Biopolymer Treatment To Upgrade Fibre Quality Of Iocc Furnish For Strength Improvement Of Packaging Paper

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Abstract- Naturally occurring polysaccharides based biopolymer are known to improve strength of paper when used as additives. These may or may not be chemically modified. The mechanism of their contribution to improvement in dry strength arises from their capacity to become adsorbed to the cellulosic fibres and enhance bonding through formation of hydrogen bonds. The recycled fibre furnish which is known to have become hornified upon drying showing low water retention value compared to virgin fibre has been found to improve the bonding strength with the addition of biopolymers. This has also resulted in improving the Water Retention Value (WRV) when the pulp is subjected to refining with the addition of biopolymers. The paper highlights the findings to show how the biopolymer treatment improved the fibre quality of Indian OCC furnish, which is known to be a low grade furnish for packaging paper. The studies indicate an improvement in Water Retention Value (WRV) and fibre bonding potential tested as Zero Span Tensile Strength (ZSTS) resulting into improved end product quality in terms of paper strength.

Besides this the paper also highlights the effect of internal sizing, wet end chemicals and surface sizing on final product quality of biopolymer treated pulp as well its impact and improving the retention of fibre & fines.

INTRODUCTION

Cellulose fibre in its virgin state is porous in nature as summarised in early research works. During pulping alkali molecules diffuse through the complex micro capillary or nanosystem of the fibre until they reach the innermost layers of the fibre and react with them. Hence it becomes evident that the fine structure of fibres and the way, the fibre structure is opened by alkali penetration, influences the rate and extent of reaction. The same applies to degree of fibre swellability by water which affects the freeness and degree of conformation of fibres in paper sheet and consequently the paper strength.

In most industrial processes cellulose fibre is worked up in a water swollen state. In paper making also all operations up to the last stage of drying the paper sheet, the cellulose fibres remains swollen with water. For chemical conversion also the cellulose fibre have to be usually pre-swollen with water or other liquids before being subjected to chemical reaction. Therefore the fine structure of the swollen, water saturated fibres could have more bearing on fibre behaviour in papermaking and during chemical conversion than that of dry fibres. Accordingly the fine structure of fibres in the water saturated state has attracted the attention of research workers (Store and Scallan 1968). Density measurements were adopted for studying the fine structure of both the dried and never dried water-saturated states (Fahmy and Mobarak 1971) and the interpretation of densities in terms of fibre crystallinity and porosity was laid down. Water uptake can also be correlated to the pore volume of the swollen cell wall. Accordingly the Water Retention Value (WRV) was adopted in the present work for studying the fine structure of the swollen and dried cell walls.

Recycled fibre furnishes are termed as once dried cellulosic fibre furnish and are known to become hornified due to drying which means that upon drying the cellulosic micro pores are no more available for hydrogen bonding thus affecting the swellability of cellulosic fibre in aqueous state . In other words these furnishes are characterized with low Water Retention value (WRV).

Use of Polysaccharides based biopolymer viz. starch, gums etc have been found to be effective in improving the dry strength of paper. The mechanism of their contribution to improve dry strength arises from their capacity to become adsorbed to the cellulosic fibre and enhance bonding through formation of hydrogen bonds. Use of these biopolymers to form nanocomposites with OCC furnish has been found to be effective in improving the water absorbency by increasing the pore volume of cell wall. In the present investigation, biopolymers have been used as nanoadditives to improve the swelling properties of OCC furnish with an objective to improve the end product quality. Zero span tensile testing has been used as a tool to study the improvement in fibre-fibre bonding potential of these nanocomposites of Indian OCC furnish.

MATERIAL & METHOD

Material

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Fibre Furnish- The studies were conducted on Indian OCC furnish to assess the efficiency of biopolymers on improving the fibre bonding potential. Repulping is done using laboratory hydrapulper without any chemical treatment followed by slot screening through 0.20 mm slot.

Biopolymers- Three Biopolymers were selected which have been designated as: B-1, B-2 and B-3.

Testing Method

Water Retention Value (WRV)- The water retention value (WRV) test provides an indication of fibres ability to take up water and swell. The WRV is also highly correlated to the bonding ability of Kraft fibres .Tests were carried out using Refrigerated Laboratory Centrifuge Model -3-16PK of SIGMA ,Germany.

Zero Span Tensile Strength (ZSTS)- This test is used to measure strength of individual fibre and involves tensile strength test with small gap (0.4 mm) between the clamping jaws as possible. Measures fundamental property of fibres.

