ECONOMIC EVALUATION OF BIOPULPING

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ABSTRACT

The fungal pretreatment of wood chips prior to mechanical pulping (biopulping) reduces the electrical energy requirements during refining, potentially increases mill throughput, and improves paper strength, which have a direct economic benefit. An economic analysis of a 600 t/d thermomechanical pulp (TMP) mill indicates that based on energy savings alone, the process is economically feasible, resulting in overall savings of about $10 per ton of pulp. Increasing the mill throughput by 20% achieves additional savings of over $40 per ton of pulp. Replacement of TMP for Kraft pulp results in additional savings. For any particular mill, the savings realized will depend on that specific mill's conditions, utility costs, and current operations. The final conclusion is that biopulping is feasble from both an engineering and economic standpoints.

INTRODUCTION

Biopulping is defined as the treatment of wood chips with lignin-degrading fungi prior to pulping. Previous work has demonstrated the efficacy of biopulping for mechanical pulping [1,2]. In this work, it was found that the fungi alter the wood cell walls, which softens the chips and substantially reduces the electrical energy needs for pulping. The treatment also improves paper strength reduces the pitch content, and reduces the environmental impact of pulping. All of these factors increase the suitability of mechanical pulping for many applications. Furthermore, mechanical pulping, with its high yield, is viewed as a way of extending the raw materials.

To be commercialized, the technology must be feasible from both engineering and economic standpoints. A series of scale-up trails have been previously described in the literature [3]. This paper deals with the economic feasibility of the process through an economic analysis of a 600 ton/day TMP mill. For this analysis, three benefits of biopulping are considered energy reduction, increased mill throughput, and improved strength properties.

PROCESS OVERVIEW

Figure 1 is a conceptual overview of the biotreatment Process in relation to existing wood yard operations. Wood is harvested and transported to the mill site for debarking, chipping, and screening. At this point, the first change in the normal operation is made. Chips are decontaminated by steaming maintaining a high temperature for a sufficient time to decontaminate the wood chip surfaces and allowing the fungus to grow effectively. After decontamination, the chips are cooled sufficiently so that the fungus can be applied. The chips are then placed in piles that can be ventilated to maintain the proper temperature, humidity, and moisture content for fungal growth and subsequent biopulping. The retention time in the pile is 1 to 4 weeks.

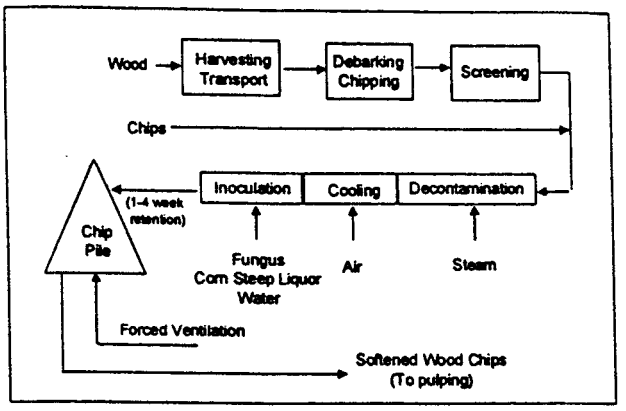

Figure 1. Overview of the biopulping process showing how the biotreatment process fits into an existing mill's wood-handling system.

ANALYSIS PARAMETERS

For this analysis, a 600 ton/day mill producing bleached TMP is considered. Table 1 summarizes the cost assumptions for the analysis. The reference [4] serves as the basis for some of these values. Of course, many of these parameters will be quite site specific and are subject to variability. The values of Kraft and TMP are market dependent and also highly volatile. For example, over the past 16 years, the price of Bleached Chemi-thermomechanical pulp (BCTMP) has ranged from $320 to $830 per ton, with the average (used in this analysis) being $550 per ton. Likewise the price of Kraft pulp has also fluctuated, with an average of $700 per ton being used in this study [5,61.

