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Dyeing performance of cotton fabrics with natural curcuminoid in supercritical carbon dioxide

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Introduction

Cotton is used in all types of garments and household fabrics, being used in clothing and hats, carpets and curtains, boots and shoes etc. Now days, chemical dyes are the most widely used dyes for cotton fabric dyeing.[1] Conventional dyeing of cotton textiles produces large amount of waste waters that must be treated before it can be discharged into the surrounding environment, thus restricts the development of textile industry.[2]

From 1980s, a new process for dyeing textiles using supercritical carbon dioxide instead of water was developed. When compared with conventional wet dyeing processes, supercritical carbon dioxide dyeing processes have many essential advantages, as carbon dioxide is a benign, nonflammable, non-toxic and inexpensive solvent, and its supercritical state is easy to get (the critical point of carbon dioxide is at 31.1°C and 7.38MPa); in addition, after the dyeing process it can be readily recycled.[3] Moreover, the energy and time-consuming dry procedure is also no longer needed as the dyeing process is water free.[4] Therefore, as an innovational and clean dyeing technology, supercritical carbon dioxide dyeing processes are more environmentally friendly and economically attractive for the textile industry.[5] To date, the coloration of synthetic fibers, such as polyethylene terephthalate (PET),[6] polylactides,[7] polyamide 6 and 66,[8] with disperse dyes in supercritical carbon dioxide has achieved commercial requirements. But it is still difficult for the dyeing of cotton fabrics in supercritical carbon dioxide. The main reason lies in the facts that disperse dyes have low affinity to cotton fibers.

Natural curcuminoid is one of effective components of the thizoma curcumae longae, it's not only used as food additive but also has a unique pharmacological functions.[9] The curcuminoid has many essential advantages, as good thermal stability, strong tinting strength, safe and non-toxic. There're more than one double bond, phenolic hydroxyl and carbonyl group in the molecular. The chemical structures of curcuminoid are shown in Figure 1.

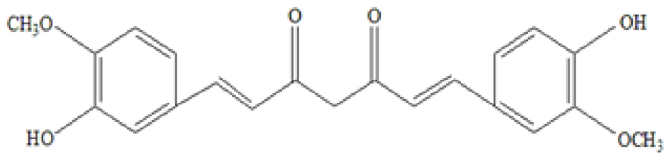

Figure 1 Chemical structural of curcuminoid.

Hydrogen bond can be formed between cellulose and curcuminoid molecular thus has good affinity between each other.

In the present work, the dyeing of cotton fabrics with natural curcuminoid in supercritical carbon dioxide was studied (Figure 2).

The cotton fabrics were put into the dyeing kettle. The curcuminoid with 10% o.m.f. (on the mass of fabrics) was added into the dye kettle. Carbon dioxide in the CO_2 tank

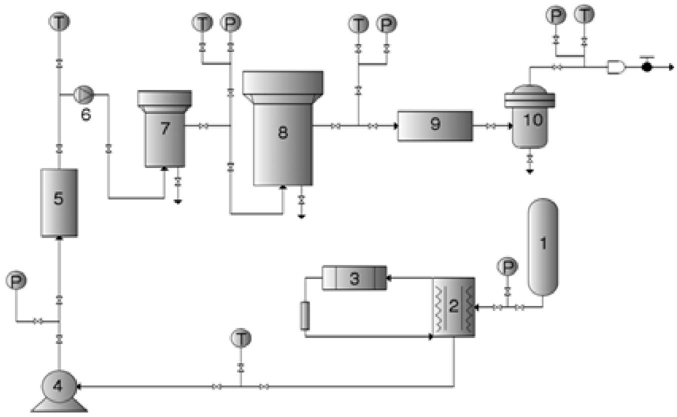

Figure 2 Schematic drawing of the supercritical carbon dioxide dyeing apparatus; (1) CO_2 tank, (2) cooling tank, (3) refrigeration units, (4) high-pressure pump, (5) heat exchanger, (6) flowmeter (7) dye kettle, (8) dyeing kettle, (9) separator,(10) separation kettle.

1) was cooled and changed into liquid by cooling tank
2) and refrigeration units
3) It was pressurized using a high-pressure pump
4) and was heated with a heat exchanger
5) First, supercritical carbon dioxide entered the dye kettle
6) the curcuminoid was then dissolved in supercritical carbon dioxide fluid and flowed through the dyeing kettle
7) In which cotton fabrics would be dyed. The dyeing experiments were conducted for 30 minutes at 90°C, 25MPa, CO_2 flow of 30g/min. When the dyeing process ended, high-pressure pump and heat exchanger were switched off in turn to reduce the pressure of the system, CO_2 and dye in the dyeing system were separated with a separator
8) The residual dye will be kept in the separator
9) CO_2 was gasified completely. Finally, the system pressure turned to normal and the dyed fabrics were taken out.

Cotton fabrics dyed under the above condition got good color, the average ΔE is 50.3, K/S value is 1.6. Tenacity of the dyed cotton fabric decreased from 23.4MPa to 21MPa. Cross section of the dyed cotton fabric yarn was shown in Figure 3 which indicates that the supercritical carbon dioxide dyeing process will have some damage on the cotton fabrics but still within the permit range.

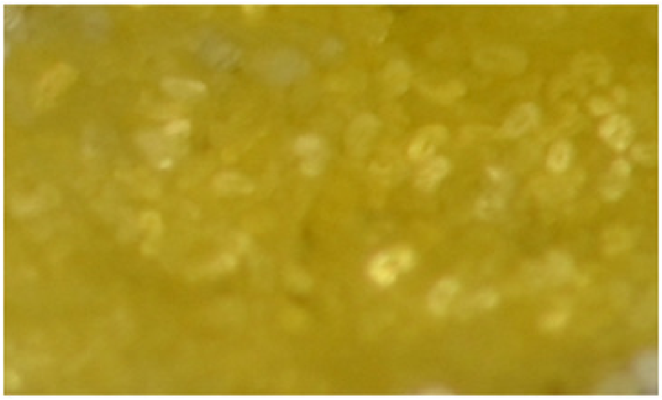

Figure 3 Cross section of the supercritical carbon dioxide dyed cotton fabric yarn.

From Figure 3 we can see that the curcuminoid dye has dispersed in the core of the yarn, which indicates that the supercritical carbon dioxide dyeing technique has the advantage of high penetration. Color of some cotton fiber is deeper and the other is lighter, it can be explained that the crystallinity of the single cotton fiber is different, since the dye molecular can just diffuse into the non-crystalline region, so fibers with lower crystallinity can be dyed into deeper color.

Conclusion

Cotton fabrics can be dyed by supercritical carbon dioxide technique successfully at temperature of 120°C, pressure of 25MPa, time of 30 min. The *DE** and *K/S* value of the dyed cotton fabrics are 50.3 and 1.6, respectively. Tensile test showed that the tenacity of the cotton fabrics declined after dyeing but still within the permitted range. The method described in this paper provides a new solution for supercritical carbon dioxide dyeing of cotton fabrics.

Acknowledgments

None.

Conflicts of interest

Author declares there is no conflict of interest in publishing the article.

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