]. Halogenated FR additives typically employ a gas phase approach to extinguish fires. These FR additives reduce flammability in the environment by interacting with ambient oxygen and hydrogen, which lowers both oxygen and fuel concentrations in the air. Because aromatic halogen FR additions have lower binding energy, they are less effective than aliphatic and alicyclic FR additives. FR additives can only be utilized with fluorine, which has a high electronegativity, and iodine, which has a low one. At greater temperatures, however, bromine creates more free radicles than chlorine. On the other hand, Flame retardant chlorine has a higher level of efficacy. The decomposition of halogenated FRs is shown in Equation 1.



6.1.1 Bromine FR Additives are a kind of bromine

Because of their low cost and high-performance efficacy, bromine FR additives are often used in commercial and domestic items such as construction materials and electrical equipment to protect against property damage and harm. These flame retardant chemicals degrade at a lower temperature to achieve the desired results, and their use is constant across all compounds[44]. The most prevalent brominated FR additives are brominated bisphenols, diphenyl ethers, cyclododecane, phenols, and phthalic acid derivatives.

6.1.2 FR Additives with Chlorine

Additives for polyalkene compounds, such as chlorinated FRs, are common. In order to be effective, they must be used in more significant amounts because of their poor stability and plasticization at higher temperatures compared to the brominated FR additions. Compared to the chloride FR additives, a combination of metal chloride may enhance flame retardancy even further[45]. Paraffin and alkyl phosphate are the most frequent kinds for most chlorinated fire retardants.

Hydrochloric compounds are released in the gaseous phase; in addition, these hydrochloric compounds break down and generate chlorine-free radicals that oxidize volatile products during the thermal breakdown of polymers.

6.2 FR Additives with Phosphorus

As a result of environmental concerns, the phosphorous FR additions are used as halogen-free FR additives with the exact flame retardant mechanism as halogenated FR additives [46]. Metal phosphates may have a gas phase action and a condensed phase effect (char formers and enhancers). These FR additives are critical with low concentration levels and compelling action against fire. Combined with the polymer's high oxygen content, they are active and restfully on the matrix structure.

Some of the most well-known phosphorus-containing FR additives include phosphate esters, phosphonates, and phosphinates. Some examples are Triphenyl phosphate, Triphenylphosphine oxide, Tris-(2-chloroethyl) phosphate, Tri (chloroprene) phosphate, Resorcinol-bil (diphenyl) phosphate, Red phosphorous, Ammonium polyphosphate, and Melamine phosphorus.

Polymeric materials' solid phase may benefit from the inclusion of phosphorus FR. These phosphoric FR additions are converted into their respective acids, then changed into polyacids by the thermal breakdown. Unsutured char compounds are formed when acids esterify and dehydrate the pyrolyzing

polymer. Polyphosphoric acids prevent the carbonaceous layer from further pyrolyzing at high temperatures, safeguarding the polymer's constituent parts from exposure to oxygen and radiant heat.

6.3 FR Additives for Nitrogen

They are environmentally friendly because of their low toxicity, less smoke during fire evaluation, and easy recycling. These compounds remain inert and do not break down even at high temperatures. As a result, they can halt the decomposition of materials at greater temperatures. A greater level of flame retardancy is achieved by nitrogen-containing additives (nitrogen-phosphorous) due to the synergistic impact between nitrogen and phosphorous. It is also a weak acid with minimal corrosion potential, making it perfect for producing electrical installation components from the combustion of hydrogen cyanide.[47]. Nitrogen FR additives such as melamine polyphosphates, melamine poly (zinc/ammonium) phosphates, melamine-based hindered amine light stabilizers, melam, and melon are the most commonly used melamine and melamine compounds. Also, ammonium polyphosphate (as described in the text) is used as a component of olefin intumescent compounds, including melamine cyanurate. Methylamine Pyrophosphates (MPPs) and other nitrogen-phosphate compounds are used in amides. Reactive compounds are urea, isocyanurates, triazines, guanidine, and cyanuric acid derivatives.

In addition to gaseous and condensed phase methods, nitrogen FR additions act several ways. Stable nitrogen-based molecules may be released in the gaseous phase to limit fire propagation, and complex nitrogen compounds can be created in the condensed phase to generate char to protect polymer materials from the breakdown in the fire. Burning may be hindered by releasing nitrogen-mixed gases from these materials.

6.4 Additives to Silicon FR

Several silicon compounds, including silicones, silica, organosilanes, silsesquioxane, and silicates, have been studied as suitable flame retardants for polymeric materials.

6.4.1 Silicones

It has long been accepted that silicones and silicon co-additive FR additives are functional and ecologically friendly. It is possible to utilize fewer amounts of these compounds because they dilute more organic components and offer a barrier on the surface of the materials to a growing flame. Flame retardant properties may be improved during deterioration because of their low surface energy characteristics. Mechanics, significantly impact resistance might benefit significantly from these.

6.4.2 Silica

As a filler, silica combines silicon and inorganic components that may also be used as an FR additive. Several commercial polymers have also been made using this material. Multi-coordinate organic silicone compounds are synthesized when silica and organic alcohols are chemically combined with a catalyst[48],[49].

6.4.3 Silanes

There are a variety of chemical structures and functional groups in silanes, which are silicon-based compounds. Polysilanes, poly carbosilanes, and poly silazanes are among the most crucial silane compounds. Silanes may bind fillers and polymer matrices utilizing simple synthetic processes as coupling agents. Char formation and the improvement of physical and dynamic properties are also enhanced by the presence of these compounds[50].

These include polyhedral Silsesquioxanes, such as dimethyldichlorosilane, methyltriethoxysilane, methyltriacetoxysilane, and other polyhedral Silsesquioxanes.

6.4.4 Silicates

Some polymers may benefit from silicates, which include anionic silicon in oxides (clay). This nanofiller is inexpensive, environmentally benign, and has unique mechanical properties. They are incorporating less silicate into the polymer matrix results in a significant reduction in inflammability. By reducing oxygen permeability, they mostly succeed in raising thermo-oxidative stability. Mechanically enhanced char, combined with silicates, lowered dripping and, hence, decreased flammability in these flame-retardant additives' principal mode of action[51].

Silicon oxomonophosphate ($\text{Si}_5\text{O}(\text{PO}_4)_6$), talc ($3\text{MgO}\cdot 4\text{SiO}_2\cdot \text{H}_2\text{O}$), Montmorillonite (phyllosilicate). The condensed and the vapor phases of silicon FR additives are essential in their performance. To arrest the degradation process, dilute organic gases, trap active radicals in the flame zone, and prevent heat and mass transfer in the condensed phase, silica may migrate to the surface at high temperatures in the condensed phase. Only when coupled with other fire-retardant additives, can the qualities of these be used to their full potential.