The capital costs for biopulping will vary according to the land and equipment that are currently available and the type of system installed. In addition to the treatment equipment needed for biopulping, these costs include land, 10 days of chip inventory, and the storage needed for the chips. Overall, we envision a silo or other enclosed storage system with a capacity based on the treatment time. The number of silos used and their configuration would depend on the availability of the land and the layout of the mill and wood yard. Belt conveyors are probably the most likely candidate for moving the chips to and from the silos.

Additionally, the silos need to be ventilated in order to remove the heat produced by the fungus. The ventilation would be provided by a series of blowers and preconditioning systems with each silo serviced **by** several blowers. This allows a certain amount of redundancy in the design of the equipment. For greatest energy efficiency, especially in the northern climates, the air should be recovered from the top of the silos and the heat recovered.

Table 1. Cost assumptions for economic analysis

Assumptions	Value	Units
Utility and Raw Materials		
Electricity	0.05	$/kWh
Steam	2.00	$/10^6 Btu
Wood	60.00	$/ton (o.d.)
Bleaching chemicals	60.00	$/ton of pulp (o.d.)
Kraft Pulp	700.00	$/ton (o.d.)
TMP Pulp	550.00	$/ton (o.d.)
Biopulping		
Capital costs (for 600 ton/day of pulp)	5.7x10^6	$
Operating costs	9.44	$/ton of pulp (o.d.)
Process Operations		
Production days	350	days/year
Refining energy	2000	kWh/ton
TMP yield	95	%
Treatment yield	98	%
Additional bleaching	15	%
TMP Manufacturing		
Labor	15.00	$/ton of pulp (o.d.)
Maintenance and operational supplies	30.00	$/ton of pulp (o.d.)
Tax and insurance	8.00	$/ton of pulp (o.d.)
Overhead	6.00	$/ton of pulp (o.d.)

For such a system, the total capital costs are estimated to be $5.7 million (Table 1). The additional operating costs for the treatment equipment, ventilation blowers, chip handling, and inoculum is estimated to be $9.44 per ton of pulp produced. This value is dependent on the costs of electricity and steam, also given in Table 1. The mill is assumed to operate 350 days/year, with a 95% yield through the refining process. Additional operating parameters, including costs for the TMP operation, are given in Table 1.

ECONOMIC BENEFITS CONSIDERED

The economic benefits of the biopulping process have been evaluated based on the process studies and engineering data obtained to date and are a result of the following effects.

Refiner Energy Savings

As discussed previously, energy savings at the refiner were used as the primary criterion for the effectiveness of biopulping. Thus, this aspect of the savings has been well quantified experimentally. For a 2-week process, the savings should be a minimum of 25% under the worst-case conditions of wood species and minimal process control, whereas up to nearly 40% can be achieved under some circumstances. In addition, utility rates can vary substantially with the time of day or magnitude of the peak usage. In these circumstances, the cost benefits of refiner load reduction could be even greater.

Process Debottlenecking

The reduction in power requirement has a further consequence that could be of great significance for some mills. Mills that are currently throughput-limited as a result of refiner capacity may assign substantial value to the debottlenecking effect that the fungal treatment will provide. Of course, even though the refiner is the rate-limiting step, additional capital may be needed to fully realize the throughput increases allowed by biopulping.

Furnish Blend Advantages

The biopulping process results in pulps that have improved strength properties. This is advantageous in situations where the product is a blend of mechanical pulps and Kraft pulps. The Kraft component is used to impart strength and is more expensive than the mechanical pulps. The improved strength of the biomechanical pulps would allow the required strength of the blend to be achieved with a lower percentage of Kraft pulp. Of course, the exact blend in any application will need to be optimized to ensure that all product specifications are met This aspect could also have a debottlenecking effect in mills that are Kraft production-limited, because the total blended pulp rates can be greater for a given production rate of the Kraft pulp component.

Other Advantages

The biopulping process itself is benign environmentally. Only benign materials are used, and no additional waste streams are generated. Furthermore, the two-week treatment with *C. subvermirpora* significantly reduces the amount of pitch in the wood chips. Biopulping chip storage is carefully contained. These features are in addition to the substantial amount of energy that is conserved by the process. Other economic benefits could be realized including the lower operating costs from an automatic system compared to a manual (bulldozer) system, better inventory control, and enclosed piles being less susceptible to environmental factors such as winter, rain, and wind.

