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The Study of Chemical Resistances in Bamboo Charcoal Polyester Fibres

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The paper studied the bamboo-charcoal polyester fibre chemical resistance properties and solubility in common fibre identification solution. Analyzed and compared the solubility and color change of bamboo-charcoal polyester fibre in various reaction acidic, alkaline and oxidizing solutions with different temperature, reagent concentration and different reaction time conditions. The result showed that: bamboo-charcoal polyester fibre is acid resistance, it can withstand 37% hydrochloric acid and 99% glacial acetic acid at boiling temperature, 50% sulfuric acid at room temperature. Bamboo-charcoal polyester fibre is not alkali resistance, it can withstand 20% sodium hydroxide and 0.6mol/l-1.2mol/l sodium hypochlorite at room temperature, it can't withstand boiled low concentration sodium hydroxide. The oxidation resistance of bamboo-charcoal polyester fibre is not strong. Finally, based on the degree of dissolution in the common fibre identification solution listed the identify solution and correction coefficient to calculate the fibre blended ratio of blending products. It is expected that all of the research results will provide the basis for the research of fibre identification and future development and application of bamboo-charcoal polyester fibre.

1. Introduction

Bamboo-charcoal fibre is one of the new functional types of fibres which was being rapidly developed in recent years. Due to the formation of porous structures under high-temperature pyrolysis, it possesses several advantages such as excellent hygroscopicity, adsorption ability, antimicrobial functions, deodorization ability, far infrared radiation and negative ions emission properties. Hence, it is a popular material that is favorably selected and has been widely used in clothing, home textiles, medical and textile industries (Chen, 2012; Okubo et al, 2004; Yan et al, 2007; Li, 2007; Zhang, 2010; Yu et al, 2008).

The chemical resistance of fibre can be referred as the strength of the fibre to protect against chemical attacks (Chen, 2014). During textile dyeing processes, the fibres involved will be exposed to varying degrees of acid, alkali, oxidants and other chemical substances (Li, 2002). By understanding the chemical resistance properties of the textile fibre, this would allow technicians to select more rational and appropriate conditions for modified fibre, yarn and fabric processing, and thereby maximizes the use of bamboo charcoal polyester fibres in a precise and efficient way.

As bamboo-charcoal polyester fibre is one of the latest types of fibre. In bamboo fabric processing, many other fibres can be intertwined to help to understand the chemical properties of the bamboo-charcoal polyester fibres. This can be done by technicians via selecting appropriate reagents to dissolve a specific fibre during the quantitative analysis of the mixed product. As a result, the content of each component in the product can be calculated, when combined with a specific correction factor (Li, 2002).

Bamboo-charcoal polyester, a brand new fabric material, is becoming more and more popular with the consumers because of its environment friendly and special functional properties. So a systematic study of bamboo-charcoal polyester, its products performance and the development of bamboo charcoal polyester fibre products will be of great significance. So far, the research has mainly focused on moisture absorption, gas permeability and antimicrobial properties; and many fundamental studies have run experiments on micro-structure analysis, raw material composition and its mechanical indexes, etc. little research has been done on the chemical resistance properties (Li et al, 2008; Wang et al, 2012; Hua et al, 2009; Hu et al, 2008; Wang,

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2007; Feng, 2009; Wang et al, 2007; Lu et al, 2011). There are currently no clear bamboo-charcoal polyester fibre identification standards.

In this paper, we mainly focus on the chemical resistances of bamboo-charcoal polyester fibres, hoping to provide the basis for further development and applications of these charcoal fibres.

2. Materials and methods

2.1 Materials and reagents

Bamboo charcoal fibre, linear mass density 1.89dtex.

Petroleum ether (distillation range 40-60°C), sulfuric acid, hydrochloric acid, glacial acetic acid, sodium hydroxide, sodium hypochlorite, hydrogen peroxide.

2.2 Instruments

HH-S6 six-hole thermostatic water bath (20-100°C), constant temperature oven, dryer, Soxhlet extractor, weighing bottle and analytical balance (accuracy 0.1mg).

2.3 Resistance tests on fibre to chemical reagents

2.3.1 Sample pretreatment

Take several samples of 1g, wrapped with filter paper and placed in the Soxhlet extractor. Extract with petroleum ether for 1 hour, and at least six cycles per hour. Wait until petroleum ether in the sample was evaporated, immerse in cold water for 1 hour, and then incubate in 65 $\pm$ 5 °C water bath for 1 hour. Make sure the solution was continuously stirred. Then suck and dry.

