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ROLE OF BIOTECHNOLOGY IN PULP AND PAPER INDUSTRY

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ABSTRACT

Biotechnological techniques like molecular biology, enzymes engineering, genetic engineering genomics, proteomics, metabolomics and bioinformatics etc. have helped in developing economically feasible and well designed methods in production of pulp and paper sector. Biotechnology increases the cost efficiency, develop environmentally feasible processes and improves the product quality.

INTRODUCTION

Indian paper industry contributes to about 2.6% of the world's production of paper with turnover about 50,000 crore and provide employment to more than 0.5 million people directly and 1.5 million people indirectly. The industry uses variety of raw material viz. wood, bamboo, recycled fiber, bagasse, wheat straw, rice husk, etc. (http://www.ipma.co.in). Consumption of paper can be correlated to a nation's GDP (Walden's North American Pulp Paper Report, 2000) on National basis. Paper is manufactured from pulp by sulphite and sulphate process. The main pulping process used globally is the kraft process (Eds. Matussek, *et al.* 1999) introduced by German chemist C. F. Dahl in 1879 (C.J. Biermann, Handbook of Pulping and Papermaking, 1996).

Conventional way of making paper pulp

Bark of wood is removed. The logs obtained are cut into smaller pieces called chips. The chips are cooked by heating under pressure using caustic soda and sulfur. By this lignin that binds the cellulose fibers are removed. This is the chemical pulping process. It gives 30% yield lesser than by mechanical pulping. In mechanical pulping, debarked logs are forced through rotating toothed steel discs. The discs tear the logs and remove the lignin. The lignin degraded gives paper a brownish tinge which are used for printing newspapers (http://www.ipma.co.in).

Making pulp using enzymes (Biopulping)

Biopulping is the treatment of wood chips with lignin-degrading fungi. It is used prior to mechanical pulping of wood. It eases subsequent mechanical and chemical pulping. It improves penetration and effectiveness of chemicals during the "cooking" of wood chips for separating the cellulose fibers from the lignin. Biopulping reduces the demand for energy and chemicals, improves paper quality, and decreases the

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environmental impact of pulp production (Pullman *et al.,* 1998). Biotechnology, silviculture, trees and other bioresources can be used to enhance the properties required in cellulose fibers (Buschle-Diller and Ren). Genetically engineered microorganisms and enzymes can displace many of the environmentally adverse practices used in pulp processing http://www. ipma. co.in). Fungi such as *O. piliferum* can degrade lignin and is used in a fermentation process. This is applied before carrying out the normal mechanical or chemical pulping. It reduces the overall energy requirements for mechanical process and reduces the quantum of chemicals for chemical pulping.

Pulp bleaching using enzymes (Biobleaching)

Chlorine is used for bleaching process which has a huge polluting potential. Pulp is usually tinged with brown color due to lignin content. Enzyme enhances this bleaching process by two ways. Xylase breaks down the carbohydrate xylan (this entraps pulp lignin) to reduce the need for chlorine in bleaching but gives numbers of byproducts dioxins and PCBs.

Xylanase treatment is used to reduce the consumption of chlorine dioxide and associated costs. Thermostable microbial xylanases are active under alkaline conditions of pulping are generally preferred for biobleaching (Raghukumar, 2004). They save production costs and prevents formation of unwanted products during pulp bleaching process. It saves chlorine leading to lower chemical costs and reduction in toxic effluents. xylanase pretreatments for kraft bleaching have been commercialized (Tolan and Guenette, 1997; Viikari *et al.,* 1991). The xylanase pretreatments of kraft pulps has reduced AOX discharges by 5-20% depending on the furnish and the type of pulping. It has also reduced chemical bleaching costs. Higher brightness ceilings have been achieved with an X-stage for a variety of bleach sequences. Oxidative enzyme such as laccase is also used for reducing costs in pulp mills.

