Leptadenia pyrotechnica - A Potential Raw Material for Pulp and Paper

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Leptadenia pyrotechnica, locally known as Khimp, is a perennial plant that grows abundantly in the Thar Desert of Rajasthan, India. The whole plant, on chemical analysis, showed 29.51% α-cellulose, 18.97% pentosan, 16.12% lignin, 7.93% ethanol-benzene extractives, 2.14% pectin, and 3.12% ash. The potential of khimp plant as raw material for pulp and paper making was evaluated by studying the pulp yield and strength properties of paper obtained by kraft and hot soda semi-chemical processes of pulping. Optimization of the pulping conditions was done by studying the process variables, viz., alkali concentration, sulphidity, time and temperature of digestion to explore the potential of the raw material in pulp and paper industry. Digestion with 10% alkali in hot soda process for 3h at 98°-99°C yielded 54.85% pulp having highest tensile index (22.22 Nm/g). Kraft pulping of khimp was optimized with 15% alkali and 20% sulphidity at 140°C for 3h digestion, which yielded 41.71% pulp having tensile index of 19.61 Nm/g.

INTRODUCTION

Increasing demand of pulp and paper products and growing environmental concerns all over the world have shifted the attention of pulp, paper and board industries to the use of hardwood, non-wood plants and different agro-residues as sources of raw material. Bamboo, cotton linters, natural fibres like flax, hemp, jute, kenaf, etc., and agro-residues like straw and bagasse are predominant pulp raw materials to meet the high demand of industries without depleting the forest resources. Pulping characteristics of some locally grown unconventional non-wood plants have also been reported (1). The world trend of paper and paperboard consumption indicates that the largest consumers are expected to be the developing countries where substantial use of non-wood pulp could meet the requirement. In India, the total demand for paper and board is about 4 million tones, which comes mainly from forest-based materials, agricultural residues and waste paper.

Khimp plant (Leptadenia pyrotechnic) is a perennial desert shrub belonging to the family of Asclepiadaceae that grows abundantly in the Thar Desert of Rajasthan, India. The plant is about 1.8m tall, highly branched with small yellow flowers and an average life span of 15 to 20 years. The plant has been a successful indigenous species for sand dune settlement (2). It also grows widely in the trophical zone of Africa and adapted in agroforestry for stabilization of sand dunes under windy condition (3). Traditionally, the local people use khimp plant in rope making, animal fodder and thatching purposes. It has also been suitable for paper manufacture (4). It contains 8% to 10% bast fibre of short fibre length (2.15±0.34 cm) which can be extracted from the green stem by crushing and retting in water. Physico-chemical characterization of the fibre (5) shows it lignocellulosic in nature having high α-cellulose (75.26%) and tenacity value (45.8 g/tex). The ultimate fibre length is fairly high (0.67±0.019 cm) and the length / breadth ratio is around 520.

The objective of this study was to determine the pulp and paper making properties of khimp plant by kraft and hot soda semi-chemical pulping processes and study of the process variables for optimization of pulping

conditions.

Materials & Methods

Khimp plant was collected from the Directorate of Research, Rajasthan Agricultural University, Bikaner, Rajasthan. The plant samples, after cleaning, were cut into chips (2-3 cm.) and thoroughly mixed. Sub-samples were randomly collected for determination of moisture content and chemical analysis.

Chemical analysis

The chemical analysis of pulverized chips (60 mesh) of whole khimp plant was performed according to TAPPI (6) standard methods as follows : T 223 CM - 84 - pentosan, T 222 OM-88-lignin, T 221 OM - 85 - ash, T 204 OM-88 - ethanol/benzene solubility, T 207 OM - 88 hot water and cold water solubilities and T 212 OM-88 - 1% alkali solubility. The α-cellulose content was determined according to the modified method of Sarkar et al. (7). The pectin content was estimated with 0.5% ammonium oxalate solution (8).

Pulping of Khimp Plant

Hot Soda Process

Chips (500g) were cooked in an open digester at 98°-99°C for 3h with four different levels of sodium hydroxide viz. 5, 10, 15 and 20% on weight of oven dry raw material. Digestions for different intervals of time from 1h to 4 h were carried out at 10% sodium hydroxide on weight of dry cooking material. The material to liquor ratio was maintained at 1:10 (w/v) in all cases. The cooked chips were washed free of liquor and pulp yield was recorded in all cases on oven dry weight of raw material.

