Fiber Modification with Enzymes

CESS Sponsored

Implementing Agencies:

ACIRD, Yamuna Nagar

CPPRI, Saharanpur

February 20, 2014

Background

- **Enzymatic pretreatment of chemical pulps before refining helps in fibrillation; this can reduce the energy requirement in mechanical refiner.**
- **Therefore, the cutting of fibres or fines generation will reduce during refining.**
- **Due to less fines in the refined stock, the drainage rate at the machine wire will increase, requiring less or no drainage aid chemicals; machine speed can also be increased to produce more paper.**
- **Due to better drainability, the moisture content of the web before going to dryer section is expected to be lower, requiring less steam for sheet drying.**

Background….Continued

- **The desired mechanical strength properties of paper can be obtained even with less degree of refining (at higher CSF), improving the bulk of the paper.**
- **Most of these enzymes are very sensitive towards raw material used and process parameters like pH, time and temperature.**
- **Indian paper mills do not have much exposure to the use of enzymes in their processes. Very little work has been carried out with indigenous raw material and literature on this subject is scanty.**
- **On the above background, the CESS Committee sponsored this project.**

Background….Continued

Work distribution under this joint project was as below:

- **Lab scale studies on mixed hardwood & mixed hardwood bamboo pulps were conducted at Avantha Centre for industrial Research and Development (ACIRD), Yamuna Nagar.**
- **Studies on recycled fibers were conducted at Central Pulp & paper Research Institute (CPPRI), Saharanpur.**
- **Plant scale studies using screened enzyme based on the lab scale studies conducted at ACIRD were conducted at Unit-Ashti of Ballarpur Industries Limited.**

Budget (Rs. in Lacs)

Project Budget	**: 55.0**
CESS Contribution	**: 39.3 (26.2- TCIRD, 13.1- CPPRI)**
ACIRD Contribution	**: 15.7**

Time Frame

Duration	**: 24 months**
Date of start	**: Nov. 2010**
Date of completion	**: October 2012**

Objectives

- **To explore possibility of energy saving during refining of pulp**
- **To study the effect of enzymatic refining on pulp properties**
- **To overcome the bottleneck of refining capacity**
- **Demonstration of results with enzymes in the plant scale**

EXPERIMENTAL

A. Wood/ bamboo pulps (Experiments carried out at ACIRD)

- ***Collection of enzyme samples***

Seven commercial enzymes marked as Enzyme-1 to Enzyme-7 collected from Novozymes, Denmark, Dyadic International, U.S.A. and Tex Biosciences, Chennai

- ***Collection of pulp samples***

$C_DE_{OP}D_1D_2$ and $OD_0E_{OP}D$ bleached unrefined pulps collected from two integrated mills in North and South India, marked as Mill-1 and Mill-2.

- ***Enzymatic treatment of pulp for reduction in refining energy***

Optimization of enzymatic treatment conditions

Refining of pulps in PFI mill at different CSF levels

Making of Hand sheets of refined and unrefined pulps

Analysis of physical strength and surface properties of paper

EXPERIMENTAL….Continued

- *Enzymatic treatment of pulp for drainage improvement*
  - **Enzymatic treatment of the refined pulp**
  - **Optimization of treatment conditions and enzyme dosage**
  - **Making of Hand sheets of refined and unrefined pulps**
  - **Analysis of physical strength and surface properties of paper**

B. Recycled fiber pulps (Experiments carried out at CPPRI)

- **Collection of different recycled fibers from paper mills**
- **Collection of different commercial enzymes from international and national companies.**
- **Enzymatic refining studies on Mix office waste (MOW)**
- **Conventional vs enzymatic pulping of new double lined Kraft cuttings (NDLKC) and enzymatic refining studies**
- **Enzymatic refining studies on Old corrugated cartons (OCC)**

ANALYTICAL TECHNIQUES

- Cellulase activity in enzymes was determined by Ghose Method (Pure & Applied Chem., Vol.59, No.2, pp.257-268, 1987)
- Drainability was determined by using DFR 04 (Dynamic drainage, freeness and retention tester).
- Drainage of the pulp at ACIRD was determined as per method of Litchfield, E (1994). APPITA J 47: 62-65.
- Fines analysis was performed with a 200 mesh Screen, according to TAPPI test method T261cm-90.
- Fines content was processed through Britt dynamic jar using -200 screen.
- Freeness of pulp was determined as per Tappi Test Method T 227 om-99 at ACIRD and as per ISO 5267-2 method at CPPRI.
- Hand sheets of the pulp were made according to Tappi Test Method T 205 sp-02 at ACIRD and as per ISO method 5364 at CPPRI.
- Laboratory refining of pulp was done as per Tappi Test Method T 248 sp-00.

ANALYTICAL TECHNIQUES….Continued

- **Moisture content of the pulp was determined as per Tappi Test Method T 210 cm-03.**
- **Physical strength properties were determined as per Tappi Test Method T 220 sp-01.**
- **Reducing sugar content in effluent was measured by DNS as per the procedure followed by Miller *as detailed in Miller G. L., "Use of Dinitrosalicylic acid (DNS) for determination of reducing sugars", Analytical Chemistry, 31, 1959*.**
- **The effluents obtained from enzymatic and chemical pulping processes were analyzed in terms of chemical oxygen demand (COD), colour and lignin accordingly to APHA (American Public Health Association) Standard Methods.**
- **Xylanase activity in enzymes were determined as per the method of Bailey et al., Journal of Biotechnology, 23 pp 257-270 (1992)**

Enzymatic refining of Wood/Bamboo pulp

Enzymatic refining of Wood/Bamboo pulp.....Continued

CMC activity (IU/ml) in enzymes at various pH (at 50° C)

pH	Enzyme-1	Enzyme-2	Enzyme-3	Enzyme-4	Enzyme-5
6.0	91.3	213.5	220.9	94.9	153.9
7.0	200.5	289.1	383.7	217.7	220.2
8.0	121.7	137.1	145.8	111.5	60.5

Xylanase (IU/ml) activity in enzymes at various pH (at 50°C)

pH	Enzyme-1	Enzyme-2	Enzyme-3	Enzyme-4	Enzyme-5	Enzyme-6	Enzyme-7
6.0	3347.7	13694	2156.6	183.3	804.6	10984	13347
7.0	3748	11406	1429.1	602.6	1324.3	10626	15156
8.0	683.3	3354.9	591.4	116.7	332.2	8108	10733

Enzymatic refining of Wood/Bamboo pulp…..Continued

Effect of Enzyme-3 on refining behavior of Mill-1 pulp

Particular	Results				
Enzyme dose (g/t)	0	50	100	150	175
PFI Revolutions	1350	1350	1350	1350	1350
Freeness, CSF (ml)	495	485	480	470	464
Reduction in CSF	--	-10	-15	-25	-31
PFI revolution to get same CSF	1350	1150	1100	1050	950
Reduction in refining energy (%)	--	14.8	18.5	22.2	29.6

Enzymatic refining of Wood/Bamboo pulp…..Continued

Effect of Enzyme-3 on physical strength properties of Mill-1 pulp

Particulars	Control	Enzyme-3			
Enzyme dose (g/t)	--	50	100	150	175
CSF (ml)	495	485	480	470	464
Substance (g/m^2)	72.4	73.1	72.4	69.5	70.7
Bulk (cc/g)	1.25	1.24	1.24	1.24	1.26
Tensile index (N.m/g)	56.2	56.5	56.6	57.5	58.4
Burst index (kN/g)	4.3	4.3	4.3	4.2	4.1
Tear index (mN.m^2/g)	5.3	5.0	4.9	4.7	4.4
Porosity (sec/100 ml)	14.5	16.6	17.8	18.6	18.9
Double fold (no.)	77	78	99	91	97
Smoothness (ml/min)	112	87	80	74	67

Enzymatic refining of Wood/Bamboo pulp.....Continued

Effect of Enzyme-4 on refining behavior of Mill-1 pulp

Particular	Results				
Enzyme dose (g/t)	0	50	100	150	175
PFI Revolutions	1350	1350	1350	1350	1350
Freeness of pulp CSF (ml)	495	485	480	472	462
Reduction in CSF	--	-10	-15	-23	-33
PFI revolution to get similar CSF	--	1150	1100	1050	950
Reduction in refining energy (%)	--	14.8	18.5	22.2	29.6

Enzymatic refining of Wood/Bamboo pulp.....Continued

Effect of Enzyme-4 on physical strength properties of Mill-1 pulp

Particular	Control	Enzyme-4			
Enzyme dose g/t	--	50	100	150	175
CSF (ml)	495	485	480	472	462
Substance (g/m^2)	69.2	71.3	69.5	71.5	69.7
Bulk (cc/g)	1.27	1.26	1.26	1.26	1.28
Tensile index (N.m/g)	56.2	57.6	57.2	57.6	57.7
Burst index (kN/g)	4.5	4.4	4.4	4.6	4.61
Tear index ($mN.m^2/g$)	5.3	5.1	5.1	5.2	4.8
Porosity (sec/100 ml)	15.90	18.6	19.83	20.73	20.91
Double fold (no.)	87	82	111	99	107
Smoothness (ml/min)	98	87	86	88	86