Lipases are used to control deposits of pitch. Cellulases are used to improve rates of dewatering of pulp; and pectinases for digesting pectins. Cellulases are used for drainage (Foster, 1986), deinking (Bhardwaj *et al.,* 1995), and fiber modification. Fungal and enzyme pitch degradation products are used in some TMP (Gehlhoff,, 1998) and sulfite mills (Fleet *et al.,* 1998). Enzymes control the properties of the pulp fiber and, therefore, the end product. Hydrophobicity of fiber surfaces can be altered by the enzyme laccase (Wright, 1998).

Catalase is used to convert residual hydrogen peroxide to water and oxygen. Bleached fibers need be rinsed only once. The enzymatic process saves water and energy and the effluent is ecologically harmless. The other enzymes such as laccase and manganese peroxidase have also been used. The laccase is used for direct delignification of pulp, enabeling replacement of current bleaching chemical stages such as oxygen or ozone stage.

Biobleaching of pulp with enzymes have several advantages like: reduction of chlorine consumption; pulp dewatering; deinking; removal of pitch; degradation of dissolved and suspended organics in concentrated effluents of mills. It enhances fibrillation to give stronger paper (Eriksson, 1997). Biobleaching eliminates few of processing steps, thereby simplify and reduce the severity of treatment of wastewater.

Lipase has been used to control pitch buildup. It has also been used for deinking applications in cases where the inks contain vegetable oil formulations (Sharyo *et al.,* 1993). Ascomycete albino fungi reduce pitch and save up to 36% of bleach costs (Blanchette *et al.,* 1997) in chip pretreatment .

Enzymes used for de-inking

Recycled paper fibers has to undergo deinking process to remove whatever ink that gets fused on to the paper during printing. Cellulase enzymes are used for this deinking process. This makes the use of recycled paper as a viable option to reduce the number of trees needed to be cut to make paper. A deinking process involving sodium hydroxide, flocculants, dispersants and surfactants is used widely currently. The alkali can make the treated pulp yellow and, consequently, hydrogen peroxide is used subsequently to bleach the alkali deinked pulp. In addition, alkaline deinking diminishes the strength of the pulp fiber and the chemicals used contribute to environmental pollution. An enzyme-based biotechnology alternative to chemical deinking is being developed.

GM trees with less of lignin

Lignin (chain of galacturonic acid) that binds the cellulosic fibers can be reduced by making GM trees with less of lignin but wood with less of lignin degrades quickly to release more carbon dioxide into the atmosphere.

Paper from bagasse

Deforestation is a matter of concern for both the environmentalists and the paper industry this has forced

paper manufacturers to use sugarcane bagasse. But the process of delignification and bleaching is necessary even if bagasse is used to make paper. Laccase (a delignifying enzyme) from the fungus Pycnoporus cinnabarinus can be used to break down the lignin in the fibers of bagasse.

Role of Biotechnology

Biotechnology can be resourceful in: improving kraft pulping specificity to lignin, reducing the loss of cellulose/hemicellulose during kraft pulping and bleaching operations and usage of more lignin in the final product without any detrimental impact on the final physical properties. It is also required to develop low capital pulping and bleaching technologies, simplified pulp bleaching operations, elimination of the inorganic recovery systems for the production of chemical pulps.

Biotechnology can be also helpful in development of biofilters to control and remove soluble organic and inorganic materials in the white water, to control microbial growth in the water systems of a paper machine and development of bio-systems to improve drainage and retention control. Biotechnology can play a leading role, including: Improved deinking and de-starching technologies, to increase drainage, strength, and other physical properties of recycled paper.

Lignin fragments, resin acids, and other low molecular weight compounds which are released during chipping and pulping can be used to generate value-added products. Genetic plant engineering used to improve the strength, yield, and bleachability of mechanical and chemical pulps (Merkle and Dean, 2000). The biotechnology is not as helpful in paper as in textiles (Chen *et al.,* 2001), detergents (http://home.ipst.edu, 1998), food (Gubitz and Cavaco-Paulo, 2001), and other mature industries. Enzymatic systems are catalytic, highly selective, and operable under mild temperature and pressures.

