Dissolving Pulp Market and Technologies: Chinese Prospective - A Mini-Review

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Cellulose is the most abundant natural polymer on earth. As the market and the public demands more and more natural products, cellulose and its derivatives are becoming increasingly more attractive. The production of dissolving pulp, which is the main feedstock for cellulose-related products, has been growing over the past decade, while the technologies for manufacturing these pulps have also been advanced. In this literature review, the production and consumption of dissolving pulp are analyzed with a focus on the Chinese market. The manufacturing processes, including raw materials, pulping methods, pulp bleaching, and post-treatments are discussed.

Keywords: Dissolving pulp; Cellulose; Chinese market; Manufacture technology; Purification; Enzyme treatment

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INTRODUCTION

Dissolving pulp, also known as dissolving cellulose, is a high-purity cellulose product that is the raw material for cellulose-derived products including viscose, cellulose acetate, cellulose nitrate, and cellulose ether (Sixta 2006). Different from paper-grade pulps, the dissolving pulps possess high levels of high-purity cellulose (90 to 98%) and very high brightness (> 90% ISO) (Ingruber *et al.* 1985; Biermann 1996), and they have good reactivity towards specific chemicals, *e.g.*, CS_2 (Miao *et al*. 2014). As a natural, renewable, and environmentally compatible material, cellulose has received increasing attention worldwide because of the tightening supply and rising price of fossil resources (Ji and Zhao 2015), so dissolving pulp has become a very important sector of the pulp and paper industry.

The market demands and production of dissolving pulps have been growing sharply in the past decade, particularly in China (Patrick 2011; Ji and Zhao 2015). New technologies have been developed and commercialized for manufacturing such pulps (Deng 2012; Sixta *et al*. 2013; Duan *et al*. 2015a; Li *et al*. 2015a). In this literature review, the production and consumption of dissolving pulps are reviewed with a focus on the Chinese market.

China is the country with the largest population and the most rapid economic development in the world. Textiles is one of the most important industries in China, and now its textile industry has been playing the biggest role in the world. The development of the textile industry has promoted the consumption and production of dissolving pulp, so China has become the world's biggest buyer and second-largest producer of dissolving with the past decade's development. On the production technologies of dissolving pulp, the properties of different raw materials including cotton linter, wood, and bamboo are compared firstly; then some technologies including pulping process, pulp bleaching, caustic extraction, acid treatment, enzyme treatment, fractionation, mechanical treatment, *etc*. are discussed secondly.

MAIN PRODUCTS PRODUCED FROM DISSOLVING PULP

Dissolving pulps are not used for paper manufacture; rather, they are dissolved under the appropriate conditions to make regenerated cellulose (*i.e*., the cellulose is dissolved and then spun into fibers, casted into films or regenerated into sponges), or are further modified to make cellulose derivatives (Sixta 2006; Miao *et al*. 2014; Duan *et al*. 2015a). Dissolving pulp is the main feedstock for manufacturing regenerated cellulose (*e.g*., viscose and lyocell) and cellulose derivatives (*e.g*., cellulose acetate, cellulose nitrate, and cellulose ether). The end products of dissolving pulp are widely used in various industrial products, such as textiles, tires, coatings, paints, and tobacco products, as well as food and pharmaceutical products (Ingruber *et al*. 1985; Duan *et al*. 2015a). Some processes and end products made from dissolving pulps are shown in Table 1.

Table 1. End Products of Dissolving Pulps

Manufacturing Process	Products	Applications
Xanthation	Viscose	textile, non-woven, tire cord, cellophane, sausage skin, sponge, industry yarn, *etc*.
Acetylation	Acetates	film, cigarette tow, plastic, acetate yarn/fiber, *etc*.
Nitration	Nitrates	explosives, lacquers, celluloid, *etc*.
Etherification	Ethers	binder, glue, thicker, *etc*.

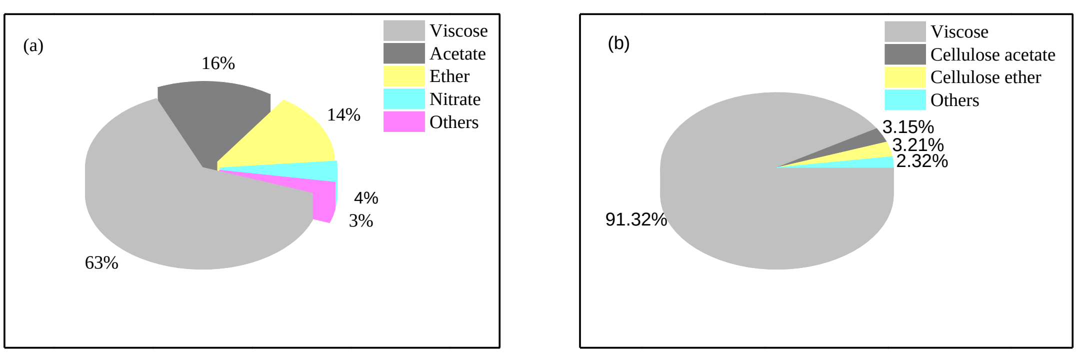

Fig. 1. Proportion of different cellulose products from dissolving pulp in the world (a) and in China (b) (Ji and Zhao 2015)

The production of viscose fibers for the textile industry accounts for most of the dissolving pulp consumption (about 63%). Cellulose acetate, cellulose nitrate, and cellulose ether account for 16%, 4%, and 14%, respectively (as shown in Fig. 1a) (Ji and

Zhao 2015). In China, dissolving pulps was used for viscose, cellulose acetate, and cellulose ether, which account for 91.32%, 3.15%, and 3.21% of the total consumption, respectively, whereas the remaining balance is used in miscellaneous applications (as shown in Fig. 1b) (Deng 2012)

The various grades for dissolving pulps are classified chiefly based upon their cellulose content. Low grade dissolving pulps have a cellulose content of approximately 90%, while the medium and high grade dissolving pulps have a cellulose content of 94 to 95% and greater than 96%, respectively (Ingruber *et al*. 1985). The low and medium grade dissolving pulps are used for textile and cellophane production, whereas the high grade dissolving pulps are mainly for cellulose acetate and other specialty products.

MARKET STATUS

The resurgence of the global market for dissolving pulps started at the beginning of the twenty-first century. The global production of dissolving pulps has increased since then with a total output of 2.67 MT in 2001 to 4.01 MT in 2011 (Shen *et al*. 2014) and 6.68 MT in 2014 (Ji and Zhao 2015). This boost in the market can be attributed to increased consumption and production of textile fibers, reduced yield and increased cost of cotton, and advances in some environmental issues for dissolving pulp production (Ji 2014). As shown in Fig. 2, China is a dominant player in the market because its consumption of dissolving pulps has increased to 3.440 MT in year 2014 from 2.113 MT in year 2010 (Shen *et al*. 2014). This consumption accounted for 51.50% of the world production in 2014 (Ji and Zhao 2015).

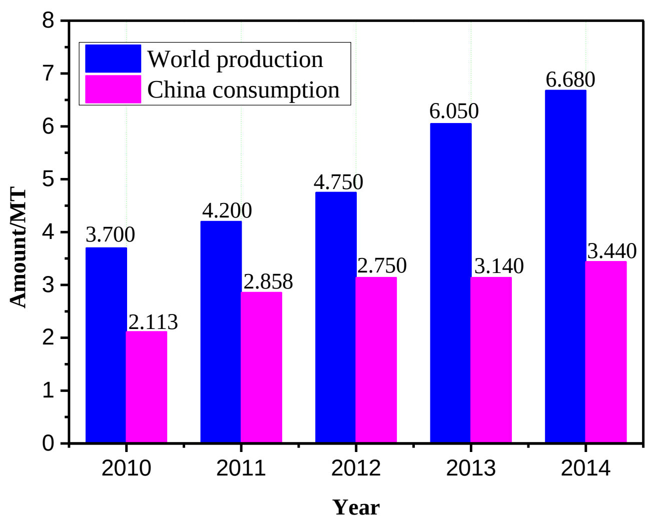

Fig. 2. Global production and China's consumption of dissolving pulp from 2010 to 2014 (Ji and Zhao 2015)

Canada, United States, South Africa, and Brazil are the largest producers of dissolving pulps (Ji and Zhao 2015). However, in the past five years (2010-2014), due to the rapid increasing of dissolving pulp consumption, many new projects have been completed in China to meet domestic demand.

It can be seen in Fig. 3 that the dissolving pulp capacity of China increased from 0.685 MT/yr in 2010 to 3.009 MT/yr in 2014. China has become the second largest dissolving pulp production country in the world, and it accounts for 18% of the total global production capacity (Ji and Zhao 2015). Traditionally, cotton linter pulp manufacturers are administrated by the textile industry in China, while pulp mills using non-cotton raw materials for dissolving pulp production are administrated by the pulp and paper industry. For this reason, the dissolving pulp statistics in China usually exclude cotton linter dissolving pulp.

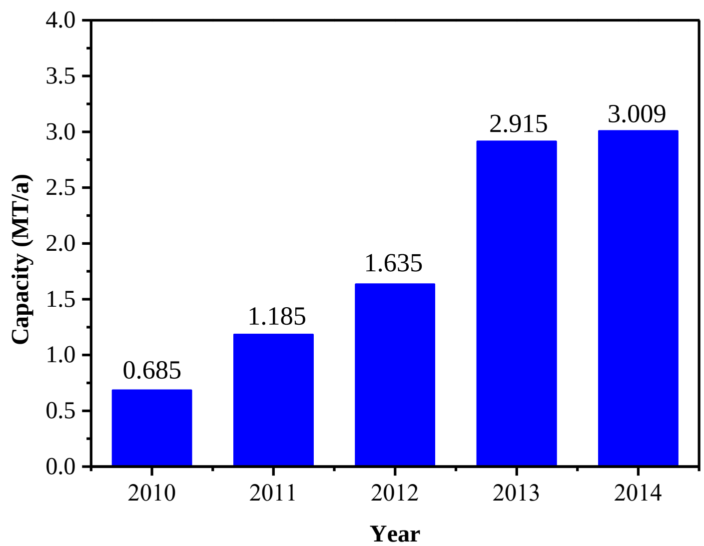

Fig. 3. Dissolving pulp production in China from 2010 to 2014; note that this data excludes 1.6 MT/yr (2014) of cotton linter dissolving pulp (CCFA 2016)

In China, cotton linter was the traditional raw material for dissolving pulp production. In 2010, there were more than 30 cotton linter pulp mills producing about 2 MT/yr. The production of dissolving pulp from cotton linters decreased to about 1.6 MT in 2014 (CCFA 2016) due to limited availability of cotton linters and high price. At the same time, the dissolving pulp capacity has increased appreciably as several paper-grade pulp mills have been converted to dissolving pulp mills, in addition to new green-field dissolving pulp mills becoming operational. The new mills utilize wood, bamboo, bags, and reed as the raw materials (Ji 2014; Shen *et al*. 2014).

Table 2 lists the main dissolving pulp mills in China. Most of them produce 50 to 100 kT/yr, although there are a number of large mills (*e.g*., Yueyang Paper, Sun Paper, and Huatai Paper). The total dissolving pulp capacity is 4.634 MT/yr, which includes 1.625 MT/yr of cotton linter pulp.

Table 3 presents the consumption and production data on dissolving pulp for China from 2010 to 2014. The dissolving pulp consumption in China increased from 2.113 MT to 3.440 MT over a five-year period. Notably, domestic dissolving pulp production was 1.15 MT in 2010, and further increased to 1.35 MT in 2014. The domestic production rates could not meet the needs of Chinese consumption; thus, China is a major importer of dissolving pulp from the world market.

