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Test and Analysis of the Dyeing Effect of Curcuma on Bamboo Pulp Fiber

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This study explores the dyeing property of extract curcumin (yellow) as a natural plant dyestuff to bamboo pulp fiber through tests. Four dyeing methods, namely direct dyeing, pre-mordant dyeing, post-mordant dyeing, and one-bath dyeing have been conducted respectively to compare the dyeing effects of the different methods so as to select the one with the best dyeing effect. Next, through the method of controlling variables, control different factors (temperature, type of mordant, dosage of mordant, PH value, dyeing time, and the soaking time before dyeing), carry out related dyeing and test the relevant data (dye-uptake, fixation rate, dyeing rate and fastness to washing) on this basis. Finally, through counting, analyzing and discussing the experimental data, turmeric dye has been provide to be the reasonable and efficient dyeing process on bamboo pulp fiber.

1. Introduction

Curcuma is the material with the main components of yellow curcumin, demethoxy-curcumin and bisdemethoxy-curcumin, and it exists in the rhizomes and root blocks. At the same time, there are also nemaline, starch, colloid, minerals, as well as the aromatic oil, which has a strong smell, and brown pigment. Curcumin is a kind of orange-yellow crystalline pigment obtained from the rhizome of curcuma. With a melting point of 183°C, curcumin belongs to phenolic derivatives. It is barely soluble in water or diethyl ether, but can dissolve in alcohol, glacial acetic acid and aqueous alkali. Curcumin turns into yellow in acid. It is sensitive to alkali and will turn into reddish brown. (Xiao, 2016)

2. The Result and Analysis of the Extraction Test of Curcuma Dye Liquor

2.1 Orthogonal Test

According to Table 1, the temperature has certain influence on the extraction of curcumin, but the influence is relatively minor. Generally speaking: the absorbency of curcuma solution shows a tendency of ascending as the temperature rises, and when the temperature reaches 100°C, the absorbency of curcuma solution reaches its peak. Therefore, the extraction of curcumin should be carried out below 100°C.

Table 1: Extraction Test of Curcuma Dye Liquor

Level		Temperature/°C	Curcuma Concentration (g.L-1)	Time/min	Extractant Concentration (g.L-1)
1		80	60	30	0
2		90	80	60	30(NACO3)
3		100	100	90	20(NAOH)
Absorbancy	K1	0.043	0.037	0.045	0.009
	K2	0.053	0.055	0.065	0.082
	K3	0.062	0.064	0.077	0.095
	R	0.041	0.040	0.057	0.076

Notes: The concentration indicates the gram of the curcuma and extraction agent per liter of distilled water.

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Curcuma concentration has a certain influence on the extraction of curcumin, but the influence is relatively minor, which is similar to that of the temperature.

Generally speaking: with the increase of curcuma concentration, the absorbency of curcuma solution increases. When the concentration reaches 100g/L, the increase of absorbency will slow down. Therefore, the concentration of curcuma is chosen to be 100g/L.

The extraction time has relatively major influence on the extraction of curcumin. Generally speaking: with the increase of time, the absorbency of curcuma solution constantly increases. And when the extraction time reaches 90min, its increasing trend slows down. Therefore the best extraction time selected is 90min.

d. Extractant concentration has a relatively major influence on the extraction of pigment, among which, the influence of extractant NaOH is larger than that of Na_2CO_3. Therefore, NaOH is selected as the best extractant.

2.2 Experiments of Single Factors

Conduct the single-factor test of caustic soda concentration according to the optimum condition obtained from the tests above, namely the temperature being 100°C, the curcuma concentration being 100g/L, and the extraction time being 90min.