6.5 FR Carbon Additives

6.5.1 Carbon Nanotubes

Single, double, or multi-walled graphite sheets and a polymer matrix as an addition make up carbon nanotubes. On the other hand, carbon nanotubes are far more costly than carbon fibers/fabrics or fillers, but they have a unique virtue of flame retardancy at low concentrations. The mechanical properties are also improved, and they are more efficient than nanoclays. In addition, the trapping of free radicals may reduce the pace at which the polymer matrix breaks down, hence increasing its thermal stability. Carbon nanotubes with hydrocarbon polymers are superior to hydrophilic additions in terms of practicality. They may be included directly into the polymer matrix without the need for any organic treatment or compatibilizer. Organophilic[52].

6.5.2 Hydroxycarbonates

Hydroxy carbonate FR additives are an environmentally beneficial alternative to metal hydroxide flame retardants. Fire retardant additives, including non-toxic substances like water and carbon dioxide, release water in the gas phase, reducing flame and creating 20 times less smoke than halogenated FR additions. These pieces are both gaseous and condensed. Breaking down and oxidizing carbon-containing compounds may help create an insulative barrier layer on the matrix polymer. The most often used hydroxy carbonate FR additions are magnesium carbonates (natural (magnesite) and synthetic (hydromagnesite)) and calcium carbonates. An increased flame retardancy and mechanical properties may be noted with other FR additives, such as clay nanoparticulates[53].

Thermal stability and flame retardant properties are influenced by carbon nanotubes, polymer matrix, and nanotube dispersion in the polymer matrix. As a result of condensed phase mechanisms, the melting viscosity of the polymer matrix is increased by using carbon nanotubes in three-dimensional cross-link network designs. The polymer matrix is protected from flame propagation by its network structure. A multiple char layer is formed over the polymer matrix when the nanotubes are combined with other flame retardant chemicals. This improves the polymer's heat stability and flame retardancy.

6.6 Hydroxides and Metallic Oxides

When metals react with oxygen in the air, they produce metallic oxides. In addition to the strong interactions between the polymer surface and the nanoparticle surface, these FR additives have proven effective additives for improving thermal stability and morphological structure of char residues and the FR of polymers because their degradation temperature is higher than polymer processing

temperature[54]. It is possible to make titanium dioxide by heating titanium (TiO_2) to a high enough temperature to form a titanium oxide (TiO_2).

Metal hydroxides are mineral FR additives that include a mixture of hydroxides and carbonates. Inexpensive-smoking FR additives typically employ them because of their low cost and wide availability. Using an endothermic process, these flame retardants generate one-third of the total metal hydroxide and an inorganic fire-retardant residue. Using these metal oxides, flame propagation is reduced. Polymer flammability is seldom improved by combining them with other flame retardants, although they are rarely used as synergists[55]. Aluminum tri-hydroxide ($\text{Al}(\text{OH})_3$), magnesium di-hydroxide ($\text{Mg}(\text{OH})_2$), antimony trioxide (Sb_2O_3), expandable graphite, and others are examples.

6.7 Borate FR Additives

Commercial inorganic family members include fillers with minimal mammalian toxicity and mild volatility safe for the environment and mammals. Additives like halogenated and mineral fillers are typically utilized as a synergist because of their poor charring performance when used on their own. Fire retardants like crystal water, boric acid, and boron oxide (endothermic decomposition (503 KJ/g) between 290 and 450o C) are formed as a result of this endothermic reaction in the combustion process, which results in the formation of a glassy shield layer that blocks fire propagation and stops polymer chain oxidation[56]. ZnO, ammonium pentaborate, melamine borate ($\text{C}_3\text{H}_9\text{N}_6\text{O}_3\text{B}$), and barium metaborate are some of the most often used forms of the mineral borates, which are also known as borates.

6.8 Nano-Clays

These fine-grained minerals (phyllosilicates) are found in rocks, sediments, and soils as nano-clays and are a kind of natural inorganic material. More smoke and carbon dioxide can be produced using nano clays because of their superior thermal stability. After burning, a thick silicate layer is formed on the polymer matrix, which functions as a fire barrier and inhibits the degradation of the composite. In addition, when burned, these materials may produce a carbonaceous layer that prevents oxygen permeability while leaving the flame unquenched. At high temperatures, nano clays lower polymer viscosity, preventing polymer composite leakage and increasing char formation. When combined with other FR additives, nano clays function even better as flame retardants. These techniques may also improve polymer composites' mechanical properties, scratch resistance, glass transition temperature, and stiffness [57].

6.9 Natural FR Additives

6.9.1 Chitosan (CS)

Deacetylated chitin (the exoskeleton of living animals such as fungi (cell walls), crustaceans (shrimps and crabs), and insect cuticles) is used to produce chitosan a non-toxic, highly biocompatible organic polymer. When it comes to carbohydrates, the most common one to use is Chitosan, which is an amino polysaccharide that may be carbonized and has many hydroxyl groups. Thus, chitosan might help to produce char during the burning process. Because of this, chitosan is used in polymer composites as an intumescent flame retardant and a natural FR additive. Burning chitosan may produce a blackened layer on polymer materials' surfaces that acts as an effective heat insulator or thermal shield to contain fire[58].

6.9.2 Oyster Shell Powder (OSP)

A mineral filler made from oyster shells that are biodegradable, non-toxic, and does not accumulate in the environment may be found on the beaches of many nations. Calcite and aragonite crystals (pH 9.8) make up around 96 percent of their composition. Above 8000 degrees Celsius, an oyster shell decomposes to produce CaO and CO_2 as a byproduct. Carbon dioxide, a byproduct of combustion, may put out a fire by blocking oxygen from reaching the flames. Carbon dioxide is the only source of energy

for the fire-retardant mechanism. Oyster shell powder is used in plastics and polymer-based composites as an FR additive for ecologically acceptable fire retardant polymers. Additionally, oyster shell powder enhances the plastic's rigidity, flexural, and dielectric properties[11].

6.9.3 Egg Shell

Recyclable, biological, and calcium-rich eggshell is common in city dustbins and rural farmyards. It comes from various sources, including the food industry, the chicken industry, and even the average household. According to a report from China, Chinese egg output in 2013 was estimated to be 484.6 billion eggs. CaCO_3 (calcium carbonate) is 96% of the egg shell's chemical composition; the rest is composed of X collagen, Sulfated polysaccharides, and various proteins (including Gly and Arg). When heated, the eggshell's calcium carbonate decomposes into CaO and CO_2 , and CO_2 is a suitable fire extinguisher, preventing the egg from catching fire. More CaCO_3 in the polymer matrix results in a composite with a decreased risk of catching fire due to the eggshell's abundance and particular composition and structure. Polymer nanocomposites may benefit from their use as a bio-filler and an FR additive[59].

