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Dyeing Behavior and Fastness Properties of Corn (PLA) Fiber

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Abstract: *Corn fibre(PLA) were dyed with two disperse dyes. The corn fibres showed better dye uptake at 110^0C.but at this temperature strength of corn fibre is decreased. In this paper Dyeing behavior of Corn fiber (PLA) was investigated. The corn fiber were evaluated for colour strength, tensile strength, elongation and fastness properties like colour fastness to washing, perspiration, hot pressing and light.*
Keywords: *Colour strength, PLA fiber, tensile strength, elongation and fastness properties*

I. Introduction

Polyester fiber (PET) is a petroleum-based fiber, its life cycle is claimed to cause a global warming. For this reason, a greener polyester fiber has been developed to use for textile production. Poly (lactic acid), PLA, is considered as the eco-polyester fiber. It is derived from renewable materials e.g. corn, sugar and starch. Fermentation of the materials yields lactic acid which is then used for PLA polymerization [1].

An attempt to use PLA as a textile fiber with the aim of replacing PET, fiber with this green polyester fiber. PLA fiber are more hydrophilic than PET, have a lower density, and have excellent crimp and crimp retention. Shrinkage of PLA materials and thermal bonding temperatures are readily controllable. These PLA fiber tend to be stable to ultra-violet light resulting in fabrics that show little fading. They also offer low flammability and smoke generation characteristics [2].

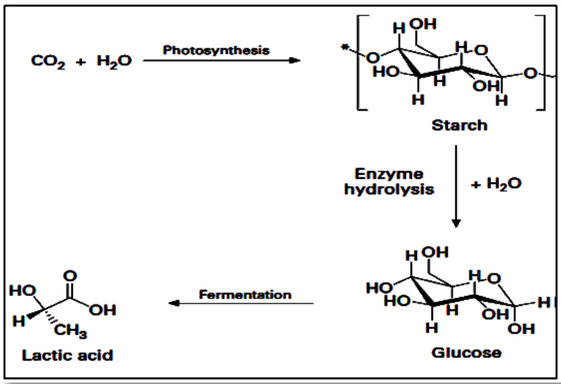

Fig. 1: Production of Lactic Acid From Renewable Resources

PLA fibers to be seen as a replacement for polyester. Since PLA is a hydrophobic fiber, disperse dyes that have a high affinity for other hydrophobic fibers such as PET are expected to have affinity for PLA. PET is commonly dyed at 130°C, which is above the melting point of PLA. PLA is generally dyed at 110°C and for shorter lengths of time. Excessive heat or extending the dyeing time will cause degradation and loss of tensile strength, molecular weight and elongation at break [3].

Advantages of corn fiber:

- PLA has over petroleum-based polyesters is that it biodegrades into nontoxic biomasses.
- Bio based polymers such as PLA are capable of biodegrading to carbon dioxide and water. Thus the products will totally biodegrade back to these atmospheric components in 20-30 months in soil and in 30-40 days in standard compost.
- PLA is considered as the eco-polyester fiber.

II. Material And Methods

2.1 Material

Corn fibers (PLA), Foron Brill Red SRI, Foron Yellow Brown S2RFLI disperse dyes and Acetic acid (pH maintaining), Sodium hydroxide (Alkali Sodium, dithionate (Reducing and wetting agent) Lissapol (Dispersing agent) these material are used for the study. All the chemicals used in the research were supplied from Merck. The fibre properties of PLA and PET fibre are shown in the table 1.

Table 1: Properties of PLA fiber

Properties	PLA	PET
Tm (0C)	130-175	254-260
Tenacity (g/d)	6.0	6.0
Moisture regain (%)	0.4-0.6	0.2-0.4
Flammability	Continues to burn for 2 min after flame removed	Continues to burn for 6 min after flame removed
Smoke generation	63 m^2 /kg	394 m^2 /kg
Limiting oxygen index (%)	26	20-22
Refractive index	1.35	1.45

2.2 Dyeing

Two disperse dye such as Foron Brill Red SRI, Foron Yellow Brown S2RFLI were procured from M/s Clariant (India) Ltd. Fibres were dyed at 2% shade using IR dyeing machine. The dyeing was carried out at pH of 5 and 2% owf depth of the shade was taken. Dyeing process began at 70^0C, dye bath containing dispersing agent, leveling agent. The holding time of the dyeing was 45 minutes. At this time three dyeing studies were carried out by changing temperature from 70^0C to 110^0C shown in figure 2, 3 and 4. After dyeing the dye bath was cooled down and reduction clearing was carried out [4].

