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Bagasse Packaging Board by Cold Soda Pulping Methods

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Abstract

Bagasse was cooked in plastic bag or in autoclave using cold soda pulp method with/without NH_4NO_3 at different degrees of temperatures and different periods of times. The pulping liquor was in the ratio of 1:6 based on bagasse. The effect of pulping processes variables was investigated. Bagasse produced acceptable unbleached pulp at 80 ^oC in plastic bag and at 105 ^oC in autoclave, with different yield % from 43 % - 61%. The mechanical and physical properties of bagasse pulp sheet using different concentrations ratios of starch and/or borax as added filler during sheets making were investigated. The prepared sheets have been characterized by breaking length, tear index, burst index density and air permeability tests. Starch and/or borax filler added during sheet making improved the mechanical and physical properties of bagasse pulp sheet.

Keywords: Bagasse, pulping, mechanical properties, air permeability, packaging.

Introduction

The global demand for market pulp increase by the year. Most of the world pulp production is based on wood. Thereby non-wood pulp contribute only8% to the world pulp market while there was large amount of non- wood fibre sources also available including agriculture residue such as bagasse, straw, corn, sorghum stalks, bamboo, reeds and grasses[1]. It is expected that the percentage of utilization of agricultural residues for global paper and board manufacture will gradually increase to at least 10 % for the near future[2].

Bagasse as non - wood fibers was suited for the smaller mills required for the limited markets in developing countries. The main advantage of bagasse for this application is its ready availability as a residue in a clean condition from sugar industry[3]. New pulping technology which is environmentally friendly in addition to diversification of the raw material to non wood sources are seen as alternative to many problems. High yield pulp require lower capital cost of the paper mills and have low environmental impact associated with their manufacture, as no or little chemicals are used[4]. Additionally, the high yield results in roughly twice the pulp produced per ton of raw material as compared to chemical pulps[5]. Successful chemical pretreatment of bagasse is the most important step before chemi-mechanical pulping process. The pretreatment step results in a softening of the fiber structure, so as facilitates refining, save energy and improve strength properties[6]. Jahan et al., study the effect of hot water pre-extraction of bagasse prior to pulping and he found that drainage resistance was improved without affecting papermaking properties. However, pulp yield dropped slightly[7]. The effect of hot-water and alkaline pre-extraction of rice straw on soda-anthraquinone pulping was also carried out[8]. One of the commonly used chemicals in the treatment of bagasse prior to refining is sodium hydroxide. Pulping of bagasse chemically and mechanically has been the subject of investigations for making different varieties of paper[9,10,11]. Recently, new pulping methods were investigated with the aim of reducing the used chemical that causes an environmental pollutant. Pulping selectivity is the other main goal to attain lignocellulosic components in a non-degraded form[12,13]. Cold soda pulping involves the treatment of the raw material with sodium hydroxide at atmospheric conditions and up to 100°C, followed by mechanical defibration or refining[14]. The most common renewable packaging materials are cellulose-based, including corrugated board, paperboard and paper. Up to 40% of all packaging is based on paper and paperboard, making it the largest packaging material used[15]. However plain papers have usually poor heat sealing properties and poor barrier properties and therefore find fewer applications. These properties could be improved by different ways[16]. The process of adding mineral fillers to paper stock prior to the formation of the sheet has been practiced to improve process economics or to provide desired functional or end-use properties of paper products. Starch and borax are of the most widely used in paper industry fillers[17].

This study aims to prepare bagasse pulp at low temperature. The effect of sodium hydroxide pretreatment and some chemical pulping additives as ammonium nitrate on pulping process was investigated. Improvement of pulp for packaging application by using starch and borax is another goal.

Material and Methods

Pulping: 100gm of oven dry dipithed bagasse was cooked in plastic bag at atmospheric pressure and using of NaOH, the liquor ratio between raw material and cooking liquor was 1:6.

The pulping process was investigated by five methods: i. Bagasse was cooked using NaOH solution at three charges of 0%, 10% and 15% (based on solution) at room temperature for 4 days. ii. In addition bagasse was cooked using mixture of 10% NaOH and NH_4NO_3 in ratio of 1: 1.4 (based on solution) for 4 days at room temperature. iii. Bagasse was cooked by 10% and 15% NaOH (based on oven dry raw material) at room temperature for 9, 16, 21, 60 and 120 days. iv. Bagasse was cooked at 80^{o}C using 4% alkali for 2,3,4 and 5 hours. v. Bagasse pretreated by hot water at 100^{o}C for 1h then cooked by 3% NaOH (based on solution) at 105 ^{o}C for 1h. Also pretreated bagasse was cooked by mixture of 4% NaOH and NH_4NO_3 (5:1) (based on solution) at 105^{o}C.