6.9.4 Lignin

Polyphenolic and structurally amorphous, lignin contributes 20 to 30 percent of the plant's total weight. When heated to 450o C in a nitrogen environment, it breaks down into stable, dense cross-linked char, increasing density as temperatures rise. Flame retardant chemicals are well-known for forming char during thermal degradation, which slows the combustion rate of polymeric materials by preventing oxygen from entering the combustion zone. Due to the cross-linked structure, including phenolic groups, lignin may be employed to improve the thermal properties of polymeric materials since it provides a large char production during decomposition[60]. Additional advances in thermal and flame retardant properties may be achieved by changing the chemical structure of lignin with phosphorus and nitrogen components[61].

6.9.5 Biochar

Charcoal formed from biomass is known as biochar. Nitrogen, hydrogen, oxygen, and ash are all present in the microporous carbon-rich material. It results from the thermochemical treatment of organic waste and subsequent pyrolysis at high temperatures. Carbonaceous material keeps its physical form and honeycomb structure with distinct functional groups on its outer surface. Polymer firms and research institutions are interested in its important position in many purification systems as remedial pollution assistance and a long-term carbon detachment technique because of these characteristics. In addition to its high porosity, antibacterial and antifungal qualities, breathability, and temperature management, biochar may also be used to reduce and absorb odors, making it an ideal material for odor control. Biochar's components inhibit reactive chemicals during the heating process and limit weight loss in composites. The thermogravimetric and differential scanning calorimetric studies found that the thermal stability of the biochar-filled composite was enhanced in the literature[62].

6.9.6 Human Hair

An alpha-helix structure of amino acid units connected by a peptide ($-\text{CO}-\text{NH}-$) bond is found in the protein keratin, which accounts for roughly 91% of hair. In hair, amino acids such as cytosine, threonine, glutamine, glycine, leucine, and valine are present. On average, hair has 45.68 percent carbon, 27.9 percent oxygen, 6.6 percent hydrogen, 15.72 percent nitrogen, and 5.03 percent sulfur in it. Because it is convenient, inexpensively, abundantly, and collectible, this is the most convenient biomaterial to transport and store. It has long been used as a biomarker for human exposure to medicines and heavy metals. In addition, since hair contains nitrogen and hydroxyl groups that may be implicated, a few studies have looked at hair to quantify human exposure to persistent organic pollutants, including flame

retardants[63]. Researchers Chai et al. have concluded their investigation into the thermal properties of human hair. Researchers are currently trying to assess bioderived composite materials' flammability by utilizing human hair as a fiber in their experiments[64].

7. Surface Treatments' Effect on Flammability

Additionally, surface treatments directly impact the fiber's mechanical and thermal properties. By removing as much amorphous material from the fabric as possible during the surface treatment process, a higher proportion of crystallinity is achieved in the fiber. The fabric's surface area is increased when the threads' connections become more organized, increasing surface area. Compared to natural fiber composites that have not undergone this treatment, the wettability and bonding between the material and the resin are improved, resulting in a more thermally stable composite[65].

8. Flame Retardancy Mechanism

FR additives suppress or diminish the flammability of polymer matrix composites by a variety of methods, including physical dilution, chemical interaction, inert gas dilution, thermal quenching, and protective (char formation) coatings.

8.1 Physical Dilution

The FR additives themselves serve as inert substances and have thermal capacity against flame to reduce the fuel concentration below the lower flammability limit. It is also impeded by cooling, barrier development, and changes in heat capacity, thermal conductivity, and viscosity throughout the physical dilution process. One or more physical mechanisms are always involved in chemical processes, such as the dissociation of fuel in the presence of heat. Nano clays and glass filler compounds operate when used as FR additives.

8.2 Chemical Interaction

Free radicals produced by the combustion of polymers are disrupted and captured by FR additives or their byproducts in this breakthrough process. Neutralizing free radicals allows for cooling and a reduction of inflammability. Most halogenated (brominated) flame retardant (FR) additives act this way. To restrict flame growth, OH^* and H^* free radicals formed from polymers react with halogen-free radicals in the gas phase.

8.3 Inert Gas

Evaporation and condensation reactions of FR additives produce large volumes of non-flammable gases or inert gases in the gas phase. These inert gases contaminate the air around them, reducing the concentration of combustible fuel. Chemicals like metal hydroxides and carbonates may produce nitrogen in this way.

8.4 Thermal Quenching

Endothermic chemical reactions release water molecules from FR additives during burning at high temperatures and use thermal quenching (sudden cooling) to dilute the combustion process (polymer matrix). Halogen-free flame retardant additives, metal hydroxides, and carbonates are all examples of products that use this technology.

8.5 Char-Formation

A carbonaceous char coating is formed on the polymer matrix, shielding it from further oxidation, preventing further flame activity. Thermal insulation is improved, combustible gases are blocked, and the layer of carbonaceous char increases thermal capacity. This approach is often used for halogen-free flame retardant chemicals, such as phosphorus and nitrogen.

9. Conclusions

Composites made of natural fiber-reinforced polymers and flame retardant additives were examined in this research. Polymer matrices with a broad range of natural fibers might exacerbate the problem of the flammability of natural fiber-reinforced composites. Flame-resistant composites may be created with the help of proper FR additives, which widens their uses. With polymers, even small amounts of additives may have a positive impact. In matrices containing oxygen or nitrogen backbones, phosphorus and nitrogen-based chemicals have shown to be highly efficient nonhalogenated FR additives, while silicon-based compounds also seem to be helpful. Even yet, it is tough to boost the flammability of natural flame-reinforced composites. However, flame-resistant natural fiber-reinforced polymers may be produced by carefully selecting and applying the best FR additives.

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Conflict of interest

All authors are confirming that there is no conflict of interest of this work

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Colorimetric Analysis and Fastness Rating of Natural Yellow Color Dyes on Cotton Fabric

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Abstract

Today's environmental concern about the harmful effects of synthetic dyestuffs has arisen in our discourse on the use of natural dyes. Plant dyes are more favorable due to their non-toxicity, non-carcinogenic, non-allergic, and biodegradability over synthetic dyes to human beings. This work is intended to investigate the effects of three different natural yellow shaded dyes on the 100% cotton knit fabric using four kinds of synthetic mordant. A series of experiments were conducted to analyze and compare the results of these three sources of natural yellow dyes. Simultaneous extraction and dyeing methods were found to yield the best hues of yellow dye, as decided by colorimetric tests and visual analysis. The final samples were tested for fastness to light, wash, rubbing and perspiration by following the ISO standards. A significant change was observed in fastness properties and colorimetric analysis on copper sulphate treated turmeric dyed sample.

