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Effect of pH and Oxidation Reduction Potential on Dyeing of Modal Knitted Fabric with Natural and Synthetic Indigo

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Abstract - *Application of natural indigo dye can be observed from the ancient time. After the invention of synthetic indigo, this dye is being used widely in producing blue jeans from the early twentieth century. In the recent time, the use of natural dyed textiles are appreciated globally considering its Eco- friendliness. In this current study, dyeing performance of both natural and synthetic indigo dye on modal fibre had been studied in terms of dye uptake (K/S value), color fastness to rubbing and color fastness to wash. It had been found that natural dye showed comparatively lower dye absorbency than synthetic dye at the same dyeing parameters but the color fastness to wash and rubbing is found comparatively better in natural indigo dyed modal than the synthetic indigo dyed modal.. This study shows the promising future of newly revived natural indigo dye for the coloration of cellulosic fibres.*

Key Words: **Indigo, ORP, Modal, K/S, Color Fastness**

1. INTRODUCTION

Indigo is one of the oldest natural coloring substances used for textile coloration [1]. Indigo dye is produced in a vat process in which chemical reactions, including fermentation, reduction, & oxidation occur. It imparts a distinctive blue to cloth that has inspired people around the world for thousands of years [2]. Dye is extracted from the indigo plant through a process of fermentation involving plant matter & water with the addition of a strong alkali [3]. Fermentation methods were replaced by synthetic indigo in the last century. Chemical synthesis of indigo in the industrial scale has abolished the natural indigo manufacturing [4]. Recently, natural indigo manufacturing is going to be revived in various zone of the world especially in Bangladesh and India which zone has long diversified history of indigo cultivation [5-8]. In the colonial period, indigo cultivation was the symbol of exploitation of farmer but nowadays it is considered revival of sustainable coloring material which is considered ecofriendly [9, 10].

Indigo is applied traditionally on cotton textiles especially in the blue jeans as well as other denim articles. Many attempts were taken to apply indigo dye on polyester, wool, nylon or even various blended fiber fabrics [11-14]. On the other hand, manufacturer are developing varieties of fabric structure dyed with indigo dye. Knitted fabric with denim effect is one the best example in this regard which is also called as knitted denim [15, 16]. In the recent time, application of regenerated cellulosic fibers are increasing day by day due to shrinkage of cotton cultivation land as well as considering the sustainability issue [17]. So, the consumers as well as suppliers are developing textiles with regenerated cellulosic fibers. In the current study, one the popular regenerated cellulosic fiber, modal is dyed with both natural and synthetic indigo dye to investigate its dyeing quality and to establish its relation with the influential parameters e.g. pH and Oxidation Reduction Potential (ORP) with the dyeing performance.

2. MATERIALS AND METHODS

2.1 Materials

100% modal yarn in this research work was collected from Lenzing Bangladesh office and knitted in a single jersey circular knitting machine. The fabric is mildly scoured to remove residual dust and spin finish chemicals during fiber manufacturing. The areal density of all the fabric was around 160 g/m^2. The origin of synthetic Indigo dye was Jiangsu World Chemical Co. Ltd., China and the natural indigo dye was collected from Bangladeshi Indigo dye manufacturing company, CARE Bangladesh brand named "Living Blue". The others chemicals used in this experiment e.g. wetting agent, sequestering agent, Turkey Red Oil (TRO) and detergent were collected from a local chemical suppliers whereas Glauber's salt, hydrose, sodium hydroxide, sodium carbonate, sodium perborate used in this study were lab grade chemicals from Merck, Germany. The ECE detergent used in color fastness to wash was from James Heal, UK. The dyeing was carried out in Laboratory Padding machine.

2.2 Methods

Modal knitted fabric was mildly scoured according to **Table -1**. As the modal are regenerated cellulosic fiber, it do not possess any natural color like cotton, No bleaching is required in these cases whereas mild scouring is sufficient to remove the possible dust, dirt or spin finish chemicals adhere on the fiber. Initial dyebath was prepared following the Dystar guidelines (developed by BASF) [18]. The experiment was conducted using full factorial design of experiment method where three parameters namely dye concentration, pH and ORP are considered. There were three levels in each parameters. So, total 3 X 3 = 27 experiments are were conducted for both synthetic and natural indigo dye as follow:

Dye Concentration: 1 g/l, 2g/l & 3 g/l
pH: 11, 11.5 & 12
ORP: -700 mv, -800 mv & -900 mv

