Enzymatic Refining of Chemical Pulp

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ABSTRACT

Laboratory scale studies were performed on mill bleached mixed hardwood pulp containing *Acacia* and MTH (mixed tropical hardwood) with different commercial imported and indigenous enzymes. The pulp was treated with enzymes at the same dose level before refining and impact on energy savings and physical strength properties were studied. The energy saving was highest, 30%, in case of Enzyme 5, 14-15% in case of Enzyme 3 and Enzyme 4 and 6-9% in case of Enzyme 1 and Enzyme 2 at 495 ml CSF. However, in case of Enzyme 5, all the strength properties of refined pulps were lower. To avoid the drop in strength properties, study with lower doses (below 175 g/T) of Enzyme 5 was conducted. Even at a lower dose of 75 g/T, the energy saving was significant (16-17% at 433-535 ml CSF). All the strength properties were better than control at 550 and 500 ml CSF. At 500 ml CSF, tensile index, burst index, tear index and double fold improved by 5%, 11.5%, 3.2%, 15.8% respectively. At enzyme dose level of 100 g/T, 125 g/T. 150 g/T, 175 g/T, the energy savings ranged from 19-21%, 22-26%, 24-28% and 31-32% respectively. However, there was drop in strength properties at lower CSF (550 to 425 ml).

Addition of Enzyme 5 to the unrefined and refined stock (prerefining and postrefining treatments) at dose level of 75 g/T and 75 g/T respectively showed 17% reduction in refining energy, 20.0% improvement in drainage and improvement in strength properties (at 500 ml CSF). Reduction in refining energy was 12% and improvement in drainage was 14.5% when Enzyme 5 was added to the unrefined and refined stock at dose level of 50g /T and 50g /T respectively. The strength properties were better in this case also. Two-stage enzyme treatment appears effective in providing energy savings, drainage and strength benefits.

INTRODUCTION

The paper industry has been using enzymes on a limited scale for many years. Typical applications have included xylanases for prebleaching pulps, amylases for starch modification, proteases for biological slime control, esterases for pitch and stickies control. Now a new application of enzymes-fiber modification is gaining wider acceptance (Bajpai et al., 2003; Bajpai et al., 2005a,b; Bajpai et al., 2006a,b; Yoder, 2007; Thomas and Murdoch, 2006; Hoekstra and Yoder, 2006). The enzymes used in this application are from the cellulase and hemicellulase family. The cellulases break down the cellulose in the fiber. This leads to the delamination of the cell walls, causes cell walls to collapse and starts fibrillation. Of course, this is exactly what is done with mechanical refiners. However, the enzymes can give a gentler, targeted refining. A concern with mechanical refining is the generation of fines. The use of enzymes makes balancing the positives and negatives of refining easier. The cellulases can be used in conjunction with mechanical refining or may replace mechanical refining completely. The various cellulases have different actions and in some cases work on different wood species. Two major types are the exocellulases and endocellulases. Exocellulases act on the end of the cellulose chain, cutting bonds on the ends of the fiber. Endocellulases act in the middle of the cellulose chains. This means that the selection of the appropriate cellulase is important.

Through the application of enzymes before refining, mills can reduce their energy requirement for refining of pulps and realize a saving in steam consumption. These benefits can also be converted into increased production capacity from the same facility. Enzymes are expected to give more benefits to those mills, which are not having captive power generation and are limited by refining capacity. Fiber modification enzymes can be used to achieve sheet qualities that a mill's mechanical refiners may not be able to. The enzyme can also be used to allow less expensive pulps to be used to reduce production costs. Significant progress has been made over the past few years in the area of enzymatic fibre modification. We have seen the benefits of using enzymes for fibre modification in mill applications (Bajpai et al., 2005a,b; Bajpai et al., 2006a,b). In this paper, we have studied more effective commercial enzyme formulations for enzymatic refining of mixed hardwood pulp containing *Acacia* and MTH. We have also studied addition of enzyme to the refined stock (postrefining treatment) with the most effective enzyme (Enzyme 5).

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EXPERIMENTAL

The study was conducted with commercial imported and indigenous enzymes. The pulp used was mill bleached mixed hardwood pulp which contained *Acacia* and MTH. Enzyme 1, Enzyme 2 and Enzyme 5 were imported enzymes and Enzyme 3 and Enzyme 4 were indigenous ones. Enzyme 2 and Enzyme 3, used in our earlier work (Bajpai et al, 2005a,b, 2006a,b), were used for comparison. Enzyme treatment of pulp (4% consistency) was carried out in the beakers with continuous stirring at 40°C and pH of 7.0 for 60 minutes. The pH of the pulp was adjusted with dilute H_2SO_4 before addition of enzyme. The reference pulps were incubated at the same conditions as the enzyme treated pulps prior to refining. Refining of the pulps was done in a PFI mill.