2.3.2 Sample drying

The pretreated sample was taken into the weighing bottle and dried in a (105 $\pm$ 3°C) oven for 4 hours or more. Transfer samples to a dryer to cool for 30 minutes and weigh.

2.3.3 Experimental procedure

Prepare different concentrations of chemical reagents according to experimental requirements; put 1g of sample into each reagent to observe the dissolution and colour change, inside the water bath and thereby adjusting the reagent temperature.

2.3.4 Calculations

The bamboo-charcoal polyesters fibre samples were then washed, dried, weighed and the weight loss rate of test sample after a chemical reaction is analysed.

Fibre weight loss rate,

$$J=\frac{M-M_0}{M}\times 100\% \qquad (1)$$

After the treatments with a variety of chemical reagents, the bamboo-charcoal polyester fibre in some reagents does not dissolve, but potentially has been damaged, this can be calculated using a mass correction factor d[8], such that:

$$d=\frac{M_0}{M} \qquad (2)$$

(M is the original dry mass of the test sample; M0 is the dry weight of the reagent after treatment; Units in g)

3. Results and discussion

3.1 Fibre acid resistance

3.1.1 The solubility of sulfuric acid on fibers

Table 1 and table 2 shows the colour change and weight loss rate of bamboo-charcoal polyesters at different temperatures and different concentrations of sulfuric acid, in various dissolution time.

As can be seen from Table 1, bamboo charcoal polyester can withstand 30%-70% sulfuric acid at room temperature and can resist 30%-50% sulfuric acid at boiling temperature, where they remained insoluble, and no colour change was observed. However, the polyesters cannot tolerate 70% sulfuric acid at boiling temperature, the fibers will slowly dissolve and resulted in small amount of black particles; Also, the polyesters cannot tolerate 98% sulfuric acid, fibers will be completely dissolved at a slower rate at room temperature, and dissolve completely at boiling temperature, where the end solution appeared in dark grey.

During fibre blending between bamboo-charcoal polyester and cellulose fibre, 70% sulfuric acid treatment can be adopted, where combined with an appropriate correction factor, the content of each component can be calculated (Chinese standard: FZ/T01057.4-2007 Test method for identification of textile fibres. Part IV: Solubility).

Table 1: The dissolubility of fibres in 30%-70% sulfuric acid

Reagent	Room Temperature			Boiling Temperature	Colour
Concentration	30min	60min	90min	15min	
30%	-0.7%	-0.7%	-0.4%	0.6%	No Change
50%	-0.6%	-0.5%	-0.8%	0.5%	No change
70%	-0.7%	-0.9%	-0.6%	93.8%	No change (Insoluble); Dark grey (Solubilised)
d	0.99	0.99	0.99	-	

(Note: There is a weight gain after the reaction between bamboo charcoal polyester and sulfuric acid. Hence the weight loss rate is negative.)

Table 2: The dissolubility of fibres in 98% sulfuric acid

Reagent	Room Temperature			Boiling Temperature	Colour
Concentration	30min	60min	90min	15min	
98%	88.3%	100%	100%	100%	Dark grey

3.1.2 The solubility of hydrochloric acid on fibers

Table 3 shows the colour change and weight loss rate of bamboo-charcoal polyesters at different temperatures and different concentrations of Hydrochloric Acid, in various dissolution time.

Table 3: The dissolubility of fibres in 7%-37% hydrochloric acid

Reagent	Room Temperature			Boiling Temperature	Colour
Concentration	30min	60min	90min	15min	
7%	0.3%	0	0.1%	0.7%	No change
17%	0.1%	0.1%	0.4%	1.6%	No change
27%	0.3%	0.5%	0.3%	2%	No change
37%	0.2%	0.3%	0.9%	1.3%	No change
d	1	1	1	1.01	

From Table 3, bamboo-charcoal polyester fibre incubated at room temperature for 30 to 90 minutes does not dissolve between 7% to 37% hydrochloric acids and that there was no colour change. Even after 15 minutes of boiling, the colour remained unchanged, and the maximum weight loss rate of bamboo charcoal polyester fibre reached 2%, which is equivalent to only 0.02g of fibre weight. Whether the quality difference is due to the corrosive hydrochloric acid or individual experiment errors will require further studies to find out.