Enzymes

Use of enzymes can modify the fiber material. Since they are proteins and work under mild condition of temperature and pH, their use is restricted to various stages at pulping level and bleaching level. Lignocellulosic material can be degraded by a set of different enzymes like cellulases, swollenins and expansions, cellulolytic, hemicellulolytic and ligninolytic enzymes. Hemicellulases is also well established with the same general trends. Many other enzymes like hydrolytic enzymes, oxidoreductases are now emerging as an important one. The trends, can be clearly seen in (Fig. 1).

Enzymatic modification of fiber, modify the surface, improved fibre properties and creates completely new fibre characteristics. It also improves the runnability of the pulping, bleaching and papermaking processes.

In the enzymatic process, cellulase and hemicellulase enzymes are mixed with the paper pulp. The enzymes hydrolyze some of the surface sugars on the pulp fiber and this releases the ink particles bound to the fiber. Washing and draining of the pulp remove most of the ink. Any remaining ink is removed during a conventional flotation step. Treatment with alkali is not used and this eliminates the need for subsequent bleaching with hydrogen peroxide.

Attaining total water recycling in paper mills

Production of paper consumes huge amounts of water which needs to be recycled. Wastewater recycling potentially saves on the expense of treating any freshwater entering the mill and greatly reduces the environmental impact of effluent disposal. Enzymes can facilitate dewatering of pulp and removal of contaminants without reducing the strength of the recycled pulp fibers. Speedier dewatering improves sheet formation and allows faster processing in paper machine (Jackson *et al.,* 1993; Rutledge-Cropsey *et al.,* 1998; Pala *et al.,* 2001). Residual enzymes are deactivated during drying of the paper.

Enzymatic deinking work with old newsprint and office waste paper. Enzyme treatment effectively removes laser printer and photocopier inks that are mostly found in office wastepaper (Prasad, 1993).

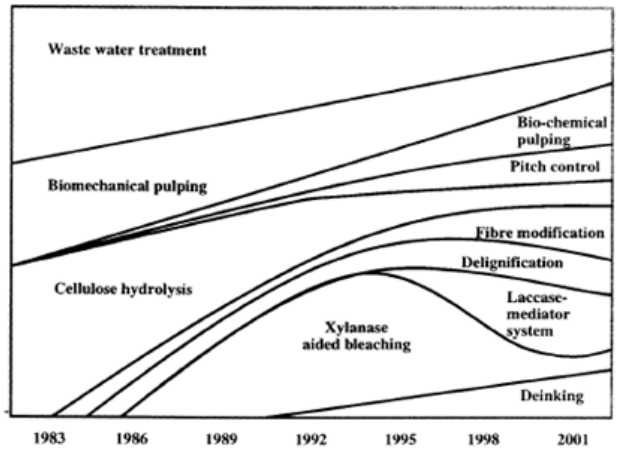

Fig. 1 Trends of applied biotechnology in the pulp and paper area.

Future Challenge

Biotechnology-based processes for paper industry should reduce the capital costs of pulp production, generate higher value fiber resources, lower total manufacturing costs and make it commercially feasible. The issues to be addressed in future are: energy efficiency/conservation issues; Environmental friendly technologies; Technology for optimum utilization of diverse raw materials; Plantation of high yielding short maturity pulpable wood species; Improved recovery and utilization of recyclable waste paper; New plant and equipment; Rebuilds of paper machines; Funding; International cooperation. Social factors like poverty, literacy, corporate spending are the factors behind low level consumption. The key challenges are poor and technology obsolete, lacking ability in achieving economy scale and lack of skilled labor (http://www.biotecharticles.com).

CONCLUSION

Unprecedented developments in genomics, biotechnology, telecommunications, artificial intelligence, material science, and engineering have provided techno economicaly feasible technologies and products for the pulp and paper industry. Biotechnology has increased more than 25% in the efficiency of pulp production using wood as feed stock. Advantage with the enzymatic route for pulp making is including lesser costs for effluent disposal. Biotechnology has positively impacted on: raw material costs, manufacturing costs, energy costs, environmental performance, and the production of high-quality products (http://www.pulpandpaper-technology.com).

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