ANALYTICAL TECHNIQUES

Presence of cellulase activity in commercial enzymes was determined by the method of Mandels and Weber (1969). Xylanase activity was

Table 1: CMC, Filter paper and Xylanase activities in various commercial enzymes (pH 7.0, 45º C)

Enzyme name	CMC activity (μmole/ml/min)	Filter paper activity (μmole/ml/min)	Xylanase activity (μmole/ml/min)
Enzyme 1	560.1	1.45	--
Enzyme 2	213.3	0.96	1938.5
Enzyme 3	168.3	2.20	662.3
Enzyme 4	359.1	2.20	822.8
Enzyme 5	601.9	6.31	30.5

Table 2: Effect of different commercial enzymes on pulp freeness at different PFI revolutions

	Freeness of pulp CSF (ml)			
Number of rev.	0	2000	2700	4000
Control	655	530	495	426
Enzyme 1	650 (-5)	524 (-6)	485 (-10)	419 (-7)
Enzyme 2	630 (-25)	521(-9)	481(-14)	420(-6)
Enzyme 3	640 (-15)	511 (-19)	478 (-17)	408 (-18)
Enzyme 4	640 (-15)	510(-20)	475(-20)	410(-16)
Enzyme 5	660 (+5)	488 (-42)	425 (-70)	333 (-93)

Table 3: Effect of different commercial enzymes on PFI revolutions to get same pulp freeness

	No. of PFI revolutions		
CSF (ml)	530	495	426
Control	2000	2700	4000
Enzyme 1	1898 *(-102)* [5]	2525 *(-175)* [6]	3860 *(-140)* [3]
Enzyme 2	1783 *(-217)* [11]	2457 *(-243)* [9]	3855 *(-145)* [4]
Enzyme 3	1714 *(-286)* [14]	2331 *(-369)* [14]	3646 *(-354)* [9]
Enzyme 4	1662 *(-338)* [17]	2289 *(-411)* [15]	3659 *(-341)* [9]
Enzyme 5	1463 *(-537)* [27]	1882 *(-818)* [30]	2745 *(-1255)* [31]

Data in square bracket show % energy saving

Table 4: Effect of different commercial enzymes on strength properties of unbeaten and beaten pulps

Unbeaten Pulp						
Particulars	Control	Enzyme 1	Enzyme 2	Enzyme 3	Enzyme 4	Enzyme 5
CSF (ml)	655	650	630	640	640	660
Tensile index (Nm/g)	19.8	31.8 (+60.3)	25.5 (+28.5)	30.6 (+54)	(+44.5)	28.6 (44.5)
Burst index (kN/g)	1.16	1.2 (+3.4)	1.36 (+17.8)	1.53 (+32.2)	1.89 (+9.3)	1.50 (+30.0)
Tear index (mN m^2/g)	3.3	5.25 (+60.0)	3.86 (+17.3)	4.94(+50.0)	4.63(+40.8)	5.36 (+62.5)
Double fold (no.)	3	4 (+33.3)	4 (+33.3)	4 (+33.3)	5 (+66.7)	4 (+33.3)
Pulps beaten at 2000 Revolutions						
CSF (ml)	530	524	521	511	510	488
Tensile index (Nm/g)	56.7	70.7 (+24.5)	62 (+9.6)	68.5 (+20.7)	69.4(+22.4)	58.9 (+3.9)
Burst index (kN/g)	3.74	4.27 (+14.2)	3.69 (-1.0)	4.35 (+16.3)	4.67(+24.1)	3.93 (+5.2)
Tear index (mN m2/g)	6.8	7.7 (+31.8)	7.5 (+27.6)	7.59 (+29.6)	7.6 (+30.6)	6.08 (+3.8)
Double fold (no.)	65	73 (+12.3)	157(+141.5)	115(+76.9)	81 (+24.6)	94 (+44.6)
Pulps beaten at 2700 Revolutions						
CSF (ml)	495	485	481	478	475	425
Tensile index (Nm/g)	62.7	64.4 (+2.7)	64.8 (+3.3)	72.1(+15.0)	69.7(+11.1)	61.1 (-2.4)
Burst index (kN/g)	4.04	4.54 (+12.4)	4.42 (+9.5)	4.87 (+20.6)	4.4 (+19.0)	4.09 (+1.2)
Tear index (mN m2/g)	7.3	7.48 (-8.5)	7.98 (-2.0)	7.71 (-5.3)	7.94 (-2.7)	5.9 (-27.5)
Double fold (no.)	132	94 (-28.8)	165 (-25.0)	157 (-18.9)	175 (-32.6)	102 (-22.7)
Pulps beaten at 4000 Revolutions						
CSF (ml)	426	419	420	408	410	333
Tensile index (Nm/g)	69.2	71.5 (+3.3)	72.6 9 (+4.9)	73.4 (+6.0)	56.1(-19.0)	60.5 (-12.6)
Burst index (kN/g)	4.36	4.91 (+12.6)	4.83 (+10.8)	5.11 (+17.1)	4.61 (+5.6)	4.38 (+0.4)
Tear index (mN m2/g)	7.15	7.13 (-3.8)	6.65 (-10.3)	7.2 (-2.9)	7.1 (-4.1)	5.78 (-22.4)
Double fold (no.)	190	146 (-23.2)	188 (-1.1)	182 (-4.2)	165 (-13.2)	136 (-28.4)