Table -1: Recipe for the pretreatment of modal fibre

Chemicals / Parameters	Amount
Wetting agent	1 g/l
Sequestering agent	1 g/l
Detergent	3 g/l
Sodium hydroxide	0.4 g/l
Sodium Carbonate	1 g/l
M:L	1:30
Temperature	70°C
Time	30 min
pH	11

2.2.1 Preparation of dye bath

Dye solution of required concentration for padding is prepared using a stock dye & dilution liquor. Stock vat dye solution is prepared with the addition of required amount of sodium hydroxide & indigo in to 100 ml water with the stirring and heating up to 50°C followed by addition of hydrose for 15-20 minutes to complete reduction of dye. The dilution liquor is prepared separately with required amount of caustic soda & hydrose in 1 Liter of water at room temperature. The required concentration of indigo dye is measure from the stock dye solution.

2.2.2 Dyeing of fabric

Fabric was dipped into dye bath. Then the fabric is to pass through the padder for ensuring 80% wet pick up.

2.2.3 Air oxidation

After padding of the fabric, it was air oxidized to fix the absorbed dye. Oxidation is a process to convert the soluble form of the indigo dye into insoluble form. So the absorbed dye cannot come out of the fabric.

2.2.4 After treatment

Hot wash is done with the 2 g/l detergent at 80°C for 10 minutes. After that the fabric was rinsed and washed at room temperature and dried.

2.3 Assessment Procedure

The dyed fabric was assessed in terms of color strength or absorbance value, color fastness to wash and color fastness to rubbing.

2.3.1 Measurement of color strength

The color strength values of dyed samples are calculated using the Kubelka-Munk equation, which defines the relationship between measured reflectance values, R, and dye concentration as mention in eq (1)

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

This value can be directly measured by the spectrophotometer. In this study, the colour value of the dyed fabrics was assessed in terms of absorbance value (K/S value) measured by spectrophotometer, Model: Datacolor SF 650, USA [19].

2.3.1 Assessment of color fastness to wash

Color fastness to wash was assessed according to ISO 105 C06 C2S. At first the samples were washed in a washing machine (Brand name: Gyrowash, Manufacturer: James H. Heal, UK) according to the recipe mentioned in **Table -2.** The shade change rating of the washed samples were graded using the grey scale for shade change.

Table -2: Recipe of color fastness to wash (ISO 105 C06 C2S)

Chemicals/ parameters	Amount
ECE detergent	4g/l
Sodium perborate ($NaBO_3$)	1g/l
Stainless steel ball (6 mm dia)	25
pH	10.5 ± .1
Liquor	50 ml
Temperature	60°C
Time	45 mins

2.3.1 Assessment of color fastness to rubbing

Color fastness to rubbing of the dyed samples were assessed according to ISO 105 X12 using a standard crock meter (Manufacturer: James H. Heal, UK). Here the staining on the ISO standard crocking cloth both in dry and wet condition is graded using grey scale for staining.

3. Results and Discussions

3.1 Color Strength

It can be observed from **Chart-1, 2 and 3** that there is significant difference in the K/S values between natural & synthetic indigo dyed modal fabrics. Synthetic indigo samples are deeper while natural indigo samples are found lighter. Due to the production of lighter shade by the natural indigo dye on modal fabric, pH has no remarkable influence in these cases. In case of synthetic indigo dye, pH dramatically changes the depth of color and pH= 12 at -800 mv ORP has been found as optimum. ORP value -700 mv does not show any satisfactory color strength for all the three dye concentrations in cast of both natural and synthetic indigo. So, the samples of -700 mv ORP is omitted for further quality assessment.