Enzymatic refining of Wood/Bamboo pulp.....Continued

Effect of Enzyme-3 on refining behavior of Mill-2 pulp

Particular	Results			
Enzyme dose (g/t)	0	50	100	150
PFI Revolutions	1350	1350	1350	1350
Freeness of pulp CSF (ml)	515	505	502	495
Reduction in CSF		-10	-13	-20
PFI revolution to get similar CSF	--	1150	1100	1050
Reduction in refining energy (%)		14.8	18.5	22.2

Enzymatic refining of Wood/Bamboo pulp…..Continued

Effect of Enzyme-3 on physical strength properties of Mill-2 pulp

Particular	Control	Enzyme-3		
Enzyme dose (g/t)	--	50	100	150
Revolution (no.)	1350	1350	1350	1350
CSF (ml)	515	505	502	495
Difference in CSF	--	-10	-13	-20
Substance (g/m^2)	73.4	70.5	71.8	73.1
Bulk (cc/g)	1.26	1.27	1.26	1.26
Tensile index (N.m/g)	65.45	65.78	66.55	67.24
Burst index (kN/g)	4.6	4.5	4.6	4.5
Tear index ($mN.m^2/g$)	5.7	5.5	5.3	5.3
Gurley Porosity (sec/100 ml)	37.84	38.97	41.58	44.53
Double fold (no.)	45	54	67	74
Smoothness (ml/min)	69	64	51	44

Enzymatic refining of Wood/Bamboo pulp.....Continued

Effect of Enzyme-4 on refining behavior of Mill-2 pulp

Particular	Results			
Enzyme dose (g/t)	0	50	100	150
PFI Revolutions	1400	1400	1400	1400
Freeness of pulp CSF (ml)	495	487	482	477
Reduction in CSF	--	-8	-13	-18
PFI revolution to get similar CSF	1400	1150	1100	1050
Reduction in refining energy (%)	--	14.8	18.5	22.2

Enzymatic refining of Wood/Bamboo pulp.....Continued

Effect of Enzyme-4 on physical strength properties of Mill-2 pulp

Particular	Control	Enzyme-4		
Enzyme dose g/t	--	50	100	150
CSF (ml)	495	487	482	477
Substance (g/m^2)	71.7	72.8	70.7	69.8
Bulk (cc/g)	1.27	1.27	1.28	1.28
Tensile index (N.m/g)	64.17	64.86	65.43	65.71
Burst index (kN/g)	4.7	4.8	4.8	4.8
Tear index (mN.m^2/g)	5.8	5.8	5.6	5.6
Gurley Porosity (sec/100 ml)	37.86	40.15	41.41	43.54
Double fold (no.)	78	84	99	117
Smoothness (ml/min)	65	59	52	42

Enzymatic drainage improvement of Wood/ Bamboo pulp

Enzymatic drainage improvement of Wood/ Bamboo pulp…..Continued

Effect of two stage treatment of Enzyme-2 on drainage of Mill-1 pulp

Particular	Results			
1st Enzyme Treatment				
Enzyme dose (g/t)	--	--	50	100
PFI Revolution (no.)	1300	1300	1100	1050
CSF (ml)	500	496	503	500
2nd Enzyme Treatment				
Enzyme dose (g/t)	--	75	75	75
CSF (ml)	495	510	515	520
Difference in CSF (ml)	--	+15	+20	+25
Drainage time (sec) for 900 ml	48.31	45.38	44.18	43.17
Improvement in drainage (%)	--	6.1	8.5	10.7

Enzymatic drainage improvement of Wood/ Bamboo pulp…..Continued

Effect of Enzyme-2 on physical strength properties of Mill-1 pulp

Particular	Results			
CSF(ml)	495	510	515	520
Substance (g/m^2)	73.4	73.3	72.1	73.4
Bulk (cc/g)	1.32	1.32	1.33	1.34
Tensile index (N.m/g)	55.6	56.0	56.3	57.2
Burst index (kN/g)	4.6	4.8	4.9	4.7
Tear factor	56.1	55.1	54.1	55.1
Tear index (mN.m^2/g)	5.5	5.4	5.3	5.4
Gurley Porosity (sec/100 ml)	15.8	19.5	18.6	18.4
Double fold (no.)	78	87	105	118
Smoothness (ml/min)	133	101	111	106

