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ENZYMATIC DEINKING OF ONP- AN EFFECTIVE WAY OF PRODUCING QUALITY NEWSPRINT

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Abstract: Deinking is an important step in the recycling process for waste paper and old newsprint. Deinking process is the heart of recycling process of old newsprint which decides the quality of the newsprint produced. In traditional deinking process large amount of chemicals are required which makes this method expensive, pollution intensive and also the quality of the news print produced is not upto the mark. In the present study an effort has been made to adopt biotechnological approach in deinking of old newsprint with an objective to make this process eco-friendly, cost competitive and to produce quality news print. Fungal cellulase enzyme produced from isolated fungus *Trichoderma longibrachiatum* via SSF was used as deinking aid. Results showed that highest enzyme activity could be achieved at a pH of 5.5 and at a temperature of 50-60^{0}C. Utilization of the cellulase enzyme thus produced from the isolated fungus *Trichoderma longibrachiatum* used as deinking aid helped in replacing the deinking chemicals used during deinking of Old News Print. This further improved the optical and strength properties of deinked pulp with significant improvement in its final pulp yield, along with reduction in pollution load in the wastewater generated from the recycling process of deinking.
Keywords: Cellulase; COD; ONP; Optical and Physical properties; *Trichoderma longibrachiatum*.
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INTRODUCTION

In traditional deinking process large amount of chemicals are required (Shrinath *et al.,* 1991) which makes this process expensive and pollution intensive. Central Pulp and Paper Research Institute, Saharanpur initiated research and development work on enzymatic deinking of Old News Print with an aim to make this process eco-friendly. Paper recycling offers several advantages**.** Substitution of virgin pulp with recycled fibers saves on wood for making pulp, which reduces the exploitation of old forests, important for biodiversity. Every ton of recycled fiber saves an average of 17 trees plus related pulping energy. By using wastepaper to produce new print, disposal its problems are reduced. For every ton of paper used for recycling, nearly 30,000 liters of water, 1200 to 1400 Kwh of electricity and 95 % of air pollution could be minimized. Various enzymes including cellulases, hemicellulases pectinases, amylases, lipases (Call and Strittmatter, 1992; Gubitz *et al.,* 1998; Morkbak *et al.,* 1999; Pala *et al.,* 2004 and Pelach *et al*., 2003) have been used to minimize the cost and pollution load of the deinking process. One of the positive impacts of using enzymes in the deinking process is the requirement of minimum treatment of effluent produced. The effluent from enzymatic deinking process has been reported to be lower in Chemical Oxygen Demand (COD) content than waste water from a conventional chemical deinking process (Putz *et al.,* 1994). Enzymatic deinking cut down the cost of deinking chemicals and reduces the pollution load to maintain the pollution

parameters under regulation in terms of Colour, Lignin and COD into the industrial wastewater system. According to (Kim *et al.,* 1991) Enzymatic deinking process ink particles will be detach from fiber by the action of enzyme to partially hydrolyzing the cellulose fibers on the fiber/ink inter-bonding regions, which facilitate the ink detachment during the process of flotation. In addition to ink removal, enzymatic deinking may improve the strength properties and increase freeness of the paper sheets, reduce fines content of the recycled fiber, and enhance the brightness and cleanliness of the pulp. On the other hand, ink particles sizes larger than 40 μm are visible to the naked eye, these ink particles size would downgrade the quality of the end product (Carr, 1991; Shrinath *et al.,* 1991; Ferguson, 1992; Borchardt and Rask, 1994).

This problem can be overcome by adopting enzymatic approach for deinking process, due to enzyme action reduction in ink particles size. Subsequently, small particles are removed more effectively during the flotation process. According to (Lee *et al.,* 2011) previous studies of deinking of Mix Office Waste and Old News Print were more effective by using enzymes in compared to conventional method shown enhancement in brightness. However, on the basis of brightness one cannot represent the overall quality of the deinked pulp. Other properties such as strength of the pulp and pollution load of waste water are also very important. Therefore, objective of this present work, Old News Print include to improved properties of deinked pulp and reduce pollution during recycling of ONP.