Data in bracket show% change in properties

measured by reducing sugar production from oat spelt xylan. One international enzyme unit is defined as the amount of enzyme necessary for the production of 1 micro-mole product/minute. Moisture content of the pulp was determined as per Tappi Test Method T 210 cm-03. Laboratory beating of pulp (PFI mill) was done as per Tappi Test Method T 248 sp-00. Freeness of pulp (CSF) was determined as per Tappi test methods T 227 om-99. Hand sheets of the pulp were made according to Tappi Test Method T 205 sp-02. Physical strength properties were determined as per Tappi test methods T 220 sp-01.

RESULTS AND DISCUSSION

Enzyme activities in commercial enzymes

Table 1 shows various enzyme activities -- carboxymethyl cellulase (CMC), filter paper activity and xylanase activity at pH 7.0 and 45°C in commercial enzymes. CMC activity is higher in Enzyme 5, Enzyme 1 and Enzyme 4 as compared to Enzyme 2 and Enzyme 3 (used in our earlier work). Filter paper activity is highest in Enzyme 5 and lowest in Enzyme 2. Xylanase activity is nil in Enzyme 1 and extremely low in Enzyme 5 whereas in Enzyme 2, it is considerably higher. Enzyme 3 and Enzyme 4 also contain high xylanase activity. One IU is defined as the amount of enzyme necessary for the production of 1 mol product/minute.

Enzymatic treatment of pulp and effect on refining

Pulp (4% consistency) was treated with different enzymes at 40°C and pH 7.0 for 60 minutes. All the enzymes were used at a dose level of 175 g/T for comparison. After the enzyme treatment, the pulps were refined in a PFI mill at 2000, 2700 and 4000 revolutions. The untreated pulp was also refined in a PFI mill at similar revolutions. Results show that treatment of the pulp before refining reduced the freeness of the pulp. Freeness reduction was maximum in case of Enzyme 5 and lowest in case of Enzyme 1. Freeness reduced by 42, 70 and 93 ml at PFI revolution of 2000, 2700 and 4000 respectively in case of Enzyme 5. The reduction in freeness was comparable in case of Enzyme 4 and Enzyme 3 (20, 20 and 16 ml at PFI revolution of 2000, 2700 and 4000 respectively in case of Enzyme 4 and 19, 17 and 18 ml at PFI revolution of 2000, 2700 and 4000 respectively in case of Enzyme 3). The reduction in freeness with Enzyme 2 was lower as compared to Enzyme 3 and Enzyme 4. Detailed results are presented in Table 2.

Table 3 shows the effect of enzymes on PFI revolutions to get same pulp freeness. Control pulp required 2000, 2700 and 4000 PFI revolutions to reach a freeness of 530, 495 and 426 ml respectively whereas pulp treated with Enzyme 5 at a dose level of 175 g/T required 1463, 1882 and 2745 revolutions to reach a freeness of 530, 495 and 426 ml respectively showing around 27-31% energy saving. In case of other enzymes, the energy saving was lower; 14-15% with Enzyme 3 and Enzyme 4 and 6-9% with Enzyme 1 and Enzyme 2 at 495 ml CSF.