Keywords: Cotton fiber, Mordant, Natural Dye, Exhaust method, Spectrophotometer, Colorfastness.

1. Introduction

The coloration of textile materials (natural & synthetic) develops the look, appeal, and value of the product. Synthetic dyes were commercialized due to the limited resource of natural coloring substances. Natural dyes have organic value and eco-friendly application which has grown awareness among people towards the use of natural products over synthetic dyes. Vegetable dyes are very popular for coloring natural fibers, leather, and food substrate from ancient times [1]. Mordant is a chemical that improves the affinity and fastness properties of natural dyes. It forms a chemical bond with the natural fiber and helps in fixation [2]. Cotton is a cellulosic fiber that can easily be treated with natural dyes with the help of mordant. Turmeric is a plant dyestuff well known for its nontoxicity, harmless application for human beings [3]. And this turmeric has also been used for antibacterial dyeing of polyamide as a natural dye [6]. Natural dyeing with turmeric increases the value of textile products and meets the customers' wants for green products [4]. Marigold is a well-known flower plant all over the world. The yellow to orange-red extract of marigold finds a wide range of applications [2]. Orange peels, a wastage of most popular fruit orange find application as a low-cost natural dye for cotton [5]. The specific objectives of this study were to evaluate the effects of yellow color natural dye yields from turmeric, marigold flower, and orange peel to explore the possibilities of natural yellow dyes in terms of color value and fastness ratings as yellow is the liveliest and perhaps the most abundant of all hues in nature.

2. Materials and Methods

2.1 Materials:

2.1.1 Substrate:

A single jersey grey cotton knit fabric with 150 GSM was used for dyeing. And the fabric details were 52 courses per inch and 58 ends per inch.

2.1.2 Natural Dyes:

The natural dyes (turmeric, marigold & orange peel) were purchased from Gazipur, Bangladesh.

2.1.3 Mordant:

Four types of mordant: alum, ferrous sulphate (FeSO_4), potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$), and copper sulphate (CuSO_4) were collected from the textile laboratory of Northern University.

2.2 Methods:

2.2.1 Recipe of pretreatment

Sample- 15 gm
Alkali (NaOH) - 4 g/l
 H_2O_2 - 6 g/l
Stabilizer- 3 g/l
Wetting agent - 2 g/l
Detergent - 2 g/l
Sequestering agent - 2 g/l
Antifoaming agent - 0.5 g/l
Temperature - 100°C
Time - 1 hour
M:L - 1:10

2.2.2 Recipe of dyeing (Using mordant)

Sample weight	: 10 gm
Dyes (Turmeric/ Marigold/ Orange peel)	: 40 ml
Mordant ($\text{K}_2\text{Cr}_2\text{O}_7$ / CuSO_4 / FeSO_4 / Alum)	: 0.8 gm
Water	: 160 ml
Temperature	: 80°C
Time	: 1 hour

2.2.3 Recipe of dyeing (without mordant)

Sample weight	: 10 gm
Dyes (Turmeric/ Marigold/ Orange peel)	: 40 ml
Water	: 160 ml
Temperature	: 80°C
Time	: 1 hour

2.2.4 Pretreatment process

Scouring and bleaching of grey cotton fabric (15 gm) was performed in a sample dyeing machine by using sodium hydroxide (4gm/L), hydrogen peroxide (6gm/L), with wetting agent (2gm/L), sequestering agent (2gm/L), and stabilizer (3gm/L) at boiling temperature for one hour to remove the natural impurities and destroy the natural coloring matter from it.

2.2.5 Extraction of dyes

50g Turmeric, 50g Marigold flower, 50g Orange peel were separately subjected to aqueous extraction with 200 ml water for every dyestuff, Blender machine was used for crushing the dyestuff and heated for 30 minutes at 80°C, and the refined extract was filtered separately and allowed to cool.

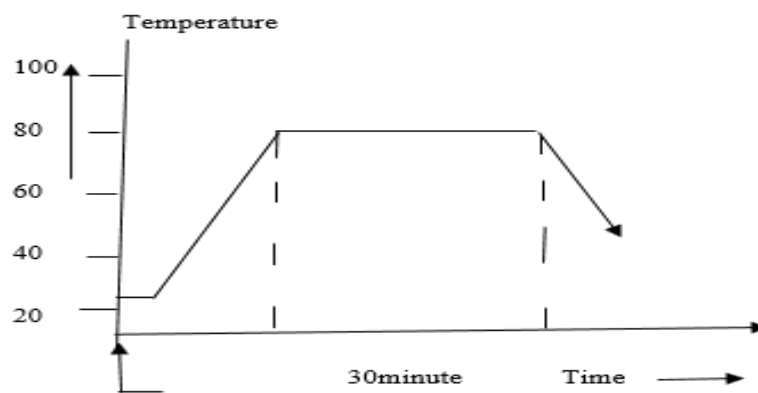


Figure 1. Extraction curve of dyes

2.2.6 Mordanting of pretreated cotton fabric

Scoured and bleached cotton fabrics were simultaneously mordanted with alum, FeSO_4 , CuSO_4 , $\text{K}_2\text{Cr}_2\text{O}_7$ at a similar concentration i.e., 8% per weight of the fabric. This mordanting was performed with dyeing in an exhaust dyeing machine.

2.2.7 Dyeing process

Cotton fabrics were dyed with the extracted dye solution from natural yellow color dyes at 80 °C for one hour following the M:L = 1:16 in a sample dyeing machine, which means that each of the 10 g cotton fabric was dyed with 160 ml extracted dye solution at the above-mentioned dyeing parameters.

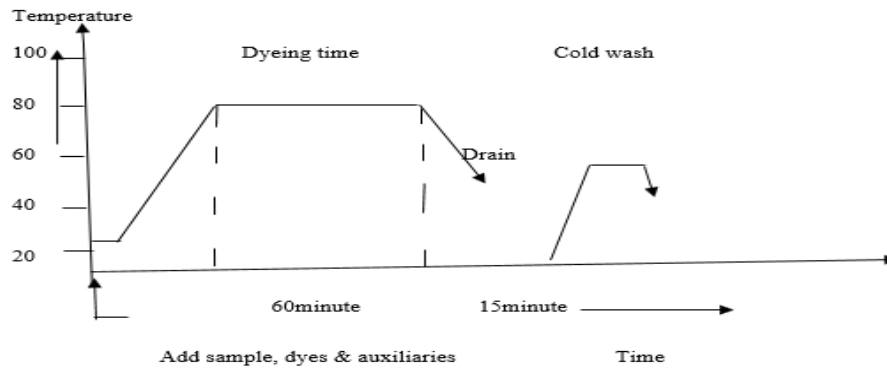


Figure 2. Process curve of dyeing

2.2.8 Different Testing Process after dyeing

Measurement of color co-ordinate

Through data color 650[®] Spectrophotometer, the color coordinate values of all dyed specimens were measured by following CIE Lab or CIE LCH method.

