Use of Biological Agents for Pulping and Bleaching in Pulp and Paper Industry

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ABSTRACT

Thermostable and alkali tolerant xylanase producing Bacillus sp. has showed to be the most potent microorganism for biopulping and biobleaching. In solid state conditions moisture content is 75%, pH is 8.5 and temperature 50°C. It required only 4 hrs. for maximum insitu solubilization of Xylan. It showed 60% reduction in Kappa no. of the treated pulp which is at par with the conventional pulping. Xylanase treatment of raw material and pulp with saved Bacillus sp. nearly 60% of energy and 2hrs time required for the whole process of kraft pulping.

INTRODUCTION

Pulp and paper industry is entering new millenium with challenges of cost effectiveness and scarcity of conventional raw material. Growing preference of consumers and Government for ecofriendly and safe products and processes, forced many industries to adopt environment friendly techniques inspite of high cost. One among such industries is the pulp and paper industry (1). Biopulping (pretreatment of raw material with microorganisms or enzymes for removal of lignin, lignin-hemicellulose complex) is emerging as a major aid to traditional techniques like mechanical and kraft pulping, because biotechnological processes put very little pressure on the environment compared to chemical processes. In recent past, the pulp and paper industries are also exploiting biotechnological processes in various stages of pulp and paper production, effluent treatment and waste management, (2, 3). Among various applications hemicellulase enzymes like xylanases aid bleaching (4, 5). Hemicellulases like xylanases which degrade xylan present in plant cell wall are most potent enzymes for biobleaching (use of enzymes and microorganisms for bleaching of pulp prior to chemical bleaching) of bagasse pulp. Xylanase has showed its potential in reducing the chemical consumption and becoming commercially viable alternative and is being used in many industries of western countries. Use hemicellulase as biopulping agent has been attempted by us.

The objectives of the study are:

- Screening of microorganisms capable of degrading xylan by producing high titer of thermostable and alkali tolerant xylanases.
- Optimization of conditions for in situ solubilization of xylan in raw material bagasse under submerged and soild state conditions.
- Evaluating the effects of biopulping and biobleaching on the quality of paper produced, using bagasse as raw material.
- Evaluation of energy saving during the process using the formula:

  Energy = Power * Time (Kw.hr)

EXPERIMENTAL

Indegenously isolated strain of a bacterium Bacillus sp. was used. Bacterium was maintained on nutrient agar slants (NA). All cultures were stored at 4°C. Depithed bagasse was treated with enzyme/ microorganism before cooking. Conditions were optimized for time, temperature, pH and some supplements if necessary. Measurement of insitu solubilization of xylan and lignin from pulp after washing was done on the basis of Kappa no. measurements using standard TAPPI methods.

Kraft pulp was generated by pulping sugar cane bagasse with 16% active alkali and 20% sulphidity. Bath ratio was 1:10. Digestion was done in SWAN digester at 100 psi and 160°C. The pulp thus obtained was then washed thorouly and shredded to uniform consistency. The characteristics of the unbleached pulp were

Kappa no. - 20

Brightness % ISO-24.5

A control was maintained without enzyme addition.

Table 1. Optimized conditions for insitu solubilization of xylan during biopulping by bacillus sp.

Parameter	Submerged conditions	Solid state conditions
Moisture %	200	75
Nitrogen source	$(NH_4)_2SO_4$	-
Initial pH	6.5	6.5
Temperature °C	37	37
Micronutrients Solution (ml)	--	250
Carbon source	Bagasse 500g	Bagasse 500g
Incubation time (hrs.)	48	48

Table 2. Optimized conditions for in situ solubilization of xylan during biopulping unsing xylanase enzyme.

Parameter	Solid state conditions
Moisture %	75
Initial medium pH	8.5
Temperature °C	50
Time required (hrs.)	48

Table 3. Estimation of Kappa no. after biopulping with B. sp. and xylanase.

Type of treatment	Kappa no.	% Reduction in Kappa no.
Bagasse control	45	0
Bacterial treated bagasse	18	60
Xylanase treated bagasse	20	55.56

After the pretreatment time, the pulp was dewatered and washed with water equivalent to 20 times the O.D. weight of the pulp. The pulp was then subjected to chemical bleaching, to see the brightness improvement due to enzyme treatment. Optimization studies for biopulping and biobleaching were carried out at laboratory scale in 500 ml conical flasks containing sugar cane bagasse. The crude enzyme produced under the optimized conditions, using xylan as the substrate, was used for further bleaching studies. The kraft pulp made from bagasse was treated with xylanase enzyme, 50 IU/g, under the following conditions (Fig. 1).

