Effects of Chitosan as Dry and Wet Strength Additive in Bamboo And Acacia Pulp

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ABSTRACT

Chitosan was evaluated as a wet and dry strength additive in laboratory produced bamboo and *acacia auriculiformis* kraft bleached pulps. Chitosan was found to increase the wet strength. Tensile, burst and tear index were also found to increase up to 0.5 -1 % chitosan addition in both pulps. The effects of chitosan depend on the pH of the stock. The best results were observed at pH 10 for bamboo pulp and pH 7 for acacia pulp.

Keywords: Paper additive, Chitosan, Wet strength, Dry strength, pH,

Introduction

It is established fact that paper fibers are held together by hydrogen bond (1-4). These bonds affect the distance between the separate cross linking fibers. A large excesses of free water weakevs the paper, which is manifested by the wet strength of paper (3). So the efficiency of paper machines is significantly reduced by sheet breaks at the machine wet end (5-6). To improve this low strength, a number of polymeric materials have been applied. These include cationic starch, cationic polyacryl amide, urea, etc. Each of those must facilitate the interfiber bonding areas to remain chemically linked in the presence of water, otherwise they would not be functional. Therefore, a furnish additive which would increase the wet-web strength, that is the strength of the freshly-formed sheet as it proceeds through the wet end of a paper machine. It would also improve paper machine runnability. But a number of these synthetic additives are non-biodegradable and may cause environmental problems and some pose occupational health and safety risks to paper industry workers (7). It was clearly proposed by Allan et al. (2) that the following feature should possess good strength additive for paper. These include:

1) Be soluble in water-based systems for easy application with conventional papermaking systems.
2) Be substantive to cellulose so that retention is efficient.
3) Be compatible with the cellulose surface so that it doest not disrupt conventional hydrogen bonding.
4) Be film-forming (of large enough Mw) to offer adhesive resistance to rupture.
5) Contain a functional group capable of ionic or covalent bonding with the paper fiber surface within the papermaking process.
6) Be nontoxic and preferably natural (thus biodegradable) to conform to environmental regulations (no problem in paper recycling).

Such numerous requirements are met by chitosan.

It is chemically modified natural polymer, which is also identified as a potential dry and wet strength additive in papermaking (8-9). Chitosan, a biodegradable, nontoxic, antibacterial, as well as renewable resource, commodity, is the second most widespread natural polysaccharide and is composed of poly[(1/4)-2-acetamido-2-deoxy-b-(D-glucopyranose] and [b-(1/4)-2-amino-2 deoxy-b-D-glucopyranose] (10-11). Its structure is therefore very similar to that of cellulose and it is easily absorbed onto the cellulosic surfaces owing to steric factors and chemical affinity (Fig. 1). So this may improve the physicomechanical properties of paper (12-14).

In this paper, we evaluated chitosan as wet and dry strength additive in bamboo and *acacia auriculiformis* pulps at different pH ranges.

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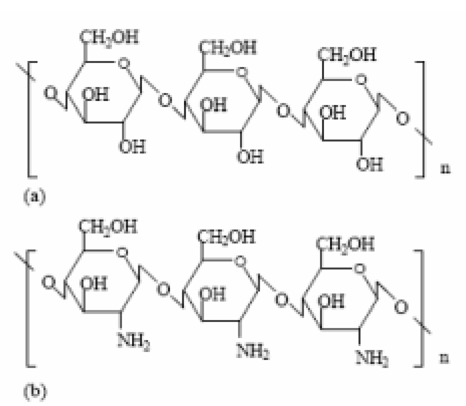

Fig. 1. Molecular structures of: (a) cellulose; (b) chitosan

Experimental

Bleached pulp is used for this study. Bamboo and acacia pulps were prepared in laboratory by kraft process followed bleaching by DED sequences. Pulps were beaten in valley beater. The chitosan was collected from Chemical Research Division, BCSIR. A solution of chitosan was prepared at room temperature by magnetic stirring for 1 h, 1 % dry material in 1 % aqueous acetic acid and filtering off the small amount of non-soluble material. The solution becomes transparent. Chitosan solution was added to a 1 % pulp suspension at pH 5, 7 and 10. The mixture was agitated for 60 min at 50 °C then diluted with deionised water to 0.5 % (15). The pulp suspension was basified by 0.5N NaOH.

Evaluation of pulps

The hand sheets of about 60g/m^2 were made in a Rapid Kothen Sheet Making

Machine. The sheets were tested for wet tensile strength (T456 on 03), tensile (T 494 om-96), burst (T 403 om-97), tear strength (T 414 om-98), folding endurance (T 511 om 96) and brightness (T525 om 92) according to TAPPI Standard Test Methods.

Results and discussion

Effects of chitoson addition at different pH on SR number, wet-tensile strength and dry strength properties of bamboo and acacia pulps are shown in Tables 1 and 2. The properties of paper sheets without chitosan are shown in zero point.

