China's High-yield Pulp Sector and Its Carbon Dioxide Emission: Considering the Saved Standing Wood as an Increase of Carbon Storage

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The production of high-yield pulp in China has increased significantly in recent years. The well-known advantages of this type of pulp include low production cost, high opacity, and good paper formation. In the context of state-of-the-art technologies, China's high-yield pulping, which is dominated by the PRC-APMP (preconditioning refiner chemical treatment-alkaline peroxide mechanical pulping) process, has a much higher energy input but a significantly lower wood consumption in comparison with the kraft pulping process. If the saved wood in the forest or plantation is considered as an increment of carbon storage, then the carbon dioxide emission from the production of high-yield pulp can be regarded as much lower than that of kraft pulp.

Keywords: High yield pulp; Carbon footprint; Wood consumption; Energy input; China

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High Flying of the High-yield Pulp Sector in China

For the production of various paper products, pulp fibers liberated from woody or non-woody biomass are used as raw materials. Two main concepts are adopted for fiber liberation. One is related to chemical action, which dissolves the native lignin that naturally binds fibers together. The dominant process of this type is known as the "kraft" process. The pulp yield for a typical kraft process is about 45%. Another approach is mainly based on mechanical action to liberate the fibers; it is known as the high-yield pulping process, and its pulp yield typically is within the range 85 to 95%.

Currently, kraft pulping is the dominant pulping process around the globe. In China, however, there has been a rapid increase in the production of high-yield pulp. For example, during the years 2000 to 2010, China's high-yield pulp production increased from about 500,000 to 4,500,000 t/a (Bräuer *et al.* 2012). This drastic increase was caused by the huge domestic expansion in paper production/consumption and the enormous demand for pulp (Jerschefske 2012). In China, the hardwoods, such as poplar and eucalyptus, are the main raw materials for producing high-yield pulp. To date, China has become the largest producer of high-yield hardwood pulp, using both the BCTMP (bleached chemi-thermo mechanical pulping) and the PRC-APMP (preconditioning refiner chemical treatment-alkaline peroxide mechanical pulping) processes, with the newly installed production lines being predominately based on the PRC-APMP process (Bräuer *et al.* 2012).

There are a number of driving factors to account for the significant expansion of high-yield pulp in China (Münster *et al.* 2004; Bräuer *et al.* 2012; Pruszynski and Sirois 2012):

- Due to wood shortage, a yield of about 90% is indeed a considerable advantage.
- The fast-growing hardwood species such as popular are most suitable for the BCTMP and PRC-APMP processes, and the domestic wood plantation or forestation program is specially geared to the pulp and paper industry.
- The production cost of high yield pulp is generally lower than that of chemical pulp.
- High-yield pulp is superior to chemical pulp in terms of light scattering, opacity, bending stiffness, and bulk. The presence of large amounts of fines also contributes to good sheet formation and surface smoothness, which can yield good printability.
- High-yield pulp has better recyclability than chemical pulp, due to less fiber hornification of the pulp.

These advantages have led to a sensational increase in the production and use of high-yield pulp in China. It should be noted that high-yield pulp has its own disadvantages, such as more soluble anionic "trash" and lower brightness stability (Ni *et al.* 2011; Pruszynski and Sirois 2012). It is also noted that high-yield pulp is mainly used in the production of coated paperboard. A partial substitution of chemical pulp with high-yield pulp (*e.g.*, up to 40%) to produce uncoated and coated paper grades is technically viable and economically beneficial (He *et al.* 2010; Liu *et al.* 2012).

High-yield Pulp and Carbon Dioxide Emission

In addition to the above-mentioned advantages of high-yield pulp, the lower carbon dioxide emission during its manufacturing process in comparison with the same tonnage of chemical pulp is not to be under-estimated (Münster *et al.* 2004, 2009; Fairbank 2012; Manda *et al.* 2012). High-yield pulp may seem to have a much higher carbon footprint than chemical pulp due to its high energy consumption in the wood refining process. However, this judgment seems to be abrupt, and a better understanding is highly needed. Münster *et al.* (2004, 2009) conducted an analysis of the carbon footprints of mechanical pulp and chemical pulp, and it was concluded that the carbon footprint of thermo-mechanical pulp (TMP) is dependent upon the power/electricity sources (*i.e.*, from renewable or non-renewable energy sources) used in the pulp production process, although it is generally lower for TMP than for kraft pulp.