Table 4 shows the effect of enzyme

Table 5: Effect of different commercial enzymes on strength properties at different CSF

Particulars	Control	Enzyme 1	Enzyme 2	Enzyme 3	Enzyme 4	Enzyme 5
600 ml CSF						
Tensile index (Nm/g)	36.8	49.0 (+33.3)	36.5 (-0.7)	43.1 (+17.3)	42.6 (+16.0)	40.2 (+9.3)
Burst index (kN/g)	2.30	2.41 (+4.7)	2.01 (-12.8)	2.40 (+4.3)	2.30 (0.0)	2.69 (+17.0)
Tear index (mNm^2/g)	4.41	6.27 (+42.2)	4.90 (+11.1)	5.78 (+31.1)	5.59 (+26.7)	5.59 (+26.7)
Double Fold (no.)	27	31(+14.8)	47 (+74.1)	37 (+37.0)	25 (-7.4)	35 (+29.6)
550ml CSF						
Tensile index (Nm/g)	52.0	64.7 (+24.5)	54.7 (+5.2)	58.3 (+12.3)	58.6 (+12.7)	49.0 (-5.6)
Burst index (kN/g)	3.38	3.71 (+9.6)	3.09 (-8.7)	3.53 (+4.3)	3.71 (+9.6)	3.28 (-2.9)
Tear index (mNm^2/g)	5.39	7.25 (+34.5)	6.57 (+21.8)	6.86 (+27.3)	6.76 (+25.5)	5.88 (+9.1)
Double Fold (no.)	52	58 (+11.5)	120 (+130)	80 (+53.8)	52 (0.0)	64 (+23.1)
500 ml CSF						
Tensile index (Nm/g)	62.5	66.7 (+6.7)	64.7 (+3.5)	71.3 (+14.1)	71.3 (+14.1)	56.9 (-9.0)
Burst index (kN/g)	4.02	4.51 (+12.2)	4.17 (+3.7)	4.61 (+14.6)	4.71 (+17.1)	3.82 (-4.9)
Tear index (mNm^2/g)	7.94	7.55 (-4.9)	7.94 (0)	7.74 (-2.5)	7.84 (-1.2)	6.57 (-17.3)
Double Fold (no.)	125	85 (-32.0)	165 (+32.0)	127 (+1.6)	95 (-24.0)	90 (-28.0)
425 ml CSF						
Tensile index (Nm/g)	69.6	70.6 (+1.4)	72.1 (+3.5)	73.0 (+4.9)	58.8 (-15.5)	61.0 (-12.3)
Burst index (kN/g)	4.41	4.85 (+10.0)	4.80 (+8.9)	5.05 (+14.4)	4.56 (+3.3)	4.07 (-7.8)
Tear index (mNm^2/g)	7.35	7.15 (-2.7)	6.76 (-8.0)	7.25 (-1.3)	7.25 (-1.3)	5.97 (-18.7)
Double Fold (no.)	190	140 (-26.3)	185 (-2.6)	175 (-7.9)	170 (-10.5)	102 (-46.3)

Data in bracket show % change in properties.

Table 6: Effect of enzyme dose (Enzyme 5) on pulp freeness at different PFI revolutions

	Freeness of pulp CSF (ml)			
Number of rev.	0	2000	2700	4000
Control	645	535	500	433
75 g/T	650 (+5)	515 (-20)	473 (-27)	396 (-37)
100 g/T	655 (+10)	505 (-30)	468 (-32)	390 (-43)
125 g/T	655 (+10)	500 (-35)	450 (-50)	390 (-43)
150 g/T	660 (+15)	500 (-35)	450 (-50)	380 (-53)
175 g/T	665 (+20)	490 (-45)	430 (-70)	350 (-83)

Table 7: Effect of enzyme dose (Enzyme 5) on PFI revolutions to get same pulp freeness

	No. of PFI revolutions		
CSF (ml)	535	500	433
Control	2000	2700	4000
75 g/T	1687 (-313) [16]	2243 (-458) [17]	3356 (-644) [16]
100 g/T	1578 (-422) [21]	2115 (-586) [22]	3229 (-771) [19]
125 g/T	1498 (-502) [25]	2000 (-700) [26]	3104 (-896) [22]
150 g/T	1453 (-547) [27]	1955 (-746) [28]	3027 (-973) [24]
175 g/T	1390 (-610) [31]	1823 (-877) [32]	2726 (-1274) [32]