EXPERIMENTAL

Source of enzyme: Crude cellulase enzyme was used in this study. This enzyme was produced under optimized condition *viz*. initial pH 5.5, temperature 30^0C, solid liquid moisture ratio 1:2.5, wheat bran as a carbon source, with NSS solution (Mandels and Reese, 1957) by isolated fungus *Trichoderma longibrachiatum* via solid state fermentation (SSF) process. The mass production was carried out by taking 20 g wheat bran in flasks of 1 liter capacity. After fermentation, Cellulase (CMCase and FPase activity) and Xylanase activity was measured in respect of IU/ml by (Ghose, 1987 and Bailey *et al.,* 1992) respectively. To proven as an industrially important product, the characterization of enzyme requires knowledge of optimum pH and temperature because CMCase, FPase and Xylanase activities are subjected to change with varying pH as well as temperature. The enzyme was stored at 4°C for further use in deinking process.

Selection and preparation of ONP: The recovered ONP was used in this present study obtained from Central Pulp and Paper Research Institute, Saharanpur library. The Old News Print was manually torn in the range of 2-3 cm sizes. The Old News Print was stored in dry and cool place in sealed polythene bags for further study.

Pulping of ONP: Before processing to maintain the homogeneity of the ONP pulping was carried out using high-density pulper (500 g capacity) for a batch of 250 gm on dry basis because floatation was carried out on laboratory Voith Flotation Cell (capacity 25 L). The process conditions used for pulping during conventional and enzymatic process are shown in table 1. The hydra pulping of ONP was carried out employing chemical/enzyme. The pH 7.0 was maintained with 1 N H_2SO_4/NaOH during the enzymatic deinking process.

Table 1. Chemicals and Process conditions of ONP during Pulping

Particulars	Chemical	Enzyme
Sodium silicate, Kg/T	20	-
Sodium hydroxide, Kg/T	2.0	-
Surfactant, Kg/T	5.0	-
Produced Cellulase enzyme, IU/Kg	-	300
Pulp consistency, %	10	10
Time, min	15	15
Temp. ^{0}C	50	50

Flotation deinking: For flotation, the pulp was diluted to approximately 1% pulp consistency. Both chemical and enzymatic pulps were subjected to flotation for 8 mins in a 25 liter capacity laboratory flotation unit at room temperature to separate toner ink particles from

the slashed fibers. At the end of flotation process, the deinked fibers were recovered on muslin cloth from the drain valve of the flotation cell. Conditions maintained during flotation are tabulated in Table 2.

Bleaching and refining of deinked pulp: After screening of both chemical and enzymatic deinked pulp was bleached (Table 3) followed by refining in laboratory valley beater at 1.57 % consistency to maintained freeness level of 250 Canadian standard freeness (CSF). The refined pulp samples were analyzed for pulp properties.

Table 2. Conditions for flotation of ONP Recovered Paper

Particulars	Chemical treated	Enzyme treated
Consistancy, %	1	1
Time, min	8.0	8.0
Surfactant, Kg/T	0.5	0.5

Table 3. Bleaching conditions of Deinked pulp

Particulars	Values
NaOH, % w/w	1.5
H_2O_2, % w/w	2.0
Temperature, ^{0}C	70
Time, hrs	1

Hand sheets Preparation: For evaluation of physical properties of chemical and enzymatic deinked pulp, TAPPI test method T 205 sp-95 was used to prepare hand sheets of the deinked pulp of ONP.

Pulp properties: Freeness (CSF level) and drainage time of deinked pulp of ONP were determined by using TAPPI standard tests T 227 om-99, T 221 cm-99.

Optical and Strength properties Hand sheets: Hand sheets of chemical and enzyme deinked pulp were compared for optical and strength properties. Tensile index, burst index, tear index and double fold numbers were determined by using TAPPI standard tests T 404 cm-92, T 403 om-97, T 414 om-98 and T 511 om-96, respectively. Brightness, opacity, and ERIC were measured, using an Elerpho-071E device (TAPPI T 452 om-92).

RESULTS AND DISCUSSION

Characterization of Cellulase Enzyme

Optimum pH: This fungal cellulase enzyme was characterized for pH for its application in deinking process of ONP. The results illustrate that, at pH 5.5 enzymes has the maximum activity in terms of CMCase and FPase, 4.62 IU/ml and 1.30 FPU/mL respectively. It was observed that in the pH range 4.0- 8.0, enzyme activity in terms of CMCase (IU/mL) and FPase (FPU/mL sharply reduced when pH was shifted from optimum value (Figure 1a). The residual activities of produced enzyme was increased when pH moves from 4.0-5.5 and gradually decreased when pH moves from 5.5-8.0 in terms of CMCase and FPase respectively (Figure 1a).