The wood consumption and energy input are decisive governing factors for the evaluation of the carbon footprints of kraft pulp and high-yield pulp. Figure 1 shows the typical consumptions of wood and electricity for China's major state-of-the-art PRC-APMP process, and its comparison with the kraft process.

A typical electricity/heat consumption in the state-of-the-art PRC-APMP process, which is the dominant high-yield pulping process in China, is around 800 kWh/t (Fig. 1). In 2011, China's average carbon dioxide emission for electricity was 0.745 kg/kWh, which was obtained by averaging those reported in the different regions of China (Brander *et al.* 2011). By multiplying the two numbers together, the carbon dioxide emission from the electricity consumption in the PRC-APMP process is around 596 kg/t. On the other hand, the state-of-the-art kraft process is essentially energy self-sufficient, *i.e.*, the combustion of black liquor in the boiler will generate sufficient steam/electricity to the overall process; thus no additional electricity/heat input is required (Fig. 1). This means that the carbon dioxide emission from the energy consumption in the kraft process can approach zero.

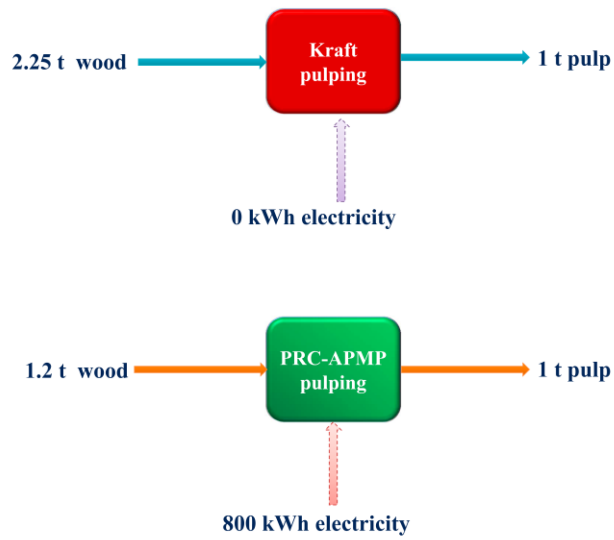

Fig. 1. Typical consumptions of wood and electricity in China's state-of-the-art kraft and PRC-APMP processes

To produce 1 ton of pulp (bleached pulp), it can be estimated based on the yield of 45%, about 2.22 tons of wood needs to be consumed in the state-of-the-art kraft process; however, only about 1.2 tons of wood is required in the state-of-the-art PRC-APMP process. Thus, for the production of 1 ton of pulp, about 1.03 tons of wood can be saved by PRC-APMP pulping (over the kraft process). In principle, the saved increment of wood would consist of trees standing either in a plantation of fast-growing poplar – or better yet – as timber in a natural, highly diverse forest saved from the need of harvesting. As 1 ton of wood is equivalent to 1833 kg carbon dioxide (Münster *et al.* 2009), the saved wood can account for carbon dioxide storage of about 1888 kg (1.03 t x 1833 kg/t=1888 kg). This number is about 1292 kg higher than the carbon dioxide emission from the energy consumption in the PRC-APMP process. Therefore, by considering the above aspects of electricity/heat input and wood consumption from the state-of-the-art high-yield pulping process, the carbon footprint of high-yield pulp can be lower than that of the kraft pulp. On the other hand, if the saved wood is considered as a feedstock for bioenergy production, the carbon footprint of high-yield pulp may also be lower than that of kraft pulp (Münster *et al.* 2009). However, it should be noted that if the saved wood is not considered in terms of carbon storage or bioenergy production, the opposite may be shown (Münster *et al.* 2009). Nevertheless, high-yield pulp is indispensable for further development of the Chinese pulp and paper industry.

Conclusions

In the context of China's state-of-the-art high-yield pulping (predominately PRC-APMP) processes, high-yield pulp can offer a significant environmental advantage of having a lower carbon footprint than kraft pulp, based on the assumption that wood saving from high-yield pulping (over kraft pulping) is considered as a repository of carbon storage. High-yield pulp is also indispensable in the Chinese pulp and paper industry for its unique features, such as high opacity/bulk and excellent paper formation.

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