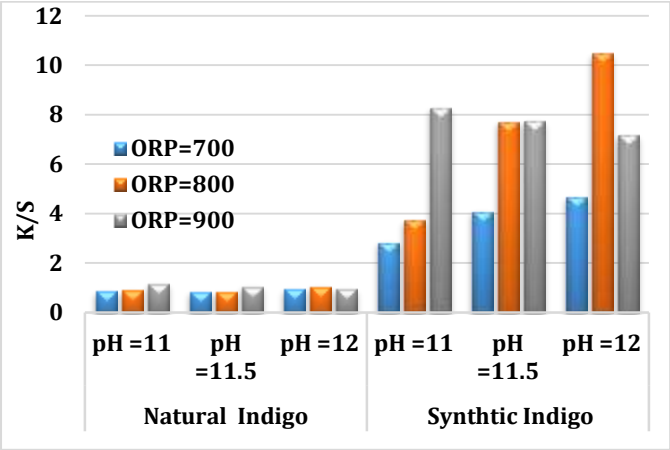
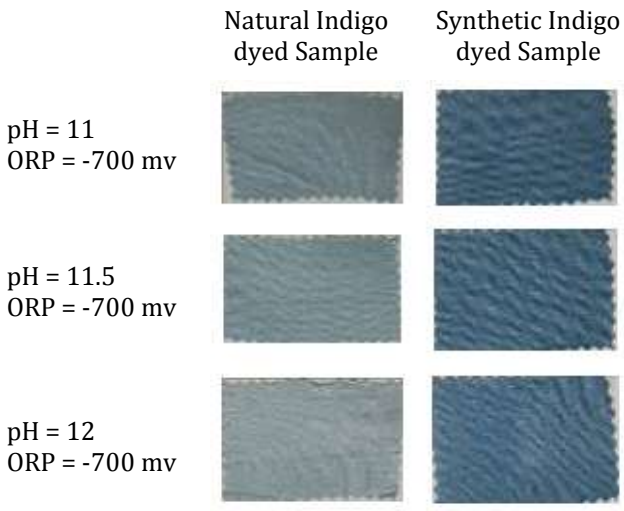


Chart -1: K/S value of Modal knitted fabric dyed with 1 g/l indigo dye with varying parameters



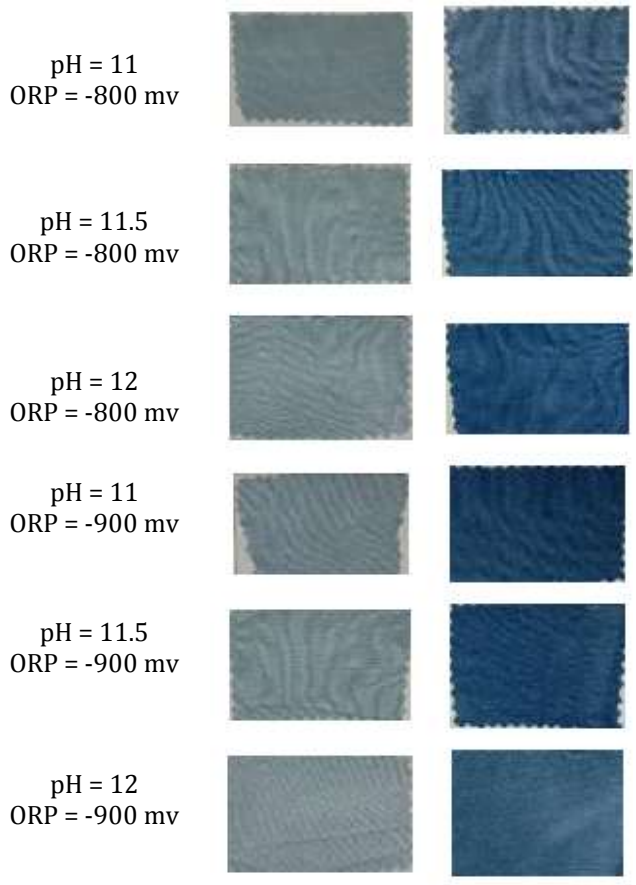


Fig -1: Modal fabrics dyed with 1 g/l indigo

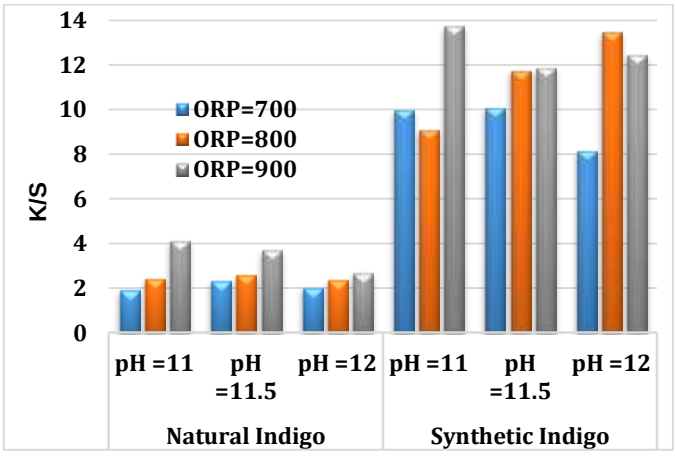


Chart -2: K/S value of Modal knitted fabric dyed with 2 g/l indigo dye with varying parameters

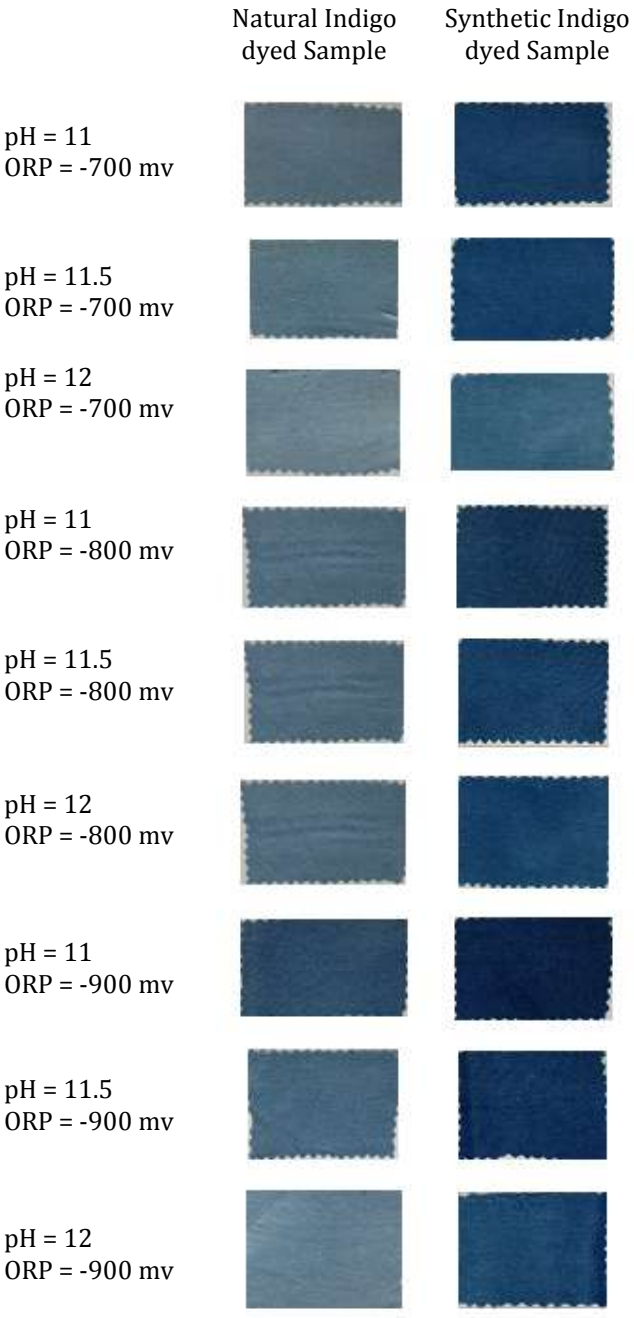


Fig -2: Modal fabrics dyed with 2 g/l indigo

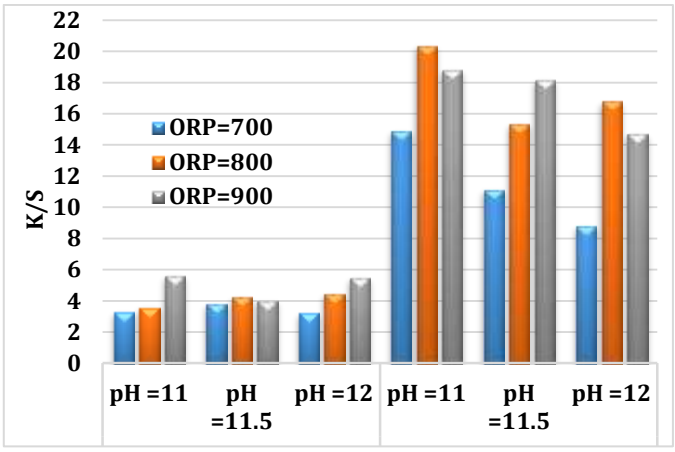
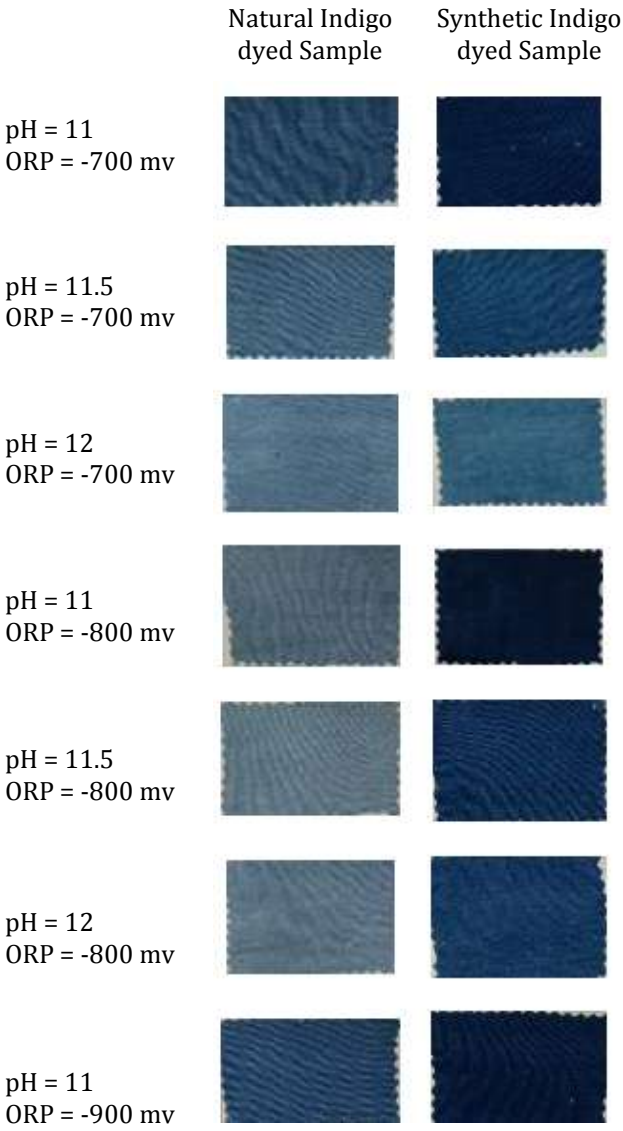


Chart -3: K/S value of Modal knitted fabric dyed with 3 g/l indigo dye with varying parameters



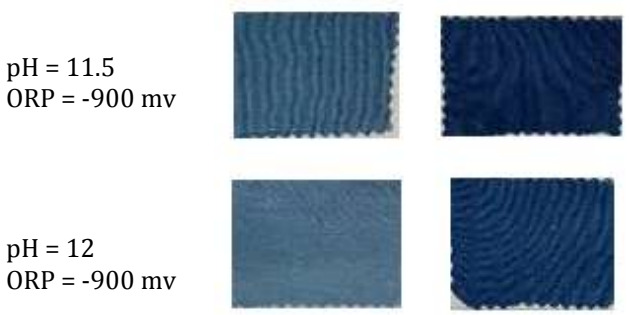


Fig -3: Modal fabrics dyed with 3 g/l indigo

3.2 Color Fastness to wash

The lower dye concentration e.g. 1 g/l indigo dyed modal fabric show