Kraft Process

Chips (500g) were cooked in a laboratory rotary digester (capacity 15L) with four different levels of sodium hydroxide at 7.4, 12, 15 and 20% and sodium sulphide at 20, 25 and 30% sulfidity on weight of cooking material at three different temperatures, viz., 120°, 140° and 160°C for 1h to 4h to optimize the cooking condition. Cooking was carried out at 1:10 material to liquor ratio in all cases. The cooked chips were washed free of black liquor and pulp yield was determined on oven dry weight of chips used in digester. The uncooked material after pulping was negligible. Single stage refining of the pulp was done in a laboratory scale disk refiner (Sprant Weldron type, U.S.A.) in each case of pulping for defibration and uniforming the pulp. Kappa Number of the pulp samples were evaluated by TAPPI (6) standard method (T 236 CM - 85).

Preparation and testing of paper sheets

The pulps were beaten in the laboratory beater (25L Hollander type, Swiss) to a freeness of 40°SR using a Schopper Reigler Fireness Tester and standard paper sheets of about 60 gsm. were made from each pulp using a sheet making machine according to TAPPI[5] standard.

Table 1 : Proximate Chemical Composition of khimp Plant

Composition	Values (%)
Holocellulose	64.30
α - Cellulose	30.51
Pentosan	18.97
Lignin	16.12
Ash	3.12
Pectin	2.14
Solubility:	
Ethanol-benzene	7.93
Hot water	14.87
Cold water	11.20
1% NaOH	26.63

Ash and ethanol-benzene extractives were based on weight of oven dry unextracted sample and other components were based on oven dried defatted sample.

Table 2 : Effect of alkali % and time on yield and strength properties of khimp soda pulp

Sodium Hydroxide (%)	Time of digestion (h)	Pulp yield (%)	Strength properties of resulting paper		
			Tensile Index (Nm/g)	Burst Index ($kPam^2/g$)	Density (g/cc)
5	3	57.25	16.52	0.75	0.53
10	3	54.85	22.22	0.82	0.55
15	3	49.71	19.15	0.81	0.79
20	3	41.08	10.71	0.61	0.73
10	1	50.48	7.85	0.72	0.65
10	2	55.42	6.66	0.66	0.65
10	4	46.93	17.42	1.20	0.70

Temperature : 98° - 99°C; Liquor ratio 1:10 (w/v)

Strength properties, viz., tensile index, folding strength and burst index of paper sheets were measured according to TAPPI[5] methods, as follows: T403 OM85 - burst, T 404 OM - 87 - tensile and T423 OM - 89 - fold. The density of paper sheets was also calculated.

RESULTS & DISCUSSION

The chemical composition of khimp plant is presented in Table 1. The ash and lignin contents are as high as those of kenaf and bagasse while the α-cellulose and pentosan show slightly lower values[8]. The plant has 22.80% extractives, corresponding mainly to polar extractives that are removed with ethanol-benzene and hot water. The high alkali solubility of khimp (26.63%) resembles that of bagasse[9] (32.4%).

Pulping khimp plant by hot soda process

The effect of alkali concentration and time on pulping of khimp plant by open digestion and strength properties of paper made from khimp soda pulp are presented in Table 2. A gradual reduction in pulp yield was found with increase in alkali concentration while digestion beyond

Table 3 : Effect of alkali % and sulfidity % on yield and strength properties of khimp Kraft Pulp

Alkali (%)	Sulfidity (%)	Pulp yield (%)	Kappa No.	Strength properties of resulting paper			
				Tensile Index (Nm/g)	Burst Index ($kPam^2/g$)	Fold	Density (g/cc)
7.4	25	42.98	58.1	9.17	0.77	4	0.42
12	25	40.52	61.2	12.73	2.04	4	0.64
15	25	39.59	55.9	14.07	1.96	6	0.59
20	25	25.74	30.4	11.01	1.54	8	0.43
15	15	24.41	57.2	11.02	1.77	9	0.49
15	20	39.00	56.5	13.23	1.87	7	0.58
15	30	40.38	47.2	17.05	1.98	8	0.58

Time : 3h ; Temperature : 160°C ; Liquor ratio 1 : 10 (w/v)

Table 4 : Effect of time and temperature on yield and strength properties of khimp kraft pulp

