Bamboo as an Emerging Resource for Worldwide Pulping and Papermaking

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As a widely distributed and fast growing graminaceous plant, bamboo has emerged as an important raw material for pulping and papermaking to mitigate the shortage of wood resources, at least in the East Asia region. New technologies such as silicon removal have been developed to overcome the disadvantage of bamboo as a pulping raw material, as well as to improve the quality of bamboo pulp products. The bamboo pulping capacity in China is continuing to increase in the near future.

Keywords: Bamboo; Papermaking industry; Fiber resources; Household paper

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Bamboo Is an Important Non-Wood Fiber Raw Material for Pulping and Papermaking

Bamboo is widely distributed in subtropical and tropical areas. As shown in Fig. 1 (Mera and Xu 2014), the main producing areas of bamboo are in the Asian-Pacific Region (I), the Americas Region (II), and Africa (III). About 80% of bamboo forest lands in the world are in the Asia and Pacific regions. Furthermore, India and China together account for approximately 70% of the bamboo forest in Asia (Mera and Xu 2014). Coincidently many developing countries that lack wood resources possess rich bamboo resources. From the view of forest conservation or sustainable economic development, bamboo is an important non-wood fiber raw material for pulping and papermaking, especially in these developing countries. In fact, bamboo has been an indispensable fiber raw material for papermaking industry in the India subcontinent and China.

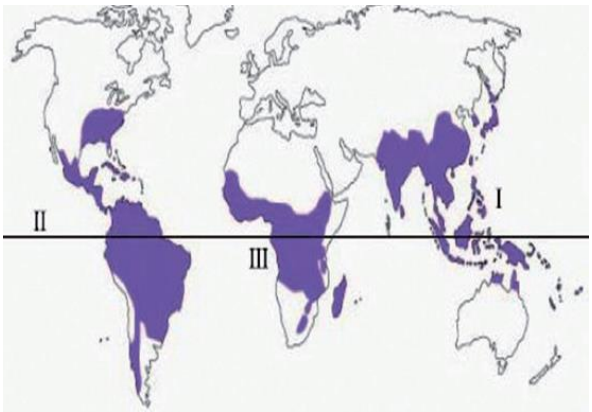

Fig. 1. World bamboo distribution

Compared with wood, bamboo has the advantages of a short growth cycle (3 to 5 years), self-reproduction, and low cost in maintenance and regeneration. Bamboo is reputed as "the second forest". As a fast growing graminaceous plant, bamboo contains 57 to 65 wt% cellulose, 27 to 30 wt% hemicellulose, and 4.9 to 5.0 wt% lignin (Wei *et al.* 2016). Considering its chemical composition, bamboo is a better fiber raw material for pulping and paper making compared with other non-wood fibers such as rice/wheat straw, reed, and bagasse. Bamboo fibers are comparable to hardwood fibers in several fiber characteristics, *i.e.*, the fiber length, aspect ratio, and fibrous cell wall cavity ratio.

The Challenges Facing Bamboo Pulping and Papermaking

There are many challenges for using bamboo as a pulping and papermaking raw material, including bamboo forest plantation, logging, storage and transportation of bamboo materials, and technical issues in the alkaline spent liquor recovery process of bamboo pulping. With respect to raw material supply, bamboo has a higher cost of logging, storage, and transportation compared with wood raw material. Moreover, due to the uniqueness of bamboo chips and their supply/ transportation issues, the production scale of bamboo pulping mills is usually smaller than that of wood pulp mills. The price of bamboo chips is influenced by the market fluctuations frequently. The fiber raw material cost for bamboo pulp can be as high as 60% of the total production cost (Wu 2016). To address this issue and ensure a stable supply of bamboo chips, pulp mills can establish their own bamboo plantations and sign long term contracts with local bamboo farmers.

Bamboo has relatively higher ash and silicon contents compared with wood materials (Sharma *et al*. 2011). This can negatively impact the recovery process for alkaline spent liquor and the quality of some high-grade pulp products such as dissolved pulp. New technologies, such as silicon removing/silicon retention, have been developed to overcome the disadvantage of bamboo as pulping raw materials, as well as to improve the quality of bamboo pulp products (Xu *et al*. 2015, 2016). A good example of bamboo pulping and bamboo pulp products can be found at Chitianhua's operation in Guizhou province of China, wherein the strong black liquor concentration reaches 70% and the alkali recovery rate is above 92%.

The Prospect of Bamboo Pulping in China

Accompanied with the rapid economic development, China has become the largest paper production and consumption country in the world during the last decade. Simultaneously, a great change in the raw material structure of the pulp and paper industry has taken place in China. The proportion of non-wood fibers in the pulp and paper industry of China has exhibited a gradual decrease. However, due to shortage of wood resources, utilization of non-wood fibers remains important in China. The total production capacity of bamboo pulp in China reached 2,400,000 tons in 2017, and most of the bamboo pulps (about 80%) are for the production of household paper grades. It is worth noting that household paper grades prepared from unbleached bamboo pulp have become a welcomed product for customers and have achieved encouraging commercial success in China.

To promote utilization of bamboo for pulp production, local governments of China are providing support for bamboo plantation and improvement of transportation conditions. A special sub-committee of Bamboo Pulp Working Committee was established in 2016 under the China Paper Association to accelerate the development of bamboo pulping technology and enhance the collaboration between paper mills and research institutions.

Several new bamboo pulp and paper projects have been planned in Sichuan Province of China, according to the 2017 Almanac of China Paper Industry. These include Yongfeng Paper's 2.0×10^5t/a integrated bamboo pulp and paper mill, Yibin Paper's 2.5×10^5t/a integrated bamboo pulp and paper mill, and the 1.5×10^5t/a integrated bamboo pulp and paper mill of Chinese Bamboo Paper Co., Ltd. As reported, the total production capacity of Chinese Bamboo Paper Co., Ltd will reach 1.0×10^6 t/a in next few years. These new bamboo pulping projects reflect China's strategy in utilizing its bamboo resources for the pulp and paper industry.

Acknowledgements

The statistical data in this editorial are from some reports and yearbooks published by China Paper Association and Sichuan Province Paper Industry Association. The authors did not list them one by one in the references, due to the restriction on the length of this editorial. The authors are thankful for their work. The authors (Z. Chen and X. Yue) are very grateful to the support of the China Scholarship Council (201707790004; 201708610046). One of the authors (Z. Chen) also would like to acknowledge the financial support from Science and Research Programs of Education Department of Jilin Province of P.R.C. (No. 201684).

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