Dyeing of Polyester and Cotton Fabrics with Dispersedly Extracted Curcumin

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Abstract: In this study, turmaric powder was ball milled in the presence of dispersing agent in order to obtain dispersedly extracted curcumin. After that the dispersed curcumin was employed as dyestuff for cotton and polyester fabrics using exhaustion method. Fabrics were dyed at 2, 4, 6 and 8, 10 % o.w.f. Dyeing results showed that in case of polyester color strength (*K/S* value) increased with an increase in absorbed dye until reaching saturation point at 8% o.w.f where high *K/S* value of 21 was achievable. In case of cotton, *K/S* values were relatively lower than those of curcumin dyed PET fabrics, indicating little dye build-up due to the fact that there was different nature between hydrophobic curcumin and hydrophilic cellulose. In a similar manner, curcumin dyed PET exhibited excellent washing fastness. However, in all cases, fastness to light was extremely poor due to its free radical scavenging activity due to its free radical scavenging activity.

Keywords: Dispersed curcumin, Polyester, Cotton, Dyeing and Fastness properties

Introduction

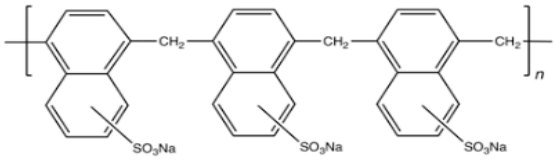
Natural colorants are divided into dyes and piments. Natural dyes are water soluble such as anthocyanins (blue and red), morin (a yellow dye from jackfruit wood), brazilin (sappan wood), betaine (a red dye from beetroot). Examples of natural pigments include blue indigo (indigo leaf), red anthraquinone from insects, carotenoid (carrot), and curcumin (turmaric). Dyeing of cotton or silk with natural dyes is simple and straight away by boiling the material in a conventional dye bath. Typically, aftertreatment with mordants (metallic salts) is carried out in order to obtain a variety of color shades and improve fastness properties (wash and light fastness). For natural pigments belong to indigo and anthraquinone, dyeing is more complex. From chemistry point of views, dyeing mechanism involves reduction-oxidation process. In practice, there are secret tricks, depending on local wisdom. Due to insolubility properties, indigo/anthraquinone dyed textiles exhibit good fastness properties. Therefore, mordants are unnecessary. Curcumin is a natural pigment containing in turmaric powder. Apart from colorant, curcumin is a potential herbal medicine due to its pharmaceutical

properties such as antioxidant (Asouri, Ataee, Ahmad, Amin, and Moshae 2013), antimicrobial (Han, and Yang, 2005), anti-UV radiation (Boonroeng, Srikulkit, Xin, and He 2015) and anticarcinogenic effects (Lee, Loo, Bebawy, Luk, Mason, and Rohanizadeh, 2013). With respect to colorant, curcumin is sensitive to light, resulting in very poor light fastness (Chou, and Tang, 2016). Moreover, it exhibits poor absorption capability due to the pigment characteristic (Nguyen, Si, Kang, Chung, Chung, and Kim, 2017). Therefore, in this study, dispersed curcumin nanoparticles were prepared by ball-milling using naphthalene sulphonate condensate as a dispersing agent. Then, curcumin nanoparticles suspension was employed for dyeing of cotton and polyester fabrics. Color yield and fastness properties were evaluated.

Experimental

Materials

Fabrics for this experiment are scoured and bleached knitted cotton fabric and woven polyester fabric. Turmaric powder can be obtained from local market. Napthaene sulphonate formaldehyde condensate powder (NAPS) was kindly supplied from Star Tech Chemical co. Ltd.



The chemical structure of napthaene sulphonate formaldehyde condensate

Preparation of Curcumin Nanoparticles Suspension

0.2 : 0.4 : 0.4 wt ratio of NAPS : turmaric : water was ground using a ball miller for 6 h. The turmaric paste having solid content of 50 wt% was kept in a seal container for further dyeing.

Dyeing of Cotton Knitted Fabric and Polyester Woven Fabric with Dispersed Curcumin

A series of concentrations based on weight of fabric (2, 4, 6 and 8, 10 % o.w.f. were prepared in dye pots. Liquor ratio of 1 :20 was chosen. Dyeing was carried out in a laboratory dyeing equipment set the dyeing temperatures of 80 ºC and 130 ºC for cotton and polyester, respectively (Kerkeni, Behary, Perwvelx, and Gupta 2012). Dyeing was conducted for 45 min. Dyed fabrics were then rinsed thoroughly with deionized water and air dried.

Evaluation of Fastness Properties

Washing fastness property was evaluated according ISO 105 standard test. Color measurement of the dyed fabrics before and after testing were measured using ICS Gretag Macbeth spectrophotometer (ColorEye 7000). The Color strength (*K/S* λmax) was recorded. For fastness to light, dyed samples were exposed to direct sunlight for 6 h. Color strength (*K/S*) was measured using ICS Gretag Macbeth spectrophotometer (ColorEye 7000).