2.3 Colour Measurement:

Colour depth of the dyed fibres were analysed by measuring the K/S values using a Macbeth Colour-Eye 3100 spectrophotometer. K/S is directly proportional to the concentration of colorants in the substrate. Higher the value of K/S, higher will be the concentration of dye in the substrate. The dyed fibres were combed to make them parallel and then attached neatly on the cupboard. The K/S values of the fibres were determined through Kubelka – Munk equation as given below:

$$K/S = (1-R)^2 /2R$$

Where,

R is the reflectance at complete opacity **K** is the absorption coefficient
S is the scattering coefficient
Dyed fibres were simultaneously evaluated in terms
CIELAB colour space (L, a*, b*) values. In general, the higher the K/S value, the higher the depth of the colour on the fibre of L correspondence to the brightness (100= white, 0= black), a* to the red –green coordinates (+ ve = yellow,-ve = green) and b* to the yellow-blue coordinates (+ve=yellow,-ve =blue).as a whole, a combination of all parameters enables one to understand the tonal variations.

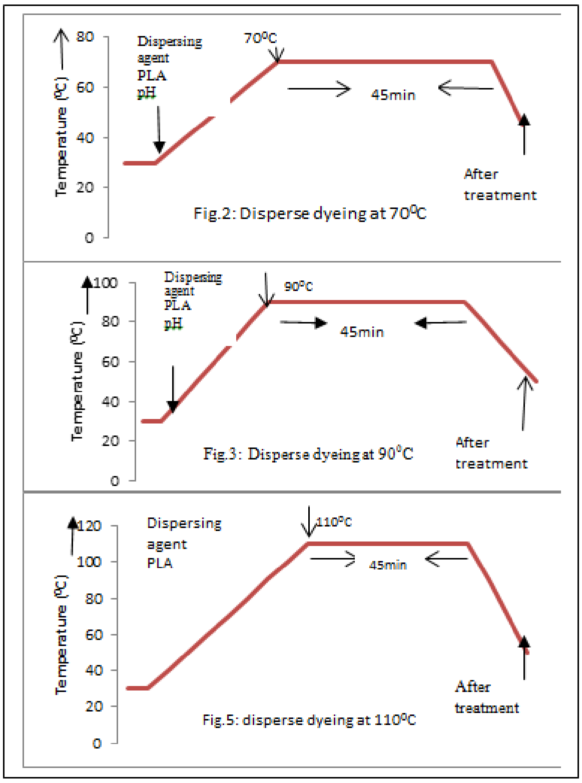

Fig.2: Disperse dyeing at 70ºC

Fig.3: Disperse dyeing at 90ºC

Fig.5: disperse dyeing at 110ºC

2.3 Colour fastness properties

For assessment of quality of dyed fibres samples ,colour fastness to washing, light, and perspiration and hot pressing properties were evaluated using ISO 105 C 10A(1), ISO 105 B02, ISO 105 E04 standard test methods respectively. Change in colour and staining on adjacent fibre of the dyed fibre were assessed by giving rating of 1(poor) to 5(excellent) by comparing with grey scale in the case of colour fastness to washing and perspiration. The colour fastness to light was assessed by comparing the exposed fibres and blue wool standard nos 1 to 8. The Following tests were carried out as per the standard mentioned in table 2:

Table 2: Standard for Tests Methods

Test name	Standard
Colour fastness to light	IS 2456:1985
Colour fastness to Perspiration	ISO: 105E-04
Colour fastness to washing	ISO: 105-C10(3)
Colour fastness to Hot Pressing	IS-689:1988
Single fiber length	ASTM D1557-07
Tensile strength	ASTM D 3822-07

III. Result and Discussion

3.1 Effect of temperature

The colour strength of dyed fibres increases with an increase the dyeing temperature. But tensile strength decreased at the temperature raised up to 110^0C. The effect of dyeing temperature on colour strength is shown in table 3 and figure 6.

The dye uptake by the fibres maximum at 110^0C temperature, but at this temperature dyed fiber is highly rigid in nature.

