# Role of biotechnology in the pulp and paper industry : A Review
# Part 1 : Biopulping

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**ABSTRACT**

Biotechnology promises a potential role in pulp and paper industry. Researchers in biopulping are concentrating on lignin degradation and composition in wood to make pulping easier, with less demand of chemicals and energy. Xylanase enzymes are being studied for making dissolving grade pulp. Several pretreatment methods used to enhance the microorganisms attack on lignin are also examined. Research in this area has accelerated during the past 10 years because of its commercial potential in many fields. This paper presents an overview of the biotechnology applications in pulp and paper industry.

## Introduction

Biotechnology defines as the use of biological organisms, systems and processes for practical or commercial purposes. The growing field of biotechnology has created interest in the application of this technology to the pulping process. Pulp and paper industry utilizes biomass as a major raw material which is biodegradable. In pulping processes delignification are carried out chemically and mechanically. These are the high energy demanding physico-chemical processes which are associated with the production of environmentally polluting hezardous substances. New approaches to pulp manufacture and the various processes are being searched out continuously. Biotechnology promises new approaches.

Biodelignification i. e. removal of lignin and other substances so as to free the fibres by microorganism such as fungi, bacteria, and enzymes. white rot fungi almost all of which are wood decaying hymenomycetes, are the most active ligninolytic microorganism described to date.

New research in biotechnology have been occuring rapidly. The purpose of this three part report is to provide a brief overview to the status of research aimed at applying biotechnology in pulp and paper manufacture. Part 1 and part 2 will cover biotechnology for pulping and bleaching. Part 3 will deal with effluent treatment.

## Biopulping

Pulping is the process by which wood is reduced to a fibrous mass. Biopulping is the bio-conversion of wood by microorganism. The most rapid and extensive lignin degradation described to date is caused by certain fungi, particularly the white rot fungi, in highly aerobic environments 1-5.

### Bacteria :

Bacterial lignin degradation has been most extensively studied in actinomycetes, particularly streptomyces sp. resulted a loss of 32-44% of the lignin in spruce and maple[6]. Recent studies with other bacteria have failed to demonstrate extensive degradation.

### Fungi :

Wood decay caused by various species of ascomycetes and fungi imperfecti involves lignin degradation,

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although wood polysaccharides are preferentially degraded[7]. Several ascomycetes, fungi imperfecti and phycomycetes that are not associated with soft rot of wood including 12 marine fungi[8], 18 Trichoderma strains[9] and Trichoderma harzianum[10] failed to degrade lignin significantly.

The white rot basidiomycetes degrade lignin more rapidly and extensively than other studied microbial groups. During its mineralization by white rot fungi, lignin undergoes a number of oxidative changes, including aromatic ring cleavage. Recent studies have shown that a progressive depolymerization occurs and release a wide range of low molecular weight fragments[11,12].

One species of white rot fungus, Phanerochaete chrysosporium (Sporotrichum pulverulentum) has been studied widely. The wild type s. pulverlentum degraded kraft lignin better than the cellulase less mutant. The presence of cellobiose is not entirely necessary since in 10 weeks cellulase less mutant degraded 31% of the lignin without loss of cellulose, 32% xylan being degraded at the same time[13]. A comparision of wood losses due to WT and cell-44 are given in Table 1.

TABLE—1

Relative Lossess In Wood Components Caused By Wild Type (WT) and Cellulase Less Mutant (Cell 44) After Different Decay Times 13

| | Incubation Period (Weeks) | WT Lignin[1] % | WT Glucan[2] % | Cell 44 Lignin[1] % | Cell 44 Glucan[2] % |
|---|---|---|---|---|---|
| Birch | 4 | 17 | 7 | 9 | 0 |
| | 6 | 24 | 10 | 13 | —2 |
| | 8 | 30 | 9 | 23 | 1 |
| | 10 | 29 | 12 | 21 | 0 |
| Pine | 4 | 14 | 8 | 5 | —1 |
| | 6 | 9 | 5 | 8 | —3 |
| | 8 | 15 | 7 | 10 | —2 |
| | 10 | 22 | 4 | 8 | 0 |
| Spruce | 4 | 8 | 4 | 2 | —5 |
| | 6 | 11 | 5 | 4 | —3 |
| | 8 | 7 | 5 | 4 | —2 |
| | 10 | 15 | 2 | 5 | —5 |

1. Based on original amount of component
2. Corrected for glucose released from glucomannan and glacto-glucomannan.

Myers et al[14] studied the effect of pretreatment of aspen wood chips with white rot fungus. Pharerochate chrysosporium and Dichomitus squalens improved the strength properties of hand sheets produced from unbleached refiner mechanical pulp. Both fungal pretreatments resulted in hand sheets strength properties better than the control when compared at an equivalent freeness. D. Squalens pretreatment gave better hand sheet properties than the P. Chrysosporium. The fungal pretreatments decreased brightness and scattering coefficient but did not adversely affect opacity.