Results and Discussion

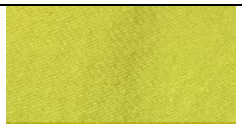
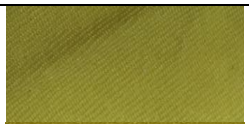
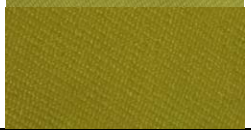
Dyeing Properties

Color strength (*K/S*) values of dyed cotton and dyed polyester are presented in Table 1. It is found that color strength value increases with an increase in % o.w.f. For polyester fabric, *K/S* values of 5.98, 16.38, 21.73, and 21.53 are corresponding to 2, 4, 6, and 8 % o.w.f., respectively. As seen, dye absorption increases with dye concentration and reaches saturation level at 8 % o.w.f with satisfactorily high color strength. An increase in dye absorption indicates that an individual curcumin molecule can diffuse and migrate inside polyester fiber in a similar manner to a disperse dye. Therefore, color strength increases with an increase in accumulated dye molecules until reaching saturation point at 8% o.w.f. In practice, dyeing above 8 % o.w.f. is redundant. Color shade on polyester fabric is brilliant due to good solubility of curcumin in polyester matrix. In case of cotton fabric (Table 2) , *K/S* values of 6.16, 8.91, 8.73, and 9.15 are corresponding to 2, 4, 6, and 8% o.w.f., respectively. As seen, *K/S* values are relatively lower than those of curcumin dyed PET fabrics, indicating little dye build-up. These results indicate that color yield is not dependent on dye concentration as found in case of polyester due to poor dye absorption, resulting from different nature between hydrophobic curcumin and hydrophilic cellulose. In this case, curcumin is present in pigment form which has not affinity to cellulose.

Wash Fastness Properties

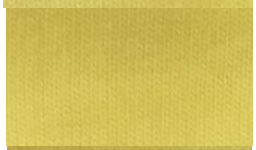
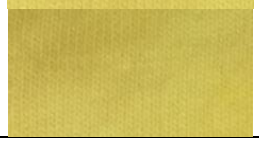
Washing fastness was carried out following ISO105-C03:1989 standard test. Results are shown in Table 1 and Table 2 for polyester and cotton, respectively, As seen, dyed PET fabric exhibits excellent washing fastness, confirmed by insignificant decrease in *K/S* values. Good fastness to washing is associated with the characteristic of polyester which is hydrophobic, trapping curcumin inside. As a result, little dye is soaped-off. For cotton fabric, significant decrease in color strength is observed after washing fastness test. This indicates that curcumin is present on fiber surface rather than inside the fiber. Moreover, it loosely attaches to fiber surface, resulting in poor washing fastness.

Table 1. Dyeing and wash fastness properties of dispersed curcumin dyed polyester fabric

% o.w.f.	Dyed PET fabric	After washing fastness	K/S	
			Before washing test	After washing test
2			5.98	5.62
4			16.38	13.90

6			21.74	19.76
8			21.53	21.43

Table 2. Dyeing and wash fastness properties of dispersed curcumin dyed cotton fabric

% o.w.f.	Dyed cotton fabric	After washing fastness	K/S	
			Before washing test	After washing test
2			6.16	1.64
4			8.91	2.24
6			8.73	2.11
8			9.15	2.52

Light fastness test.

Curcumin is known to have poor light stability, leading to poor light fastness. Therefore, improving light fastness of curcumin on dyed fabrics is an attractive challenge. Practically, there were widely studied that light fastness of natural dyes including curcumin could be improved by mordants (metal ions such as Al^{3+}, Fe^{2+}, Cu^{2+}, Sn^{2+} etc) (Hasan, Hossain, Azim, Ghosh, and Reza (2014), Zhou, Zhang, Tang, and Zhang, (2015), Bhardwaj, and Dadsena, (2017). However, improved light stability adversely affects antioxidant property deriving from deactivated phenolic moiety by mordants. In this study, it was expected that good dye penetration in case of polyester dyeing will result in improved light fastness when compared to cotton dyeing. Unfortunately, poor light fastness is observed in all cases, indicating that virgin curcumin is light sensitive chromophore due to its free radical scavenging activity. It should be noted that curcumin on the back side of fabric which resembles the inner side remains intact. Advantageously, curcumin

dyed fabrics without mordants are potentially garmented for protective wears against sunlight.

Table 3. Light fastness property of dispersed curcumin dyed cotton fabric

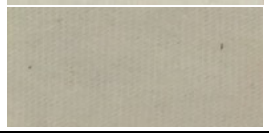
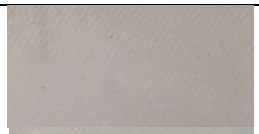
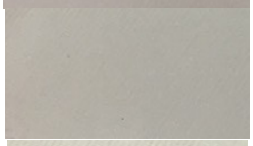
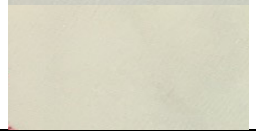
% o.w.f.	Dyed cotton fabric	After light fastness	K/S	
			Before testing	After testing
2			6.16	0.09
4			8.91	0.12
6			8.73	0.12
8			9.15	0.12

Table 4. Light fastness property of dispersed curcumin dyed polyester fabric .

% o.w.f.	Dyed PET fabric	After light fastness	K/S	
			Before testing	After testing
2			5.98	0.80
4			16.38	0.80
6			21.74	0.86
8			21.53	0.96

Conclusion

A simple and easy method of curcumin extraction from turmeric powder was achieved by ball milling in the presence of dispersing agent. Extracted curcumin by this technique resulted in curcumin dispersion in water. Dyeing of dispersed curcumin was carried out using exhaustion method. Dyeing results showed that in case of polyester color strength (*K/S* value) increased with an increase in accumulated dye absorption until reaching saturation point at 8% o.w.f where high *K/S* value of 21 was achievable. In case of cotton, *K/S* values were relatively lower than those of curcumin dyed PET fabrics, indicating little dye build-up due to the fact that there was different nature between hydrophobic curcumin and hydrophilic cellulose. In a similar manner, curcumin dyed PET exhibited excellent washing fastness. However, in all cases, fastness to light was extremely poor due to its free radical scavenging activity. due to its free radical scavenging activity.

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