Studies on Effects of Pulp Blending on Paper Strength

* Dutt Dharam, *Upadhyay J.S., *Agarwal Gaurav and Upadhyay M.K.**

ABSTRACT

The hardwood fibers differ from softwood fibers chemically and morphologically in many respects. The short fibered pulps result in poor drainage, lower wet web strength and tendency of pikcing at press rolls. To combat these problems, besides other remedial measures, blending of long fibered pulps with short fibered pulps is one of the important aspect. Blending can be done in three distinct ways, e. g. chips blending, pulp blending before beating and pulp blending after beating. The physical strength properties in case of chips blending are severely affected due to different chemical compositions of raw materials requiring different dose of chemicals and processing conditions. The pulp blending before beating improves physical strength properties marginally, because morphological behaviour of different fibers and their response towards refining are different. The pulp blending after separate beating showed exellent physical strength properties In present investigation, the blending of chips/pulps of Ipomea carnea with chips/pulps of Cannabis sativa, Cannabis sativa hemp ribbon, and bamboo (Dendrocalamus strictus) has been studies.

INTRODUCTION

The steady increase in production of paper has raised serious problem of raw material supply even in technically and culturally advanced countries. Conifers, the chief raw material for paper making, since long, are not available in sufficient quantity due to climatic, topographic and various other reasons in most of the countries. The other raw materials suitable for paper making are almost exclusively short fibered, with an average fiber length of about 1 mm or even less. Obviously, in their own interest, all countries have exploited to the maximum possible extent, their existing resources of fibrous raw material. It is well known that several properties of the paper produced from short fibered pulp are of inferior quality in comparison to conifers and also pose several problems during manufacturing. The present study was undertaken with an aim to produce blends of pulps from short fibered as well as long fibered pulps to produce paper of acceptable quality.

Peckham and May [1] worked with blends of pine and gum bleached kraft pulps and concluded that "The strength of a pulp blend can be predicted very closely if the two pulps are beaten before combining simply by obtaining a weighted average of the strength properties at the two freeness level". Brecht (2) concluded that when the two pulps differ only slightly in their physical properties, the blend follows a linear relationship. More extended work on this subject has

*Institute of Paper Technology,
University of Roorkee
Saharanpur-247 001
**Global Board Ltd.,
K-5, Additional MIDC Industrial Area,
Mahad- 402 309 (Maharashtra)

been carried out by the Institute of Paper Chemistry (3). In experiment with blends of aspen and western softwood pulps, they found that blends were inhibited consistently higher tearing resistance that could be predicted by assuming linear relationship. Nordeman (4) concluded that the properties of a blend of two pulps can be predicted by weighting the properties of the respective blend components in proportion to their fraction of the blend, was investigated by testing blends of upto 30% high yield unbleached hardwood pulps with high yield unbleached pine pulps.

Short thin-walled fibrers pulps are currently used for the manufacture of many varied grades of paper Higging (5), Algar (6), Grant (7), Rydholm and Gedda [8] and Giertz [9] have pointed out the usefulness of incorporating such fibers in paper making furnishes. Short thickwalled fibers from the genus Eucalyptus have not been generally accepted because paper made from this type of fiber have relatively low strength [10,11,12] and since most of the previous work done on this material was in relation to high strength wrapping paper this source of pulp wood has often been regarded as being unsuitable for paper making. Hardwoods and annual plants fibers differ from conifers fibers in fiber. Dimensions and fiber morphology etc. produce paper of different properties. If these short fibered materials are to be used in large quantities, it is to be essentially kept in mind that for achieving good paper properties, long fibered pulp has to be blended to counterbalance the deficit of short fibered pulps. The short fibered pulps present problem of difficult drainage, lower wet web strength, and tendency to press picking. Further, breaks occur frequently at the presses and dryers. These difficulties can be controlled to a greater extent by using a longer wire, increasing the suction areas, appropriate refining, addition of synthetic material and blending of long fibered pulps.

Most commercial papers contain more than one fibers. The choice of material for a given furnish is influenced by factors such as the relative costs, availability, beatability and over all wet end performance, say runnability and formation etc.

EXPERIMENTAL METHODOLOGY

The stalks of Ipomea carnea, Cannabis sativa and bamboo were chipped and screened separately. The chips passing through 30 mm screen but retained on a 3 mm screen were collected and air dried. The hemp ribbon of Cannabis sativa were removed by retting i.e. by keeping it under water for a week, removing the ribbons, washing, drying and cutting into pieces of about 20 mm length.

FIBER MORPHOLOGY

For morphological study, a small piece of Ipomea

Table-1

Morphological Characteristics of Ipomea Carnea and Cannabis Sativa hemp Ribbons.

Sl. No.	Particulars	C. