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Short communication

A green degumming process of ramie

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ABSTRACT

Ramie provides the longest and strongest natural fiber in textile industry, but its traditional degumming process is costly and requires a large amount of alkali, which causes serious environmental concerns. In the current work, a steam explosion (STEX) treatment followed by sodium percarbonate (SP) soak degumming process was investigated. Microstructure, chemical composition and mechanical properties of the refined ramie fibers were comprehensively characterized. The residual gum content was below 5%, the fineness was higher than 1600 Nm (6.25 dtex), the breaking tenacity was 5.4 cN/dex, and the whiteness was above 50%. All of the properties met the requirements of Chinese national standard, and the breaking tenacity and whiteness were notably better than those of the fibers degummed traditionally. In addition, environmental impacts of the new degumming process were evaluated. Only 50% chemicals were needed for the new process, and chemical oxygen demand (COD) of the waste reduced to 35% of the traditional method. Therefore, the new method was more environment-friendly and economically feasible. It has great potential for industry applications.

1. Introduction

Ramie is widely used in clothing fabrics, twines, industrial packaging, cordages and fiber reinforcements (Li et al., 2015; Liu et al., 2012; Luan et al., 2017; Ni et al., 2018). However, before ramie fiber could be used in textile, gummy matters in the raw bast have to be removed through a degumming process (Angelini et al., 2015; Yang et al., 2016; Zheng et al., 1988). The traditional degumming process requires two steps of treatments with large amounts of NaOH and other hazardous chemicals. The process not only has high cost, but also causes serious environment concerns (Zheng et al., 2001). Therefore, new environment-friendly degumming method with lower cost is desired.

Steam explosion (STEX) treatment is an efficient and environment-friendly method for degumming of various natural fibers (Gao et al., 2015; Zhang et al., 2014). Previous studies suggest that STEX is also effective on plant bast degumming. It can remove part of gummy matter from the raw materials, degrade some polysaccharides, and break bast to fiber bundles (Zhang et al., 2016). But STEX treatment alone couldn't complete the degumming process, and only fiber bundles could be obtained from this process (Jiang et al., 2017a,b). Therefore, a subsequent chemical degumming treatment is still necessary. As an environment-friendly and economically feasible reagent, sodium percarbonate (SP) has been traditionally used as beaching agent in textile industry, (Hage and Lienke, 2006; JC, 1964). Recently, its effects on ramie degumming were reported (Liu et al., 2011). Although the quality of ramie fiber extracted with SP alone is not good enough for textile production, the reagent showed positive effects on the degumming.

Therefore, the combination of STEX and SP treatment was hypothesized to be a promising method to degum ramie with low pollution and high fiber quality. This method was investigated in detail in this study.

2. Experimental details

2.1. Material

The ramie bast samples were supplied by the Research Center of Bast-fiber Plant in Hunan Province, China. All the ramie material was tiled under the ambient conditions (20–30 °C and < 50% humidity) for

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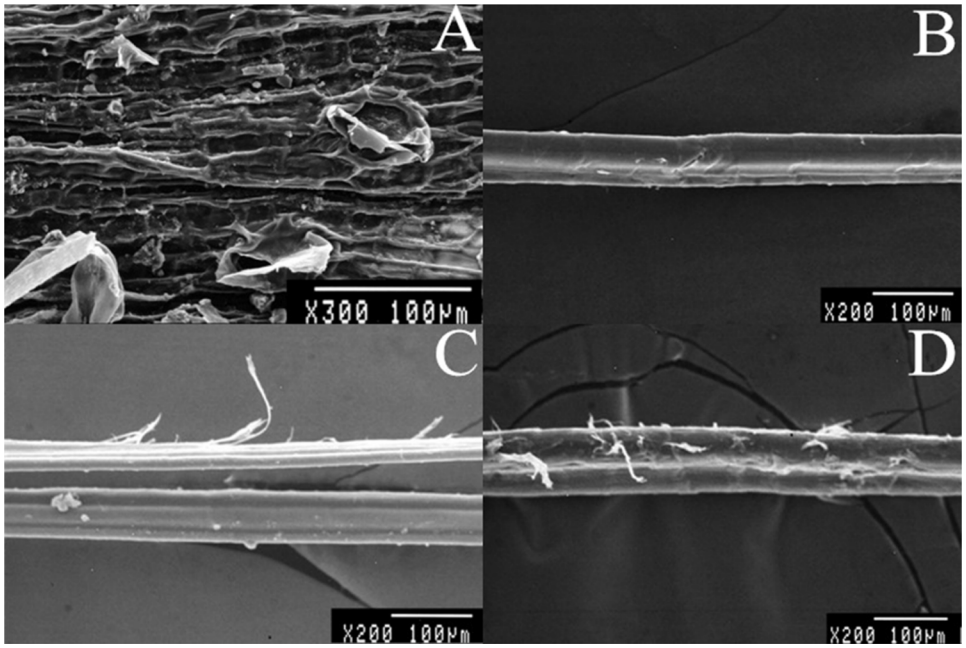

Fig. 1. SEM images of (A) raw ramie bast; (B) ramie fibers treated with traditional alkali degumming; (C) ramie fibers treated with STEX only; (D) ramie fibers treated with STEX-SP degumming.