ECONOMIC SCENARIOS

These advantages must be compared with the costs of implementing and operating the biopulping process. A preliminary assessment was conducted for a 2-week treatment and a flat-pile geometry operating in a northern climate. A southern climate scenario would show somewhat lower costs because of reductions in containment and air handling requirements. Table 2 summarizes the three scenarios investigated in this paper. Each scenario assumes a base TMP production of 600 tons/day. In scenario #3, the TMP is blended with equal parts of Kraft pulp for a total production of 1200 tons/day. For all three scenarios, biopulping conferred an energy reduction at the refiner of 30%. For scenario #2, a 20% increase in throughput is realized. For scenario #3, a 10% throughput increase is achieved, with the additional TMP production reducing the amount of Kraft needed.

Table 3 shows the economic analysis for scenario #l, where a 30% energy reduction is realized. Comparing the base case to scenario #1, the annual energy costs drop from $21.00 million to $14.70 million. After taking into account the additional costs for the wood and biopulping treatment, an annual savings of $2.14 million is achieved. This is a savings of $10,21 per ton of pulp produced. Under different scenarios and assumptions for utility costs, equipment needs, and operating costs, the net savings can range up to more than $26 per ton of pulp produced, with an estimated capital investment of $5.7 million. Simple rate of return can range from 25% to

95%, resulting in a payback of 1.0 to 3.9 years. Using typical values for the parameters of the analysis, a savings of $10.21 per ton of pulp can be expected after the cost of capital with a simple payback of 2.66 years.

It is important to remember that this considers only the economic benefit of energy savings. The additional advantages of debottlenecking are considerable. Mills that are refiner limited can experience throughput increases of up to 30% from the reduction in refining energy by running the refiners to a constant total power load. Table 3 also shows the analysis when a throughput increase is achieved. In scenario #2, production increases by 20% to 720 tons/day. Comparing this to the base case, the annual energy costs went down from $21.00 million to $17.64 million, even with the increased production. Due to the greater production, the other costs went up proportionally, but the total annual product value increased by over $23 million. The total additional profit achieved through biopulping is $13.82 million, which translates to over $50 per ton and a payback period of about 6 months.

Table 2. Process capacities and biopulping effects for economic scenarios.

	units	Scenario #l	#2	#3
Base process capacity	(tons/day)	600	600	1200
TMP production	(tons/day)	600	600	600
Kraft pulp requirements	(tons/day)	0	0	600
Energy savings per unit weight	(%)	30	30	30
production increase	(%)	0	20	10
TMP substitution for kraft	(%)	0	0	5

Table 3. Economic analysis for scenarios #1 and #2

	Units	Base	Scenario #l	#2
TMP production	(tons/day)	600	600	720
Biopulping capital costs	(10^6 $)		5.7	6.8
Manufacturing costs				
Energy	(10^6 $/year)	21.00	14.70	17.64
Wood	(10^6 $/year)	13.26	13.55	16.26
Bleaching chemicals	(10^6 $/year)	12.60	14.49	17.39
Biopulping treatment	(10^6 $/year)		1.98	2.38
Other costs	(10^6 $/year)	12.39	12.39	14.87
Total Costs	(10^6 $/year)	59.25	57.11	68.53
Product value	(10^6 $/year)	115.50	115.50	138.60
Marginal profit	(10^6 $/year)		2.14	13.82
Simple payback period	(years)		2.66	0.49
Savings	(S/ton)		10.21	54.85

Figure 2 shows the savings as a function of the throughput increase. The savings are from the increase in the production using the same capital. The solid, lower line shows the saving as a function of the throughput increase. Even a modest throughput increase of 10%, coupled with the energy savings of 30%, results in a payback of less than 1 year. At a 20% throughput increase, the savings are more than $50 per ton of pulp. Even if additional capital expenditures are needed, throughput increases of 20% result in a payback of less than 1 year. These values depend on the value of the product, in this case TMP pulp, which has ranged from less than $400 per ton of pulp to more than $800 per ton of pulp in the past 15 years (6,7).

