Utilization of Starch in Paper Industry

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Abstract

Starch has been one of the most important wet end additives used in paper industry. Basically, it was used as beater additive to substitute for refining time, thus saving equivalent energy. Besides its use as beater additive it was also observed that, addition of starch enhances physical properties such as bursting, tearing, tensile and folding endurance of paper. The properties of starch could be considerably enhanced by physical and chemical modification. In the present work, starch has been chemically modified in the form of cationic starch and its effect on strength properties of sheets made from rice straw, wheat straw, bagasse and waste paper were studied.

INTRODUCTION

Starch is one of the cheapest and most widely used materials in the paper making processes such as sizing and coating of paper and wet end additives. The starch, which is based on renewable agricultural resources, has the advantage of a measure of stability in cost and supply; and being nontoxic and biodegradable. Traditionally starch is added to improve interfibre bonding, however chemical modification of starch has extended the range of functions to include improvement of drainage and retention and even to some degree an improvement in wet strength.[1]

Modifying them into ionic starches, such as cationic, anionic and ampholytic, can extend the properties of native starch. Ionic derivatives of starch are extensively used for application that involve strength, retention and drainage. The objective of the present work is to study the effect of addition of cationic starches in the furnish obtained especially from the various agricultural residues such as rice straw, wheat straw, bagasse etc. on the retention of loading and filling material and physical strength properties of the standard sheets obtained from these raw materials.

EXPERIMENTAL

Preparation of pulps from agricultural residues and waste paper

Different pulps were made from various agricultural residues such as rice straw, wheat straw, bagasse, waste newsprint paper and waste corrugated boxes. The details of cooking conditions and making pulps from these agricultural residues and waste paper are shown in Table 1.

Preparation of cationic starch

There are several methods of preparation of cationic starch (Modified starch). In the present work the cationic starches were prepared by following methods.

Table 1. Details of preparation of pulps from agricultural residues and waste papers.

Particulars	Newsprint waste paper	Rice starw	Wheat straw	Bagasse	Waste corrugated box
Wt. of Raw material gms	1000	500	500	500	1000
Wt of Sodium Hydroxide gms	50	50	50	50	100
Liquor to Raw Material Ratio	10:1	10:1	10:1	10:1	10:1
Time for Cooking at 90 PSI in hrs.	-	1.5	1.5	2	-
Time for Hydra Pulping in min.	30	-	-	-	60
Yield %	86%	47%	49%	43%	90%
Beating of pulp					
Time for beating min.	-	90	90	120	-
Consistency in Beater, %	-	3	3	5	-
9. Freeness of Pulp, °SR	45	45	47	44	47

Preparation of cationic starch (A) by using diethyl amino ethyl chloride

A mixture of water (200ml), sodium sulphate (60 gms), sodium hydroxide (5 gms) and starch (100gms) was stirred in a 500ml beaker at 50°C for 30 mins. the reagent 2- diethyl amino ethyl chloride (DEAEC, 3 gms) was added to the mixture and stirring of mixture was continued at 55°C for 2 hours. The mixture was cooled, filtered and washed with ice cold water, till it was free from sulphate ions and dried at 60°C, in an oven, cooled and weighed.

Weight of cationic starch obtained = 122gms.

Yield = 73.9%

Preparation of cationic starch (B) by using epichlorohydrin[3]

Water (35gms) and glacial acetic acid (2.4 gms) were taken in a 250-ml beaker. To this 25% water solution of trimethyl amine was added until the pH of the mixture reached 8.5. Epichlorohydrin (3.7 gms) was added to the above mixture and the mixture was allowed to react for one hour at 35°C the pH of the mixture was 7.9 at the completion of the reaction.

25% of aqueous solution on trimethyl amine (4 gms) was added to the mixture in (2), the pH of the mixture was adjusted to 8.5, and the mixture was reacted for additional hour at 35°C. The pH of the mixture was 7.9 at the end of the reaction.

In this manner, the reagent comprising the reaction product of the acetate salt of trimethyl amine and epichlorohydrin was prepared. The reaction product was substantially free of unreacted epichlorohydrin. Sodium hydroxide (0.55gms) and the sodium sulphate (5 gms) were dissolved in water (25ml) and in this mixture, the reagent product 18 gms was added. At this point the pH of the mixture was 12.2. The mixture was reacted in a reaction vessel, at 35°C for 2 hours. The starch (30gms) was

added to the reaction vessel, the pH at this stage was 11.2. The temperature of the reaction vessel was adjusted to 45°C and mixture was heated for 17 hours. The starch was then neutralized with HCl to pH 5.78 dried and weighed.

Weight of cationic starch B obtained = 28gms

Yield = 77.7%

Apart from these two cationic starches A and B the cationic starch C (available in the market) was used for comparison. Results of analysis of these cationic starches A, B and C are shown in Table 2.

Standard 60 gsm sheets from different pulps were prepared on standard sheet making machine (as per TAPPI standards[5]) using rosin soap 3%, talc 5%, alum 4.5% (on O.D. weight of pulp). The sheets without and with the addition of starch were prepared under identical conditions. The results of the effect of addition of starch on the physical properties of sheets prepared from rice straw, wheat straw, bagasse, waste newsprint paper, and waste corrugated

Table 2. Analysis of cationic starch A, B and C

Modified starch	Moisture Content %	Ash Content %	Nitrogen[4] Content %
Cationic starch-A (Prepared by using DEAEC)	12.8	1.4	7.5
Cationic starch B (Prepared by using epichlorohydrin	10.9	1.3	7.9
Cationic starch C Available in market	10.2	1.2	8.1

Table 3. Effect of addition of different starch on physical properties of sheets from rice straw.

S. N.	Test	Without starch blank	Natural starch	Cationic starch A		Cationic starch B		Cationic starch C	
			1%	1%	1.5%	1%	1.5%	1%	1.5%
1	Burst index	2.36	2.47	2.76	3.1	2.85	3.26	2.82	3.33
2	Double fold for 250 g	6	7	8	11	22	28	24	30
3.	Tensile index	2.11	2.24	2.27	2.68	2.42	2.84	2.40	2.85
4.	Tear index	5.2	5.39	6.70	6.94	7.18	8.06	7.2	8/09
5.	Ash content, %	7.6	7.6	7.6	7.7	7.6	7.7	7.6	7.7
6.	Drainage time, secs.	8	9	9	11	9	11	9	11

Note: Addition of rosin soap 3%, Talc 5% and alum 4.5% (on o.d. basis of pulp) were common to all sheets.

Table 4. Effect of addition of different starch on physical properties of sheets from wheat straw.

Test Without starch	Natural blank	Cationic starch	Cationic starch A		Cationic starch B		Cationic starch C	
		1%	1%	1.5%	1%	1.5%	1%	1.5%
Burst index	2.41	2.86	2.75	3.26	2.86	3.33	2.82	3.33
Double fold for 250 g	5	6	11	15	22	28	24	30
Tensile index	2	2.14	2.21	2.49	2.34	2.75	2.37	2.75
Tear index	5.4	5.68	5.71	6.37	6.2	6.69	6.37	6.82
Ash content, %	7.2	7.2	7.2	7.3	7.3	7.3	7.3	7.4
Drainage time, secs.	8	9	9	11	9	11	9	11

Note: Addition of rosin soap 3%, Talc 5% and alum 4.5% (on o.d. basis of pulp) were common to all sheets.

Table 5. Effect of addition of different starch on physical properties of sheets from bagasse pulp.

Test	Without starch blank	Natural starch	Cationic starch A		Cationic starch B		Cationic starch C	
		1%	1%	1.5%	1%	1.5%	1%	1.5%
Burst index	1.3	1.42	1.62	1.98	1.65	2.1	1.70	2.1
Double fold for 250 g	7	10	12	16	12	17	13	18
Tensile index	2.39	2.6	2.73	2.83	2.83	3.17	2.75	3.0
Tear index	6	6.52	7.85	8.35	8.09	8.82	7.84	8.48
Ash content, %	3	3	3.0	3.09	3.1	3.09	3.0	3.1
Drainage time, secs.	10	11	12	11	12	11	11	12

Note: Addition of rosin soap 3%, Talc 5% and alum 4.5% (on o.d. basis of pulp) were common to all sheets.

boxes are shown in Table 3, 4 5, 6, and 7 respectively.

RESULTS AND DISCUSSION

It was evident from Table 3 that cationic starch A and cationic starch B enhanced the burst index by 16.9%, and 20.7% at 1% addition level; and 31.3%, 38.1% at 1.5% addition level respectively. It also enhanced the tensile index by 7.58% and 14.69% at 1% addition level and 27.01% and 34.59% at 15% addition level respectively. Similarly increase in tear index is found by 28.8% and 38% at1%

Table 6. Effect of addition of different starch on physical properties of sheets from waste straw newsprint.

