Enzymatic Deinking An Alternate Technology for Quality Upgradation of Mix Office Waste

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Despite the greater availability of the mix office waste (MOW), the use of these papers to produce higher-grade pulps is very much restricted because of bigger visible specks and contaminants in the end products. Enzymes enhanced deinking shows promise as a process for improving toner removal so that lower quality office wastepaper can be upgraded for better end use. Studies conducted at CPPRI on enzymatic deinking using commercial enzymes have shown that the quality of MOW can be upgraded at a lower cost. Improvement in yield, brightness, drainability and reduction in residual ink, dirt count, stickies, and deink sludge generation were obtained with enzymatic deinking as compared to conventional alkaline deinking. Enzymatic deinking with added benefits in terms of both quality and cost when compared with alkaline deinking may emerge into an alternative deinking technology for recovered paper.

The Central Pulp & Paper Research Institute, which is an apex organization, dedicated to applied research in the area of pulp & paper in India and South East Asian region is engaged in promotion of cleaner production technologies for Pulp & Paper Industry. Enzymatic deinking is one of the thrust areas where focus has been laid upon evaluation of efficacy of various enzymes available and being developed indigenously on pulps and process conditions of enzymatic deinking, so that suitable enzymes are made available to the industry which could be effectively utilized under existing mill conditions for quality upgradation of office waste.

INTRODUCTION

The recycling industry is in search of new technologies, which can improve the quality, reduce the production cost and can be accommodated easily into the existing process design. Recent research with enzymes showed that enzymatic deinking might be an alternative solution.

Non-impact printed papers are more difficult to deink and the amount of such recycled waste continue to grow as a proportion of total recovered paper volume. Thus removal of ink remains a major technical obstacle to greater use of recycled paper. Enzymatic deinking may provide a means to meet these needs. An alternative to the conventional chemical deinking and mechanical dispersion of toner particles is the enzymatic treatment of office waste paper. One of the advantages of enzymatic deinking is the avoidance of alkaline deinking chemicals. Enzymes at a neutral pH prevent alkaline yellowing of the recycled fiber and simplify deinking chemicals. Enzymatic deinking also changes particle size distribution, apparently reducing the average particle size. In addition to ink removal enzymatic deinking may contribute to improve strength properties of the paper sheets and freeness and reduced fines content of the recycled fiber.

Several research groups have examined the application of enzyme in deinking of different type of waste papers. Regardless of ink type or printing process, enzyme treatment tends to reduce ink particle size, it has been reported that reduction in particle size varied with pulping time in the presence of enzyme, the overall reduction was greater than that noted in conventional deinking.

MECHANISM OF ENZYME ACTION

Korean researchers pointed out that enzyme partially hydrolyze and depolymerize cellulose between fibres, freeing them from one another; ink particles are dislodged as the fiber separate during pulping.

Researchers also believe that enzyme treatment weakens the bond, probably by increasing fibrillation or removing surface layer of individual fibres. Woodward et al. suggested that catalytic hydrolysis might not be essential, since enzymes can remove ink under non-optimal conditions. Mere Cellulase binding alone may be enough to disrupt the fiber surface to an extent sufficient to release ink during pulping. It is also reported that Cellulase peel fibrils from fiber surfaces, thereby freeing ink particles for dispersal in suspension

Enzymatic effects may be indirect, removing micro fibrils and fines and thereby improving freeness and facilitating washing or flotation. Fines content, however is not always reduced during enzymatic deinking. Enzymatic treatment of non impact-printed paper has been reported to remove binding material from ink particles, thereby making the particle hydrophobic and facilitating separation during floatation. Mechanical action is supposed to be critical and prerequisite to enzymatic activity, however research conducted by Putz et al. disputes the importance of mechanical action.

It is likely that a particular deinking system would involve more than one of these mechanisms. However, the relative importance of each mechanism would be dependent on fiber substrate, ink composition, and enzyme mixture. The present paper discuses the findings of enzymatic deinking of MOW in comparison with conventional deinking based on the studies conducted at CPPRI.