Where,

L*=Lightness/darkness value

a*=Red/Green axis, +a represents Redder, and -a represents Greener

b*=Yellow/Blue axis, +b represents Yellower, and -b represents Bluer

C*=Chroma, +ve represents brighter and -ve represents duller

h*= Hue

Measurement of Color strength:

The K/S value was assessed by a Spectrophotometer to observe the color strength of dyed samples which works on the Kubelka-Munk equation:

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

Where R is the decimal fraction of the reflectance of dyed fiber.

K=light absorbed

S=light scattered

Evaluation of colorfastness to washing (ISO 105-C06-A2S)

To measure the colorfastness to wash properties of the dyed samples, the following parameters were maintained. To assess color change (ISO 105 A02) and color staining (ISO105 A03), standard grayscale was utilized to obtain ratings.

Assessment of wet and dry rubbing color fastness (ISO 105 X12:2016)

Dyed specimens were mounted on the crock meter and the finger of the crock meter was covered with a 5× 5 cm crocking cloth. The samples were rubbed with the finger of the meter at 10 turns within 10

seconds yielding 9 ± 2 N pressure on fabrics. But for the wet rubbing test, this process was followed after soaking the fabric at 100% pickup.

Determination of light fastness (ISO 105-B02)

The resistance of color of textiles to fade or bleed against light is called colorfastness to light. A light fastness tester was used to assess the fastness rating. Then the test specimen was compared with the blue scale or computer color matching system (CCMS).

Assessment of colorfastness to perspiration (ISO 105-E04)










The ability to resist change in color and stain in color against perspiration is called colorfastness to perspiration. Colorfastness test against perspiration of all dyed samples was measured in media like acid and alkali according to the ISO 105 E04 testing method. Then the assessment of the sample was performed.







3. Results and Discussions

3.1 Visual appearance

The pictorial assessment of turmeric, marigold flower, and orange peel natural dyes when individually applied to cotton fabric samples using four different types of mordants following continuous mordanting technique is tabulated in Table 1. From the visual assessment, it has been found that among the three dyestuff, Turmeric dyestuff gave the best yellow shade with the mordants copper sulphate and alum. But it was observed that among all mordants, Copper sulphate exhibited the best properties as a mordant on cotton fabric for yellow shade in Turmeric dye. Likewise, alum worked well with marigold flowers whereas ferrous sulphate was found better in orange peel color.

Table 1. Image of yellow shade natural dyed cotton sample with and without mordant.

Sl. No.	Dyestuff	Mordant	Shade
S-1	Turmeric	Without Mordant	
S-2	Turmeric	$K_2Cr_2O_7$	
S-3	Turmeric	$FeSO_4$	
S-4	Turmeric	$CuSO_4$	
S-5	Turmeric	Alum	
S-6	Marigold	Without Mordant	
S-7	Marigold	$K_2Cr_2O_7$	
S-8	Marigold	$FeSO_4$	
S-9	Marigold	$CuSO_4$	

S-10	Marigold	Alum	
S-11	Orange Peel	Without Mordant	
S-12	Orange Peel	K ₂ Cr ₂ O ₇	
S-13	Orange Peel	FeSO ₄	
S-14	Orange Peel	CuSO ₄	
S-15	Orange Peel	Alum	

3.2 Color co-ordinate value

From Table 2, it can be seen that samples S₄ and S₅ dyed with turmeric dyes using copper sulphate and alum as mordant describes brighter yellow shade than with other two mordants under D₆₅ illuminant. Similarly, for marigold dyes, the value b* of the S₁₀ sample exhibits a better depth of yellow color than the other three mordant treated cotton samples. Likewise, for orange peel dyes, the color value indicates that the use of ferrous sulphate provides a brighter yellow shade in the case of the S₁₃ sample. Comparatively, without mordant S₁ presents an excellent shade than the other two sources of natural yellow color.

Table 2. CIE color coordinates of three natural dyed samples (Turmeric, Marigold, and Orange peel).

Sample no.	Illuminant	L*	a*	b*	c	h
S-1	F11	82.17	4.51	39.19	39.45	83.44
	D65	80.21	5.24	35.16	35.55	81.53
S-2	F11	83.53	3.12	33.26	33.41	84.64
	D65	81.93	3.33	29.72	29.91	83.6
S-3	F11	82.44	4.13	32.21	32.48	82.69
	D65	80.81	4.62	28.71	29.08	80.86
S-4	F11	80.02	3.58	63.59	63.69	86.78
	D65	77.47	4.2	58.02	58.17	85.86
S-5	F11	79.27	7.03	57.88	58.31	83.07
	D65	76.62	8.2	52.29	52.93	81.09
S-6	F11	74.62	3.09	20.17	20.4	81.28
	D65	73.87	2.41	18.07	18.23	82.39
S-7	F11	90.83	-0.08	7.17	7.17	90.63
	D65	90.62	-0.73	6.45	6.49	96.47
S-8	F11	77.84	1.73	10.13	10.28	80.32
	D65	77.4	1.4	9.07	9.17	81.25
S-9	F11	78.49	2.68	27.4	27.53	84.41
	D65	77.29	2.21	24.39	24.49	84.83
S-10	F11	75.2	4.07	33.62	33.87	83.1

	D65	73.81	3.56	30	30.21	83.24
S-11	F11	93.01	0.06	4.96	4.96	89.33
	D65	92.84	-0.32	4.5	4.51	94.07
S-12	F11	91.38	-0.17	6.95	6.95	91.39
	D65	91.2	-0.91	6.27	6.33	98.26
S-13	F11	82.56	5.3	29.02	29.5	79.65
	D65	81.02	5.72	25.62	26.25	77.41
S-14	F11	88.17	-1.18	14.69	14.73	94.59
	D65	87.71	-2.26	13.23	13.42	99.69
S-15	F11	91.78	-0.05	10.58	10.58	90.29
	D65	91.39	-0.69	9.52	9.54	94.15

3.3 Evaluation of color strength value

The color strength value of sample S₄ is higher than all other samples colored with three different sources of natural yellow dyes. The mostly light-yellow shade was achieved for the S₄ sample treated with CuSO₄ mordant and a dark shade of turmeric yellow hues with alum obtained for the S₅ sample. Untreated sample S₁ shows better color strength for turmeric dyes.