Table 2. China Main Dissolving Pulp Mills in 2014 (CCFA 2016)

Fiber Materials	Mill	Capacity (kT/yr)	Overall Capacity (MT/yr)
Cotton linter	Shandong Yinying	240	1.625
	Shandong Hailong	240	
	Xinjiang Taichang	140	
	Aoyang Tech.	135	
	Henan Haiyang	130	
	Fulida Group	100	
	Weifang Henglian	100	
	Shandong Yamei	80	
	Nanjing Chemical Fiber	65	
	Hubei Jinhuan	60	
	Jilin Chemical Fiber	55	
	Anhui Xuelong	52	
	Hebei Baixiang	50	
	Shumeite Chemical Fiber	50	
	Baoding Tiane	48	
	Yibin Grace Group	40	
	Xinxiang Chemical Fiber	40	
Softwood	Yueyang Paper	300	0.776
	Qingshan Paper	186	
	Nanping Paper	150	
	Shixian Paper	90	
	Chenming Paper	50	
Hardwood	Sun Paper	100	0.198
	Huatai Paper	98	
Mixed Wood	Chenming Paper	700	1.100
	Henan Haiyang	200	
	Jilin Chemical Fiber	150	
	Yibin Grace Group	50	
Bamboo	Jilin Chemical Fiber	100	0.305
	Leeman Paper	95	
	Fujian Xinrixian Group	70	
	Chitianhua Pulp	40	
Converted from Paper-Grade Pulp	Tangshan Sanyou	330	0.630
	Sun Paper	200	
	Baijin Chemistry	100	
Grand Total			4.634

Table 3. Dissolving Pulp Consumption in China from 2010-2014

Year	2010	2011	2012	2013	2014
Consumption (MT)	2.113	2.585	2.750	3.410	3.440
Domestic production (MT)	1.150	1.440	1.180	1.630	1.350
Import volume (MT)	0.963	1.145	1.570	1.780	2.090

Comparing the production capacity (Table 2) to the actual production (Table 3), the total dissolving pulp capacity was 4.634 MT/yr in 2014, but the actual output was 1.35 MT in this year. The actual output level was comprised of 0.67 MT of cotton linter pulp, 0.6 MT of wood pulp, and 0.06 MT of bamboo pulp (Ji 2014), which represents 29.13% capacity utilization. The low utilization of capacity can be attributed to: 1) short supply and high price of the raw materials; 2) low market price for dissolving pulps; and 3) inexperience of operation (Shen *et al*. 2014). Chinese dissolving pulp producers showed weak competitiveness due to high production costs and low product quality. In addition, the sluggish downstream viscose fiber industry in China and the cheap dissolving pulp in the international market caused some dissolving pulp mills to switch to other pulp/fiber products or to suspend production in 2014 (Shen *et al*. 2014).

However, the increase demand for dissolving pulps that started at the beginning of the twenty-first century is expected to continue in the near future (Shen *et al*. 2014). The consumption of dissolving pulps in countries other than China has been limited, and only the Chinese consumption has increased (which is attributed to the rapid growth of viscose and textile industries) (Ji 2014). In China, the main use of dissolving pulps is for viscose manufacture, with a small portion (about 10%) used for miscellaneous cellulose products. As shown in Table 4, the consumption of viscose increased rapidly, whereas consumption for other products was relatively stable from 2010 to 2014.

Table 4. Dissolving Pulp Consumption of China in Viscose and Other Products

Year	2010	2011	2012	2013	2014
Viscose (MT)	1.764	1.989	2.628	3.068	3.150
Other products (MT)	0.249	0.596	0.122	0.342	0.290

China viscose output from 2010 to 2014 is presented in Fig. 4. It can be found that the Chinese viscose industry increased very quickly from 2010 to 2014. In 2014, China had 24 viscose producers, and production output reached 3.42 MT/yr (CCFA 2016), which accounted for 63% of the world production (Shen *et al*. 2014). The capacity of the cellulose ether industry was 180 kT/yr; there were 30 cellulose ether producers that afforded 66 to 70 kT (CCFA 2016), which represented a capacity utilization of about 37%. The capacity of cellulose acetate production was 350 to 400 kT/yr in 2014, and there were about 10 producers in China. Their output of cellulose acetate products was 151 kT, whereby the acetate cellulose base was 55 kT and the acetate cellulose fiber was 96 kT (Shen *et al*. 2014).