Data in square bracket show % energy saving

Table 8: Effect of enzyme dose (Enzyme 5) on strength properties at different CSF

Enzyme dose (g/T)	0	75	100	125	150	175
600 ml CSF						
Tensile index (Nm/g)	37.3	40.2 (+7.9)	39.0 (+4.6)	40.4 (+8.6)	40.4 (+8.6)	38.2 (+2.6)
Burst index (kN/g)	2.30	2.52 (+9.8)	2.35 (+2.1)	2.35 (+2.1)	2.35 (+2.1)	2.15 (-6.4)
Tear index (mNm^2/g)	6.66	6.91 (+3.7)	6.91 (+3.7)	6.66 (0.0)	6.22 (-6.6)	5.83 (-12.5)
Double Fold (no.)	26	32 (+23.1)	28 (+7.7)	27 (+3.8)	24 (-7.7)	22 (-15.4)
550 ml CSF						
Tensile index (Nm/g)	47.1	510.0 (+8.3)	47.6 (+1.0)	47.1 (0.0)	47.1 (0.0)	45.8 (-2.6)
Burst index (kN/g)	3.04	3.43 (+12.9)	3.14 (+3.2)	3.04 (0.0)	2.94 (-3.2)	2.65 (-12.9)
Tear index (mNm^2/g)	74.5	76.5 (+2.7)	74.5 (0.0)	71.5 (-4.0)	67.7 (-9.1)	62.8 (-15.7)
Double Fold (no.)	50	62 (+24.0)	53 (+6.0)	48 (-4.0)	43 (-14.0)	36 (-28.0)
500 ml CSF						
Tensile index (Nm/g)	57.8	60.8 (+5.1)	55.9 (-3.4)	54.4 (-5.9)	54.4 (-5.9)	52.9 (-8.5)
Burst index (kN/g)	3.82	4.26(+11.5)	3.72 (-2.6)	3.62 (-5.1)	3.52 (-7.7)	3.23 (-15.4)
Tear index (mNm^2/g)	7.69	7.94 (+3.2)	7.64 (-0.6)	7.25 (-5.7)	6.96 (-9.6)	6.27 (-18.5)
Double Fold (no.)	7.45	8.63(+15.8)	7.35 (-1.3)	6.57 (-11.8)	5.49 (-26.3)	4.70 (-36.8)
425 ml CSF						
Tensile index (Nm/g)	63.7	64.7 (+1.5)	61.3 (-3.8)	60.3 (-5.4)	59.3 (-6.9)	58.3 (-8.5)
Burst index (kN/g)	4.51	4.80 (+6.5)	4.36 (-3.3)	4.21 (-6.5)	4.07 (-9.8)	3.82 (-15.2)
Tear index (mNm^2/g)	7.20	7.20 (0.0)	7.10 (-1.4)	69.0 (-6.1)	6.76 (-6.1)	6.07 (-15.6)
Double Fold (no.)	118	114 (-3.4)	95 (-19.5)	91(-22.9)	78 (-33.9)	68 (-42.4)

Data in bracket show % change in properties

treatment on strength properties of pulps. All the important strength properties were higher in case of enzyme treated unbeaten pulps. Tensile index, burst index, tear index and double fold increased by 28-60%, 3-32%, 17-62%, 33-67% respectively in case of different enzymes. At 2000 PFI revolutions, all the enzyme treated pulps showed better strength properties in comparison to the reference pulp. However, at higher PFI revolutions (2700 and 4000), some of the strength properties like tear and double fold dropped. Enzyme 5 was the exception; in this case all the strength properties with the exception of burst index dropped at higher PFI revolutions (2700 and 4000).

Tables 5 show the comparison of important physical strength properties of control and enzyme treated pulps at different CSF. At 600 ml CSF, all the strength properties of enzyme treated pulps were better in comparison to the reference pulps. At 550 ml CSF, all the strength properties were better/ comparable in case of Enzyme 1, Enzyme 2, Enzyme 3 and Enzyme 4. However, in case of Enzyme 5, there was slight drop in tensile index (-5.6%) and burst index (-2.9%) but the tear index and double fold were better. At 500 ml and 425 ml CSF, all the strength properties were lower in case of Enzyme 5. In case of other enzymes, the tensile index and burst index were better but tear index and double fold were lower (at 425 ml CSF).