MATERIAL AND METHODS

Source of paper

The recovered paper, imported mix-office waste collected from a waste paper based mill was used for present study.

Enzyme

Commercial enzymes were used.

Enzyme I- Cellulase (Imported)

Enzyme II- Cellulase & Xylanase (Indigenous)

Pulping

Repulping experiments were conducted using high-density pulper (500g capacity) for a batch of pulping 250g of dry weight sample. Hydrogen peroxide, Sodium silicate and surfactant were added to the pulper during conventional deinking experiment. In case of enzymatic deinking optimized doses of enzymes and surfactant were used. The pulping conditions were as follows:

Flotation

Flotation was carried out in 25L laboratory Voith flotation cell. Floated pulps were screened using 0.2 mm slot screen in both the cases. The process conditions used for floatation during conventional and enzymatic deinking are shown in Table-2.

Hand sheet preparation and Testing

Hand sheets were prepared following TAPPI procedure. Brightness was determined by the method, TAPPI-T 452. Dirt count was performed on PAPRICAN MICROSCANNER accordingly by the method T-563. Residual ink analysis was determined by PAPRICAN ink scanner meeting the requirement of TAPPI method T-568. TAPPI T-277 measured Canadian Standard freeness. Strength properties and Drainage time were analyzed following the TAPPI standard methods.

RESULTS AND DISCUSSION

(i) Optimization of Enzyme Dose

Optimization studies were conducted only for enzyme-I. For optimization studies five parameters viz. fibre yield, brightness, dirt count, residual ink concentration and freeness of the pulp has been taken into consideration. For all the studies the values for conventional deinking is taken as base line. The optimum dose obtained for enzyme was 0.04% w/w. The results are depicted in Fig 1-6.

(ii) Effect of Enzyme Deinking on Pulp Yield & Pulp Quality

Reduction in pulp yield might be expected from hydrolytic activity of cellulases and hemicellulases. Published data indicate that losses can be held at

Table 1 : Process Conditions Used for Pulping of Mix office waste

Process conditions	Conventional Deinking	Enzymatic Deinking
Time, min	20	20
Consistency, %	12	12
Temp., °C	40-50	40-50
H_2O_2 %	0.8	-
NaOH %	0.8	-
Na_2SiO_3 %	0.1	-
Enzyme dose %	-	0.04
Surfactant %	0.04	0.08
Retention Time, min	-	30
pH10-11	7.0-7.5	

Table 2 : Process Conditions Used for Flotation of Mix office waste

Process conditions	Conventional Deinking	Enzymatic Deinking
Time, min	8	8
Consistency, %	0.8	0.8
Temp. °C	35	35
Airflow rate. L/min	12	12

