Economics of Biopulping Compared to Other Mechanical Pulping Technologies

Thomas C. Marcin

ABSTRACT

The economics of biopulping require estimates of (1) the value of pulp from biopulping relative to competing pulping technologies, (2) production costs of alternative pulping technology, and (3) environmental costs. Pulping technologies that are close substitutes to biopulping are groundwood (GW) grinding process, refiner mechanical pulping (RMP), thermomechanical pulping (TMP), and chemi-thermomechanical pulping (TMP). This paper examines the comparative costs of mechanical pulping methods and the possible development of biopulping technology. The potential economic and environmental benefits of biopulping are discussed.

INTRODUCTION

Biopulping offers a number of potential economic benefits when compared to other types of mechanical pulping. Pulping mills can achieve substantially reduced energy costs if biological pretreatment is used prior to the mechanical pulping process for refiner mechanical pulping (RMP) and thermomechanical pulping (TMP). Other benefits of biopulping compared to chemical pretreatment include increased strength and refiner throughput, decreased waste treatment costs, and lower capital investment per unit. A survey of mechanical pulping mills in North America is underway to determine the importance of biopulping to the industry and to obtain relevant information on production costs, raw materials, waste treatment, and capacity. This information will then be used to construct a detailed mill model comparing biopulping to other mechanical pulping alternatives. This paper examines the comparative advantages of biopulping relative to other mechanical pulping methods and makes a preliminary assessment of the economic feasibility of investing in biopulping. A discussion of the prospects for commercializing biopulping in the mechanical pulping industry follows.

MECHANICAL PULPING PROCESSES

The use of mechanical energy to convert pulpwood or chips to woodpulp is the distinguishing feature of the mechanical pulping process. Technical advances in the process include the addition of heat, pressure, and chemical pretreatment of chips to the refining process. The traditional mechanical pulping groundwood (GW) grinding process, in which short logs are used, has been only marginally improved since its invention a century ago. Use of this process has declined in recent decades but still has a residual capacity of about 8 million tons per year in North America. The pressurized groundwood (PGW) process was developed in Finland by Tampella Oy (Miller Freeman Publications 1990). This process makes GW pulp by grinding logs in a pressurized atmosphere with a conventional grinder and improves the strength of the GW pulp (Miller Freeman Publications 1990). The refiner mechanical pulping (RMP) process fiberizes wood chips in large nonpressurized disc refiners. The RMP process typically uses sawmill residues and is especially popular in the Pacific Northwest. Thermomechanical pulping (TMP) improved the RMP process by presteaming the chips and fiberizing them in a pressurized refiner in one or more stages. This process is particularly successful in the South. A further modification of the TMP process includes chemically pretreating chips prior to the exposure to steam heat. This process is called chemi-thermomechanical pulping (CTMP) and was developed in Scandinavia in the late

1 Economist, USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin. The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin. This article was written and prepared by U.S. Government employees on official time, and it is therefore in the public domain and not subject to copyright.
1970s. It is particularly popular in Canada. Substituting biological pretreatment for chemicals is the distinguishing feature of biomechanical pulping, which will be discussed in detail later.

The principal advantage of mechanical pulpign methods is much higher yields (90 to 95 percent) than those of chemical pulping methods (40 to 50 percent). The main disadvantages of mechanical pulping are high energy consumption and less desirable pulp attributes. Mechanical pulpign mills are less expensive to build and can be economical at smaller scales of production. Mechanical pulping methods produce pulps with less desirable attributes, such as lower strength and brightness, but higher opacity and light scattering coefficient compared to those of chemical pulping methods. Chemical pretreatment of wood chips in the mechanical pulping process enhances the strength properties of chips. Chemical pretreatment also results in lower pulp yield by removing wood substances. An alternative pretreatment of wood chips is to use white-rot fungi instead of chemicals; this we call biopulping.

BIOPULPING BACKGROUND

Biopulping involves highly specialized white-rot fungi that selectively modify the wood cell wall leaving the cellulose for pulping. The selected fungal organisms soften up the chips for easier delignification by either mechanical or chemical pulping methods. In this study, mechanical pulping procedures are used. We will refer to biopulping as biomechanical pulping when the pulping method was mechanical.

Biopulping research was conducted by a number of companies and research institutions in the United States and Sweden in the 1950s and 1960s. In the 1970s extensive concurrent work was conducted at the Forest Products Laboratory (Madison, WI) in the United States and in Sweden. Research in Sweden resulted in the first published report on biopulping (Ander and Eriksson 1975) and a patented method for producing cellulose pulp (Eriksson and others 1976). Research continued in Sweden in the 1980s and resulted in continued refinement of biopulping (Eriksson and Kirk 1985). Results of this work and research at the Forest Products Laboratory led to the establishment of Biopulping Consortium I in 1987, which involved the Forest Products Laboratory, the University of Wisconsin, and industrial participants from the pulp and paper industry and the supplier industry from the United States and other countries. The Consortium conducted a 5-year program to evaluate the technical feasibility of biopulping. The research focused on mechanical pulping aspects of improved paper properties and energy savings in the pulping process. The results of the first consortium were encouraging enough to demonstrate the technical feasibility of biopulping and led to the formulation of a 3-year, second consortium, Biopulping Consortium II, to (1) further refine the engineering process for biomechanical pulping and (2) begin examining the possible application of biopulping to chemical pulping. Two promising organisms were found for aspen and loblolly pine that yielded good results in laboratory experiments. In subsequent processing, energy for electricity was saved by 25 to 50 percent. Improved strength properties relative to GW, RMP, and TMP were also obtained. The results of these experiments are summarized in Table 1 and indicate that biomechanical pulping (BMP) could almost substitute for CTMP. Kraft chemical pulps are much stronger than mechanical pulps. However, stronger mechanical grades like CTMP or BMP require less chemical pulp to be mixed in for additional strength.