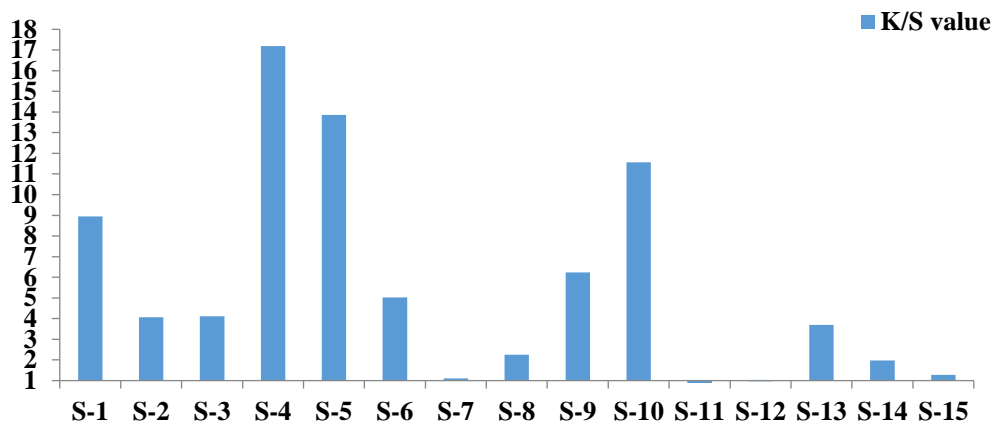


Figure 3. Color strength value of the natural yellow color dyed sample.

3.4 Colorfastness to wash

In the colorfastness to wash test, it has been found that the color change rating of S₄ & S₅ was poorer than other samples although the color value of these two samples falls in the darker yellow region. Color staining of the S₃ sample defines a fair wash fastness rating. Sample S₉, sample S₁₃ & another two samples address the yellow region of color space and provide good fastness against color staining but poor to fair result was achieved for S₉ and S₁₃ samples.

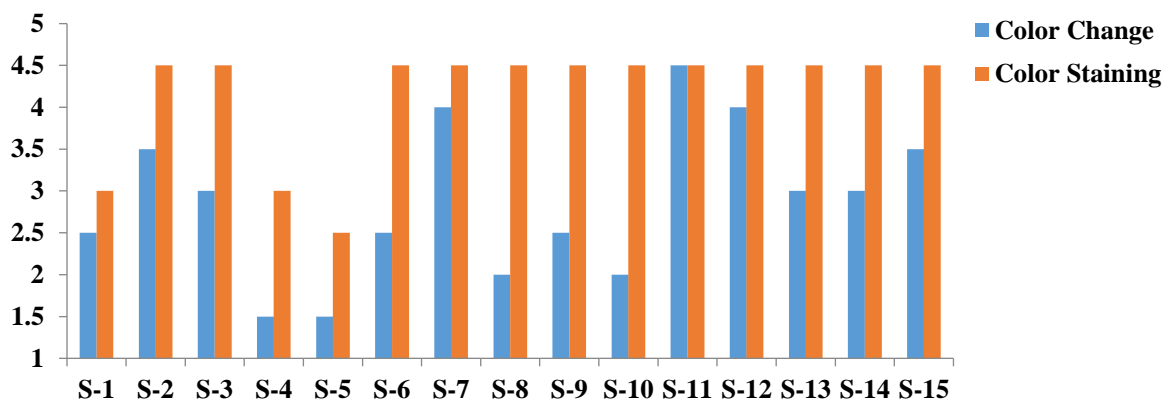


Figure 4. Rating of colorfastness to the washing test result of dyed samples

3.5 Colorfastness to rubbing

It was a noticeable matter that dyeing individually by three natural dyestuffs with different mordants gave excellent rubbing fastness results. Sample S₄, S₅, S₉, and S₁₀ exhibit good to excellent dry rubbing fastness whereas wet rubbing was found to be fair to a good. Without mordant, samples S₁, S₆ and S₁₁ show excellent dry and wet rubbing performance.

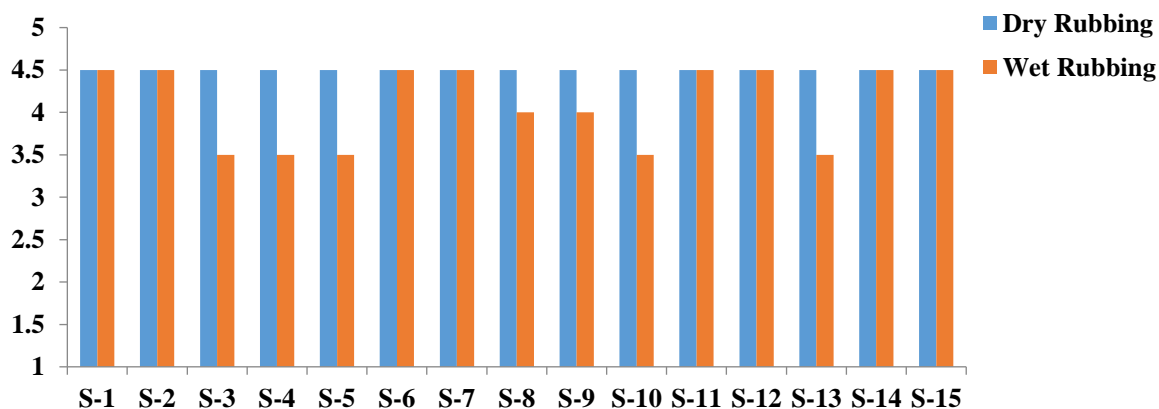


Figure 5. Rating of colorfastness to the rubbing test result of dyed samples

3.6 Colorfastness to perspiration

In the colorfastness to perspiration test, a good fastness rating against acid and alkaline perspiration were obtained for S₅, S₉, and S₁₃ samples. Here sample S₄ has shown a poor rating of perspiration fastness. Without mordant, samples S₁, S₆ and S₁₁ give a good effect in colorfastness to perspiration.