With the increase of the amount of caustic soda, the optical density of the extract increases, namely the concentration of curcuma increases, but when the amount of caustic soda is more than 20g/L, the change in optical density is little, the reason for that is: from 0 to 20g/ L, with the increase of the concentration of caustic soda, the degree of ionization of phenolic hydroxyl in curcumin molecule increases, making the solubility of curcumin increase; When the concentration is higher than 20g/ L, since the phenolic hydroxyl in the curcumin is oxidized, leading to the decrease of optical density in the extract. Therefore, the concentration of 20g/L is taken as the optimum concentration of caustic soda. (Al-Ameen A. et al., 2015)

In summary, the best condition for extracting curcumin: curcuma concentration 100g/L, caustic soda concentration 20g/L, temperature 100°C, extraction time 90min.

3. Test Result of the Maximum Absorption Wavelength of Curcuma Dye Liquor

As shown in Figure 2, when the wavelength is 440nm, the absorbency of curcuma dye liquor reaches the maximum value, so the maximum absorption wavelength of tumeric dye liquor is λmax=440nm. The absorbencies of following tests are all tested on the basic of this wavelength.

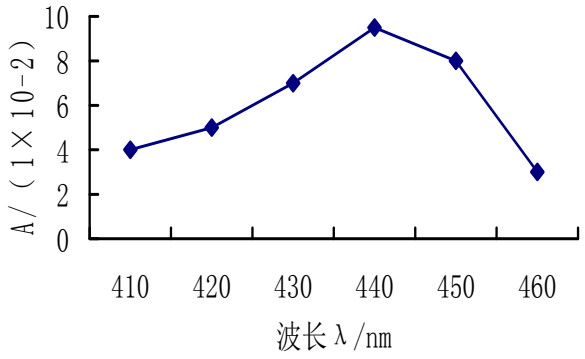

Figure 2: Test of the Absorption Wavelength of Curcuma Dye Liquor

4. The Test Result and Analysis of the Curcuma Dye Liquor's Dyeing to Bamboo Pulp Fiber

4.1 The Test of Selecting the Dyeing Method

According to Figure 3, it can be seen that: among the four dyeing methods, the dye-uptake of the direct dyeing method is the biggest, and the difference between the two is the smallest. The following are the post-mordant dyeing method and the pre-mordant dyeing method. E and F are the minimum with the one-bath dyeing method. The fixation rate of the direct dyeing method is the largest among the four dyeing methods, and the difference of values between fixation rate and dye-uptake is the smallest. Thus, the direct dyeing method is the best for the curcuma dyeing liquor to dye the bamboo pulp fiber.

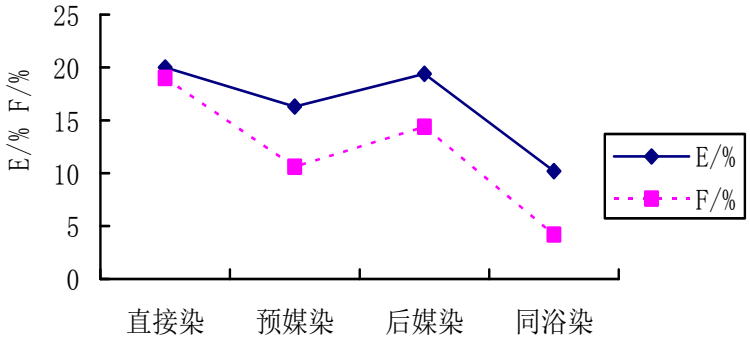

Figure 3: Selecting the Dyeing Method

4.2 The Influence of Temperature, Time, Acid and Alkali on the Dyeing Property of Bamboo Pulp Fiber

It is known from Figure 4 that the differences between the dye-uptakes of fiber in different acid-base property are relatively big. Therefore, the acid-base properties of the dye liquor has a great influence on the dye-uptake of fiber. Among which, the dye-uptake is obviously lower under the acidic condition than that under the neutral condition, while the dye-uptake under the neutral condition is lower than that under the alkaline condition. Thus, the dye-uptake is the best under the alkaline condition. (Mahmood et al., 2017)

There is certain regularity in the influence of the dyeing time on fibre dye-uptake. Taking the neutral and alkalinity conditions as example: in the first 90min, as the time increases, the dye-uptake shows a tendency of ascending, and when the time exceeds 90min, the dye-uptake shows a tendency of declining. As a result, at the time of 90min, the percentage of dye-uptake of curcuma to bamboo pulp fiber is the highest.