Table 1. Pulp freeness, wet web strength and papermaking properties bleached bamboo pulp with chitosan at pH 5, 7 and 10.

pH	Chitosan addition	°SR	Wet-tensile strength	Tensile index	Burst index	Tear index
	0.0	30	1.7	21.5	2.2	9.9
	0.5	34	5.9	27.0	4.9	10.2
5	1.0	36	5.7	19.2	4.0	10.6
	2.0	39	5.6	19.6	2.6	9.3
	3.0	39	5.8	19.4	2.2	9.2
	4.0	41	5.7	19.5	2.3	8.8
	5.0	42	5.6	18.0	1.9	8.5
7	0.0	31	1.9	26.1	2.7	9.2
	0.5	34	6.9	26.9	2.9	11.2
	1.0	35	6.7	21.3	2.4	10.0
	2.0	33	6.8	23.1	2.3	9.8
	3.0	38	6.5	23.2	2.0	9.3
	4.0	37	6.3	22.0	1.9	9.1
	5.0	39	6.4	21.1	1.9	8.2
10	0.0	31	1.9	29.3	2.7	9.1
	0.5	35	7.0	31.1	2.9	10.8
	1.0	36	6.9	31.0	2.7	11.7
	2.0	38	6.9	26.8	2.8	12.0
	3.0	38	6.8	26.7	2.4	10.0
	4.0	40	6.7	23.9	2.2	8.8
	5.0	41	6.5	23.1	1.9	8.2

Table 2. Pulp freeness, wet web strength and papermaking properties bleached acacia pulp with chitosan at pH 5, 7 and 10.

pH	Chitosan addition	°SR	Wet-tensile strength	Tensile index	Burst index	Tear index
	0.0	35	2.8	28.9	3.0	2.8
	0.5	37	4.4	31.7	3.3	3.7
5	1.0	37	4.8	31.2	4.9	3.6
	2.0	38	4.9	31.5	3.3	3.3
	3.0	39	4.8	33.7	3.3	3.4
	4.0	41	4.8	33.1	3.1	3.5
	5.0	41	4.7	31.0	3.0	3.5
7	0.0	36	2.7	33.1	3.0	3.0
	0.5	38	3.7	36.3	3.4	3.5
	1.0	37	5.3	33.4	5.1	3.3
	2.0	39	5.5	27.4	5.0	3.3
	3.0	41	5.4	27.2	4.1	3.0
	4.0	40	4.7	27.6	3.6	3.0
	5.0	42	4.6	26.7	3.5	2.8
10	0.0	37	3.7	28.1	3.1	3.0
	0.5	39	4.2	36.9	3.9	3.3
	1.0	39	4.2	39.7	5.2	3.5
	2.0	40	5.1	39.9	4.1	3.2
	3.0	41	4.8	36.1	4.0	3.3
	4.0	40	4.7	33.4	3.5	3.1
	5.0	42	4.7	33.0	3.3	2.9

Drainage resistance (SR)

It is clearly seen that chitosan addition increased pulp SR value at any pH. The higher SR value (drainage resistance) for the chitosan treated pulp was probably due to a higher viscosity of white water caused by the portion of chitosan which was not absorbed by pulp fibers. The SR value increase was 8-12 for bamboo and 5-6 for acacia pulp with the addition of chitosan (Tables 1 and 2). Similarly higher drainage resistance of chitosan added pulp was observed by Laleg and Pikulik (15).

Wet tensile strength

Wet tensile strength of bamboo pulp was significantly improved with chitosan addition at any pH. Without chitosan addition to pulp, the wet tensile strength was 1.7 mN.m/g, while for 0.5 % chitosan addition, wet tensile strength increased to 5.9 mN.m/g at pH 5. Further increase of chitosan percentage, wet tensile strength did not increase. The wet tensile strength was increased with the increase of pH value (Fig. 2). At 0.5 % chitosan, wet tensile

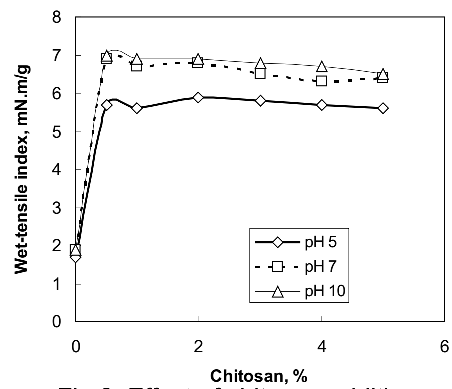

Fig 2. Effect of chitosan addition on the wet tensile strength of bamboo pulp at different pH