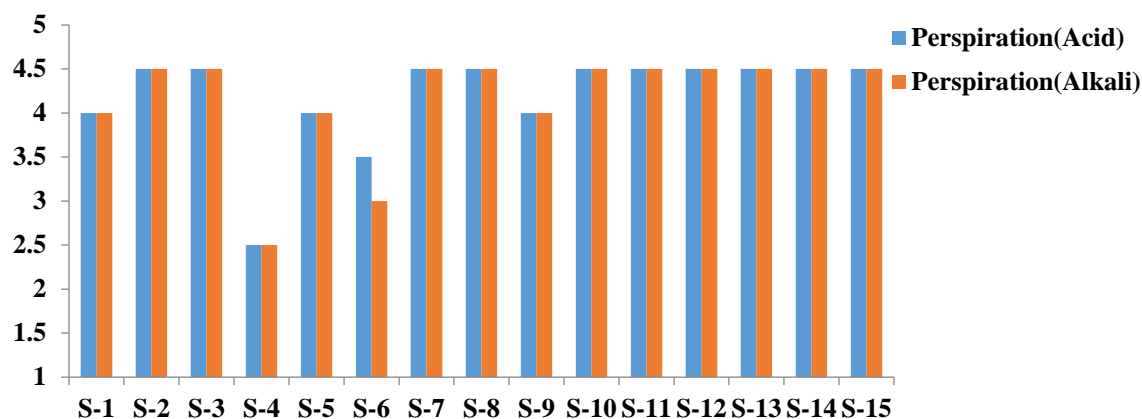


Figure 6. Rating of colorfastness to the perspiration test result of dyed samples

3.7 Colorfastness to light

Without mordant of cotton fabric dyeing with turmeric dyestuff gave very poor result. But sample S₃, S₄, S₉, and S₁₃ indicate good ratings against the light. Here copper sulphate acts as a very good mordant for this sample.

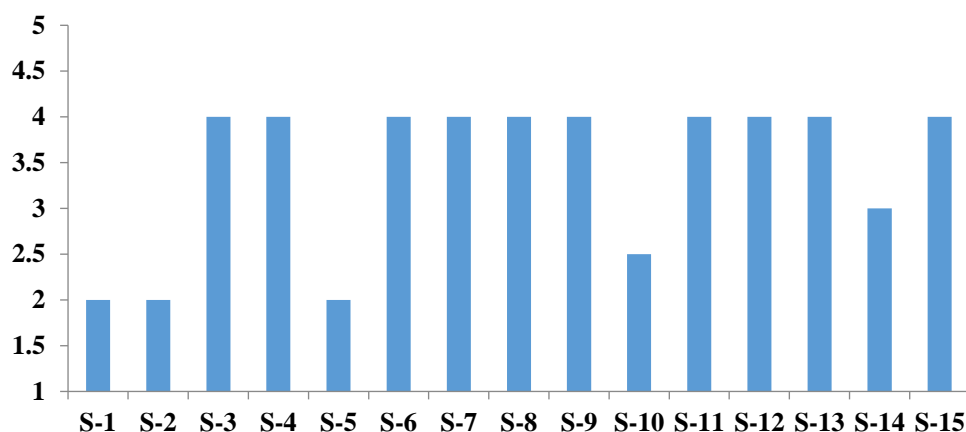


Figure 7. Rating of colorfastness to the light test result of dyed samples

4. Conclusions

This work has been conducted to analyze the yellow hues extracted from natural turmeric, marigold, and orange peel sources on 100% cotton knit fabric. Four different types of inorganic substances (copper sulphate, ferrous sulphate, alum, and potassium dichromate) have been used as mordanting agents or fixing agents, resulting in greater depth of shade and colorfastness. Without any mordant, the natural yellow hue was found on cotton fabric for turmeric dyes. Likewise, marigold and orange peel didn't produce any color on cotton in the absence of mordanting agents. Applying turmeric with four different mordants changed the yield of yellow hues. Sample S₄, S₅, S₁₀, and S₁₃ produce a different depth of yellow shade on cotton by creating a larger complex with mordanting agents. Copper sulphate and alum with natural turmeric yield the best results among all the samples. But the light, perspiration, and rubbing fastness properties show improvement while washing fastness exhibits deterioration.

Furthermore, most of the fastness properties of this natural dye are poor, but somewhat comparable when the fabric is treated with mordants. Alum and copper sulphate considers as the best mordant for turmeric and marigold dyes and ferrous sulphate for orange peel dyes.

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Conflict of interest

All authors are confirming that there is no conflict of interest of this work

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Application of Nanotechnology in Antimicrobial finishes for Textiles

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Abstract

Pathogens may spread illness via contact with infested fabrics, which generate odor when close to the skin. Microbial degradation causes fabrics to become discolored, tinted and lose their ability to perform their intended purpose. For medicinal and hygiene applications, non-toxic and environmentally friendly antimicrobial agents are in high demand. Poly hexamethylene biguanide (PHMB), quaternary ammonium compounds (QACs), metals (including metal oxides and salts), triclosan, and n-halamines were among the synthetic biocides whose effects were intensively studied. Aside from the natural biocides, such as essential oils and plant-based chitosan, plant-based extracts (AMPs) were the most often used plant-based biocides. A review of recent research on antimicrobial finishing, types of finish agents, and various current developments in antimicrobial finishing will be briefly covered to minimize the risks associated with the application of organic and inorganic antimicrobial finishes and plant-based antimicrobial finishes.

Keywords: Antimicrobial finishes, nanotechnology, Textiles, Micro-organism, Plant based finish

1. Introduction

The medical and pharmaceutical industries were the primary users of antibiotics. Nevertheless, other applications may be developed in the future. Antimicrobial reagents are being used more often to treat textile fibers[1]. Medical, surgical, and sanitary items, as well as food packaging, are further examples. Biocidal treatments in textiles (sportswear, undergarment, bed linen) and water filtration are becoming more popular as people's standards of living rise. Medical, surgical, and healthcare operations have grown more dependent on final antibacterial treatment owing to the possible dangerous microorganisms present in the hospital environment, which may cause cross-infection disorders[2]. In addition to viruses, bacteria, unicellular plants and animals, some algae and fungus, there are many more microorganisms. Gram-positive, gram-negative, spore-bearing, and non-spore-bearing bacteria all fall within this category. Pathogenic microorganisms have been found in several of the samples[3]. It is common for a microorganism (e.g., bacterium or fungus) to have an exterior cell wall made of polysaccharides. Under the cell wall, a semi-permeable membrane houses internal organelles, enzymes, and other cellular constituents, ensuring the integrity of these components and protecting the cell from the external environment.

DNA, RNA, and other types of nucleic acids. Enzymes in the cell wall are responsible for the chemical processes inside the cell wall. The genetic code of all creatures is stored in nucleic acids. Therefore, substrate creation and chemical processes may favor microbe development; a damp and warm climate further exaggerates the issue[1]. Microbes are frequently prevalent in the environment. Peptidoglycan and teichoic acid are found in gram-positive bacteria. Peptidoglycan makes up 90% of the cell wall and is composed of amino acids and sugars. Staphylococcus aureus, a gram-positive bacterium, is an example of a pair, short-chain, or graphic cluster. It may develop to a diameter of 0.5 to 1.0 mm at a temperature of 35 to 40 °C.