Enzymatic drainage improvement of Wood/ Bamboo pulp.....Continued

Effect of two stage treatment of Enzyme-3 on drainage of Mill-1 pulp

Particular	Results			
1st Enzyme Treatment				
Enzyme dose (g/t)	--	--	50	100
Revolution (no.)	1350	1350	1150	1100
CSF (ml)	495	500	505	502
2nd Enzyme Treatment				
Enzyme dose (g/t)	--	75	75	75
CSF (ml)	495	515	518	525
Difference in CSF (ml)	--	+20	+23	+30
Drainage time (sec) for 900 ml	44.28	40.58	39.52	36.71
Improvement in drainage %	--	8.4	10.7	17.1

Enzymatic drainage improvement of Wood/ Bamboo pulp.....Continued

Effect of Enzyme-3 on physical strength properties of Mill-1 pulp

Particular	Results			
CSF (ml)	495	515	518	525
Substance (g/m^2)	71.3	70.4	71.1	72.1
Bulk (cc/g)	1.26	1.25	1.25	1.27
Tensile index (N.m/g)	54.93	54.95	55.01	55.38
Breaking length (m)	5601	5603	5609	5647
Burst factor	41.8	41.8	41.8	42.8
Burst index (kN/g)	4.1	4.1	4.1	4.2
Tear factor	50.0	49.0	46.9	46.9
Tear index (mN.m^2/g)	4.9	4.8	4.6	4.6
Gurley Porosity (sec/100 ml)	11.75	12.73	14.97	16.87
Double fold (no.)	77	85	97	109
Smoothness (ml/min)	110	100	97	82

Enzymatic drainage improvement of Wood/ Bamboo pulp…..Continued

Effect of two stage treatment of Enzyme-2 on drainage of Mill-2 pulp

Particular	Results		
1st Enzyme Treatment			
Enzyme dose (g/t)	--	75	100
Revolution (no.)	1400	1200	1100
CSF (ml)	495	498	500
2nd Enzyme Treatment			
Enzyme dose (g/t)	--	75	75
CSF (ml)	490	505	505
Difference in CSF (ml)	--	+15	+15
Drainage time (sec) for 800 ml	31.3	27.8	26.9
Improvement in drainage (%)	--	11.2	14.2

Enzymatic drainage improvement of Wood/ Bamboo pulp…..Continued

Effect of Enzyme-2 on physical strength properties of Mill-2 pulp

Particular	Results		
CSF (ml)	490	505	505
Substance (g/m^2)	71.9	73.2	70.2
Bulk (cc/g)	1.20	1.21	1.21
Tensile index (N.m/g)	63.6	65.7	64.4
Burst index (kN/g)	4.7	4.8	4.6
Tear index ($mN.m^2/g$)	5.3	4.8	4.8
Gurley Porosity (sec/100 ml)	51.7	54.2	52.4
Double fold (no.)	47	66	50
Smoothness (ml/min)	65	60	62

Enzymatic drainage improvement of Wood/ Bamboo pulp…..Continued

Effect of two stage treatment of Enzyme-3 on drainage of Mill-2 pulp

Particular	Results			
1st Enzyme Treatment				
Enzyme dose (g/t)	--	--	50	100
Revolution (no.)	1350	1350	1150	1100
CSF (ml)	498	500	500	505
2nd Enzyme Treatment				
Enzyme Dose (g/t)	--	75	75	75
CSF (ml)	495	507	520	527
Difference in CSF (ml)	--	+12	+25	+32
Drainage time (sec) for 900 ml	49.18	46.48	42.46	41.17
Improvement in drainage (%)	--	5.4	14.2	16.3

Enzymatic drainage improvement of Wood/ Bamboo pulp…..Continued

Effect of Enzyme-3 on physical strength properties of Mill-2 pulp

Particular	Results			
CSF (ml)	495	507	520	527
Substance (g/m^2)	71.9	73.2	70.2	70.4
Bulk (cc/g)	1.28	1.27	1.29	1.29
Tensile index (N.m/g)	62.74	64.54	63.80	64.34
Burst index (kN/g)	4.3	4.4	4.6	4.5
Tear index (mN.m^2/g)	5.8	5.7	5.5	5.4
Gurley Porosity (sec/100 ml)	35.73	38.63	41.68	47.3
Double fold (no.)	47	66	79	83
Smoothness (ml/min)	59	57	50	48

Enzymatic refining of recycled fiber pulps

Enzymatic refining of recycled fiber pulps….Continued

Enzyme activity of different enzymes used in study

Enzymes	Activity (IU/ml)		
	CMCase	FPase	Xylanase
Enzyme-8	31.00	8.8	95.5
Enzyme-9	129	40	195

Enzymatic refining of recycled fiber pulps….Continued

Effect of Enzyme-8 on drainability of mix office waste pulp

Parameters	Control	Dose of enzyme (%)		
		0.03	0.05	0.07
Drainability, gm/sec	9.3	9.45	9.55	9.75
Improvement in drainability, %	-	1. 1	2.7	4.8