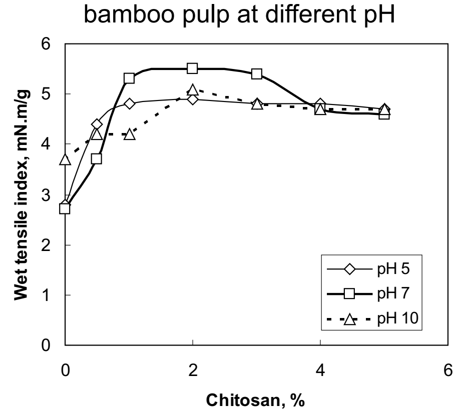

Fig. 3. Effect of chitosan addition on the wet tensile strength of acacia pulp at different pH

strength was increased about 17 and 19 % with increasing pH 7 and 10, respectively. Similar behavior was observed for acacia pulps as shown in Table 2. At pH 5, 1.6 mN.m/g wet-tensile strength was increased with the addition of 0.5 % chitosan. Further increase of chitosan addition, wet-tensile index increased slightly. Wet-tensile strength was increased slightly with the increase of pH value to 7 at the chitosan addition range of 1-3 %. Further increase of pH, wet-tensile strength did not increase (Fig. 3). The lower wet-web strength of paper sheets at higher levels of chitosan might, in part, be due to the damage the light basis weight sheets suffered when peeled from the blotter. Similar observation was observed by Laleg and Pikulik (15). Alternatively, 0.5 % and 1.0 % chitosan addition might be the optimum fiber surface coverage for interfiber bonding for bamboo and acacia pulps, respectively.

Tensile index

Figures 4 and 5 show the effect of chitosan addition on the tensile index of

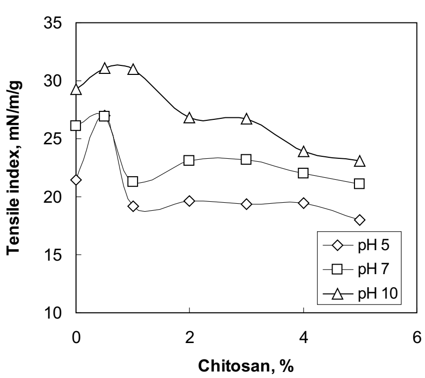

Fig. 4. Effect of chitosan addition on the tensile index of bamboo pulp at different pH

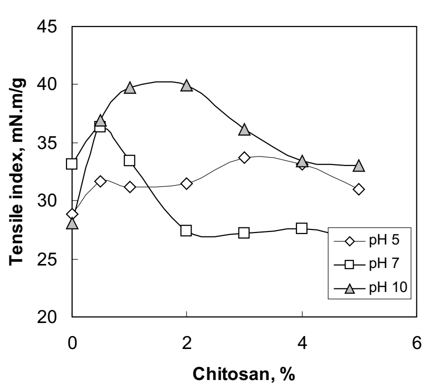

Fig 5. Effect of chitosan addition on the tensile index of acacia pulp at different pH

bamboo and acacia pulps. The tensile index was increased with the addition of chitosan up to 0.5 % then decreased with further addition of chitosan in all pH ranges. This may be due to complete adsorption of chitosan onto the fiber surface at 0.5 % addition. Li et al (16) showed that the chitosan additive was almost completely adsorbed onto the surface of cellulosic fibers, especially onto the surface of fines at low dosages. Authors also observed that adsorption increased as the degree of deacetylation of chitosan increased. Best tensile index was observed in alkaline range (pH 10). Acacia pulp had almost similar tensile index at pH 7 and 10. At pH 10, tensile index of bamboo pulp increased by 19 % and acacia pulp by 31 % with the addition of 0.5 % chitosan. Ramachandran (17) observed that the paper containing chitosan was at least 5 % greater tensile strength than the similar paper without chitosan. It is assumed that the strongest interaction between the anionic groups of cellulose and the cationic groups of chitosan occur at this pH range.

Burst index

Figures 5 and 6 show the effect of chitosan addition on the burst index of bamboo and acacia pulp. Addition of 0.5 % chitosan caused a 1.1-fold increase of burst index for bamboo pulp and 2.2-fold increase for acacia pulp at pH 5. Further increase of chitosan caused a decrease of burst index in both pulps. Bonding dependent properties of chitosan added pulp were improved may be due to the retention of fines. The retention of fines has also been found to be improved by the addition of chitosan at the wet-end (16).

Tear Index

As shown in Tables 1 and 2 the tear index of bamboo and acacia pulps increased when chitosan was added to the stock up to 0.5 %, further increase of chitosan addition to the stock did not increase tear index. The pH of the stock did not affect tear index of these pulps.

The improvement of dry handsheets tensile, burst and tear (Tables 1 and 2) indicates that the precipitated chitosan contributed to the interfiber bonding. A large strength increase was achieved with the first 0.5 % of chitosan. Surface treatment of printing paper with a 1 % solution of chitosan in acetic acid has also been reported to improve the strength properties (18). Nada et al (19) also observed that the addition of chitosan or its derivatives during paper sheets formation caused an improvement of the mechanical properties. The improvement obtained by addition of chitosan derivatives is less than that produced by the addition of chitosan itself.

Conclusions

Addition of chitosan to stock achieves an improvement in the wet and dry strength properties of paper sheets. The effect of chitosan on properties of paper depends strongly on the pH of the furnish. The best improvement of the wet and dry strength is achieved at alkaline pH. It is assumed that the strongest interaction between the anionic groups of cellulose and the cationic groups of chitosan occur at this pH range. Addition of higher percentage of chitosan decreased dry strength properties.

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