There is certain regularity in the changes of the dyeing speed. In the former 30 min, it's under the alkaline condition that the dyeing speed is the fastest, followed by the neutral condition, and the speed in the acid condition is the slowest. During 30min to 60min, the dyeing speeds under the three conditions are about the same. When the time exceeds 60min, the dyeing speed under the alkaline and neutral conditions increases first and then decreases, and this change is larger under the neutral condition, while the dyeing speed under the acidic condition shows a slight downward trend.

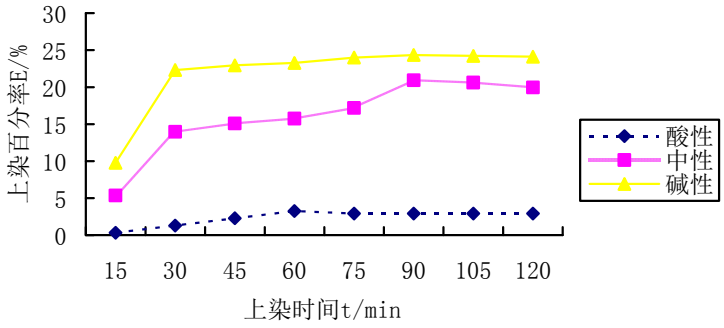

Figure 4: The Influence of Acid, Neutral and Alkaline Condition on the Dyeing Property of Bamboo Pulp Fiber

According to Figure 5: the dye-uptakes in different temperatures are similar, so the temperature has a little influence on the dye-uptake of the fibre. With the increase of the temperature, the dye-uptake shows an upward trend, which will maximize at 60 °C and will be stable or even decrease over 60°C. Therefore, the dye-uptake of the fiber is the best at 60°C, followed by 80°C. The overall dye-uptake of the fiber at 40°C is relatively low.

The effect of dyeing time on fiber dyeing rate obeys a certain law. During the first 90 minutes, as time increases, dyeing rate increases, while longer than 90 minutes, dyeing rate is almost constant, even showing a decreasing trend. Therefore, at the time of 90 minutes, the dyeing percentage of turmeric on bamboo pulp fiber reaches the highest. The change of dyeing rate shows a certain law. Within the first 30 minutes, the dyeing rate at 80 °C reaches the highest. When the temperature is higher than 30□, the dyeing rate of the three is similar. In contrast, the dyeing rate at 40 °C has a larger variation.

Under the neutral and alkaline conditions, the fixation rate is better, and it gets the best at 60 °C, besides, the difference value between dyeing rate and fixation rate is relatively smaller at 60 °C under the alkaline condition. At 90min, the fixation rate reaches maximum, and the difference value between dyeing rate and fixation rate is relatively smaller (Giachet et al., 2017).
In summary: alkaline, 60 °C and 90min are the most appropriate conditions for turmeric to dye bamboo-pulp fiber.

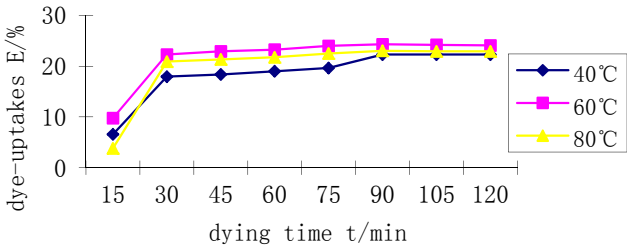

Figure 5: The Influence of Temperature on the Dyeing Property of Bamboo Pulp Fiber

4.3 The effects of PH on dyeability of fiber

According to Figure 6: PH values have a greater effect on the dyeing percentage of fiber, among which, when PH = 8, the dyeing percentage of fiber is the largest.
The effect of PH values on dyeing rate of fiber has a certain regularity. During the first 30 minutes, when PH=8, the dyeing rate is the maximum; during 30 to 60 minutes, when PH=10, the dyeing rate is the maximum; during 60 to 75 minutes, when PH=9, the dyeing rate is the maximum; during 75 to 90 minutes, when PH=11, the dyeing rate is relatively the maximum.
PH has a certain effect on the fixation rate of fiber. And when PH=8, the effect is the maximum. With the increase of PH value, the dyeing rate increases, the fixation rate decreases, and the difference value between them increases (Gawish et al., 2017)
It can be known from the above-mentioned experiments, at 90min and PH=8, the dyeing rate of turmeric to bamboo pulp fiber is the best.