Enzymatic refining of recycled fiber pulps....Continued

Effect of Enzyme-8 on strength properties of mix office waste pulp

Parameters	Control	Dose of enzyme (%)		
		0.03	0.05	0.07
Tear index, $mN.m^2/g$	5.6	5.9	5.2	5.0
Improvement in Tear index, %	-	.54	-	-
Tensile index, N.m/g	36.8	45.4	45.2	39.0
Improvement in Tensile index, %	-	23	22.8	6.0
Burst index, $kPa.m^2/g$	2.2	2.5	2.3	2.2
Improvement in Burst index, %	-	14	4.5	-
Double fold	15	15	16	19
Improvement in Double fold , %	-	-	6.7	26.7
Porosity , ml/min	608	617	694	594
App. Density , g/cm^3	0.63	0.63	0.68	0.64

Enzymatic refining of recycled fiber pulps….Continued

Effect of Enzyme-9 on drainability of mix office waste pulp

Parameters	Control	Dose of enzyme (%)		
		0.03	0.05	0.07
Drainability, gm/sec	9.3	9.6	10.48	10.3
Improvement in drainability, %	-	3.2	12	10.8

Enzymatic refining of recycled fiber pulps….Continued

Effect of Enzyme-9 on strength properties of mix office waste pulp

Parameters	Control	Dose of enzyme (%)		
		0.03	0.05	0.07
Tear index, $mN.m^2/g$	5.6	5.3	5.3	5.6
Tensile index, N.m/g	36.8	38.1	37.5	36.8
Improvement in Tensile index, %	-	3.4	2.0	-
Burst index, $kPa.m^2/g$	1.9	1.92	1.9	1.7
Double fold	15	14.5	14.3	17
Improvement in Double fold , %	-	-	-	13
Porosity , ml/min	608	768	600	598
App. Density , g/cm^3	0.63	0.64	0.64	0.70

Enzymatic refining of recycled fiber pulps….Continued

Effect of enzymes on pulp yield and refining energy during treatment of NDLKC

Parameter		Control	Enzyme-9	Enzyme-8		
			0.075%	0.03%	0.05%	0.075%
Yield, %		97.8	96.0	97.6	96.3	95.1
Refining energy consumed, KWH		0.05	--	0.05	0.04	0.03
Energy saving, %		-	--	-	20	40
Freeness, CSF, ml		300	--	300	300	290
Fines study	Fines,%	27.48	23.24	26.5	27.0	27.4
	Fiber,%	72.52	76.76	73.5	73.0	72.6

Enzymatic refining of recycled fiber pulps….Continued

Characterization of effluents of chemical and enzyme treated NDLKC pulps

Parameters	NDLKC pulp	
	Chemical	Enzymatic
Colour, kg/tp	34.3	2.7
Reduction in colour, %	-	92
Lignin, kg/tp	5.8	1.3
Reduction in lignin, %	-	78
COD, kg/tp	56.8	23.2
Reduction in COD, %	-	59
Reducing Sugars, kg/tp	1.37	3.58
Total solids, kg/tp	48.2	20.4
Reduction in solids, %	-	58

Enzymatic refining of recycled fiber pulps....Continued

Pulp yield and drainability of chemical and enzyme treated OCC pulps

Parameter		OCC pulp	
		Chemical	Enzymatic
Yield, %		92	96
Drainability, gm/sec		7.05	7.5
Fines study	Fines, %	36.48	26.3
	Fiber, %	63.6	73.7

Enzymatic refining of recycled fiber pulps....Continued

Strength properties of chemical and enzyme treated OCC pulps

Parameter	OCC pulp	
	Chemical	Enzymatic
Tear index , $mN.m^2/g$	8.5	8.41
Tensile index, N.m/g	44.34	46.84
Improvement in Tensile index, %	-	5.3
Burst index, $kPa.m^2/g$	2.59	2.67
Improvement in burst index, %	-	3.0
Porosity , ml/min	331	413
Improvement in Porosity, %	-	12.6

Enzymatic refining of recycled fiber pulps….Continued

Characterization of effluents of chemical and enzyme treated OCC

Parameters	OCC pulp effluents	
	Chemical	Enzymatic
Colour, kg/tp	23.3	2.9
Reduction in colour , %	-	88
Lignin, kg/tp	5.1	1.0
Reduction in lignin , %	-	83
COD, kg/tp	36.9	12.9
Reduction in COD , %	-	65
Reducing Sugars, kg/tp	1.2	2.3
Total solids, kg/tp	42.5	25.9
Reduction in solids , %	-	39

Salient Findings

Enzymatic refining of wood/ bamboo pulp

- **Out of the seven enzymes analysed, Enzyme-4, Enzyme-3 and Enzyme-2 were found to be more effective in reducing refining energy requirement targeting the same strength properties as those of control.**
- **Enzyme-3 and Enzyme-4 were capable to reduce refining energy by 29.6% whereas Enzyme-2 was able to reduce refining energy by 26.9%.**

Drainage improvement of wood/ bamboo pulp

- **Enzyme 3 and Enzyme 2 were found effective in improving the drainage of pulp.**
- **Enzyme-3 was found most effective to improve drainage, as it improved the drainage of the pulp up to 17.1%.**
- **Tear index was a little reduced with treatment with Enzyme-3 at higher dose.**

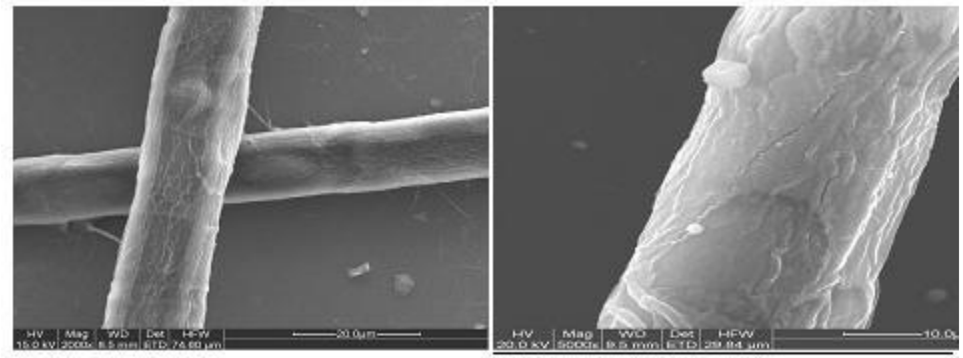
Salient Findings

Enzymatic refining of recycled fiber pulps

- ***Enzymatic refining of Mix office waste***
  - **Improvement in strength properties along with marginal improvement in drainability of pulp was observed with enzymes.**
- ***Enzymatic refining of NDLKC and OCC varieties***
  - **It is possible to eliminate the use of caustic (2%) used by the industry by replacement of enzymes under optimized conditions.**
  - **Savings in energy during refining of enzyme treated pulps is 10-40% with varying doses of enzymes**
  - **Improvement in yield 2-4%**
  - **Improved strength properties in respect of tensile index by 3-5% , in burst index, 3.0 % and in porosity by 12-20%.**
  - **Reduction in pollution loads of colour (80-90 %) & COD (50-60%).**

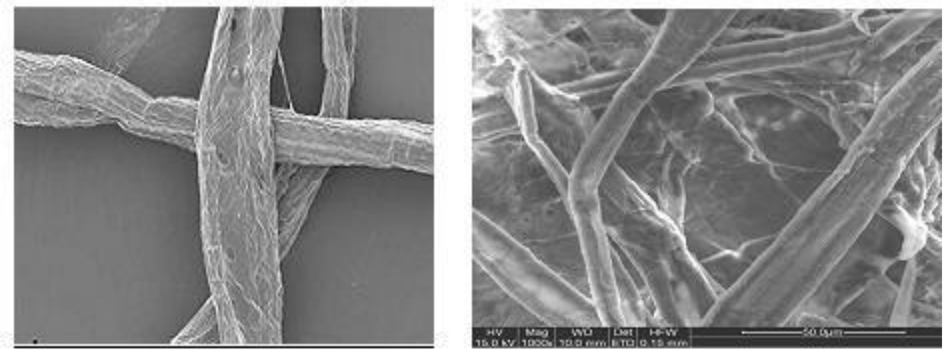
SEM analysis

No fibrillation as well as delamination of cell wall/ cell wall collapse was observed in the unrefined untreated fibers of mixed hardwood pulp fibers.



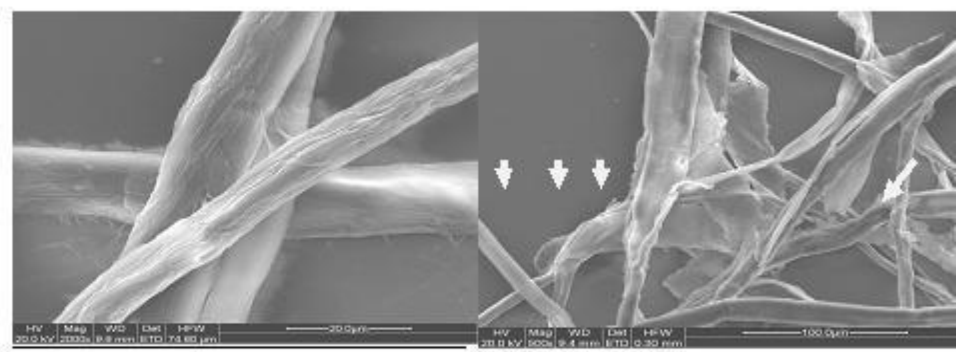
SEM micrographs of Mixed hardwood pulp fibers (Control, Unrefined)

Marginal fibrillation on the surface of fiber as well as delamination of cell wall/ cell wall collapse was observed with mechanical refining of the pulp .