Optimum Temperature: Maximum cellulase enzyme activity was observed in terms of CMCase and FPase 4.59 IU/mL and 1.30 FPU/mL respectively at 50^{0}C. It was noticed that temperature ranges from 30–80^{0}C, enzyme efficiency in terms of residual activity (%) sharply reduced when increasing or decreasing the temperature from optimum value. At 60^{0}C residual activity was slightly lower than optimum temperature. This result indicates, this enzyme can be used between 50-60^{0}C in enzymatic deinking of ONP (Figure 1b). Though the best pH condition for efficiency of cellulase enzyme is 5.5 to 6.0 but studies were carried out at pH 7.0 as process requirement. The industry avoid the acidic range for deinking process, enzyme was evaluated in respect to enzyme activity viz. CMCase, FPpase and Xylanase 2.16 IU/mL, 0.47 FPU/mL and 78 IU/mL respectively at pH 7.0.

Pulp properties: After refining, enzymatic deinking process has shown an improvement in pulping yield (2.68 %), drainability (8.89%) and significant reduction in fines content (15.45%) when compare to chemical deinking process of ONP (Figure 2a).

Effect of enzyme on Optical Properties of ONP: The optical properties of ONP deinked pulp have a remarkable effect by enzymatic approach. An improvement was observed in brightness (1.52 units), opacity (2.10%). Pelach *et al.,* (2003) reported the lower opacity with respect to present study. It was also observed that significant reduction in the PC number (35.10 %) and ink count reduction (5.69%) in enzymatic deinking of ONP with respect to chemical deinking process (Table 4).

Table 4. Effect of enzyme on Optical properties of ONP pulp

Particulars	Chemical treated	Enzyme treated
Brightness, %	50.67	52.19
Yellowness, %	11.73	10.38
Whiteness, %	31.79	32.64
PC number	0.94	0.61
Opacity	93.3	95.3
Ink count (Speck 8μ-1996μ)	2565	2419

Table 5. Effect of enzyme on Strength properties of ONP

Particulars	Chemical treated	Enzyme treated
CSF	250	250
Tear index , (mN.m^2/g)	7.2	7.0
Tensile index , (N.m/g)	17.6	19.2
Burst index , (kPam^2/g)	2.15	2.28
Double fold , (Kohler Molin log)	22	22
Porosity, (ml/min)	313	297

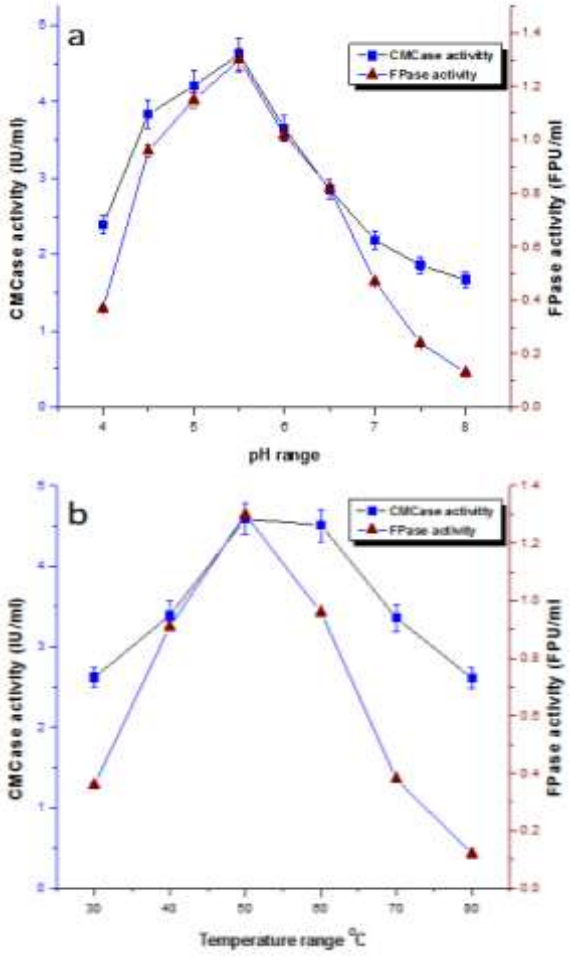

Figure 1. Enzyme Activity Profile (a) pH and (b) temperature of Cellulase Enzyme produced from Fungus