relatively better color fastness to wash (Chart-4) for the cases of natural and synthetic indigo. With the increased of dye concentration e.g. 2 g/l and 3 g/l (Chart-5 & 6) dyed modal fabrics showed lower rating in shade change which is on average 2-3 in grey scale rating. This is because that the darker shaded fabric is prone color bleed than the lighter one.

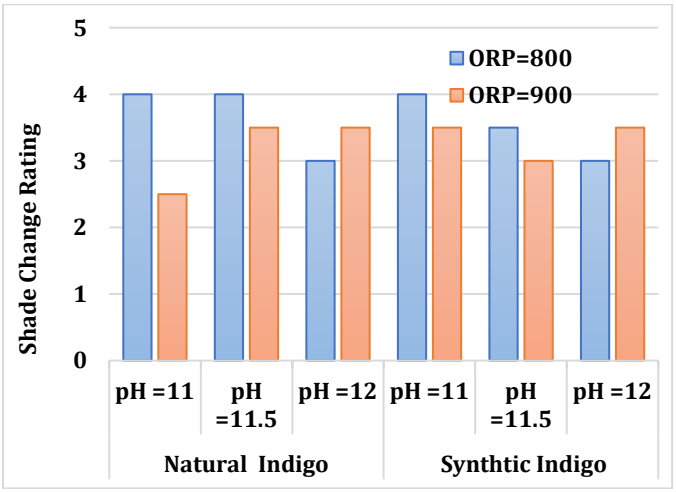


Chart -4: Grey Scale rating for shade change (1 g/l indigo)

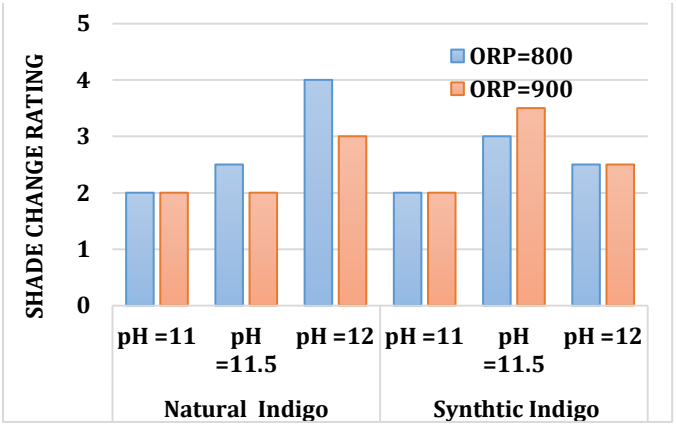


Chart -5: Grey Scale rating for shade change (2 g/l indigo)

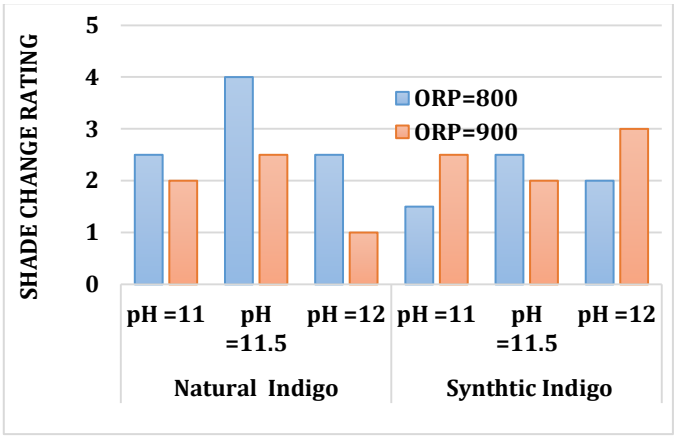


Chart -6: Grey Scale rating for shade change (3 g/l indigo)

3.2 Color Fastness to rubbing

Color fastness to rubbing at dry condition is excellent for natural indigo dyed modal but fair or average in case of natural indigo dyed modal. The same trend was also found in staining rating rubbing at wet condition.

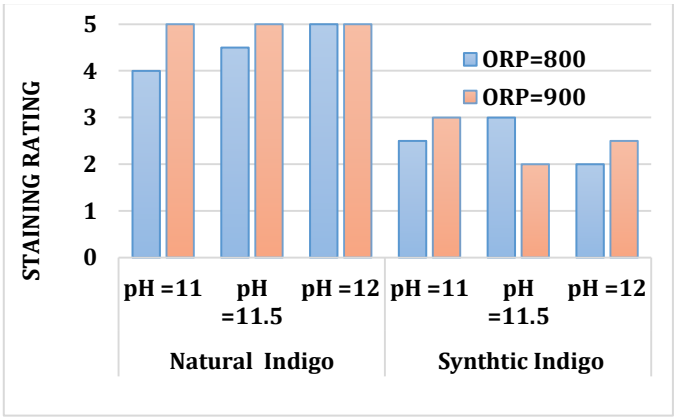


Chart -7: Staining Rating of color fastness to rubbing at dry condition (for 1 g/l indigo dye)

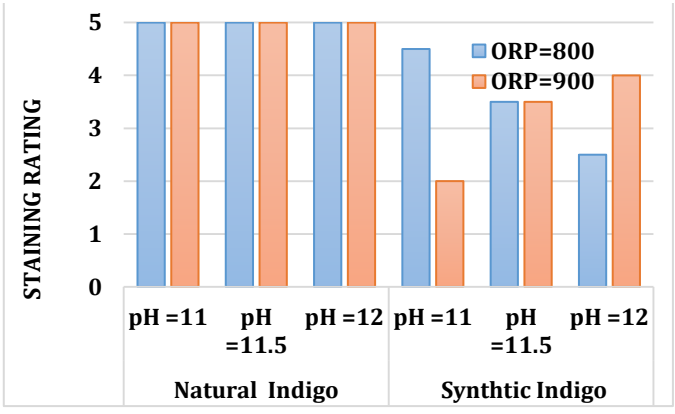


Chart -8: Staining Rating of color fastness to rubbing at dry condition (for 2 g/l indigo dye)