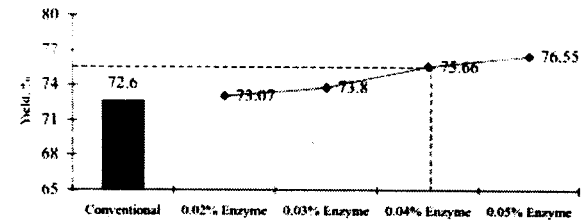


Fig.1- Enzyme dose Vs Yield

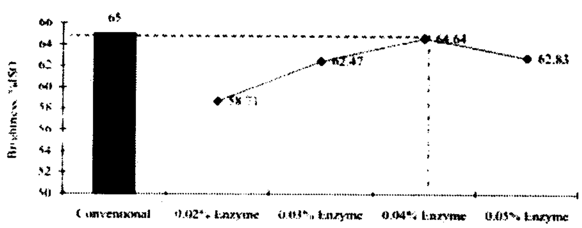


Fig.2- Enzyme dose Vs Brightness

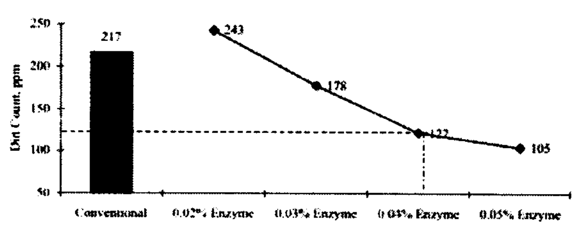


Fig.3- Enzyme dose Vs Dirt Count

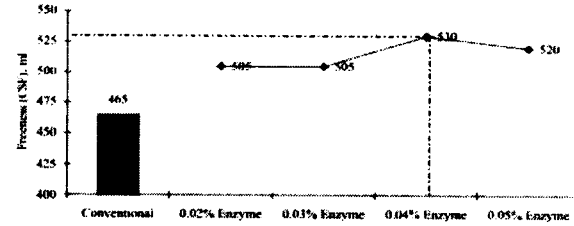


Fig.4- Enzyme dose Vs Freeness

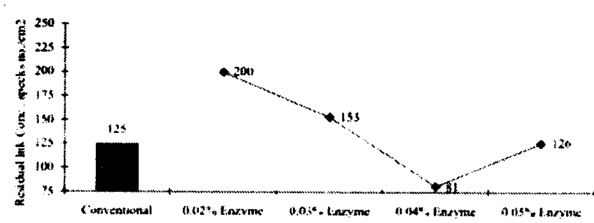


Fig.5- Enzyme dose Vs Residual Ink Conc. (20-80 micro mt. -Subvisible)

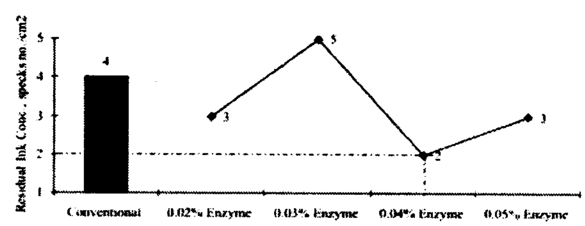


Fig.6- Enzyme dose Vs Residual Ink Conc., (80-224 micro mt. -Visible)

acceptable levels provided enzyme dosage and retention time are optimum. In the present study an improvement in pulp yield is observed with enzymes. Improvement in pulp freeness was observed for Enzyme I only, however, the drainability remained the same. The results are depicted in Table-3.

(iii) Evaluation of Deinking performance with respect to brightness, visible specks and residual ink concentration

In the present study though the brightness improvement could not be observed, but enzymatic treatment has significantly changed the ink particle size distribution and also the removal of different sized ink particles. The results are depicted in Table-4.

The speck number (8-2000 m) of enzyme treated pulp are 195 and 205 compared to 459 for conventional deinked pulp. This reflects that the ink removal efficiency of enzyme treated pulp is high i.e. 57.5% & 55% when compared to ink removal efficiency of conventionally treated pulps. The particle size distribution of ink in various ranges i.e. subvisible, visible and large (8-20 m, 80-224 m, 224-2000 m) also shows the same trend i.e. residual ink of enzyme treated pulp is lower than conventionally treated pulps.

(iv) Effect on physical strength properties

Table 5 shows the physical strength properties of handsheets made from the unbeaten pulps. Enzymatic

Table 3

	Conventional Deinking	Enzymatic Deinking	
		Enzyme I	Enzyme II
pH	10-11	7.0-7.5	7.0-7.5
Fibre Yield, % (Ash free)	72.6	78.2	75.2
Freeness, CSF, ml	465	480	440
Drainage Time, Sec.	5.0	5.0	5.5

Table-4

	Conventional Deinking	Enzymatic Deinking	
		Enzyme I	Enzyme II
Brightness, ISO%	64.5	66.5	61.0
Dirt count, ppm	21	19	18
Residual Ink conc., Specks no/cm²)			
8-2000 µm	459	195	205
8-20mm (Sub visible)	405	130	127
20-80 µm (Sub visible)	52	62	75
80-224 µm (Visible)	2	3	3
224 -2000µm (large)	0	0	0

deinking did not affect the strength properties, instead improvement in tensile index and tear index is observed with both the enzymes while the burst index is on par with conventional deinked pulps.

(v) Effect on Environment

Significant improvements in overall pollution loads have been observed with enzymatic deinking process. One of the biggest advantage of the process is that it works at neutral pH range, which has several advantages. The result depicted in table-6 clearly shows that there is an increase in BOD, improving the biodegradability of the effluent as indicated by higher COD: BOD ratio. The cationic demand is also low compared to conventional process, which indicates that the generation of anionic trash is relatively low in enzyme deinking process. The amount of deinked sludge generation is 27% less than the conventional process due to lower fibre loss.

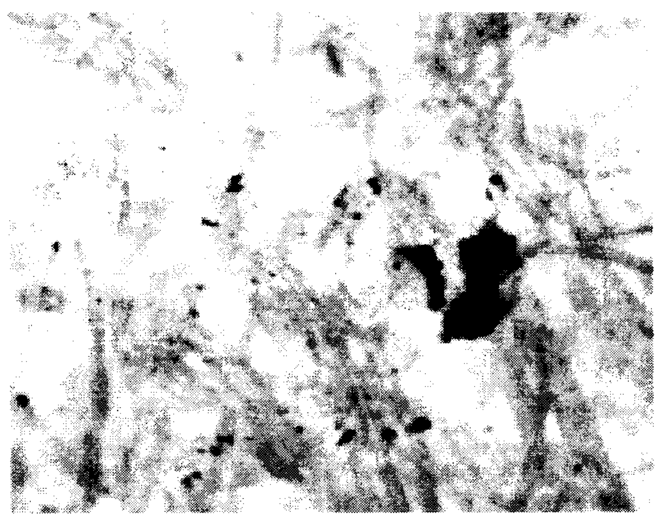
(vi) Economic viability of Enzymatic deinking process

The findings of enzymatic deinking process clearly indicate that the process is promising and is equally competitive with the existing alkaline deinking process. The process also has some added benefits of quality & environmental improvements. Based on the laboratory findings and considering only the cost of chemical, a cost economic analysis has been made for both enzymatic deinking and conventional deinking process and is summarized in table- 7, which clearly indicates that the enzymatic deinking process is truly a cost effective technology and as much as 56% savings can be achieved with improved product quality and environmental benefits as per the findings of present study.

CONCLUSIONS

1. Results from enzymatic deinking of mix office waste

Ink Particle Size (Conventional Deinking)



Ink Particle Size (Conventional Deinking)

Table 5 : Strength Properties of Conventional and Enzymatic Deinked Pulps

Particulars	Conventional Deinking	Enzymatic Deinking	
		Enzyme I	Enzyme II
Burst Index, Kpa.m²/g	2.2	2.4	2.2
Tensile Index, Nm/g	34.0	38.0	36.0
Tear Index, mN.m²/g	11.0	11.6	12.3

trials are promising and their use offers significant advantages over conventional methods.

2. Enzymatic deinking of mix office waste yield-encouraging results in terms of both quality and cost when compared with the present alkaline deinking and may emerge as an alternative deinking technology for recovered paper.
3. Mix office waste can be effectively deinked with cellulolytic and hemicellulolytic enzymes.
4. Cellulase, hemicellulase & their combinations behave differently and they should be evaluated critically for each grade of paper.

Table 6 : Effect of Enzymatic & Conventional deinking on sludge and effluents

Particulars	**Conventional Deinking**	**Enzymatic Deinking**	
			Enzyme I
Enzyme II			
COD, kg/ton	72.6	71.6	87.3
BOD kg/ton	27.5	45.1	36.7
Cationic demand, ppm	8	5	5
COD: BOD ratio	1:2.6	1:1.6	1:2.4
Sludge generation, Kg/ton	94	68	

Table 7 : Comparative Cost of Conventional & Enzymatic Deinking

Particulars	**Conventional deinking**		**Enzymatic deinking**	
Chemicals /Enzymes	**Kg/ton**	**Rs./ton**	**Kg/ton**	**Rs./ton**
NaOH	8	128	-	-
$H_2O_2$8	352	-	-	
Na_2SiO_3	1.0	6	-	-
Surfactant	0.4	100	0.4	100
Enzyme	-	-	0.4	160
Total, Rs.		586		260
Cost Reduction, %		-		56

** As per Lab scale trials*

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