SEM micrographs of mixed hardwood pulp fibers (Control, Refined)

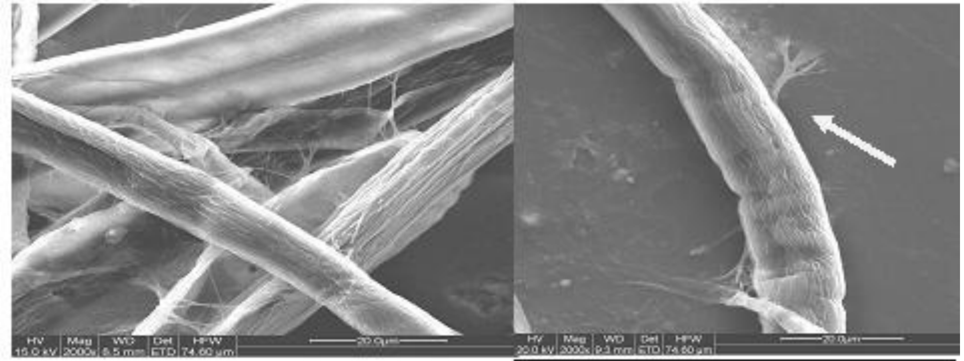
With the addition of Enzyme-3 there was marginal delamination of cell wall as well as cell wall collapse even in unrefined pulps.



SEM micrographs of Enzyme-3 treated mixed hardwood pulp fiber (Unrefined)

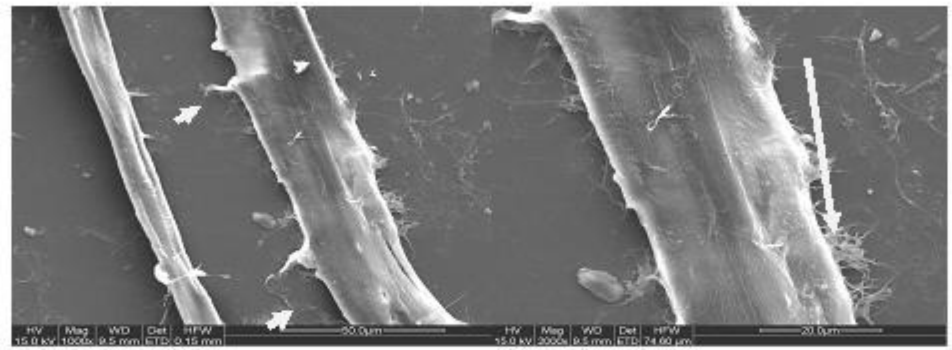
SEM analysis

With the addition of Enzyme-4 there was marginal delamination of cell wall as well as cell wall collapse even in unrefined pulps.



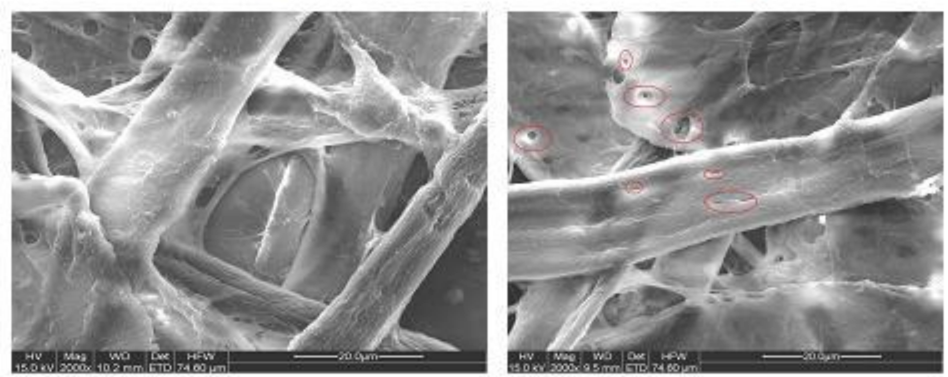
SEM micrographs of Enzyme-4 treated mixed hardwood pulp fiber (Unrefined)

Treatment of pulp with Enzyme-3 afterwards mechanical refining, resulted in improved fibrillation on the surface of pulp fibers, delamination of cell wall and collapsed cell wall.



