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Laboratory Scale Comparison of Enzymatic Versus Chemical Deinking of Inkjet Printed Paper

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Now a days, out of nearly 370 million tons paper and board produced annually, worldwide more than half is produced by recycling the recovered paper. Deinking is indeed a sophisticated way of recycling by which high grade paper can be produced using enzyme treatment. In the present study deinking of HP laser printed paper has been examined at laboratorial scale. The operating conditions like pulping consistency, enzyme dose and retention time for enzymatic treatment of pulp were optimized by studying the brightness. Then, Enzymatic and Chemical deinking were compared by studying physical and mechanical properties of paper. Enzymatic deinking showed brightness (ISO) 69.3, Burst index 2.1KPam²/g, tear index 8.5 mNm²/g, tensile strength 43 Nm/g and deinking efficiency 35.5%. Thus enzymatic deinking using cellulase removes the problem of pollution which arises due to chemical treatment. This study shows that Enzymatic treatment is both ecofriendly and economical as it reduces or eliminate the use of chemicals.

Key words: Enzymatic Deinking, Pulp consistency, Brightness, Cellulase, Ecofriendly.

The fast depletion of forest resources and its impact on the ecological balance has forced the paper industry to turn to the recycling of waste papers. The waste paper used to make high grade recycled paper consist mainly of magazine waste (OMG), mixed office waste (MOW) and old newspaper (ONP)[1]. Recycling of paper requires the removal of print ink from the used paper through a process called deinking to obtain brighter pulp[2]. Deinking involves the dislodging of ink particles from the fiber surface and the separation of the dispersed ink from fiber suspension by washing and flotation[3, 4]. Non contact printed paper which includes photocopies and laser print out bind the ink to the fiber making it difficult and expensive to remove by conventional methods[5]. An alternative to conventional method of deinking is biological or enzymatic deinking. Researchers in the recent years suggested that microbial enzymes such as cellulases, hemicellulases, xylanases, lipases, esterases have important role to play in biological deinking[6, 7]. Enzyme remove attached toner (ink) particle and reduces ink particle size. In order to prevent adsorption of detached ink particle on to the fiber surface again, surfactant such as hydrocarbon oil is added along with enzyme[8]. Most of the conventional deinking techniques require large amount of chemical agent such as sodium hydroxide, sodium silicate, hydrogen peroxide and surfactants resulting in production of large amount of effluent which is highly toxic and needs to be treated to meet environmental regulations. Using

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enzyme for deinking is environment friendly as ink is removed from fibers without discharge of any pollutant or very less polluting solution to overcome disposal problems[9]. Sludge treatment is also important in the deinking industry. There are several studies performed to find way to treat and dispose the sludge includes composting the sludge with forced aeration and letting the cellulosic fraction degrade[10] and bioconversion of the cellulosic fraction of sludge to ethanol which is used as fuel[11]. .

This study compares the enzymatic treatment with chemical deinking of HP printed paper. Firstly, various parameters of enzymatic treatment including pulping consistency, enzyme dose and retention time are optimized. Then physical and mechanical strength of paper in both cases are compared. Cellulase used for deinking has been produced from newly isolated strain *Flavobacterium bolustinum* under solid state fermentation which is cheap and economical system for any strategy to be feasible.

MATERIAL AND METHODS

Organism

Bacterial strain *Flavobacterium bolustinum* having MTCC no.10203 given by IMTECH, Chandigarh isolated from soil sample collected from sugarcane mills using Carboxymethylcellulose (CMC) as substrate. The organism was sub cultured over the interval of 1 month and stored at 4°C.

Solid state Fermentation for enzyme production

SSF was carried out in flask (250ml) that contained pineapple peel as solid substrate (5g) and basal medium (15ml) consisting $(NH_4)_2SO_4$ (1%), KH_2PO_4 (0.4%), $MgSO_4$ (0.1%) pH 9 by inoculating with 20%v/w from 20 hrs old culture broth. The flask was incubated for 72 hrs at 40°C. The enzyme was harvested by adding 50 ml of glycine- NaoH buffer (0.1 M) to flask and kept at 40°C for 1h under mild shaking. Resultant slurry was filtered through muslin cloth and centrifuged at 10,000 for 25 min and the extract was subjected to dialysis for concentrating the enzyme. This partially purified enzyme was used for deinking experiments.