Preparation of laboratory hand-made paper sheets[18]: Pulp beating: After soaking in water for 24 h, pulp samples were beaten in Valley beater. The beating process was at 2% pulp consistency. At the end of the beating, the stock was processed in disintegrator then the degree of the Schopper Riegler SR was determined.

Sheet formation: Paper sheets were prepared according to Tappi standard method using the sheet former AB Lorentzen and Wettre (Stockholm, Sweden).

Treatment of paper sheets using different fillers: Bagasse pulp was treated with different concentrations of starch and/or borax during making sheets.

Characterization of paper sheets: The sheets were tested for tensile strength according to German Standard method by means of a Karl Frank 468 tester (Weinheim–Berkenau) and burst strength according to TAPPI Standard test method 403.A.Mullen (Perkins, Chicopee, MA, USA) was used. The tearing resistance was measured according to Tappi, standared 414 by means of an Elmendorf Tearing Tester (Thwing-Albert Institute Co., Philadelphia, U.S.A.) The Air permeability test was carried out on BENDTSEN Smoothness and Porosity Tester, made in denemark, Model 5, No. 11772, andersson and sørensen, ccopenhagn.

Density of the papers was calculated from the relation between the sheets basis weight and its thickness. Density (kg/m^3) = Basis weight (g/m^2)/ thickness in mm

Results and Discussion

Pulping of bagasse at room temperature: In a previous studies good pulp was successfully prepared from bagasse by soaking it with sodium hydroxide followed by beating[6,14]. Now, a trial was carried to prepare bagasse pulp without mechanical action (beating) by using higher sodium hydroxide concentrations or longer soaking time. Different concentrations of sodium hydroxide (up to 90% to bagasse) and longer soaking time (up to four months) at room temperature was failed to give a satisfied pulp without beating even in presence of some chemical pulping additives (as NH_4NO_3).

Table (1): shows the effect of 4% NaOH solution on pulp yield during bagasse pulping in plastic bag at liquor ratio (1:6) based on bagasse and pulping temperature 80^{0}C for different periods of pulping time (2, 3, 4 and 5 h). From the table, it is clear that good pulp with reasonable yield could be obtained after 2h pulping and the pulp obtained after 3h is the economic pulp because of the low energy and time of the pulping process with higher screened yield.

Table-1
Effect of time on pulp yield of bagasse

Pulping time (h)	2	3	4	5
Yield %	46.8	48.9	43.4	48.9

4% NaOH solution, liquor ratio (1:6) at 80^{o}C.

Table (2) shows the effect of temperature and NH_4NO_3 addition during NaOH pulping of bagasse. The pulping process under mentioned conditions gave good pulp, but pulping in autoclave at 105^{o}C took only 1h and gave 57.5 % pulp yield while pulping in plastic bag at 80^{o}C take 3h and gave 48.9 % pulp yield. Much more 3% increase in pulp yield could be attained by NH_4NO_3 addition during NaOH pulping of bagasse. Schopper Riegler degree (°SR) after beating time 20 minutes was 36-38 °SR for the obtained pulp.

Pulping in autoclave at 105^{0}C instead of plastic bag at 80^{o}C increases the mechanical and physical properties (Burst Index and Breaking length) by about 25 and 12 % respectively, while Tear Index decreases by about 20%. Additional 25 and 12 % improvement in those properties was attained by NH_4NO_3 addition during pulping, but also Tear Index decreases by about 20%.

Effect of some additives on paper properties: Effect of Starch and/or Borax as filler added during making sheets. The effect of using different ratios of starch and /or borax at 2% concentration added during sheets making was investigated. The mechanical and physical strength results are given in table (3).

Table (3) shows the relationships between mechanical properties of hand-sheet paper (breaking length, burst index and tear index) with borax/starch additives. Mechanical properties, especially burst index are sensitive to the degree of hydrogen bonding within the fibers but tear index, is more sensitive to fiber length and fiber strength. Hand sheet papers made by adding 1% starch + 1% borax at the same time have superior mechanical properties. This may be due to that mineral filler filled pores and the organic filler forms hydrogen bonds with cellulose chains of bagasse. It could be also noticed that borax is superior to starch as additive when used alone or when used at first addition in mixed additives.