Table. 3: K/S Value of Corn Fibre

Temperature (°C)	**Dyes Name**	**K/S**	**L***	**a***	**b***
70	Foron yellow brown S2RFLI	0.77	34.720	9.852	26.243
	Foron brill Red SRI	.38	21.671	14.866	9.373
90	Foron yellow brown S2RFLI	11.03	57.800	28.119	60.924
	Foron brill Red SRI	2.35	31.546	32.420	20.971
110	Foron yellow brown S2RFLI	20.61	58.208	32.297	64.024
	Foron brill Red SRI	27.29	38.843	47.777	30.323

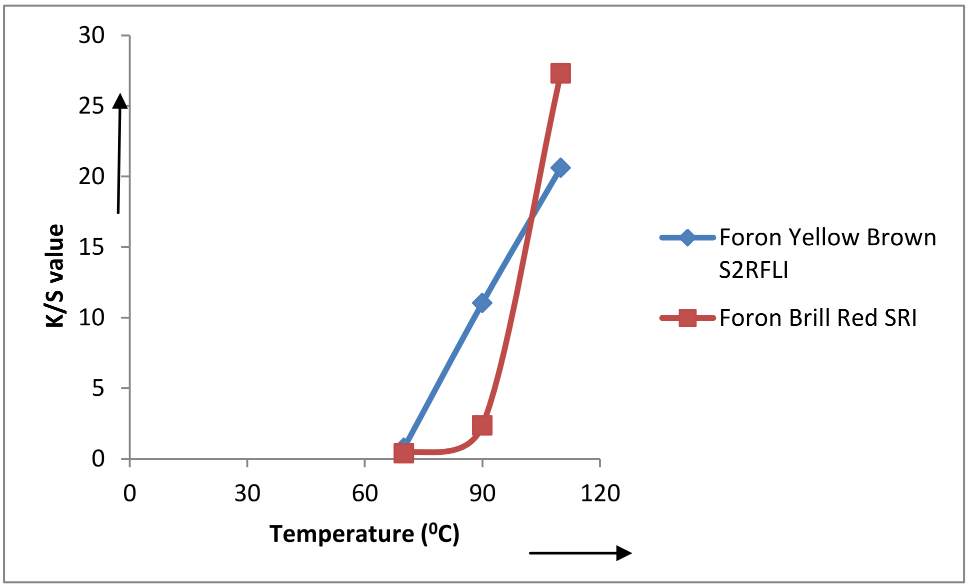

Fig.6: K/S value vs temperature

3.2 Colour fastness properties

The results of colour fastness to light, washing, perspiration and hot pressing are reported Table 4, 5, 6 and 7.

Table 4: Colour Fastness to Light

Temperature °C	**Dye class**	**Rating for change in colour**
70°C	Foron brill Red SRI	4
	Foron yellow brownS2RFLI	3/4
90°C	Foron brill Red SRI	4-5
	Foron yellow brownS2RFLI	5
110°C	Foron brill Red SRI	4-5
	Foron yellow brown S2RFLI	5

Table 5: colour fastness to washing

Temp (0C)	Dye class Acid dye	Change in colour	Staining on white cotton	Staining on multi fiber					
				wool	Acrylic	Polyester	nylon	cotton	Acetate
70^{0}c	Foron brill Red SRI	4-5	5	5	5	4-5	4-5	5	5
	Foron yellow brown S2RFLI	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
90^{0}c	Foron brill Red SRI	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	Foron yellow brown S2RFLI	4-5	4-5	4-5	4-5	4-5	4	4-5	4-5
110^{0}c	Foron brill Red SRI	4	4-5	4-5	4-5	4	3-4	4-5	4
	Foron yellow brown S2RFLI	3	4-5	4	4-5	3-4	4-5	4-5	4

Table.6: Colour fastness to perspiration (90^{0}C)

‘	**Alkaline perspiration**							
Dye class Disperse dye	**Change in colour**	**Staining on white cotton**	**Staining on multi fiber**					
			Wool	**Acrylic**	**Polyester**	**Nylon**	**Cotton**	**Acetate**
Foron Brill Red SRI	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Foron Yellow Brown S2RFLI	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Acidic perspiration								
Foron Brill Red SRI	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Foron Yellow Brown S2RFLI	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Table 7: Colorfastness to Hot Pressing (90^{0}C)

Dye class	**Change in colour**	**Staining on white cotton cloth**
Foron Brill Red SRI	4-5	4-5
Foron Yellow Brown S2RFLI	4-5	4-5

3.3 Single fibre length and tenacity

From the table 8 and 9 indicate that after dyeing single fibre length of the corn fibre decreased. Tenacity and elongation of dyed fibres decreased as well as temperature increased.