The disadvantage of current thermal and machanical treatments have promoted interest in developing biological treatments as alternatives which include both chip and pulp treatments. The aim of these treatments is to increase paper strength or reduce refining energy by using fungi and their isolated enzymes to relatively remove lignin The effect of fungal treatment on energy consumption and strength properties can be seen from Table 2,

Fungal species and treatment duration affected the extent of energy saving [14—15]. Four week long treatment with white rot fungi including Phlebia sp. or Pholiota[16—17] mutabilis in a stationary wire tray bioreactor resulted in at least 35% energy saving for pulping chips to 100 ml with phanerochaete chrysosporium the optimal treatment duration was four weeks. Treatments with a brown rot fungi also resulted in energy saving but did not improve strength properties. A detailed chemical analysis indicated that strength improvements by white rot fungi does not correlate with bulk removal of any material including lignin.

Fungal post treatment of refiner mechanical pulp has been investigated to improve paper properties. Amongst various fungi tested, polyporus versicolor gave the best overall improvement in hand sheet properties with no reduction in tear[18].

It has been suggested that biological thermomechanical pulping may be more practicable than the original idea of full biological pulping [19].

## ENZYMES :

The recent discovery of several enzymes that are thought to have roles has projected lignin bio-degradation research. These enzymes include ligninases, Mn peroxidases, Phenol oxidizing enzymes and $H_2O_2$ producing enzymes. In 1983, two groups announced the discovery in P. Chrysosporium of an extracellular $H_2O_2$ requiring enzyme that catalyses several of reactions formerly seen with intact cultures. The enzyme called Ligninase[20]. The advance research in biotechnology has been carried out on ligninases and manganese dependent peroxidases. Ligninase is able to attack the lignin[21]. A number of potential applications of ligninases are being evaluated in pulping, bleaching, converting lignin to useful products, treating lignin derived waste waters and detoxification of several organopollunants[22].

Hiroshi et al[23] determined the optimum conditions for enzymes production such as pH, temperature, nutrients and nitrogen availability. The optimized conditions were used to delignify deinked pulp. The Klason lignin content of deinked pulp was reduced from 18.5 to 12.5% after 14 days treatment. The reduction in lignin content improved the strength properties but reduced the brightness. These data are shown in Table 3.

Paice et al[24] studied the effect of xylanase from Schizophyllum commance to remove residual xylan from a bleached hardwood pulp for the industrial production of dissolving pulp. The xylan content was particularly reduced, but pulp viscosity was decreased markedly. Viscosity drop can be minimized by using cellulase free xylanase. There is a wide scope to be done in this field.

TABLE—2

Physical Properties Of Hand Sheets From Unbleached Refiner Mechanical Pulps Of Aspenwood[14-15]

| Property measured | Untreated control | D. squalens | P. chrysosporum | phlebia | phanerochaete |
|---|---|---|---|---|---|
| Freeness, ml CSF | 90 | 85 | 95 | 110 | 100 |
| Burst index ($kPam^2/g$) | 0.35 | 1.21 | 0.75 | 2.11 | 2.04 |
| Tear index ($mNm^2/g$) | 1.69 | 4.30 | 2.14 | 6.13 | 4.64 |
| Tensile index (Nm/g) | 21.3 | 36.6 | 30.6 | 51.4 | 52.5 |
| Density ($kg/m^3$) | 408 | 382 | 405 | 425 | 402 |
| Brightness % | 51.4 | 39.7 | 40.7 | 42.9 | 40.5 |
| Opacity % | 96.8 | 97.1 | 98.5 | 93.0 | 94.8 |
| Scattering coefficient ($m^2/kg$) | 59.0 | 45 7 | 54.2 | 37.9 | 39.9 |
| Fibre length index (mm) | 0.0825 | 0.1162 | 0.0815 | 0.1060 | 0.1201 |
| Pulping energy ($whkg^{-1}$) | 2400 | — | — | 1560 | 1480 |

TABLE—3

Strength of Secondary fibre at different freeness levels[23]

| | Reference Pulp | | | *Biodelignified Pulp | | |
|---|---|---|---|---|---|---|
| Freeness, ml | 180 | 120 | 55 | 160 | 100 | 60 |
| Tear index ($mNm^2/g$) | 7 | 6.21 | 5 | 8 91 | 7.2 | 6 56 |
| Burst index ($Kpa/g/m^2$) | 2.38 | 2.3 | 2.29 | 2.36 | 2.74 | 2.73 |
| Tensile index (Nm/g) | 41.5 | 41.5 | 46.8 | 40 | 51.3 | 50 1 |
| Brightness (ISO) | 52.7 | 51.3 | 49.0 | 37.1 | 37.3 | 35.4 |

*After alkali extraction, Klason lignin=14.1, Initial klason lignin=18.5

The major tehcnical problems related to the implementation of bio-pulping and many[25]. For example.

1. It required careful control of humidity, aeration and temperature and preventing contamination by unwanted microorganism.
2. Slow rate of the process.
3. Preparation of fungal inoculum, sterilization of wood chips if required and environmental control during treatment are very expensive methods.

Despite all these drawbacks, the work is under progress to implement the biotechnology in industry. However, the biopulping. offers energy saving and at the same time can provide pollution free process.

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