Photoluminescent textile using biobased riboflavin derivative (FMN)

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Abstract Riboflavin derivative such as Flavin mononucleotide possesses distinctive biological and physicochemical properties such as photosensitivity, redox activity and fluorescence. Flavin mononucleotide widely known as FMN is a biomolecule having molecular formula as $C_{17}H_{20}N_4NaO_9P$ and is produced from biobased riboflavin by enzymatic reaction in living organisms. In contrast to riboflavin which is sparingly soluble in water, FMN is highly water soluble due to the presence of an ionic phosphate group. The presence of isoalloxazine ring in FMN is responsible for its properties such as UV absorption and fluorescence. This study evaluates the potential use of Flavin mononucleotide (FMN) for production of photoluminescent textile.

***Keywords*— biobased, fluorescence, Flavin mononucleotide, photoluminescent textile**

I. Introduction

Photoluminescence occurs in the form of fluorescence and phosphorescence. Fluorescence is the emission of light by a substance that has absorbed light such as fluorescent minerals which emits visible light when exposed to ultraviolet light, as a result of singlet-singlet electronic relaxation whereas phosphorescence is type of photoluminescence where light emission is delayed as a result of triplet-singlet electronic relaxation [1]

Luminescent textiles are finding increasing applications in various fields such as safety alert, in apparel and sportswear, as fluorescent strips in the high visibility vest, to alert wearer's presence. These are also used for buildings, agriculture (tarpaulins, nettings, coverings) and are being explored for interior or architectural textiles as well as automotive interior illumination, as a design feature or a promoter of a well-being.

Various kinds of organic substances have been identified for their fluorescence ability. Fluorescent substances have been known since long time, and currently different category of dyes such as xanthene, rhodamine and pthalein derivatives exhibits photoluminescent property [2].

Optical brighteners also known as fluorescence whitening agents are mostly introduced to the textile usually during finishing, wherein they absorb UV and visible light emitting at a different wavelength to give brighter appearance on the fabric [3]. However the washing of the optical brighteners during laundry process have led to environmental concerns [4]. It is therefore necessary to find alternative biobased photoluminescent molecules to obtain photoluminescent textiles.

Flavin mononucleotide (FMN) is a biomolecule produced from riboflavin (Vitamin B_2) by the enzyme riboflavin kinase. Riboflavin naturally occurs in milk, green leafy vegetables and also in plant and animal cells. Flavin mononucleotide (FMN) is present in bound forms naturally in foods.

The fluorescent property of riboflavin and its derivative Flavin mononucleotide (FMN) lead to study in various application fields such as targeted drug delivery, biosensors and bioengineering study [5] [6] [7].

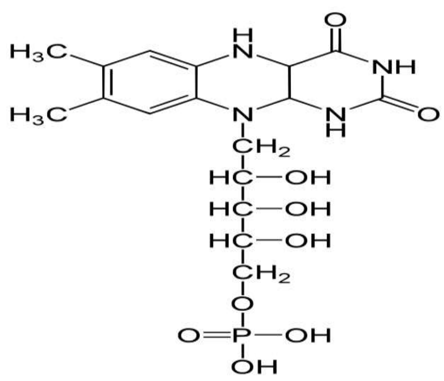

Fig. 1. Chemical structure of FMN

Hence due to its distinctive fluorescence property, the chemistry and application of Flavin mononucleotide (FMN) as a fluorescent yellow dye on textiles have been studied to discover the new scope for photoluminescent textile using biobased resource.

The main aim of this paper is therefore to study the application of Flavin mononucleotide on textiles, to identify the fluorescent property on different types of fabric, optimizing condition using various application methods such as dyeing and also coating using biopolymer.

II. Materials And Methods

Materials used for the experiment were modacrylic, cotton, polyester, silk and viscose. All chemicals Flavin mononucleotide (FMN) and phosphate buffer were purchased from Sigma Aldrich.

A. *Fabric cleaning method*

Prior to dyeing cellulosic fabric such as cotton and viscose were cleaned subsequently using hot and cold water for removal of starch.

B. *Diffusion method*

The diffusion procedures were performed in accordance with the general dyeing method using the diffusion method in a HTHP (High Pressure and High Temperature/Beaker Dyeing Machines) at 60°C for cellulosic and 130°C for modacrylic, polyester, silk fabric respectively. The FMN dyestuff to fabric weight of 4% (owf) was analyzed while the dye/liquor ratio was always kept constant 1:4. The temperature of the exhaustion bath was then gradually raised (about 1.5°C/min) to about 60°C, 130°C respectively and was kept at this temperature for about 45 min. The bath was then cooled to about 45°C; then the fabric was squeezed, rinsed thoroughly with hot water and air dried.

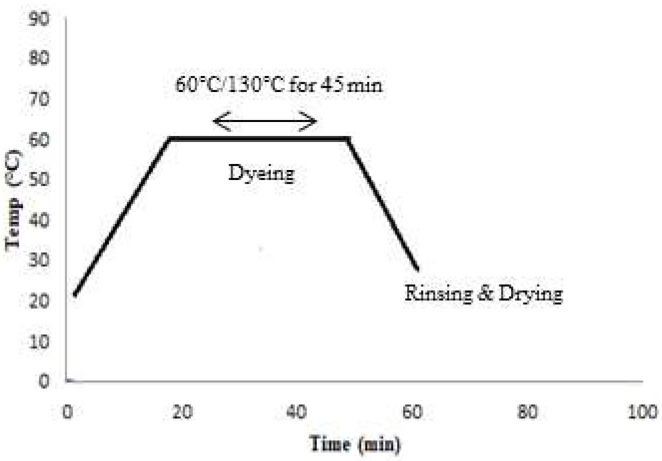

Fig. 2. Dyeing condition for treatment of fabric with FMN

The dried fabrics initially were assessed by observation using UV chamber (Fig. 3.) and the fabric showing fluorescence such as Viscose fabric (Table 1) were assessed for color strength value (K/S).