FS number- It is an index of average Fibre Strength expressed in Newton's per cm (N/cm) at standard basis weight. Any change in FS number indicates change in average fibre strength caused by mechanical degradation of fibre wall due to chemical or mechanical action (Refining).

Electrokinetic Properties- This includes testing of Cationic Demand in the present investigation. The Cationic demand of the paper making stock or process water equals the amount of highly charged Cationic polymer i.e. Poly-DADMAC required to neutralise its surface .The test was carried using Model PCD 02, Mutek, Germany and expressed as µeq./gm.

Burst Factor- It is an important property for packaging grades of paper and paperboard and is an indicator of sheet bonding. Bursting strength is the maximum pressure that paper can resist without breaking when force is applied perpendicular to the plane. Increase fibre length gives higher bursting strength but is more affected by fibre bonding. It is predominantly an internal sheet property.

Ring Crush Test (RCT)- Ring crush test is considered to be an important property for paperboards. It measures the resistance of paperboard to edgewise compression.

RESULTS AND DISCUSSION

In the present investigation, repulped Indian OCC furnish has been subjected to treatment with three different biopolymers with an objective to develop de-hornification effect on dried cellulose fibre of IOCC furnish. The purpose was to provide more bonding sites for hydrogen bonding thus improving fibre–fibre bonding potential. Structurally the biopolymers also provide bonding sites like cellulose fibre and making use of this chemical structure of biopolymers, nanocomposites of IOCC furnish were prepared having higher wettability Index.

The experimental plan included biopolymer treatment in the pulper and stock chest followed by application of wet end chemicals to study the impact of Dry Strength Resin (DSR), Wet Strength Resin (WSR), sizing chemicals and finally the overall effect on paper strength after surface sizing.

The performance of biopolymer treatment were assessed based on WRV, ZSTS tests and were correlated with strength properties evaluation. A correlation with electrokinetic properties has also been studied to assess the effect of biopolymer treatment on stock charge and overall strength.

1. Characterisation of Biopolymers

Table -1 summarises the characteristics of selected biopolymers used in the present study with respect to pH, surface charge measured as Zeta Potential (mV) and cationic demand.

Table-1
Characterisation of Biopolymers

Particular	B-1	B-2	B-3
pH	6.0	6.8	6.1
Surface Charge (mV)	-61 ***(anionic)***	-282 ***(anionic)***	-194 ***(anionic)***
Cationic demand, µeq/litre	11,186 ***(low)***	1,64,260 ***(high)***	1,69,760 ***(high)***

All the three selected biopolymers are anionic in nature. In terms of cationic demand two samples B-2 & B-3 showed high cationic demand in comparison to B-1.

2. Effect of Biopolymer Treatment on Fibre Properties during Pulper Addition

Table -2 summarises the findings of the study with respect to fibre strength, Zero Span Tensile Strength (ZSTS), Water Retention value (WRV) and burst factor. The biopolymers were added at 0.4% dosage in order to achieve the maximum benefit of addition towards improving fibre-fibre bonding.

The findings of Table-2 clearly indicate that biopolymers addition at pulper has been found to be beneficial in improving the WRV of IOCC furnish. The WRV improved by 9% after refining thereby resulting into improvement in Fibre Strength (FS) by 32%, Zero Span Tensile Strength (ZSTS) by 33% and burst factor by 6.6 units.

Table-2
Effect on Fibre Properties of Treated Pulp during Pulper Addition

Particular	Control	B-1	B-2	B-3	Overall improvement, %
Pulp freeness, CSF (ml)	380	380	370	410	**-**
Biopolymer dose, %	-	0.4	0.4	0.4	**-**
Fibre strength, N/cm	45	57	47	74	**32**
ZSTS, km	7.6	9.7	8.0	12.6	**33**
WRV, %	138	151	140	150	**9**
Burst Factor	19.7	26	26	27	**6.6 units**

3. Effect of Biopolymers Treatment on Fibre Properties of Treated Pulp during Stock Chest Addition

Table -3 summarises the findings of the study with biopolymer addition at stock chest. The result from Table-3 reveals that when biopolymers were added at stock chest more or less similar trend was observed. There has been an improvement of 14.5% in WRV value, leading to overall improvement of 31% in fibre strength, 22.3% in ZSTS value and 7.3 units improvement in burst factor.