During fibre blending between bamboo charcoal polyester and cellulose fibre, 37% hydrochloric acid treatment can be adopted, where combined with an appropriate correction factor, the content of each component can be calculated. (Chinese standard: FZ/T 01057.4-2007 Test method for identification of textile fibres. Part IV: Solubility).

3.1.3 The solubility of glacial acetic acid to fibers

Table 4 shows the colour change and weight loss rate of bamboo-charcoal polyesters at different temperatures and different concentrations of Glacial Acetic Acid, in various dissolution time.

Table 4: The dissolubility of fibres in 40%-99% glacial acetic acid

Reagent	Room Temperature			Boiling Temperature	Colour
Concentration	30min	60min	90min	15min	
40%	0.1%	0.1%	0.2%	0.3%	No change
60%	0.1%	0.1%	0.3%	0.5%	No change
80%	0	0.2%	0.3%	0.3%	No change
99%	0.2%	0.3%	0.6%	0.3%	No change
d	1	1	1	1	

From Table 4, bamboo charcoal polyester fibre incubated at room temperature or boiling temperature for 15 minutes and above does not dissolve in 40% to 99% glacial acetic acid; where there was no colour change.
The fibre blending in bamboo-charcoal polyester fibres with acetate and triacetate fibres, a 99% hydrochloric acid treatment can be adopted, where combined with an appropriate correction factor, the content of each component can be calculated. (Chinese standard: FZ/T 01057.4-2007 Test method for identification of textile fibres. Part IV: Solubility).
According to the above experimental results, bamboo-charcoal polyester fiber can't withstand boiled 70% sulfuric acid and 98% sulfuric acid at room temperature, it can withstand 37% hydrochloric acid and 99% glacial acetic acid at boiling temperature. To conclude, the fibre is relatively stable upon both strong and weak acid.

3.2 Fibre alkali resistance

3.2.1 The solubility of sodium hydroxide to fibers

Table 5 shows the colour change and weight loss rate of bamboo-charcoal polyesters at different temperatures and different concentrations of sodium hydroxide, in various dissolution time.

Table 5: The dissolubility of fibres in 5%-20% sodium hydroxide

Reagent	Room Temperature			Boiling Temperature	Colour
Concentration	30min	60min	90min	15min	
5%	0.1%	0.3%	0.5%	100%	No change (Insoluble); Dark grey (Solubilised)
10%	0.3%	0.6%	0.2%	100%	No change (Insoluble); Dark grey (Solubilised)
15%	0.2%	0.1%	0.3%	100%	No change (Insoluble); Dark grey (Solubilised)
20%	0.3%	0.2%	0.3%	100%	No change (Insoluble); Dark grey (Solubilised)
d	1	1	1	-	

It can be seen from Table 5 that the bamboo-charcoal polyester fiber can tolerate 5% to 20% sodium hydroxide at room temperature, and the fiber has no weight loss, no change in solution or fiber color; Also, complete fiber dissolution can be seen at boiling temperature incubated with 5% to 15% sodium hydroxide; Instantaneous dissolution at boiling temperature with 20% sodium hydroxide, where the solution appeared as dark grey and the formation of black particles in bottom of the container can be seen.
During fibre blending between bamboo-charcoal polyester and non-protein fibre, 5% sodium hydroxide treatment can be adopted, where combined with an appropriate correction factor, the content of each component can be calculated (Chinese standard: FZ/T 01057.4-2007 Test method for identification of textile fibres. Part IV: Solubility).

3.2.2 The solubility of alkaline sodium hydorchlorite to fibers

In correspondence to different dissolution time that was set, the colour change and weight loss rates of bamboo-charcoal polyester fibres at different temperatures and alkaline sodium hypochlorite concentrations are shown in Table 6.