C. *Experimental Set Up to observe fluorescent samples*

All the treated fabric samples were observed under UV 370nm chamber and images for the same were taken. Table (1) tabulates the fluorescence property.

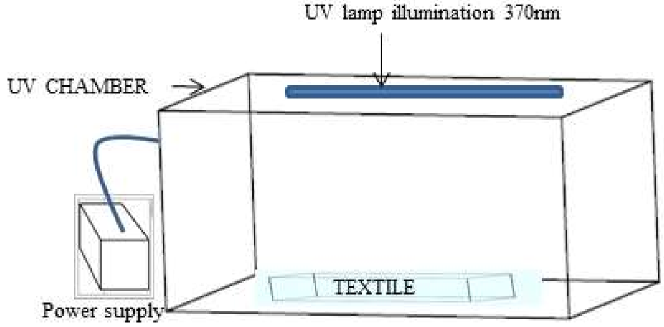

Fig. 3. UV chamber for observation of samples

D. *UV/Visible Spectroscopy*

The aqueous solution of FMN was analyzed using UV Visible spectrophotometer of Make-VWR, Model No. UV-3100 PC.

E. *Analysis of dyed fabrics using spectrophotometer*

Kubelka-Munk theory has been widely used to describe the depth of color for a due on textile substrate. Reflectance of the functionalized samples was measured with a Konica-Minolta CM3610A spectrophotometer Relative color strengths K/S_{max} (with λ varying from 360 nm to 700nm) were then determined using the Kubelka-Munk equation (1)

$$K/S = (1-R)^2/2R = A\,c\,/s$$

Where
R = reflectance,
k = absorption coefficient
s = scattering coefficient
c = concentration of the absorbing species
A = absorbance

III. Characterization & Results

A. *Observation of samples under daylight and UV light*

Table (1) shows the pictures of undyed and dyed samples under normal daylight, as well as pictures of samples under UV light. Only the cellulosic fabrics, viscose and cotton exhibit fluorescence.

Type of Fabric	Undyed fabric under visible light	Dyed fabric under visible light	Dyed fabric under UV light
Modacrylic			
Cotton			
Polyester			
Silk			
Viscose			

Table 1: Fabric observation under daylight and UV light

B. Spectral curves of FMN in aqueous solution and of FMN dyed viscose fabric

The spectral data showed maximum absorbance at 287nm, 374nm and 446nm.

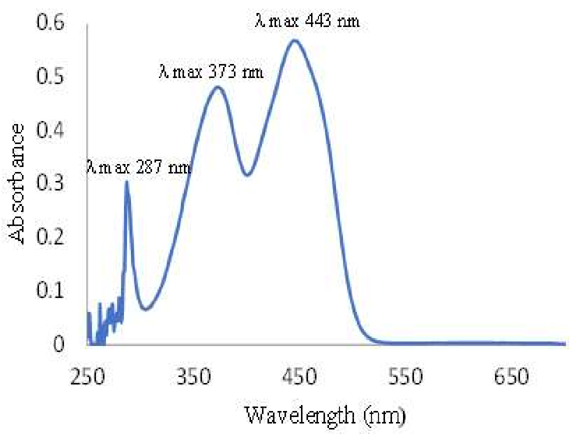

Fig. 4. Spectral analysis of FMN aqueous solution

The color strength of the fabric samples were determined using the spectrophotometer with λ varying from 360nm to 700nm. The two major absorbance (K/S) peaks (Fig. 5.) of the viscose dyed fabric appearing at 370nm and 450nm were also depicted in aqueous FMN solution (Fig. 4.).

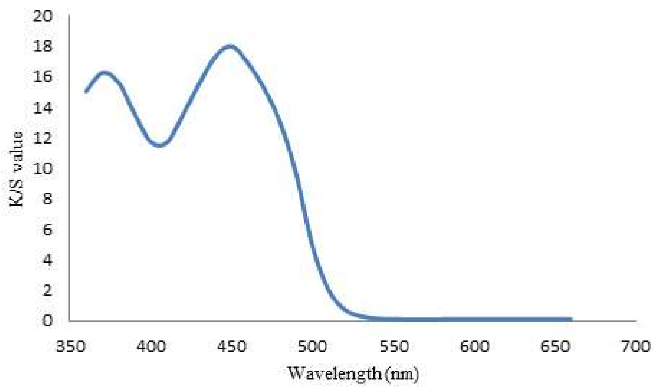

Fig. 5. K/S value for viscose dyed fabric

IV. CONCLUSION

From the above work we can conclude that Flavin mononucleotide can exhibit fluorescence property and biobased photoluminescent textile can be produced using dyeing techniques. Fluorescence property of dyed fabrics is observed for the cellulosic fabrics only (cotton and viscose). Further work will be carried out to quantify the photoluminescence property which will help us to identify and define the optimal condition for obtaining fluorescent property on textile substrate.

V. ACKNOWLEDGMENT

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