Enzyme assay

Cellulase activity was determined at 65°C by using carboxymethylcellulose (Sodium salts, Sigma, India) as substrate. A reactive mixture contained 450µl of 1 %(w/v) substrate in 0.1M Glycine-NaOH (pH 9) and 50µl of culture supernatant. The mixture was incubated at 65°C for 10 min. The reducing sugar released was measured using 3, 5-dintrosalicyclic acid (DNSA)[12]. One unit of enzyme activity was expressed as the amount of enzyme required to release 1 µg reducing sugars per ml under the above assay condition by using glucose as a standard curve.

Deinking experiment

Ink-jet printed paper from HP printer was pulped by soaking in hot water for 15-20 minute, and then macerated in a domestic mixer grinder. Macerated pulp was oven dried at 50°C overnight. The pulp (25g) at 10% consistency was incubated with enzyme for 30 minutes at room temperature. The pulp suspension was boiled for 10 minutes to inactivate the enzyme. Pulp was washed with tap water and hand sheet was obtained by drying the deckle in air. Then the paper was removed from deckle and the moisture was removed by sponging the paper and uniformity was obtained by steam ironing the hand sheet. Parameters like pulping consistency, enzyme dose and incubation time were optimized for enzymatic deinking experiment by measuring brightness index. Control (without enzyme) and chemical deinking (Sodium silicate 5%, NaOH 2%, H_2O_2 2%) was carried out under identical conditions. Brightness and other physical and mechanical properties were analyzed according to standard TAPPI method[13].

RESULTS

Cellulase enzyme produce under SSF was used for deinking experiments (6851.63U/g). Deinking results were evaluated by determing the Brightness index of hand sheet prepared after enzyme treatment. Various parameters including pulping consistency, enzyme dose and incubation time were optimized for efficient deinking. Fig 1. Shows that 10% consistency was more effective for deinking. Mohandass *et al.* (2005) showed best results at low consistency (3%). High consistency results in decrease in brightness as it allow finely dispersed ink particle to readhere into porous part of fibers[14]. Fig 2. Shows brightness index of deinking paper at different enzyme doses. Low dose

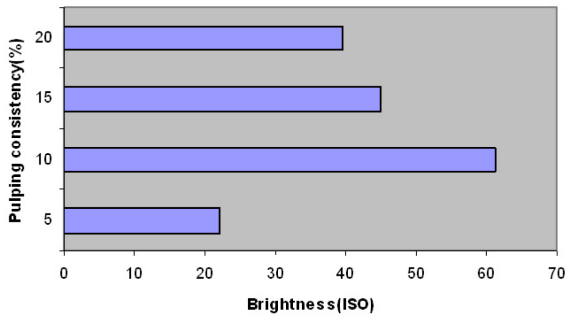


Fig. 1. Brightness index of pulp at different pulping consistency

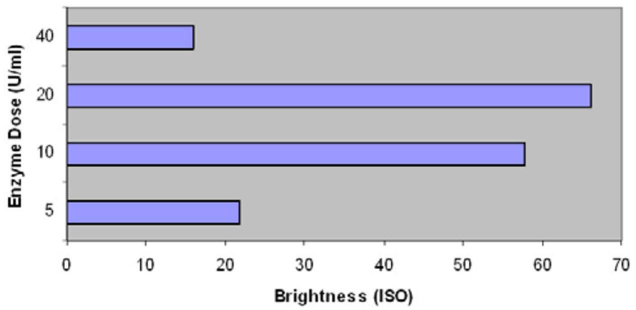


Fig. 2. Brightness index of pulp using different enzyme dose

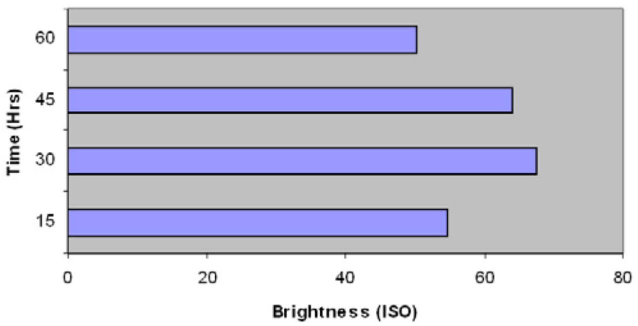
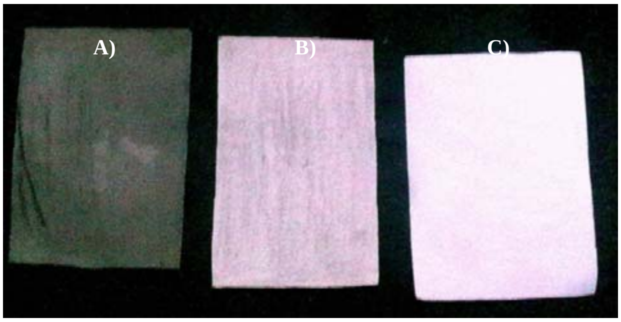