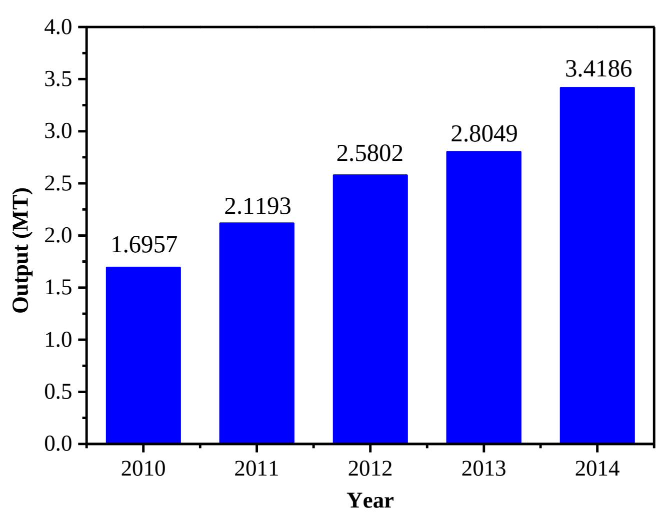

Fig. 4. China viscose output from 2010 to 2014 (CCFA 2016)

Based on the above results, the Chinese dissolving pulp production capacity has been severely underutilized. Therefore, it is reasonable to assume that new additions of dissolving pulp production capacity in China will be rather limited in the near future, while filling up the existing capacity is the best option to keep up the growth rate, which is predicted to be about 10% in the upcoming years (PRNewswire 2015). In 2014, the Chinese government implemented an anti-dumping tariff on some grades of dissolving pulps from different countries, which has been helpful in increasing the utilization of domestic production.

DISSOLVING PULP MANUFACTURE

Raw Materials

Cotton linters are the most commonly used raw material for manufacturing dissolving pulps due to their very high cellulose content (> 86%) (Louis 1985; IPS Engineering 2015). Softwoods and hardwoods have been utilized because of their advancements in pulping technologies and increased demand (Louis 1985; Sixta 2000). Non-wood raw materials, such as bamboo (Batalha *et al*. 2012; Ma *et al*. 2012), reed (Song 2011), bagasse (Andrade and Colodette 2014), and corn stalk (Behin *et al*. 2008), have also been used to produce dissolving pulps. It should be noted that some bamboo dissolving projects have been completed and put into production in China (Ji and Zhao 2015). About 85% of the global dissolving pulp is made from softwoods (*e.g*., pine and spruce) and hardwoods (*e.g*., beech and eucalyptus), whereas about 10% is made from cotton linters and approximately 5% is made from bamboo and other lignocellulosic materials (Ji and Zhao 2015; CCFA 2016). In China, the total domestic production was 1.35 MT in 2014; wood, cotton linters, and bamboo pulps accounted for 44.44%, 49.63%, and 4.44%, respectively, of the raw materials used. Different raw material has unique characteristics that are dependent on the morphological structure and chemical composition of the lignocellulose. The manufacturing process and the final product quality of dissolving pulp are affected by the species and qualities of the raw material used.

In the case of cotton linters, impurities constitute less than 20% of the total content, and 60% of these impurities (*i.e*., seed hulls, sand, foreign matter, *etc*.) are easily removed by mild physical and chemical methods that inflict minimal damage to the native cellulose. Very high-quality cellulose products are required to have a 99% alpha-cellulose content and a molecular weight of 7000. Cotton linters can be regarded as the best raw material, as they have the advantage of greater M_w homogeneity than other raw materials (IPS Engineering 2015).

Wood is the main raw material for dissolving pulp production, but not all wood species can be used. Wood chemistry and composition must be considered in order to select the appropriate pulping process. Some wood species are not suitable for acid sulfite (AS) pulping. In the AS process, phenolics, such as pinosylvin in pine heartwood or taxifolin in Douglas fir, react with lignin to form condensed structures that impede delignification (Erdtman *et al*. 1950; Sixta 1998). Also, taxifolin decreases the stability of the sulfite cooking liquor by converting sulfite to thiosulfate (Hoge 1954). Therefore, wood species that are rich in resin, like pine and larch, are not suitable for AS pulping.