Table (4) shows the relationships between mechanical properties of hand-sheet paper (breaking length, and tear index) with borax/starch additives at different concentrations. It is clear that increasing the percent of both starch and borax up to 1% (based on o.d. pulp) improves these properties by good percent reached to 30.5% for breaking length and 30.9 %for tear index.

The higher fillers ratios 1:4, 4:1, 4:4 and 2:4 have no pronounced effect. There are disadvantages due to the use of too much mineral filler. It is known that high loading levels of mineral fillers in papermaking reduced paper strength. Mineral fillers have poor bond abilities to fibers and replacement of fibers with mineral fillers reduced fibers amount in the paper sheet, which causes a decrease of paper strength[19]. Table 4 shows clearly that starch: borax ratio 1:1 addition gave the most satisfied results, so this ratio was investigated for the other prepared pulps (mentioned at table 2).

The characteristics of pulp and hand sheet papers of bagasse cooked with 3% NaOH are shown in table 5. Table 5 shows that the Starch and Borax ratio (1:1) increased all of mechanical properties breaking length, burst index and tear index.

Table (6): shows that the addition of (1:1) Starch and Borax on pulp cooked by 4 % (5: 1) NaOH: NH_4NO_3 for 1h, during sheets making. The similarity of results in tables 4 and 6 indicates that the cooking chemicals selectively remove the lignin, and carbohydrates (cellulose and hemicelluloses) are not attacked significantly by the chemicals. There are no significant differences between 4% NaOH at 80°C at atmospheric pressure and 4 % (5: 1) NaOH: NH_4NO_3 at 105°C at autoclave in presence of 1:1starch: borax fillers. For example breaking length of hand sheet in table 4 was 4470 m and in table 6 was 4657 m.

Table-2
Effect of temperature and NH_4NO_3 addition during NaOH pulping of bagasse

Pulping condition	Pulping time	(°SR)	Yield %	Breaking length (m)	Burst Index (Kpa.m^2/g)	Tear Index (mN.m^2/g)
4% NaOH plastic bag at 80°C	3h	36	48.9	3425	2.16	10.98
3 % NaOH at 105°C	1h	38	57.46	3889	3.02	9.62
NaOH :NH_4NO_3 4 % (5 : 1) at 105 °C	1h	38	60.47	4296	4.00	6.73

Liquor ratio (1:6), in plastic bag at 80 °C or in autoclave at 105 °C, beating time 20 min

Table-3
Effect of different ratio between starch and borax at 2% concentration (based on o.d. pulp) on the paper strength properties of pulp

Additives	Breaking length		Burst Index		Tear Index	
	meter	% Increase	(Kpa.m^2/g)	% Increase	(mN.m^2/g)	% Increase
Control	3425	--	2.16	--	10.98	--
Starch (2% for pulp.)	3433	0.23	2.02	-6.50	11.45	4.29
Borax (2% for pulp.)	3900	13.87	2.39	10.65	12.20	11.08
1% starch : 1% borax after 5min	2470	-27.88	2.24	3.80	13.73	25.04
1% borax : 1% starch after 5min	3364	-1.78	1.95	-9.82	15.02	36.76
1% starch : 1% borax at once	4470	30.51	2.61	20.83	11.68	6.40

4 % NaOH at 80 °C in plastic bag for 3h

Table-4
Effect of different ratio between starch and borax at different concentrations added during sheets making on the strength properties of pulp

Starch : borax	Breaking length	% Increase in Breaking length	Tear Index (mN.m^2/g)	% Increase in Tear Index
Blank	3425	--	10.98	--
0.5 : 0.5	3321	-3.04	12.63	15.00
0.5 : 1	3855	12.55	17.03	55.12
1:0.5	3204	-6.45	12.90	17.48
1:1	4470	30.51	11.68	6.40
1:2	3668	7.09	10.23	-6.83
2 :1	3680	7.45	14.38	30.97
2: 2	3408	-0.50	13.18	20.07
1: 4	3252	-5.05	12.21	11.16
4 : 1	3683	7.53	13.95	27.03
4 : 4	3651	6.60	11.97	9.01
2: 4	3344	-2.36	9.32	-15.10

4% NaOH at 80 °C in plastic bag for 3h

Table-5
Effect of added 1:1 starch: borax during sheet making of NaOH pulp on sheet properties