Table-3
Effect on Fibre Properties of Treated Pulp during Stock Chest Addition

Particular	Control	B-1	B-2	B-3	Overall improvement, %
Pulp freeness, CSF (ml)	380	390	390	380	**-**
Biopolymer dose, %	-	0.4	0.4	0.4	**-**
Fibre strength, N/cm	45	63.5	54.2	55.5	**31**
ZSTS, km	7.6	9.4	9.2	9.4	**22.3**
WRV, %	138	150	155	151	**14.5**
Burst Factor	19.7	25.6	28.4	27.2	**7.3 units**

From the above findings it has clearly been found that the biopolymer treatment improves the quality of recycled fibre as evident by improved Water Retention Value (WRV) indicating opening up of more sites for hydrogen bonding.

4. Effect of Dry Strength Resins (DSR) and Wet Strength Resins (WSR) on Treated Pulp

Conventionally Dry Strength Resins (DSR) are added to the pulp stock to improve the strength of the paper. Therefore, further investigations were focussed on to study the effect of wet end chemicals like Dry Strength Resins (DSR) and Wet Strength Resins (WSR) on biopolymer treated pulp to further enhance the strength properties. The results summarized in Table-4 revealed that addition of Dry Strength Resins (DSR) in treated pulp marginally improved fibre strength and ZSTS value whereas bursting strength, which was not significant.

Table -4
Effect of DSR on Biopolymer Treated Pulp

Particular	B-1 Treated Pulp	B- 1 Treated Pulp + DSR + RA	Overall improvement, %	B-2 Treated Pulp	B- 2 Treated Pulp + DSR + RA	Overall improvement, %
DSR Dose, %	-	0.6	-	-	0.6	
Retention Aid dose, %	-	0.04	-	-	0.04	
Fibre strength, N/cm	45.3	46.1	**1.8**	47	48	**2**
ZSTS, km	7.7	7.9	**2.6**	8.0	8.1	**1.2**
Burst Factor	25	25	**Nil**	26	27	**1 unit**

Table-5 summarized the findings of adding Wet Strength Resin (WSR) to biopolymer treated pulp. The results indicate an overall improvement to 3-5% in fibre strength and Zero Span Tensile Strength and only 1 unit increase in bursting strength.

Table -5
Effect of WSR on Biopolymer Treated Pulp

Particular	B-1 Treated Pulp	B- 1 Treated Pulp + WSR + RA	Overall improvement, %	B-2 Treated Pulp	B- 2 Treated Pulp + WSR + RA	Overall improvement, %
WSR Dose, %	-	0.5	-	-	0.5	-
Retention Aid dose,	-	0.04	-	-	0.04	-

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%						
Fibre strength, N/cm	61.1	62.9	**2.9**	63.1	66.6	**5.5**
ZSTS, km	10.4	10.7	**2.9**	10.7	11.3	**5.6**
Burst Factor	26	27	**1 unit**	26	27	**1 unit**

The above result clearly indicates that addition of DSR & WSR to treated pulp has not resulted in significant improvement on overall strength of the paper.

5. Effect of Internal Sizing on Treated Pulp

Table-6 summarizes the findings of the study on effect of acid sizing and alkaline sizing on fibre properties and overall strength of the treated pulp. The results revealed that acid sizing adversely affect the fibre properties and overall strength of the final product in comparison to alkaline sizing, which restores the fibre properties attained with biopolymer treatment.

Table -6
Effect of Internal Sizing on Treated Pulp

Particular	Control	Treated Pulp	Overall improvement in Treated Pulp + (Acid Sizing)	Overall improvement in Treated Pulp + (AKD Sizing)
Pulp freeness, CSF (ml)	380	370	370	370
Biopolymer dose, %	-	0.4	0.4	0.4
Fibre strength, N/cm	42	51.8	49	51.9
ZSTS, km	7.12	8.8	8.3	8.8
Burst Factor	19.3	25 ***(+5.7 units)***	23 ***(+3.7 units)***	25.6 ***(+6.3 units)***

6. Effect of Surface Sizing on Treated Pulp

In order to study the effect of surface sizing with biopolymer on treated pulp, three different cases were studied and were compared with control pulp.

In first case treated pulp was subjected to acid sizing followed by addition of Dry Strength Resin (DSR) for strength improvement. In second case acid sized treated pulp was subjected to surface sizing with biopolymer and in third case Dry Strength Resin (DSR) was added to acid sized biopolymer treated pulp to study the overall effect on strength improvement after surface sizing. The studies were conducted on two furnish- 100% Indian OCC and 80/20 blend of IOCC and Tetra Pak carton (UTPC). UTPC is considered to be one time virgin fibre and have shown better properties. The findings of the study are summarized in Table-7 w.r.t. burst factor and RCT values.