In China, bamboo is an important raw material for the pulp and paper industry, not only for paper-grade pulp production, but also for dissolving pulp production (Ji and

Zhao 2015). Bamboo is in the grass family, and it contains 45 to 55% cellulose, 23 to 30% lignin, 20 to 25% hemicelluloses, 10 to 18% total extractives, and 1.5% ash (Batalha *et al*. 2012). Its fibers are 1.5 to 2.5 mm in length (Fu *et al*. 2012). Its composition and structure (lignin, cellulose, and hemicellulose) are similar to those found in some hardwood species; however, the minor substances, such as extractives (organic and water extractable compounds) and ash, are more abundant in bamboo than in hardwood (Alén 2000). These factors present challenges during pulp manufacturing processes, including pulping, bleaching, and chemical recovery. The fiber cell volume of bamboo is less than that of wood, for example, 40 to 70% for bamboo (Salmela *et al*. 2008) *versus* 60 to 80% for hardwoods and 90 to 95% for softwoods. Bamboo has other disadvantages that include high impurities (ash and metal ions) (Lv *et al*. 2012), cellulose with low molecular weight and intrinsic viscosity, and poor uniformity (Tan *et al*. 2013). Bamboo fiber structures possess multiple layers with complex orientations and arrangements in the secondary cell wall (Fengel and Shao 1984). By contrast, wood fibers have a simple three-layer (outer, middle, and inner layers) secondary wall. The compact structure, thicker cell wall, and higher hybrid cell content of bamboo may result in negative effects during dissolving pulp manufacture. Therefore, harsh cooking and bleaching conditions may be necessary for making good quality dissolving pulp from bamboo (Sixta and Schild 2011).

Pulping Methods

Pulping is a critical step in dissolving pulp manufacturing. The traditional pulping method uses acid sulfite (AS). The AS process is carried out under acidic conditions, where most of the hemicelluloses and some of the cellulose with low molecular weight are removed, which results in an unbleached pulp with a high cellulose content (Annergren and Rydholm 1959). During the past several decades, the pre-hydrolysis kraft (PHK) pulping process has been successfully commercialized for manufacturing dissolving pulps (Sixta and Schild 2011). In contrast to the acidic conditions of AS pulping, the PHK process is performed with both acidic (pre-hydrolysis) and alkaline (kraft cooking) conditions. In the pre-hydrolysis step, short-chain carbohydrates, particularly hemicelluloses, are hydrolyzed by the release of acetic acid from acetyl groups. Therefore, most hemicelluloses are extracted from the chips prior to kraft pulping (Sixta and Schild 2011).

The key properties of dissolving pulps from AS and PHK with respect to carbohydrate composition, molecular weight distribution (MWD), accessibility, and reactivity are different because different chemical reactions occur in acidic or alkaline environments. Duan *et al*. (2015b) compared the properties of AS and PHK pulps, finding that AS pulps had lower cellulose content, higher S_{10}/S_{18} contents, wider MWDs, and higher reactivity.

PHK is popular in new dissolving pulp mills because of the advantages associated with the capital investment, operation, and environmental compatibility. Sixta (2000) indicated that the PHK process accounted for 56% of the world dissolving pulp production (as of 2014), while the AS process accounted for 42%. For Canada's dissolving pulp sector, the AS process still accounted for 64% of dissolving pulp production capacity, although the PHK process has become increasingly important. In China, PHK accounts for 78% of the total production capacity (Chen *et al.* 2016).

Pulp Bleaching

The bleaching process not only increases the brightness of the dissolving pulp, but it also increases the purity, adjusts the viscosity and molecular weight distribution (MWD) of the cellulose, and modifies the reactivity of the dissolving pulp to meet the requirements of premium end-use products (Xu *et al*. 2012; Chen *et al*. 2016). Therefore, bleaching is a critical process during dissolving pulp manufacturing. Currently, the main methods being used are the combination of oxygen delignification (O), chlorine dioxide delignification (D_0) and brightening (D_1 and D_2), hypochlorite bleaching (H), and hydrogen peroxide bleaching (P) (Carlos *et al.* 2004; Vivian 2010; Xu *et al*. 2012).