Table 6: The dissolubility of fibres in 0.6mol/l-1.2mol/l alkaline sodium hypochlorite

Reagent	Room Temperature			Boiling Temperature	Colour
Concentration	30min	60min	90min	15min	
0.6mol/l	0.1%	0	0.2%	0.3%	No change
0.8mol/l	0.3%	0.3%	0.3%	0.5%	No change
1mol/l	0.2%	0.3%	0.5%	0.3%	No change
1.2mol/l	0.2%	0.4%	0.3%	0.3%	No change
d	1	1	1	1	

It can be seen from Table 6, the bamboo charcoal polyester fibre incubated at room temperature or boiling temperature for 15 minutes and above, does not dissolve in the 0.6mol/L ~ 1.2mol/L alkaline sodium hypochlorite, and the colour remained unchanged.
During fibre blending between bamboo-charcoal polyester fibre and protein fibre, 1mol/L alkaline sodium hypochlorite treatment can be adopted, where combined with an appropriate correction factor, the content of

each component can be calculated (Chinese standard: FZ/T01057.4-2007 Test method for identification of textile fibres. Part IV: Solubility).

Based on the above experimental results, it can be summarized that the bamboo-charcoal polyester fiber can withstand not more than 20% sodium hydroxide incubated at room temperature, or 0.6mol/L~1.2mol/L alkaline sodium hypochlorite, or low concentrations of sodium hydroxide, and considered to have a weaker tolerance to alkaline substances than the ordinary polyester fiber (WU et al, 2010).

3.3 Fibre oxidation resistance

3.3.1 The solubility of hydrogen peroxide to fibers

In correspondence to different dissolution time that was set, the colour change and weight loss rates of bamboo charcoal fibres at different temperatures and hydrogen peroxide concentrations are shown in Table 7.

Table 7: The dissolubility of fibres in 5% - 35% hydrogen peroxide

Reagent	Room Temperature			Boiling Temperature	Colour
Concentration	30min	60min	90min	15min	
5%	4	5.1	5.4	5.2	Grey turn yellow
15%	4.6	5.4	5.4	5.4	Grey turn yellow
25%	5.2	5.7	5.6	5.7	Grey turn yellow
35%	5.3	5.7	5.6	5.8	Grey turn yellow

From Table 7, the concentration of bamboo charcoal in 5% to 35% hydrogen peroxide will lose weight at different temperature and different dissolution time. However, the change in fibre weight loss rate is insignificant, and the fibre colour will gradually turn from grey to yellow. The fibre weight loss rate is proportional to the reagent concentration as well as the reaction time. Fibre oxidation resistance is not strong.

4. Conclusion

(1) Acid and Alkali Resistance

Bamboo charcoal polyester fibre is intolerant to high concentrations of sulfuric acid, however, can withstand below 50% of sulfuric acid, hydrochloric acid and glacial acetic acid. The stability of bamboo charcoal fibre upon strong and weak acid is considerably good and similar to other polyester fibres. It can also withstand below 20% of sodium hydroxide at room temperature, 0.6mol/L-1.2mol/L of sodium hypochlorite, low concentrations of sodium hydroxide and considered to have a weaker tolerance to alkaline substances than the ordinary polyester fiber (Wu et al, 2010). The overall performance of bamboo charcoal polyester fibre showed that it is acid tolerable but intolerant to alkali.

(2) Oxidation Resistance

The solvent reaction between bamboo charcoal polyester fibre and hydrogen peroxide has shown slight weight loss at each concentration and reaction time. Moreover, the fibre weight loss rate and the reagent concentration were found directly proportional to the reaction time. This is associated with the reducing properties of carbon, and the strong oxidising property in hydrogen peroxide, that both are easy to react under certain conditions, contributing to the outcome that bamboo charcoal polyester fibre has relatively weak oxidation resistance.

(3) Fiber Identification

According to the reactions between bamboo-charcoal polyester fibres and various chemical reagents, the following fibre identification pattern can be acquired:

Table 8: Fibre identification pattern

Reagent	Concentration	Temperature	Fibre A	Fibre B
H_2SO_4	70%	Room Temperature	bamboo-charcoal polyester fibre not dissolve	cellulosic fibre Completely dissolve
HCl	37%	Boiling Temperature	bamboo-charcoal polyester fibre not dissolve	regenerated cellulose fibre Completely dissolved immediately
$C_2H_4O_2$	99%	Room Temperature	bamboo-charcoal polyester fibre not dissolve	acetate fibre/triacetate fibre Completely dissolve
NaOH	5%	Boiling Temperature	bamboo-charcoal polyester fibre Completely dissolve	Non-protein fibre not dissolve
NaClO	1mol/l	Room Temperature	bamboo-charcoal polyester fibre not dissolve	protein fibre Completely dissolve

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