Optimization of dose of Enzyme 5 was studied in order to avoid the drop in physical strength properties. The dose was varied from 75 g/T to 175 g/T of pulp. The results are presented in Tables 6 & 7. Even at a lower dose of 75 g/T, the energy saving was significant (16-17% at 433-535 ml CSF). All the strength properties were better than control at 550 and 500 ml CSF (Tables 8). At 500 ml CSF, tensile index, burst index, tear index and double fold improved by 5%, 11.5%, 3.2%, 15.8% respectively. At enzyme dose level of 100 g/T, 125 g/T. 150 g/T, 175g/T, the energy savings ranged from 19-21%, 22-26%, 24-28% and 31-32% respectively. However, there was drop in strength properties at lower CSF (550 to 425 ml).

Two-stage enzyme treatment

A study was conducted in which enzyme (Enzyme 5) was added both to the unrefined and refined pulps (prerefining and post refining application). The results are presented in Table 9. It was found that pre-refining application, resulted in improved refining efficiency and strength improvement and post refining treatment resulted in increased fiber freeness and also better strength properties. The refining energy reduced by 16% and drainage improved by 20% when the enzyme was added to the

Table 9 : Treatment of unrefined and refined pulp with Enzyme 5 (two-stage enzyme treatment)

Particular	Control	50 g/T+50 g/T	75 g/T+75 g/T
Enzyme treatment before refining			
Enzyme dose (g/T)	0	50	75
PFI revolutions (Nos.)	2700	2700	2700
CSF (ml)	500	485	478
Energy saving (%)		12	16
Drainage Time (Sec.)	40.3	37.5	37.0
Improvement in drainage (%)		6.9	8.2
Bulk (cc/g)	1.30	1.30	1.30
Tensile index (Nm/g)	57.5	61.4 (+6.8)	62.9 (+9.4)
Burst index (kN/g)	3.81	4.30 (+12.9)	4.48 (+17.6)
Tear index (mN m2/g)	7.78	7.80	7.75
Porosity (sec/100 ml)	11.3	13.1 (+15.9)	15.2 (+34.5)
Double fold (no.)	78	82 (+5.1)	88 (+12.8)
Smoothness (ml/min)	145	140 (-3.4)	140 (-3.4)
Enzyme treatment after refining			
Enzyme dose (g/T)	0	50	75
CSF (ml)	498	499	500
Drainage Time (Sec.)	40.6	34.7	32.4
Improvement in drainage (%)		14.5	20.2
Bulk (cc/g)	1.31	1.30	1.30
Tensile index (Nm/g)	57.5	63.4 (+10.3)	63.1 (+9.7)
Burst index (kN/g)	3.81	4.6 (+20.7)	4.7 (+23.4)
Tear index (mN m2/g)	7.78	7.75	7.50
Porosity (sec/100 ml)	11.3	14.6 (29.2)	15.8 (39.8)
Double fold (no.)	78	88 (12.8)	75 (-3.8)
Smoothness (ml/min)	145	136 (-6.2)	130 (-10.3)

unrefined and refined pulps at a dose level of 75 g/T and 75g/T respectively. The strength properties also improved with the exception of tear strength. It may be noted from the Table that the strength properties in two-stage treatment (with the exception of tear strength) were better in comparison to the single stage treatment. Another experiment was conducted in which unrefined and refined pulps were treated with Enzyme 5 at a dose level of 50 g/T and 50 g/T respectively. In this case, refining energy reduced by 12%, drainage improved by 14.5% and the strength properties were better in comparison to the single stage treatment.

The papermaker can take advantage of this in several ways, including the following: Lower refining energy to meet strength specifications, improved strength properties at equal refining energy, increase machine speed to produce more tons, decrease headbox or cylinder vat consistency for improved formation, increase refining energy for improved strength or lower basis weight. The two methods for adding enzyme can be combined for strength and drainage benefits. Keeping in mind that the enzyme is a catalyst, its function should continue from a pre-refining application into a post-refining effect. In other words, the enzyme should weaken the fiber walls prior to refining, then continue to work on the fibers, improving drainage after refining. By two-stage enzyme treatment, the new fiber surfaces created by refining can be treated with a fresh dose. This appears to be most effective in providing strength and drainage benefits.

CONCLUSION

Enzyme 5 appears to be better enzyme as compared to other commercially available enzymes like Enzyme 1, Enzyme 2, Enzyme 4 and Enzyme 3. It shows more saving in refining energy, better strength properties and requires lower dose (60% less). Two-stage enzyme treatment of pulp i.e. addition of enzyme to the refined and unrefined stock reduces refining energy and improves drainage and physical strength properties.

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