Although hypochlorite has been almost phased-out from pulp bleaching for paper grades due to environmental reasons, it is still commonly used for dissolving pulp manufacture. Hypochlorite can oxidize and degrade cellulose in such a way that it can adjust its molecular weight and viscosity to improve the uniformity of pulp (Sixta 1998).

Dissolving Pulp Post-Treatments

Post-treatment refers to special treatments, *i.e.* the pulp is treated with chemicals, enzymes, mechanical actions, microwave, or combinations for improving the quality of pulp, especially with its purity and reactivity. The methods of post-treatment include caustic extraction, acid treatment, fractionation, enzyme treatment, mechanical treatment, *etc*., which can occur before bleaching, and also occur after bleaching (Sixta 2006). Many of these treatments have been applied commercially. In addition, these post-treatments also play an important role in the process of converting paper-grade pulp to dissolving pulp (Viviana 2010).

Caustic Extraction

Hemicelluloses are readily dissolved in alkali (NaOH); thus, caustic extraction is an efficient way to remove hemicelluloses from pulp fibers, especially in acid sulfite pulps (Hanif *et al.* 2013). Generally, alkaline purification is carried out as a cold caustic extraction (CCE) or hot caustic extraction (HCE). The CCE process is conducted at 20 to 40 °C and 8 to 10% NaOH; HCE is carried out at 95 to 135 °C and 0.4 to1.5% NaOH (Ingruber *et al*. 1985; Sixta 2006; Hanif *et al.* 2013). In CCE (lower temperatures and higher alkali concentrations), the mechanism involves fiber swelling and the dissolution and removal of hemicelluloses from the inner fiber to the bulk phase. The alkali consumption in the CCE process is negligible. The cellulose content of the pulp treated by CCE can reach 98% and higher (Ingruber *et al*. 1985). However, in HCE (higher temperatures and lower alkali concentrations), the fibers do not sufficiently swell due to the low alkali concentration, so the hemicellulose in the deep wall of fibers cannot be removed more completely; but the chemical reactions of carbohydrate degradation and further oxidations do occur at the high temperatures, which has many disadvantages. The disadvantages include lower yields, additional consumption of chemicals, and lower pulp viscosities. It is more difficult to make high-purity dissolving pulps (alpha-cellulose content of 96% or higher) by HCE (Ingruber *et al*. 1985).

Acid Treatment

In contrast to alkaline extraction, acid extraction (A) allows for the dissolution of a fraction of alkali-resistant hemicelluloses. Acid extraction is carried out at pH 2.5 to 3.5 and 95 to 150 °C for 1 to 2.5 h (Marechal 1993). Under these conditions, the alkaline-resistant hemicelluloses are removed easily, and therefore, they are suitable for treating

PHK pulps. Both the hemicelluloses and metal cations (*e.g.*, transition metals) are removed (Clavijo *et al*. 2012). Arnoul-Jarriault *et al*. (2015) treated an oxygen-delignified softwood kraft pulp with an A stage at pH 3 and 150 °C for 2 h. The hemicelluloses in the pulp decreased from 16.27% to 11.08%, which represented a 31.9% decrease.

Fractionation

Pulp fibers can be fractionated according to their size. The fractionation treatment has been applied in traditional pulp manufacturing process for the purpose of improving bleached pulp brightness (Bäckström and Brännvall 1999) and mechanical pulp strength (Lei *et al*. 2013). Recently, Li *et al*. (2015a) applied fiber fractionation to improve the purity of dissolving pulps. By fractionating a softwood sulfite pulp, the authors found that the long-fiber fraction retained on a 30-mesh screen had lower hemicellulose levels (9.59%) than the short-fiber fraction that passed through a 30-mesh screen (11.65%). The alpha-cellulose content of the long-fiber fraction was about 2.5% higher than that in the short-fiber fraction (91.08% *vs*. 88.53%). Zhao (2015) studied the effects of fractionation on bamboo dissolving pulp and showed that the cellulose purity can be improved by removing the fines. As more fines were removed, the purity of the resulting dissolving pulp was higher. For a bleached bamboo pulp with the removal of 14.7% (w/w) of original pulp, the alpha-cellulose content increased from 94.7% to 96.2%, lignin content decreased from 0.86% to 0.63%, and ash content decreased from 0.89% to 0.41%.