Consistency % - 25
Temperature °C-55
Time min. - 120
pH - 10.5

RESULTS AND DISCUSSION

Tables 1 and 2 show optimum conditions of Bacillus

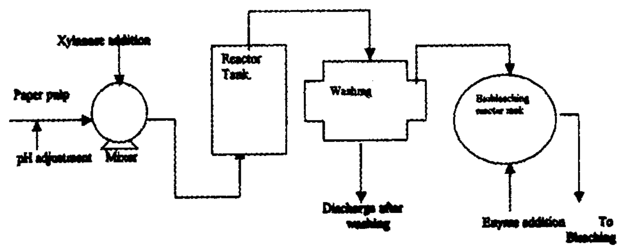

Fig. 1 Schematic representation of enzyme pretreament stage in bleaching of pulp

sp. and its enzyme for maximum insitu solubilization of xylan during biopulping. Results show that for maximum ligninolysis, bacteria prefer agitated conditions towards neutral pH. Similarly presence of readily metabolizable substrate and nitrogen stress induce lignin degradation. Based on these in solid state conditions, Bacillus sp. and enzymes were used for biopulping and biobleaching of sugar cane bagasse. The use of xylanase for purifying cellulose was first proposed by Paice and Jurasek (1984). It was found that complete enzymatic hydrolysis of hemicellulose within the pulp is difficult to achieve. Even with very high loading of enzymes, only a relatively small amount of xylan could be removed (6-10). The xylan content in delignified mechanical aspen pulp reduced from approximately 10 to 20% whereas in bleached hardwood sulphite pulp, the xylan content decreased from 4% to 3.5% only (11). The complete removal of hemicellulose seems thus unattainable, probably due to the inaccessible location of the substrate. Nevertheless, xylanase treatment may reduce the chemical loading required during the caustic extraction or facilitate xylanase extraction from kraft pulps. It is evident from Table-3 that bagasse treated with Bacillus sp. and xylanase showed remarkable reduction in Kappa number, which is due to xylanolytic effect as xylan is a major hemicellulose link between cellulose fibres and lignin which is broken down by xylanase, facilitating removal of lignin. The properties of pulp and paper obtained after biopulping and biobleaching by Bacillus sp. and xylanase are compared in Table-4. There is considerable decrease in Kappa number of pulp and improvement in brightness. Yield, tear index and burst index are also comparable to that of control. Similar results were obtained by other workers also (12).

Xylanase pretreatment of pulps, prior to pulping reduces bleach chemical as well as pulp chemical requirements and permits higher brightness to be achieved. The reduction in chemical charges can translate into significant cost savings. From the results shown in Table 5 it can be said that as much as 30%

Table 4. Handsheet evaluation

Partic Ulars	Kappa no.	Thickness gsm	Tear Index $mN.m^2/g$	Burst Index $Kpa.m^2/g$	Brightness % ISO	Yield %
Untreated bagasse	32	60	5.22	2.55	44.5	40
Bacterial treated bagasse	14	60	5	2.55	48.7	30
Enzyme treated bagasse	15	60	6	2.55	50	38

Table 5. Energy chart bagasse treated at prepulping and prebleaching stage.

Bagasse samples	time required for digestion (hours)	Energy required for digestion (Kwh)	time required for beating (hours)	Energy required for beating (Kwh)
Control	6	22.5	2	1.5
Xylanase treated	5	18	1.5	1.12
Bacillus sp. treated	4	13.5	1	0.75

of the energy can be saved by using bacterial and enzymic pretreatment at prepulping and prebleaching stage of kraft pulping. Reduction in the use of chlorine chemicals clearly reduces the formation and release of chlorinated organics in the effluents and in the pulps. The ability of xylanases to activate pulp and increase the effectiveness of bleaching chemicals may allow new bleaching technologies to become more effective. This means that for expensive chlorine-free alternatives such as enzyme and hydrogen peroxide, xylanase pretreatment may eventually permit them to become cost effective (13,14).

CONCLUSION

Xylanolytic microorganism i.e. the Bacillus sp. has contributed to the significant reduction in lignin content of pulp and bagasse and thus it could be applicable for biopulping and biobleaching in large scale and would decrease chemical consumption thereby releasing less amount of hazardous chemicals into the water streams which is otherwise a threat to flora and fauna.

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