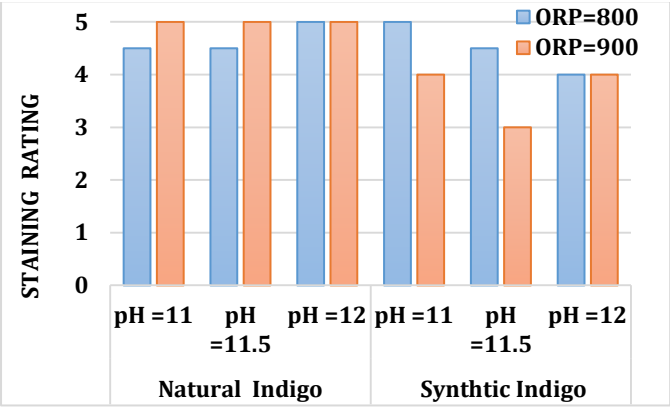


Chart -9: Staining Rating of color fastness to rubbing at dry condition (for 3 g/l indigo dye)

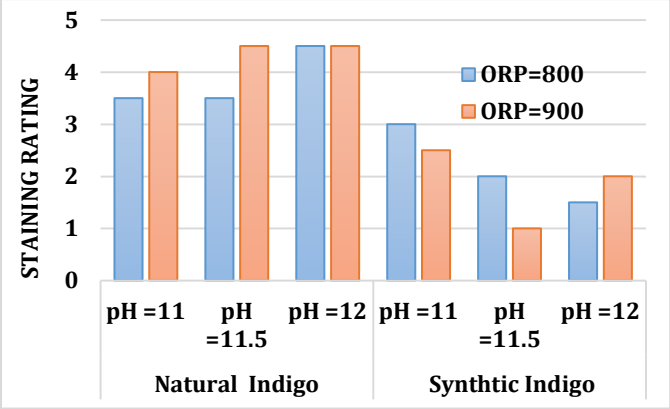


Chart -10: Staining Rating of color fastness to rubbing at wet condition (for 1 g/l indigo dye)

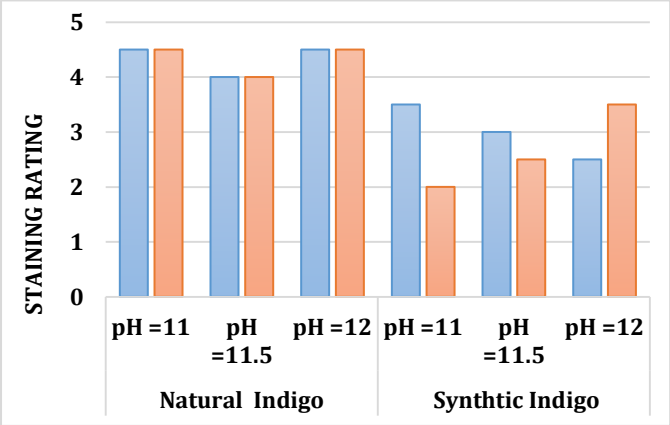


Chart -11: Staining Rating of color fastness to rubbing at wet condition (for 2 g/l indigo dye)

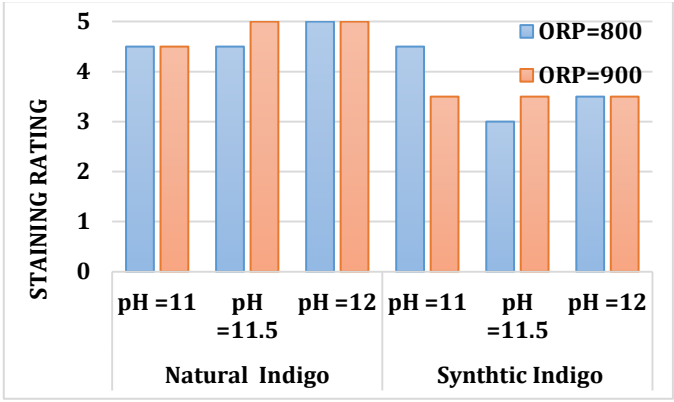


Chart -12: Staining Rating of color fastness to rubbing at wet condition (for 3 g/l indigo dye)