PRELIMINARY ECONOMIC ANALYSIS

Mechanical pulps including TMP and CTMP accounted for 24 percent of the world pulp capacity in 1991 according to the Food and Agricultural Organization (FAO) of the United Nations (Table 2). Interest in mechanical pulping is increasing because of environmental and timber supply concerns. Further, technological improvements are likely to accelerate in TMP and CTMP pulping processing according Heikki Salonen of Ekono OY, Finland (Salonen 1988). In fact, the processing capacity of TMP and CTMP has grown steadily since its beginning in 1975. As Figure 1 shows, TMP
suggests that a less capital-intensive system, such as a chip-pile management system, is more likely to be adopted commercially. Additional calculations indicated that ROI would be 37 percent without aeration, 64 percent without the reactor, and 121 percent without aeration or the reactor. Therefore, a simple chip-pile management system provides the best prospect for commercial development. Future research efforts will be directed to the study of chip-pile management procedures and costs.

FUTURE ECONOMIC RESEARCH ON BIOPULPING

Economic research at the Forest Products Laboratory focuses on developing better methods to estimate all possible benefits and processing costs of biopulping and on pretreatment chip processing. This includes increased strength properties and refiner throughput and decreased energy consumption and waste treatment costs. Estimating further benefits from biopulping will proceed as follows. First, a model of the TMP and CTMP pulping processes with a biological pretreatment system will be constructed to conduct sensitivity analyses of alternative mechanical pulping processes. Ince (1990) used a process model to assess CTMP pulping and the press drying process for papermaking. Second, estimates of production and capital investment costs are needed for current industry practices. Basic data will be obtained on consumption of water, energy, and chemicals. Wood supply consumption and handling patterns and chip management and storage data will greatly affect potential biological treatment. In addition to cost of production information, data are also needed for a financial analysis of the environmental benefits and a market assessment of the industry's interest and willingness to pay for the potential benefits of BMP. Data for the model were collected from existing literature and experts. A questionnaire was prepared to obtain additional information on current mill practices and to assess industry attitudes about BMP.
The questionnaire was prepared and mailed to 72 managers of RMP, TMP, and CTMP mills in North America. The survey is strictly confidential and will be used only to obtain an acceptable range of data for the mechanical pulping model and to assess current industry interest in biopulping. Survey topics include information on (1) mill type, grade of pulp produced, and production in 1991; (2) roundwood and wood chip supply, storage, and consumption organized by species; (3) the pulping process, its water, energy, and chemical requirements, and data on pulp yield and grades; (4) pulp properties, end-use markets, recovery of chemicals, steam, and water, and waste and sludge disposal; (5) capital investment, operating costs, effluent treatment and sludge disposal costs, and financial rates; (6) mill interest in potential biopulping benefits such as energy savings, increased mill throughput, enhanced pulp properties, and customer acceptance of BMP grade and willingness to pay for biological agents.

Data collected in the survey will be supplemented by information from other published sources and consultation with industry experts. Results from the survey will be confidential, but aggregate information should help the members of the mechanical pulping industry understand the potential of biopulping.

**POTENTIAL ECONOMIC ADVANTAGES OF BIOPULPING**

Biopulping provides an opportunity to reduce the energy required to refine wood chips and increase the refiner throughput for mechanical pulping. The biopulping process uses biological organisms rather than chemicals, which are used in the CTMP process for pretreatment. Mechanical pulping uses mechanical energy to convert wood to pulp. Thus, mills can be built in a wide range of sizes compared to the large-sized, new kraft mills where scales are much greater. Biopulping has been successfully demonstrated using aspen and loblolly pine. In the future, biopulping may be adapted to a wide range of species by developing designer biopulping organisms using genetic engineering techniques. Biopulping may also be used in conjunction with chemical pulping processes, such as kraft, to pretreat wood chips and reduce chemical use.

**CONCLUSIONS**

The world pulp and paper industry is expected to continue to grow. The outlook for pulp and paper export is favorable, but international competition will likely increase as pulps from Brazil and other countries with favorable fiber production conditions become more available. As concerns about rising prices of wood and energy continue, biopulping offers one possible alternative to improve pulping technology. Biopulping may also be an attractive alternative to the huge capital costs of new greenfield chemical pulp mills. Finally, the use of a biological agent instead of chemicals may be less costly and more environmentally acceptable. Thus, biopulping offers some intriguing potential benefits that need to be explored further.

**LITERATURE CITED**


