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Turbidimetric Evaluation of Dispersion Stability of Disperse Dyes

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1. Introduction

Disperse dyes are insoluble in water and usually milled in the presence of dispersing agents. When the dispersion of disperse dyes is destroyed, the precipitated dyes are not exhausted onto the fiber. Hence, the dispersion stability during dyeing and on storage are of critical importance[1]. The objective of this study is to use the turbidity as test method for the particle size and the dispersion property of disperse dye. By applying the Mie's theory to the dispersion of disperse dyes, the theoretical turbidity ratio of disperse dye was calculated. The dye dispersion was analyzed by the turbidity ratio.

2. Theoretical Background

Since the aqueous dispersion of disperse dyes is not the homogeneous solution, the extinction of light is attributed to the scattering as well as the absorption by the disperse dyes. Hence, turbidity should be introduced instead of absorbance. Turbidity is defined by

$$\tau = \frac{1}{\ell} \ln \frac{I_0}{I_t} \tag{1}$$

where ℓ is the path length and, I_0 and I_t are the intensities of the incident and transmitted beams, respectively. The turbidity ratio can be defined by

$$\frac{\tau_{\lambda_{max}}}{\tau_{850nm}} = \frac{\left[\int_0^\infty r^2\ Q_{ext}\ f(r)\ dr \right]_{\lambda_{max}}}{\left[\int_0^\infty r^2\ Q_{ext}\ f(r)\ dr \right]_{850nm}} \tag{2}$$

where λ_{max} is the maximum absorption wavelength, r is the particle radius, Q_{ext} is the extinction efficiency, and $f(r)$ is the particle size distribution function. The extinction efficiency can be calculated from the Mie's theory, and can be expressed by

$$Q_{ext} = \frac{2}{\alpha^2} \sum_{n=0}^{\infty} (2n+1) \times \mathrm{Re}\{ a_n + b_n \} \qquad (3)$$

where a_n and b_n are the complex function of α and m. In this study, Mie's equation was calculated by using Bohren and Huffman algorithm[2]. The distribution function is a log-normal distribution, which can represent real size distributions of colloidal particles[3].

3. Experimental

The presscake of C. I. Disperse Blue 56(DB 56, I) from JES Co., Korea and the anionic dispersing agent(Matexil DA-N) from ICI-Woobang were used in the milling process. The real refractive index of the dyes was determined by Fresnel's law, and the imaginary refractive index was measured by the transmittance-reflection method. The milling equipment was composed of stainless steel beaker, mechanical stirrer and stainless steel disk impeller. Dye presscake was milled with 2 ㎜ glass bead. The turbidity measurements were made on Unicam 8700 UV-visible spectrophotometer. The particle size distribution of dye dispersion were measured with the laser particle size analyzer(Mastersizer, Malvern Instrument, UK).

4. Results and discussion

Turbidity contains many informations on the dispersion such as particle concentration, size, and spread of distribution. The effect of the mean radius and the standard deviation on the theoretical turbidity ratio of DB 56 is shown in *Figure 1*. As the mean radius and the standard deviation increase, the theoretical turbidity ratio rapidly decreases. These relationships thus verify that the theoretical turbidity ratio is closely correlated with both the particle size and the spread of distribution. The measured turbidity ratio of the aqueous dispersion of disperse dyes can also represent the change of the particle size.

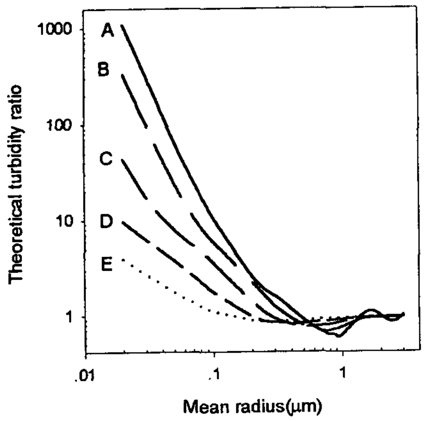

FIGURE 1. Theoretical turbidity ratio of DB 56 at 600 nm to at 850 nm calculated adapting different mean radius at various standard deviations; A= 1.1, B=1.4, C=1.7, D=2.0, E=2.7.

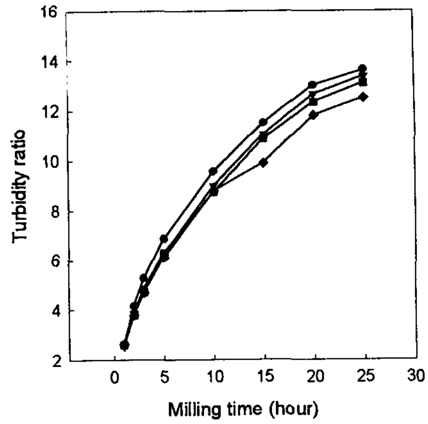

FIGURE 2. Turbidity ratio of C. I. Disperse Blue 56, the ratio of turbidity at 600 nm to that at 850 nm, as a function of milling time containing different dye concentration. Concentration of dye : ● =22.2 mg/l, ▼=44.4 mg/l, ■ =66.6 mg/l, ◆ =88.8mg/l.

Table 1. Arithmetic mean radius and geometric standard deviation of C. I. Disperse Blue 56 and C. I. Disperse Yellow 54 with milling time measured by Malvern particle size analyzer

Milling time (hour)	C. I. Disperse Blue 56	
	r_n [a]	σ [b]
1	2.21	1.74
3	1.87	1.51
5	1.46	1.29
10	1.16	1.43
15	0.93	1.64
20	0.75	1.67
25	0.58	1.94

[a] arithmetic mean radius,
[b] geometric standard deviation

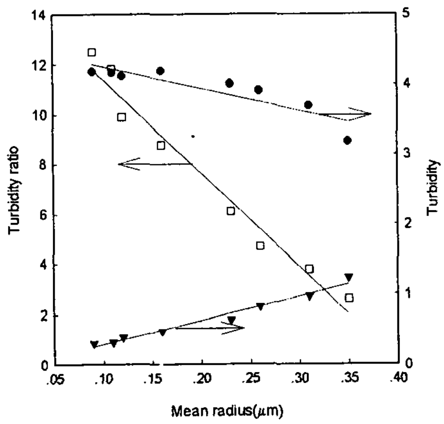

FIGURE 3. The variation of the turbidity at 600 nm(●) and 850 nm(▼) and the turbidity ratio(□) of C. I. Disperse Blue 56 with mean radius measured by Malvern particle size analyzer.

The turbidity ratio of DB 56 is on the increase with milling time, *Figure 2*. Since the particle size of disperse dyes progressively decreases by milling process, the turbidity ratio can be used for evaluating the dispersion stability. As the dye concentration increases, the turbidity ratio shows slightly lower values. The values of arithmetic mean radius and standard deviation of DB 56 with milling time are listed in *Table 1*. *Figure 3* shows the relationships between the turbidity ratio of dye dispersion and the mean particle radius and between the turbidity at each wavelength and the mean particle radius. The turbidity at 850 nm is related to the scattering property of dyes and that at the maximum absorption wavelength is related to the absorption property as well as the scattering. The variation of the turbidity ratio is larger than that of the turbidity.

5. Conclusions

A simple method for testing the dye dispersion using the turbidity ratio has been presented. As the mean radius and the standard deviation increase, the theoretical turbidity ratio decreases. The measured turbidity ratio is also closely related to the particle size and the spread of distribution. It can characterize the variation of particle size with a single value. The turbidity ratio shows more noticeable dependence on the mean radius of particle than the turbidity. The dispersion property of disperse dyes can be effectively evaluated by the turbidity ratio.

6. References

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3. Rowell R. L. and Levit A. B., *J. Colloid Interface Sci.* **34**, 585-590 (1970).