4. CONCLUSIONS

Manufacturing of natural indigo was fully suspended in the Indian subcontinent more than hundred years ago for several political & financial reasons. But it is now newly revived due to gradual increase of its demand. In this study, the performance of newly revived natural indigo was compared with the synthetic indigo applying on modal knitted fabric. It was observed that the natural indigo produced lighter shade than the synthetic one with the same concentration. Both the color fastness to wash & rubbing were found much better in case of natural indigo due to producing lighter shaded fabric. Moreover, the color produced by the natural indigo much appealing. But synthetic indigo is still preferable for producing darker shade. This current study will open door for developing new product with natural indigo & contribute to our national economy.

REFERENCES

1. G. A. Nadri, "The Political Economy of Indigo in India, 1580-1930: A Global Perspective". Brill, 2016.
2. J. A. Greer and G. R. Turner, "Indigo Denims: The Practical Side," Textile Chemist and Colorist, vol. 15, no. 6, 1983.
3. S. Dutta, S. Roychoudhary, and B. K. J. B. Sarangi, "Effect of different physico-chemical parameters for natural indigo production during fermentation of Indigofera plant biomass," vol. 7, no. 5, p. 322, 2017.
4. Joanna Lo et al., "Synthetic Indigo From China" 2006.
5. N. Faruque, "The revival of Indigo," in The Daily Star, ed. Bangladesh, 2018.
6. N. C. Market. Bluer than blue: the revival of Philippine indigo. Available: https://www.fibre2fashion.com/industry-article/3281/bluer-than-blue-the-revival-of-philippine-indigo. Access date: 15 December, 2019.
7. R. V. Singh. "The revival of indigo", 2015. Available: https://www.downtoearth.org.in/coverage /the-

revival-of-indigo-16056. Access date: 5 December, 2019.
8. P. Patil, C. Rao, and A. Wasif, "Revival of natural dyes: Smart use of biodiversity," Colourage, vol. 10, pp. 33-38, 2012.
9. J. Balfour-Paul, "Indigo in South and South-East Asia," Textile history, vol. 30, no. 1, pp. 98-112, 1999.
10. P. Kumar, "Scientific experiments in British India: Scientists, indigo planters and the state, 1890-1930," The Indian Economic and Social History Review, vol. 38, no. 3, pp. 249-270, 2001.
11. K. Kunttou, S. Hongyo, S. Maeda, and K. Mishima, "Dyeing polyester fabrics with indigo," Textile research journal, vol. 75, no. 2, pp. 149-153, 2005.
12. G. Baig, "Dyeing nylon with indigo in various pH regions," AUTEX research Journal, vol. 10, pp. 21-25, 2010.
13. S. Komboonchoo and T. Bechtold, "Natural dyeing of wool and hair with indigo carmine (CI Natural Blue 2), a renewable resource based blue dye," Journal of cleaner production, vol. 17, no. 16, pp. 1487-1493, 2009.
14. P. Kongkachuichay, A. Shitangkoon, and S. Hirunkitmonkon, "Thermodynamics study of natural indigo adsorption on silk yarn," Chiang Mai Journal of Science, vol. 37, no. 2, pp. 363-367, 2010.
15. A. Marmaralı, G. Ertekin, N. Oğlakcıoğlu, M. Kertmen, and İ. S. Aydın, "New knitted fabric concepts for denim products," in IOP Conference Series: Materials Science and Engineering, , vol. 254, no. 9, pp. 092002, 2017.
16. S. A. Didar, S. U. Patwary, S. Kader, M. M. K. Akter, and T. Ahmed, "Development of different denim effect on knitted fabric and comparative analysis with conventional woven denim on the basis of physical and dimensional properties," Research Journal of Engineering Sciences pp. 9-15, 2015.
17. "Measuring sustainability in cotton farming systems. Towards a guidance framework," International Cotton Advisory Committee, 2015.
18. J. Chakraborty, "Fundamentals and practices in colouration of textiles 2Ed". WPI Publishing, 2015.
19. W. Baumann, B. Groebel, and M. Krayer, "Determination of relative colour strength and residual colour difference by means of reflectance measurements," Journal of the Society of Dyers and Colourists, vol. 103, pp. 100-105, 1987.