Cross-infection in the hospital setting is caused by Staphylococcus aureus, accounting for 19 percent of all surgical infections. Boils and scaling skin infections are also caused by it. Staphylococcus epidermidis, Streptococcus pneumonia, Streptococcus pyogenes, and Streptococcus viridian's are all examples of gram-positive bacteria. Lipoproteins attached to peptidoglycan by the outer membrane of

gram-negative bacteria differ from the outer membrane of gram-positive bacteria in that they are utilized to transport molecules with too low a molecular weight. In contrast to gram-positive bacteria, gram-negative bacteria are more difficult to eradicate since they have more cell walls. As an example of gram-negative bacteria, *E. coli* (also known as *E. coli*) may be found in the human digestive tract. The bacteria *Escherichia coli* can grow in the body when raw food is consumed and used. *E. coli* symptoms include severe diarrhea (particularly in children) and renal damage. Others in this family include *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Salmonella Typhi*, *Salmonella enteritidis*, and *Haemophilus influenzae*, to name just a few [4]. Fabrics that come into close touch with the human body might get infested by a microorganism, causing cross-infection by diseases and an unpleasant odor. Furthermore, microbial degradation causes fabrics to become discolored, tinted and lose their functional properties [5]. Fungi moths or mildews are organisms with a reduced rate of development; they discolor the substrate and impair the fabric's functional properties. This kind of microorganism, which may be either fungus or bacteria, causes black stains to appear on the material's surface. Dust mites may be found in various household fabrics and bed linens, although they are most prevalent in mattresses and carpets. Allergies are caused by the healing waste products of dust mites, which feed on human skin.

2. Methodology

2.1 Methods of Antimicrobial Finishing

Some germs may be inhibited (static) or killed (cidal) due to antimicrobial finishing on textile substrates. Because enzymes produce microorganisms' sustenance, an antimicrobial finish must prevent protein synthesis in germs and hinder enzyme production from killing them. Silver, quaternary ammonium compounds (QAC), N-Halamines, triclosan, and polyhexamethylenebiguanide (PHMB) are examples of well-established antibacterial agents that are almost biocides [6].

2.2 Antimicrobial Finishing Mechanism

The antibacterial function of a given finish on a textile may be used to identify three different finishing techniques. Control-release, regeneration, and barrier-block are examples of these systems. There are issues with the first two mechanisms of ending.

An antimicrobial agent from fabric that comes into touch with the wearer's skin concerns the control release mechanism's longevity after laundry. These substances can irritate and cause allergies in people with healthy skin. After washing, the antibacterial characteristics of fabrics treated with a regenerate mechanism are no longer activated, leading to these issues. Chlorine bleach is not only bad for cotton, but it is also bad for your skin as well. In contrast to the other two ways, barrier-blocking does not have drawbacks. In order to destroy germs that come into touch with the fabric, these agents are attached to the fabric surface and do not leach [7]. Types of Antimicrobial Finish are :

- Organic antimicrobial agents
- Inorganic antimicrobial agents
- Eco-Friendly Antimicrobial Agents (Natural Plant and Fruit Extracts)
- f Nanotechnology in Antimicrobial Finishing

There were some interesting findings and some interesting discussions.

3. Results and Discussions

Infectious diseases may be thwarted by nanotechnology. Several characteristics were used to regulate, modify, and assemble nanoscale components to produce materials, systems, or devices using nanotechnology. The antimicrobial properties of silver nanoparticles against bacteria were outstanding in studies. Polycaprolactone (PCL), an FDA-approved polymer, was combined with antibacterial metals such as zinc, copper, and silver to form filaments. Hot-melt extrusion was employed to make metal-homogeneously loaded filaments to extrude pellets made by vacuum-drying PCL and metal solution mixtures. Filaments with varied metal concentrations were used to create a variety of wound dressings. Silver and copper wound dressings were shown to be the most effective in killing germs when evaluated using a thermal activity monitor device[8].

In the modern-day, metal oxide nanoparticles (MeO-NPS) have emerged as a viable substitute for antibiotics that are both toxic and resistant to many antibiotics. Antibacterial and antifungal activity of ZnO nanostructured particles on cotton textile surfaces with different surfactants stabilized, homogenized, increased its resistance to leaching, and showed the highest antibacterial activity against different pathogenic bacteriological and fungal species with a high reduction of more than 90%. Using Zn-nano-particles and soluble starch as capping agents to study antimicrobial property demonstrated that the capping agents oversee antibacterial activity, resulting in reduced particle size of 3-5nm and increased antimicrobial rate[9]. Nanoparticles of copper in a glycerol-polyvinyl alcohol matrix in gel and moldable plastic form show that it is possible to develop and apply this technology.

At high temperatures, this is an easy puzzle to solve. Both *Escherichia coli* and *Enterococcus fecal* bacteria are inhibited in the presence of copper nanoparticles formed by the materials (. They have shown antibacterial efficacy against several different bacterial species with a minimum inhibitory concentration (MIC) against *Staphylococcus aureus* of 960 L/ml, making biocompatible nanogold (AuNPs) an attractive candidate for use in nanomedicine due to their unique size-dependent chemical, electronic, and optical properties[10].

Chitosan-neem nanocomposites were employed to solve the toxicity and washing-durability issues associated with plant-based extracts in the production of antimicrobial cotton. In contrast to chitosan, silver nanoparticles chelated with surfactant-aided chitosan gelation demonstrated perfect antibacterial activity at lower concentrations based on poly-(N-isopropyl acrylamide) chitosan micro-gel[11]. The biosynthesis of AgNP utilizing pre-hydrolysis fluid of *Eucalyptus* wood has been validated in another investigation as a beneficial antimicrobial agent for numerous biological purposes. Chitosan and acrylic acid bi-grafted polypropylene melt-blown nonwoven membrane immobilized with silver nanoparticles also shown good antibacterial and hydrophilic characteristics[12].

4. Conclusions

Antimicrobial finishing agents come in a wide range of intriguing varieties. On the other hand, limitations are possible to meet performance, environmental friendliness, and price criteria. Acceptable levels. While organic antimicrobial compounds have fewer side effects than their inorganic counterparts, they are less effective against a broader spectrum of bacteria and are not as durable in the wash. The usage of nano-particles has enhanced the efficacy of several antimicrobial agents, decreased environmental hazards connected with these chemicals (such as toxicity and washing durability), and demonstrated outstanding antibacterial properties vs. microorganisms. Despite their washing-durability problem, natural plants-based antimicrobial finishes are generally recognized antimicrobial agents for textile finishing because of their eco-friendly and non-toxic features. An increasing number of fields are turning to plant-based nanoparticle antimicrobial agents because of their superior characteristics and protection against pathogens compared to conventionally used biocides, and such value-added finishes could provide sustainable healthcare applications in textile.

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Conflict of interest

All authors are confirming that there is no conflict of interest of this work.

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