The results indicate that the individual effect of acid sizing and Dry Strength Resin (DSR) is not effective enough in improving the bursting strength and RCT. On the contrary when the paper was surface sized with biopolymer, the bursting strength and RCT improved in 100% IOCC furnish. The furnish blend with 20% of good quality fibre have shown remarkable improvement to the tune of +7 and +9 units in bursting strength in comparison to non surface sized treated pulp containing PAC/ Rosin and DSR.

Table -7
Effect of Surface Sizing on Biopolymer Treated Pulp

Particular	100% IOCC		80% IOCC + 20% UTPC	
	Burst Factor	RCT, N	Burst Factor	RCT, N
Control	22.1	114	24.1	122
Treated pulp + PAC / Rosin + DSR	24.8 ***(+2.7 units)***	102↓ ***(-10.5%)***	26.5 ***(+2.4 units)***	114↓ ***(-6.5%)***
Treated pulp + PAC / Rosin + Surface sizing (BP)	28.4 ***(+6.3 units)***	122↑ ***(+7%)***	31.4 ***(+7.3 units)***	117↓ ***(-4.1%)***
Treated pulp + PAC / Rosin + DSR + Surface sizing (BP)	28.9 ***(+6.8 units)***	141↑ ***(+24%)***	31.2 ***(+9.1 units)***	126↑ ***(+3.3%)***

7. Effect of Biopolymer Treatment on First Pass Retention

Table-8 summarizes the findings of the retention studies. First Pass Retention was studied using Britt Dynamic Drainage Jar apparatus. The results indicate that treated pulp showed improved First Pass Retention to the tune of 96.5% and also improved fines retention.

Table -8
Effect of Biopolymers on Fines Retention and First Pass Retention (FPR)

S.No.	Parameters	Control	B-1	B-2	B-3
1.	Fines retention, %	-	50.0	48.1	20.5
2.	First Pass Retention (FPR), %	93.2	96.6	96.5	94.6

8. Comparative effect of Biopolymer Treatment on Electrokinetic properties of OCC furnish

Fig.1 gives an overview of cationic demand for the pulp stock in both the cases of biopolymer treatment. The results reveal that the cationic demand of control stock was 91.3 μeq/gm, which after treatment reduced to 24.7 μeq/gm with B-1 polymer in pulper treatment and between 50-60 μeq/gm in rest of two cases. This clearly indicates that the cationic demand of the pulp stock is reduced to an extent of 40% on an average.

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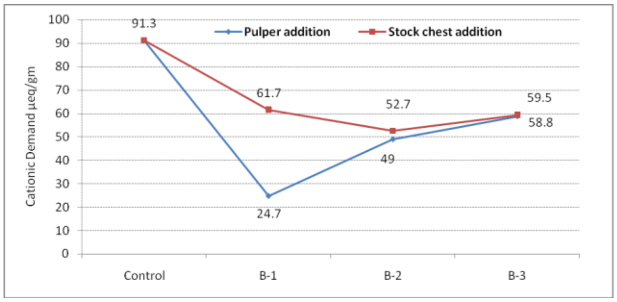

Fig.1- Effect on Cationic Demand of Treated Pulp

SUMMARY

- Due to hornification effect, the recycled fibres are characterised to have low Water Retention Value (WRV) in comparison to virgin fibre.

- CPPRI made an attempt to treat the RCF with Biopolymers to induce de-hornification effect through adsorption of biopolymers on cellulose fibre and thereby increasing pore volume of the cell wall.
- The studies have found that biopolymer treatment improves the swelling properties of IOCC furnish as evident by increased WRV %, which helps in opening up of new sites for bonding upon refining.
- The biopolymer treated pulp have shown remarkable improvement in Zero Span Tensile Strength (ZSTS) and burst factor.
- The studies also revealed that addition of synthetic polymers (Dry Strength Resins and Wet Strength Resins) improves the bursting strength by 1 unit only.
- The studies also indicated that acid sizing is detrimental improve the bonding properties in comparison to alkaline sizing, which restored the bonding strength of treated pulp.
- It is also established that surface sizing with biopolymers is mandatory to improve the overall bonding strength of the packaging paper.
- Biopolymer treatment is also advantageous in decreasing the cationic demand of the stock leading to reduced generation of anionic trash.
- The criteria for biopolymer selection-biopolymer in native form with high anionic surface charge are suitable for treatment to improve swelling property of pulp stock.

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