SEM micrographs of Enzyme-3 treated mixed hardwood pulp fiber (refined)

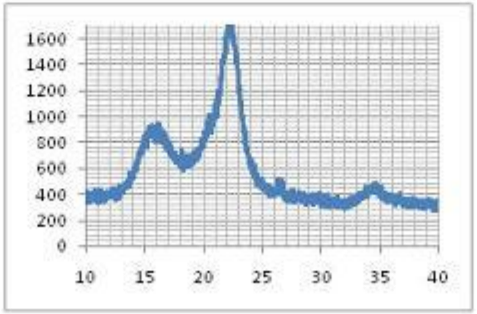
Treatment of pulp with Enzyme-4 afterwards mechanical refining, resulted in improved fibrillation on the surface of pulp fibers, delamination of cell wall and collapsed cell wall.



SEM micrographs of Enzyme-4 treated mixed hardwood pulp fiber (refined)

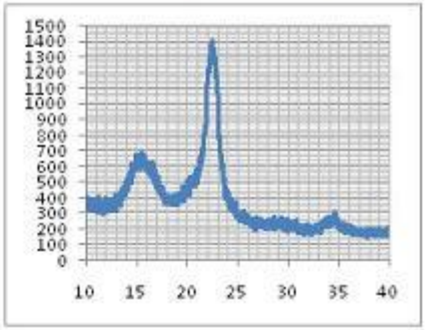
XRD analysis

XRD diffractogram of control pulp



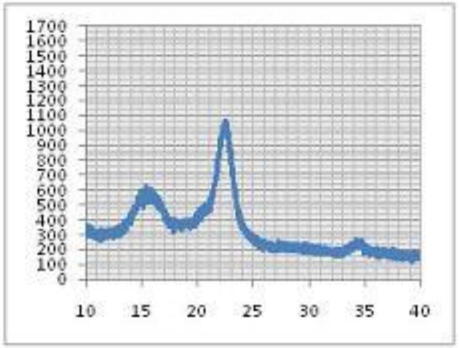
XRD diffractogram of untreated unrefined mixed hardwood pulp

Treatment of pulp with Enzyme-3 decreases the amorphous part of the cellulose



XRD diffractogram of Enzyme-3 treated unrefined mixed hardwood pulp

Treatment of pulp with Enzyme-4 decreases the crystalline part of the cellulose.



XRD diffractogram of Enzyme-4 treated unrefined mixed hardwood pulp

Mill Trials

- **Demonstrated the outcome of the project by plant scale trial at Unit-Ashti of BILT which showed about 20% reduction in refining energy using Enzyme-4 dose of 80 g/tonne of pulp.**
- **Machine DDR was bypassed in the trial.**
- **FPAR and FPR were also improved.**
- **Improvement in freeness of the Head box and Machine chest pulp was observed.**
- **Breaking length of the paper was also improved whereas tear factor was reduced marginally.**

Mill Trials

Results of the plant scale trials taken with Enzyme-4

Particulars	CONTROL DATA			Trial with Enzyme-4		
	Min	Max	Avg.	Min	Max	Avg.
Enzyme dose (g/TP)	--	---	--	60	100	80
^{0}SR (Head Box)	22	27	24	27	33	29
Refiner loads						
Stock DDR (kWh)	98	108	103	62	96	83
M/C DDR (AMP)	31	71	61	--	--	--
Wet end properties						
Back Water Cy (%)	0.10	0.15	0.12	0.09	0.13	0.11
FPR (%)	72.1	80.8	77.1	77.2	83.2	79.4
FPAR (%)	41.4	50.1	46.9	47.1	53.1	48.6
Paper properties						
Breaking length (m)	2481	3386	2961	3190	3953	3475
Tear Factor	54	70	62	52	61	56

Scope

Mills can utilize the suitable enzyme/ enzymes for:

- **Saving of electrical energy used during refining**
- **Saving of steam during drying of paper**
- **Improvement of drainage, thereby production**
- **Improvement of physical strength properties**
- **ACIRD can help the mills for optimization studies and easy adoption of process in initial stage**

Scientific Development

Publication

Chetna Gupta, Dhermendra Kumar, Vasanta V Thakur, R K Jain, R M Mathur. Improved Papermaking Through Enzymatic Modification of Recycled Fibres. Souvenir of 2nd Paper+ Conference held at Coimbatore during November 24-26, 2012, pp 49-59.

Fundamental Research

A part of the project work was used for the training of four students of Biotechnology from Thapar University, Patiala and Kurukshetra University.

Thank You

AVANTHA

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