Test Without starch	Natural blank	Cationic starch	Cationic starch A		Cationic starch B		Cationic starch C	
		1%	1%	1.5%	1%	1.5%	1%	1.5%
Burst index	2.33	2.67	3.0	3.10	3.0	3.55	3.05	3.37
Double fold for 250 g	4	6	7	16	19	25	16	22
Tensile index	2.18	2.26	2.34	2.72	2.34	2.80	2.28	2.72
Tear index	5.46	5.63	5.96	7.35	6.2	8.1	6.3	7.84
Ash content, %	7.5	7.6	7.6	8.1	7.9	8.2	7.6	8.1
Drainage time, secs.	10	12	12	13	12	13	12	13
Note: Addition of rosin soap 3%, Talc 5% and alum 4.5% (on o.d. basis of pulp) were common to all sheets.								

Table 7. Effect of addition of different starch on physical properties of sheets from waste corrugated board.

Test Without starch	Natural blank	Cationic starch	Cationic starch A		Cationic starch B		Cationic starch C	
		1%	1%	1.5%	1%	1.5%	1%	1.5%
Burst index	1.61	1.97	2.10	2.5	2.15	2.63	2.23	2.64
Double fold for 250 g	5	6	6	12	20	26	24	28
Tensile index	2	2.14	2.21	2.49	2.34	2.75	2.38	2.76
Tear index	5.49	5.71	5.73	6.4	6.22	6.72	6.38	6.81
Ash content, %	7.4	7.6	7.6	7.67	7.5	7.61	7.38	7.81
Drainage time, secs.	10	11	11	12	11	12	11	12
Note: Addition of rosin soap 3%, Talc 5% and alum 4.5% (on o.d. basis of pulp) were common to all sheets.								

addition level and 33.4% and 55% at 1.5 addition level respectively. Similarly folding endurance has been tremendously increased by the addition of cationic starch. These values are comparable when commercial cationic starch C was used. It was also observed that the cationic starch is more effective than unmodified natural starch. It is use to the fact cationic starches have the advantage of high degree of dispersion because of the repulsive effect of the charged substituents and high retention. Cationic starch contributes to the formation of additional fibre-fibre bonds as a result of anionic fibres being forced together thereby increasing the retention of fibre fines. The higher retention of cationic starches

Table 8. Percentage increase in physical strength properties of standard sheets of different raw materials prepared by the addition of different starch

Raw material	Cationic starch	Burst index		Tensile index		Tear index	
		1%	1.5%	1%	1.5%	1%	1.5%
Rice straw	A	16.9	31.3	7.58	27.01	28.8	33.4
	B	20.7	38.1	14.69	34.58	38.0	55.0
	C	19.5	41.1	13.74	35.07	38.4	55.5
Wheat straw	A	14.1	35.3	10.5	24.5	5.74	17.9
	B	18.6	38.1	17.0	37.5	14.8	23.9
	C	17.0	38.0	18.5	37.5	17.9	26.2
Bagasse	A	24.6	52.3	14.22	18.41	30.8	39.1
	B	26.9	61.5	18.41	32.63	34.8	47.0
	C	30.7	61.5	15.06	25.52	30.6	41.3
Waste newsprint	A	28.7	33.0	7.34	24.77	9.2	34.6
	B	28.7	52.3	7.34	28.44	13.5	48.3
	C	30.9	44.6	4.58	24.77	15.4	43.6
Waste Corrugated Board	A	30.4	55.3	10.5	24.5	4.4	16.6
	B	33.5	63.3	17.0	37.5	13.3	22.4
	C	38.5	63.9	19.0	38.0	16.2	24.0

relative to unmodified starch provides an overall economic gains in terms of physical strength and retention. Slightly it reduces the drainage rate. In addition, economic need to reduce the quantity of fines and fillers in the effluents from the paper machine provides a strong incentive for usage of such products.

The results tabulated in Table 4, 5, 6 and 7 is a case of wheat straw, bagasse, waste newsprint and waste corrugated board respectively shows that the addition of cationic starch A, cationic starch B enhance the bursting strength, folding strength, tensile strength and tearing strength considerably.

The comparative percentage increase in physical strength properties of standard sheets of different raw materials are given in Table 8.

CONCLUSION

The cationic starch B prepared by using epichlorohydrine appears to be more effecitve in enhancing the physical properties of standard sheets prepared from different raw materials.

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