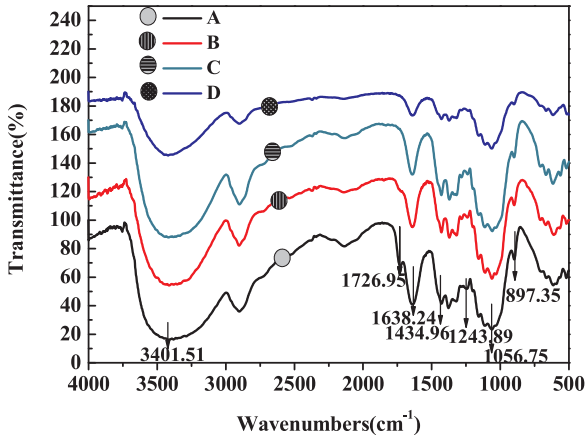

Fig. 2. FT-IR spectra of (A) raw ramie bast; (B) ramie fibers treated with traditional alkali degumming; (C) ramie fibers treated with STEX only; (D) ramie fibers treated with STEX-SP degumming.

more than one week before degumming. All chemicals used in the treatments were analytical pure and used without further purification. All the experiments were conducted in triplicates in this study.

2.2. Traditional alkali degumming

Ramie (30 g) and NaOH (concentration 1%, liquid-to-solid ratio (LSR) 20:1) were boiled with additives for 1 h twice. The additives include 3% hydrogen peroxide, 3% $NaSiO_3$, 2% anhydrous Na_2SO_4, 3% carbamide and 3% Sodium polyphosphate.

2.3. STEX followed by SP soak (STEX-SP) treatment

The STEX-SP treatment includes the following three steps:

Peracetic acid (PAA) presoak: Ramie (30 g) and PAA (concentration 2%, LSR 12:1, pH 5.0) were soaked at 55 °C for 10 min. The PAA solution could be reused for 6–8 batches.

STEX treatment: The STEX treatment on presoaked ramie was conducted at 0.5 MPa for 5 min.

SP soak: Pretreated ramie, SP (concentration 2%, LSR 12:1) and additives reacted at 90 ± 5 °C for 1 h. The additives include 3% hydrogen peroxide, 3% $NaSiO_3$ and 2% Sodium polyphosphate.

2.4. Degumming evaluation

The ramie fibers at different stages of degumming processes were characterized with SEM (JSM-840) and FT-IR (Nicolet iS50). The gum content (GB 5889-86, Jiang and Shao, 1986b), fiber fineness (GB 5884-86, Jiang and Shao, 1986a), breaking strength (GB 5886-86, Jiang and Shao, 1986c) and the whiteness (GB/T 5885-1986, Jiang and Shao, 1986d) were measured based on Chinese national standards.

The COD of the degumming waste was analyzed based on HJ 828-2017 (China National Enviromental Monitoring Centre, 2017), the pH value was measured with a pH meter (Leici PHS-25), and the colority was determined by the dilute method, which diluted the degummed water to the level that color was invisible, and recorded the dilute ratio.

3. Results and discussion

3.1. Surface morphology of ramie fiber

SEM images of ramie fibers presented a clear of view on degumming capability. The raw ramie bast has a rough and coarse surface with no fiber exposed (Fig. 1A). After different degumming process, the gummy materials in ramie bast were dramatically destroyed and separated, which resulted in several types of fibers. It was found that the traditional alkali treatment showed the strongest degumming ability, single fibers with clean and smooth surface could be produced using the method (Fig. 1B). However, the steam explosion treatment only had the strength to yield fiber bundles (two or more single fibers together); there are still some gummy materials on and inside the fiber bundles (Fig. 1C). Then, after the SP soaking, gummy materials were significantly reduced and single fibers were revealed, only a little gummy materials (white pieces) can be seen on the surface of the fiber (Fig. 1D). In summary, the new method had comparable degumming efficiency to the traditional treatment.