Fig. 3. Brightness index of pulp after various time intervals



A) Untreated (control) sheet **B)** Enzyme treated sheet **C)** Chemical treated sheet

Fig. 4. Hand sheets of biologically, chemical and untreated control deinked printed paper

Table 1. Quality control test of recycled paper after enzymatic and chemical treatment

S. No.	Quality test	Control	chemical	Test
1	Brightness (ISO)	28	81.9	69.3
2	Burst index (K Pa m^2/g)	0.9	2.8	2.1
3	Tear index (mN m^2/g)	9.1	9.8	8.5
4	Tensile strength(Nm/g)	31	56	43
5	Residual ink	57.2	26.7	36.89

(5IU) produces only 21.7 ISO brightness and all ink particles are not effectively removed from the fiber surface. High dose (40IU) also decreases brightness (15.9) because it causes cellulose degradation thus decreases strength of fiber[15]. Fig 3. Shows the effect of duration of enzyme treatment on brightness. By optimizing different parameters, enzymatic treatment was compared with chemical treatment and results are showed in Table 1. Evaluating the physical and mechanical strength of hand sheet results shows an increase in burst index and tensile strength as compared to control and is comparable to the chemical treatment. Fig. 4 depicts the decolorizing of printed paper hand sheet in both chemical and enzymatic treatment as compared to control.

DISCUSSION

Using cellulase for biological deinking is a good approach for recycling of waste paper. We optimized the production parameter for high enzyme titer in culture extract using pineapple peel as solid substrate for enzyme production under SSF. The cellulases that have mainly been tested are the commercial available sources of multi/mono component enzyme preparations of *Trichoderma reseei*, *H. Insolens* supplied by Novo-Nordisk, IOGEN, Genencor, etc[5, 16]. More recently deinking and decolourization using a combination of commercially available amylase, laccase, endoglucanase, and hemicellulase has been reported[17, 18]. Although enzyme like hemicellulase, cellulase, and xylanase facilitate ink detachment by acting on bonding region of ink and fiber, they also remove small fibers. This problem is overcome by using low dose and reducing retention time of enzyme during treatment. In our experiment we use low dose (20 IU) and reaction time (30 minute) for deinking trails and obtained hand sheet showing improvement of the strength properties compared to the untreated control. Similar improvement in physical and mechanical properties of enzyme treated pulp has been reported[5, 13]. Several authors have used highly purified and concentrated enzyme for deinking purpose[13]. However in our case concentrated culture supernatant could bring about deinking of printed paper with increased deinking efficiency 35.5%. Kim et al (1991) showed that crude cellulase applied to pulp could facilitate the deinking process.

Thus enzymatic deinking pulp shows superior physical and mechanical properties. Also dewatering step was removed as much washing is not essential thus save capital cost and energy consumption. In general enzymatic treatment reduces the use of chemicals thus reduces the load on waste water management. Enzymatic treatment is so efficient but still it faces limitation as cost of production of enzyme is very high as most of the commercial enzymes available are too expensive. Moreover, Enzymes are very sensitive to environment fluctuation. Using tailored enzyme is one approach which consists of multiple components that perform singular and synergistic function and thus help in increasing the efficiency and effectiveness of desired goal of deinking to better fit the paper mills[19].

CONCLUSION

The deinking process detailed above at the laboratory level can replaces the existing conventional process as it is eco friendly and more efficient. There was improvement in the tensile strength, Burst and tear index. Although these strength and index are lower as compared to chemical treatment but the enzymatic treatment shows better drainage as less effluents is produced. Balancing these effects, enzymatic deinking is an alternative to the intensive use of chemical in the conventional methods for deinking by accounting the environmental impacts.

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