Time (h)	Temperature (°C)	Pulp yield (%)	Kappa No.	Strength properties of resulting paper			
				Tensile Index (Nm/g)	Burst Index ($kPam^2/g$)	Fold	Density (g/cc)
1	160	38.65	61.7	11.80	0.95	12	0.69
2	160	37.45	60.2	10.56	1.01	10	0.67
3	160	39.59	55.9	14.07	1.96	6	0.59
4	160	30.09	56.7	15.20	1.05	14	0.88
3	100	45.57	62.2	11.64	0.78	10	0.78
3	120	43.30	61.1	13.01	0.95	7	0.72
3	140	41.71	57.1	19.61	1.37	10	0.48

Sulphidity : 25%; Sodium hydroxide : 15%; Liquor ratio 1 : 10 (w/v)

3h showed sharp reduction in pulp yield. The yield of pulp is low for the moderate conditions of cooking indicating a high alkaline reactivity of low molecular weight components. This is supported by the high alkali solubility of khimp plant (Table 1). It was observed that digestion with 10% alkali at 98°-99°C for 3h yielded 54.85% pulp having highest tensile index (22.22 Nm/g).

Pulping khimp plant by kraft process

Several pulping experiments were conducted with khimp plant chips by kraft process to study the effect of different process variables, viz., alkali concentration, sulphidity, time and temperature of digestion. Pulp yield and kappa number were recorded and strength properties of paper made from respective pulps were evaluated. The results are recorded in Tables 3 and 4. Table 3 showed that pulp yield decreased with increase in alkali concentration but increased with sulphidity for 3h digestion at 160°C. Increase in alkali concentration upto 15% at 25% sulphidity increased tensile index but the pulp yield and tensile index decreased significantly at 20% alkali concentration with maximum delignification indicated by reduced kappa number. It was observed that digestion for 3h at 160°C with 15% alkali at 20% sulphidity yielded 39.0%pulp of tensile index 13.23 Nm/g. and kappa number 56.5 indicating removal of appreciable quantity of lignin from the pulp. Pulping at higher sulphidity did not increase the pulp yield and tensile index to a significant extent. Table 4 showed the effect of temperature and time of digestion with 15% alkali and 25% sulphidity on khimp kraft pulp. It was observed that pulp yield decreased for digestion beyond 3h and with increase in temperature. Digestion at 140°C for 3h yielded 41.71% pulp having the highest tensile index (19.61 Nm/g).

Kraft pulping of prehydrolysed plant Leptadenia pyrotechnica with low pulp yield was reported by Manavalan et. at (11). The results of the effect of process variables on kraft pulping of khimp plant indicated the optimum pulping condition at digestion for 3h at 140°C with 15% sodium hydroxide and 20% sulphidity yielding 41.71% pulp. The yield and strength properties of khimp pulp are less compared to those of the pulps obtained from cotton waste, jute, mesta and bagasse (Table 5) (12). Paper and board of superior strength properties could be produced from khimp pulp by blending with a pulp of better strength

Table 5 : Comparison of yield and strength properties of handmade paper made from unbleached pulp of cotton waste, jute, mesta, bagasse and khimp by hot soda process

Type of paper	Yield of pulp (%)	Tensile Index (Nm/g)	Burst Index ($Kpam^2/g$)	Density (g/cc)
Paper from cotton waste	96.0	87.18	8.75	0.69
Paper from jute	62.1	30.96	2.38	0.59
Paper from mesta	76.6	21.27	2.22	0.40
Paper from bagasse	63.0	25.37	1.77	0.70
Paper from Khimp	54.85	22.22	0.82	0.55

properties in approximate proportions.

CONCLUSION

Khimp plant has been identified as a raw material for pulp and paper. Optimization of pulping conditions by hot soda semi-chemical process showed good pulp yield (54.85%) with maximum tensile index of 22.22 Nm/g by digestion with 10% sodium hydroxide on weight of cooking material for 3h at 98°-99°C. Kraft pulping of khimp plant was optimized at digestion with 15% sodium hydroxide and 20% sulphidity on weight of cooking material for 3h at 140°C which yielded 41.71% pulp having 19.61 Nm/g tensile index. Due to low yield and strength properties of khimp pulp compared to those of the pulps from cotton waste, bagasse, jute, etc., it can be used for making superior quality of paper and board by blending khimp pulp with a pulp of better strength properties.

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