Many mills blend mechanical pulps and Kraft pulps to achieve the optical and strength properties desired. The biotreated pulp, being stronger, may require less Kraft pulp to meet the product specifications. Table 4 summarizes the economic analysis for scenario #3 in which a mill is blending TMP with purchased Kraft. There is a 10% increase in the TMP production, which is used to replace Kraft in the product. The total energy costs drop from $21.00 million to $16.17 million; Kraft costs drop by almost $l5 million per year. Overall, $11.13 million is saved per year, which is equivalent to $48.19 per ton of TMP produced. The payback period of this technology is slightly over 6 months for this scenario. Figure 2 also shows the effect of additional Kraft substitution on the savings for incorporating biopulping into the mill. The dotted line represents the total savings on a per ton basis that are realized when the additional TMP is used as a substitution for Kraft. As can be seen, for a 10% increase in production, an additional savings of $13 dollars is achieved through this substitution.

Table 4. Economic analysis for scenarios #3.

	Units	Scenario Base	#3
Total production	(tons/day)	1200	1200
TMP production	(tons/day)	600	660
Kraft pulp requirements	(tons/day)	600	540
Biopulping capital costs	(10^6 $)		63
Manufacturing costs			
Energy	(10^6 $/year)	21.00	16.17
Wood	(10^6 $/year)	13.26	14.90
Bleaching chemicals	(10^6 $/year)	12.60	15.94
Biopulping treatment	(10^6 $/year)		2.18
Kraft pulp	(10^6 $/year)	147.00	132.30
other costs	(10^6 $/year)	12.39	13.63
Total Costs	(10^6 $/year)	206.25	195.12
Product value	($10^6$$/year)	262.50	262.50
Marginal profit	(10^6 $/year)		11.13
Simple payback period	(years)		0.56
Savings	($/ton)		48.19

CONCLUSIONS

Our economic analyses indicate that the biopulping process is technologically feasible and economically beneficial. Under the assumptions detailed here, savings of about $10 per ton of pulp were obtained. Even greater benefits can be realized when the other benefits of biopulping--such as increased throughput and substitution for Kraft-are considered. Throughput increases brought the simple payback period of the process to less than one year. Substituting this increased production for Kraft pulp in blended products results in additional savings. From this analysis, biopulping can produce substantial economic savings for TMP producers.

This preliminary analysis is subject to appropriate qualifications. The capital costs are subject to some variability, in particular the costs associated with integrating the new facility into an existing site. The additional advantages of biopulping, including the environmental benefits and pitch reduction, have not been quantified in this paper. Finally, much of this analysis is site-specific, depending on the operating conditions at the particular mill considering incorporating biopulping into its operations.

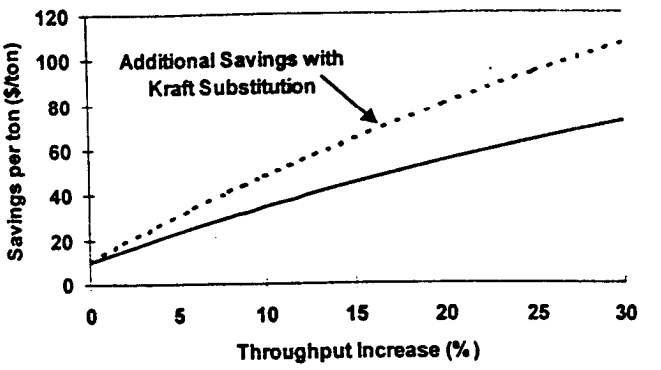

Figure 2. Effect of debottlenecking of the process through biopulping for a 600 ton/day TMP plant. The solid line shows the savings per ton as a function of the throughput increase. The dotted line demonstrates the additional savings that can be realized when the added TMP production is used as a replacement for Kraft pulp.

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