Enzyme Treatment

Enzymatic treatment, including cellulase and hemicellulase treatment, can be used to modify dissolving pulps, enhancing pulp properties such as purity, viscosity and reactivity (Rahkamo *et al*. 1998). Cellulase targets the amorphous cellulose located on the fiber surface and between the microfibrils. This enzyme increases the swelling and accessibility of cellulosic fiber, which increases its reactivity to derivatization (*i.e.*, it opens up the fiber structure and increases fiber porosity) (Rahkamo *et al*. 1998; Gehmayr and Sixta 2011; Miao *et al*. 2015). Miao *et al*. (2015) treated a PHK hardwood dissolving pulp using 0.5 U/g cellulase; cellulase treatment opened up the structure and increased the porosity of the fibers, which improved the accessibility and reactivity of the treated pulp. The pore volume of fibers increased from 4.79 to 6.74 μm^3/g, and the Fock reactivity improved from 47.67 to 66.02%. Compared with cellulase, hemicellulases (*e.g.*, mannase and xylanase) are mainly used for pulp purification. Gehmayr and Sixta (2011) treated oxygen-delignified *E. globulus* kraft pulps with xylanase (*i.e.*, 3% consistency, pH 7, 60 °C, 1 h, and 500 U xylanase/g oven-dried pulp) and observed that the xylase content of the pulp decreased from 22.5% to 12.1%.

Mechanical Treatment

Refining, milling, and shredding are typical mechanical methods that open the fiber wall structure and improve the penetration of chemical into the fiber; these positive changes in fiber morphologies significantly enhance the reactivity of the cellulosic fibers (Tian *et al*. 2014; Li *et al*. 2015b). Some mechanical treatments can be readily implemented in the mill and commercialized. Tian *et al*. (2014) reported that mechanical refining of a hardwood PHK pulp resulted in increased surface area, pore size, and pore volume; these changes increased the Fock reactivity of the resultant pulp. Refining a PHK hardwood pulp sample with 25,000 revolutions in a PFI refiner increased specific surface area from 0.98 to 1.20 m^2/g, decreased crystalline ratio from 1.27 to 1.17, and increased Fock reactivity from 49.27 to 58.32%.

Other Treatments

Hydrogen bonding in dissolving pulps hinders the penetration and diffusion of chemicals into the inner fiber, which is essential for cellulose derivatization of dissolving pulps. In addition to the methods mentioned above, there are other methods that improve purity and/or cellulose reactivity in dissolving pulps. These methods include ionic liquid solvent (ILS) treatment (Isogai *et al*. 2009), microwave treatment (Tang *et al*. 2005), and electronic radiation treatment (Rajagopal *et al*. 1994); however, these treatments have not been commercialized yet.

SUMMARY

1. China is an important market for and producer of dissolving pulp. The increased demand for dissolving pulp in China in the last 15 years has led to a resurgence in global demand. In China, the vast majority of dissolving pulp is used for viscose manufacture, and only a small portion (10%) is used to produce other cellulose products. Currently, the Chinese dissolving pulp capacity is significantly under-utilized, although it has increased significantly in the last 5 years due to the conversion of a number of paper-grade pulp mills as well as new green-field dissolving pulp mills coming on-line. In 2014, about 60% (2.09 MT out of 3.44 MT) of the dissolving pulp consumed in China was imported.
2. Wood-derived dissolving pulp accounted for 44.4% of the total dissolving pulp produced in 2014 in China, while cotton-derived pulp accounted for 49.6%. The remaining pulp was made from bamboo and other nonwoods. In the past decade, the manufacturing and the treatment processes for dissolving pulps have advanced appreciably. In China, the prehydrolysis kraft (PHK) process accounted for 78% of the total production capacity in 2014. Recent research has demonstrated that new treatment methods, such as modified caustic extraction, acid extraction, enzyme treatment and mechanical treatment, are very efficient in improving the quality of dissolving pulps.

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