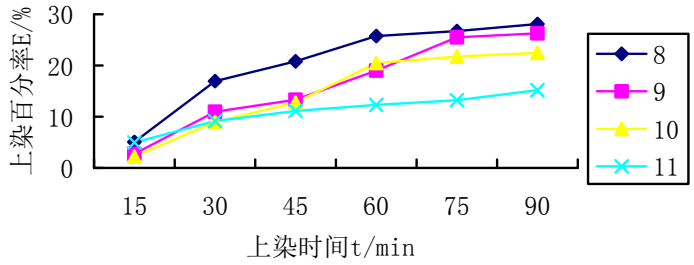

Figure 6: The effect of different PH values on the dyeability of bamboo pulp fiber under alkaline condition

4.4 The effect of the pre-dyeing soaking time of fiber on the dyeability of fiber

According to Figure 7, the pre-dyeing soaking time of fiber has a bigger effect on the dyeing rate and fixation rate of fiber. With a certain dyeing time, dyeing rate reaches its maximum when the soaking time is a whole day, and it meets its minimum when it is not soaked.
Dyeing rate shows a certain trend, that is, in the first 60 minutes, the dyeing rate reaches its maximum when soaked for a whole day, during 60 to 90 minutes. The dyeing rate of the three is similar.
The effect of pre-dyeing soaking time of the fiber on its fixation rate is larger. The fixation rate of non-soaked fiber is much lower than that of soaked fiber, and the difference value between them is quite large; The fixation rate of soaking for a night is less than that of soaking for a day, and their difference value is quite large; Soaking for a day, the fixation rate is the maximum, and their difference value is the minimum.
According to the above-mentioned experiments, the pre-dyeing soaking time of fiber is helpful for turmeric to dye bamboo pulp fiber. In this experiment, when dyeing for 90 min, with soaking for a day, it's best for turmeric to dye the bamboo pulp fiber.

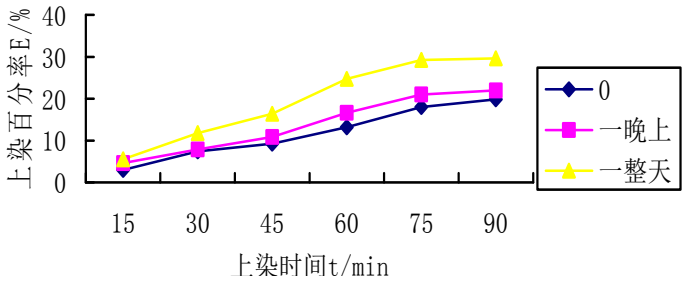

Figure 7: The effect of different soaking time on the dyeability of bamboo pulp fiber

4.5 Effect of bath ratio of dye liquid on the dyeability of the fiber

The Figure 8 shows: The bath ratio has a bigger effect on the dyeing rate of the fiber, and dyeing rates with different bath ratios are quite different. Among them, at the time of 90 min, when the bath ratio is 1:40, the dyeing rate is the largest, followed by 1:60, and when the ratio is 1:30, it is the smallest.
The dyeing rate shows a certain trend, that is: in the former 15 min, the dyeing rate is the largest under 1:40; during 15 to 30 min, the dyeing rate is the largest under 1:60; longer than 30 min, the dyeing rate is the largest under 1:40.
According the above experiments, when dying for 90min, with bath ratio of 1:40, it's best for turmeric to dye bamboo pulp fiber.

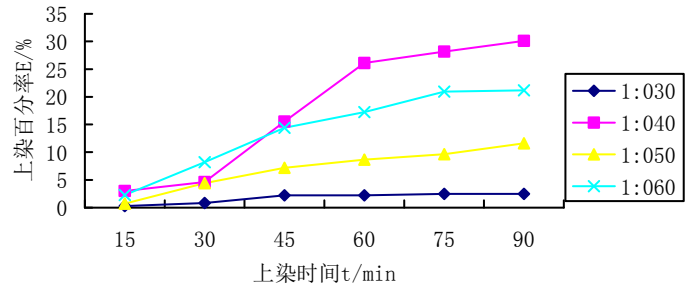

Figure 8: Effect of different bath ratios on the dyeability of the bamboo pulp fiber

4.6 Strength test of single fiber

According to the Table 2, as for undyed bamboo pulp fiber, dry strength is stronger than wet strength (dry strength is nearly two times wet strenghth), elongation of dry breaking is less than that of wet breaking.
After being dyed by turmeric dye, the breaking strength of bamboo pulp fiber is stronger than that of non-dyed fiber, and its breaking elongation is less than that when not dyed.

Table 2: Strength test experiment of single fiber

Dyeing conditions of fiber	Breaking strength/cN		Breaking elongation/%	
Table size	Dry strength	Wet strength	Dry	Wet
	2.90	1.40	19.52	20.56
Turmeric Dyeing	3.99		16.64	

4.7 Color fastness test

According to Table 3, in the first group of experiment, the soaping color fastness grade of bamboo pulp fiber is relatively minimum, among which, the color changing grade is equal to or lower than the cotton staining grade. With the increasing of the experimental group number, that is, the dyeing process gradually improves, the soaping color fastness grade of bamboo pulp fiber is higher and higher. In the 6th experiment group, that is, under the best dyeing process, the soaping color fastness grade of bamboo pulp fiber is the highest. By contrast, with the improvement of dyeing process, the variation of color changing grade is close to the variation of color staining grade. (Suresh, 2017)

Table 3: Color fastness test

The experiment group number	The best for each group sample	Test item	Wash durability color fastness
1	Direct dyeing method	Color changing	2
		Cotton staining	2-3
2	PH=8	Color changing	2-3
		Cotton staining	2-3
3	60□	Color changing	3
		Cotton staining	2-3
4	90min	Color changing	3
		Cotton stainning	3
5	Soaking for a day	Color changing	2-3
		Cotton staining	3
6	1:40	Color changing	3
		Cotton staining	3-4

Note: each group of experiment is conducted on the basis of the optimum process of the previous group.

Thus it can be known that, in the 1st experiment group, the soaping color fastness grade of bamboo pulp fiber is relatively the worst, among which, the color changing is worse than cotton staining. With the increasing of the experiment group number, that is, the dyeing process gradually improves, the soaping color fastness of bamboo pulp fiber is the best. In the 6th experiment group, under the best condition of dyeing process, the soaping color fastness of bamboo pulp fiber is the best. In contrast, with the improvement of dyeing process, color changing variation is similar to cotton staining variation.

5. Conclusion

Optimum extraction process for natural plant dye turmeric: turmeric concentration 100g/L, temperature 100 °C, extraction time 90 minutes, extractant 20g/L NaOH.

The optimum dyeing process of natural plant dye turmeric: direct dyeing, alkaline condition, temperature 60 °C, dyeing time 90 minutes, PH value 8, bath ratio 1:40 and pre-dyeing soaking time: a day.

For undyed bamboo fiber, the dry strength is stronger than the wet strength (dry strength is nearly two times wet strength), dry breaking elongation is slightly smaller than wet breaking elongation. After being dyed by turmeric, the breaking strength of bamboo pulp fiber is stronger than that of undyed bamboo pulp fiber (almost twice), and the breaking elongation is slightly smaller than that when not dyed.

On the basis of above conclusions, turmeric dye has better color fastness to washing, which can fundamentally meet the production requirements, having certain use value.

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