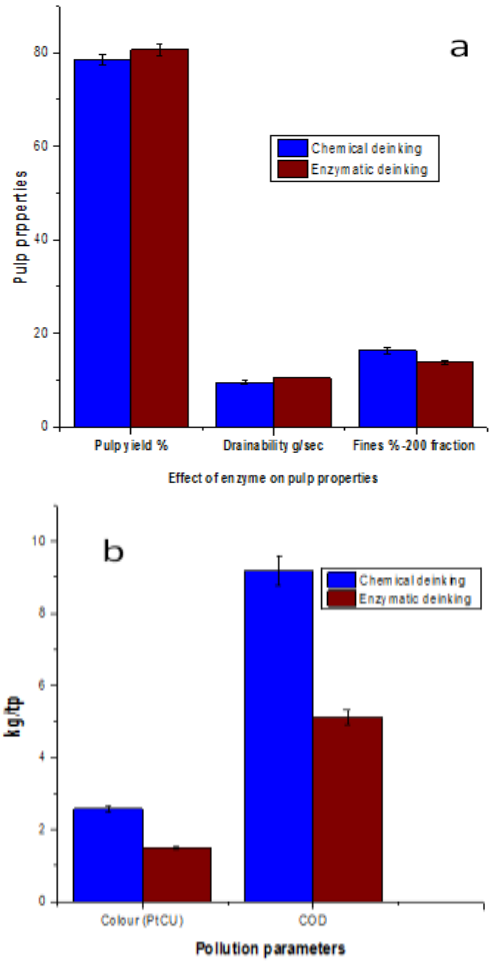

Figure 2. Effect of Cellulase on (a) pulp properties and (b) pollution load generated from chemical and enzymatic deinking process.

Effect of enzyme on Strength properties of Old News Print: Significant improvement was observed in strength properties of enzymatic deinking of ONP (Table 5). An improvement was observed in strength properties of tensile index (8.33%), burst index (5.70%) and porosity (5.11%). The strength properties of handsheets increased after enzymatic treatment were also reported earlier (Heise *et al.,* 1996; Lee *et al.,* 2007; Mayeli and Talaeipour 2010; Pala *et al.,* 2004; Pathak *et al.,* 2011 and Prasad *et al.,* 1993). Marginally reduction in tear index (2.78%) was observed at similar freeness level of both chemical and enzyme treated deinked pulp. Researcher have also observed similar reduction trend in tear index (Gliese *et al.,* 1996; Vyas, and Lachke 2003). An improvement in strength properties may be due to internal as well as surface fibrillation of the enzymatic deinked fiber (Pathak *et al.,* 2011).

Effect of enzymatic Deinking on Pollution Load: Application of enzyme in deinking of ONP is a biotechnical tool to making eco-friendly process as compare to chemical deinking process. In chemical deinking process large amount of chemicals are using, due to this reason this process makes it very polluted. By taking up enzymatic approach significant reduction in pollution parameters in form of colour (42.25%) and COD (44.23%) present in the effluent generated through process of ONP (Figure 2b). Hiese *et al.,* (1996) also reported lower COD load produced from enzymatic deinking process as compare to chemical deinking process.

CONCLUSION

The cellulase enzyme produces from isolated fungus *Trichoderma longibrachiatum* via solid state fermentation process under optimized conditions have shown potential for its application in deinking of ONP. The studies conducted on enzymatic and chemical deinking have shown that the enzymatic deinking with the isolated cellulase based enzyme showed the encouraging results in respect of pulp yield and quality of effluent with significant improvement in optical and strength properties. Further studies are in progress to upscale the enzyme production on large scale to demonstrate the process in an identified news print mill in order to promote the enzymatic deinking in Indian paper industry as a clean and green technology initiative. Thus we can say that implementation of isolated fungal cellulase enzyme has great potential as alternative to chemical deinking process of Old News Print.

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