Table 8: Single fibre length

S.No.	(Before Dyeing) (mm)	(After Dyeing) (mm)
1.	34	37
2.	38	27
3.	39	26
4.	40	36
5.	38	22
6.	43	38
7.	40	25
8.	25	23
9.	42	36
10.	39	36
Mean	37.8	30.6

Table 9: Tensile strength of dyed and undyed Corn fiber

Temperature	**Undyed fiber**	**90^0c**	**110^0c**
Fiber denier	1.61	1.37	1.60
CV%	18.11	15.47	19.22
Tenacity(grm/denier)	3.44	3.30	.97
CV%	20.00	27.00	16.81
Elongation at break %	48.42	33.96	11.84
CV%	34.00	32.12	34.23
Single Fiber length in mm	37.8	34.2	30.6

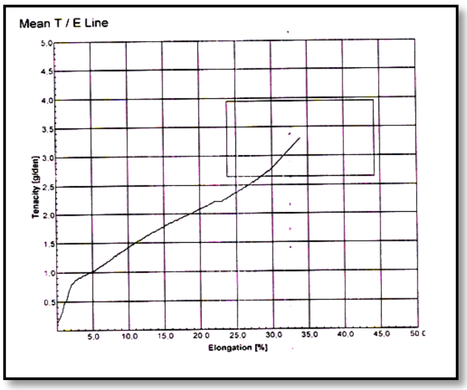

Fig. 8: Mean Tenacity vs E Line Graph of Undyed Corn Fiber

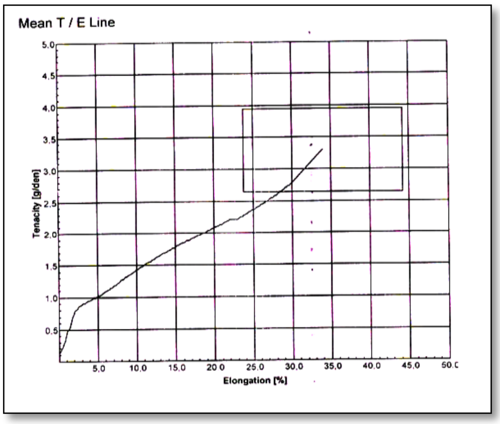

Fig. 9: Mean Tenacity vs E Line Graph of Dyed Corn Fiber at 90^0C

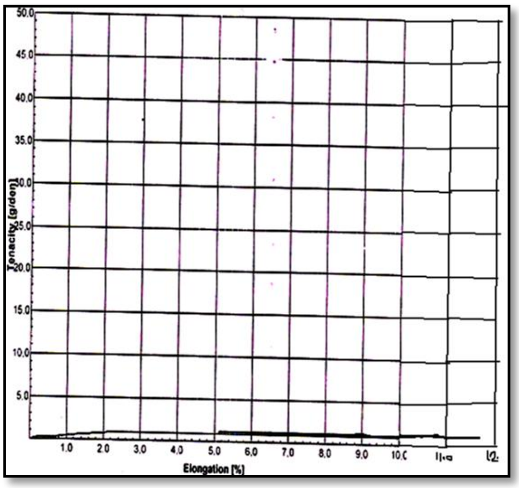

Fig.10: Mean Tenacity vs E Line Graph of Dyed Corn Fiber at 110^0C

IV. Conclusion

Dyeing behavior of corn (PLA) fibre is showed that at higher temperature the colour strength of Corn fiber was higher as compared to other lower temperature but tenacity decreased at higher temperature due to the structure degradation. Effect of dyeing on fibre properties also studied. It is clear that the tenacity (3.44) and elongation at break (48.42) of undyed fiber was higher as compared to dyed corn fiber (3.30, 33.96). As the temperature increased the value of tenacity (.97) as well as elongation at break (11.84) decreased.

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