Starch: borax	Breaking length	% Increase in Breaking length	Burst Index (Kpa.m^2/g)	% Increase in Burst Index	Tear Index (mN.m^2/g)	% Increase in Tear Index
blank	3889	--	3.02	--	9.62	--
1:1	4032	3.69	4.2	39.06	12.75	32.5

3% NaOH at 105 ^{0}C in autoclave for1h

Table-6
Effect of added 1:1 starch: borax during sheet making of NaOH: NH_4NO_3 pulp on sheet properties

Starch :borax	Breaking length	% Increase in breaking length	Burst Index (Kpa.m^2/g)	% Increase in Burst Index	Tear Index (mN.m^2/g)	% Increase in Tear Index
blank	4296	--	4.00	--	6.73	--
1:1	4657	8.41	3.67	-8.27	11.28	67.61

4% (5: 1) NaOH: NH_4NO_3 at 105 ^{0}C in autoclave for1h.

Air permeability and density: Air permeability (also known as porosity) and density are other two important properties of the papers. Paper permeability is a physical parameter that characterizes the degree of web resistance to gas flow. Porosity is a non-dimensional quantity which represents the volume fraction of the porous media that is not occupied by the porous media. The effect of filler addition on air permeability and density is useful to recognize the impact of fillers on paper properties.

Table (7): shows the effect of added different ratios of starch: borax during sheets making on the air permeability and density for bagasse hand-sheet pulp prepared by 4% NaOH on plastic bag for 3h. Table 7 shows that the air permeability had lower values for all samples after the addition of starch: borax because the resistance against air flow increases with the decrease of void which occupied by the fillers. It could be noticed that density is largely affected by filler content and type.

Table-7
Effect of different ratio between starch and borax at different concentrations added during sheets making on the air permeability and density

Starch :borax	air permeability (ml/min)	Density kg/m^3
blank	1330	463
2 : 0	890	575
0 : 2	750	488
1 : 1 starch first	774	546
1 : 1 borax first	960	537
1:1 at once	558	465
0.5 : 0.5	565	525
0.5 : 1	705	563
1:0.5	585	491
1:2	750	543
2 :1	490	652
2: 2	675	506
1: 4	695	512
4 : 1	520	511
4 : 4	630	522
2: 4	440	510

4% NaOH at 80 ^{0}C in plastic bag for 3h

Table (8): shows the Effect of 1:1 starch: borax addition added during sheets making on the air permeability and density of pulp cooked at 105 ^{0}C by both of 3 % NaOH for 1h or 4% NaOH: NH_4NO_3, (5: 1) for 1h.

Table-8
Effect of 1:1 starch: borax addition added during sheets making on the air permeability and density of pulp cooked at 105 ^{0}C by both of 3 % NaOH for 1h or 4% NaOH: NH_4NO_3, (5: 1) for 1h.

Samples	Air permeability	Density kg/m^3
3 % NaOH for 1h	240	605
1:1 Borax: starch on pulp 3 % NaOH 1h	155	650
4 % (5: 1) NaOH :NH_4NO_3,1h	217.5	619
1:1 Borax: starch on pulp 4 % (5: 1) NaOH :NH_4NO_3,1h	160	652

Results show a good improvement in the air permeability properties after the addition of starch 1:1 borax. Air permeability decreases by 35 and 26 % for NaOH and NaOH: NH4NO_3 pulp respectively. Paper additives results in higher paper density compared with plan paper.

Conclusion

Bagasse, a sugarcane fibrous residue that remains after crushing the stalks, plays a highly significant role as a raw material for pulp and paper industry. Bagasse was cooked by 4% NaOH in plastic bag at liquor ratio (6:1) and pulping temperature 80^{o}C for different periods of pulping time (2, 3, 4 and 5 h). Good pulp with reasonable yield could be obtained after 2h. Much more, 3% increase in pulp yield could be attained by NH_4NO_3 addition during NaOH pulping of bagasse. Hand sheet papers made by adding 1% starch + 1% borax at the same time have superior mechanical properties. The higher fillers ratios 1:4, 4:1, 4:4 and 2:4 have no pronounced effect. The investigation into the effect of filler addition on air permeability and density can be beneficial to the better understanding of the influence of fillers on paper properties. Results show a good improvement in the air permeability properties after the addition of starch and borax at

2% based on oven dry pulp (1:1). Air permeability decreases by 35% and 26 % for NaOH and NaOH: NH_4NO_3 pulp respectively. Paper additives results in higher paper density compared with plan paper. Paperboard obtained from virgin bagasse pulp at atmospheric pressure was economically suitable for packaging applications.

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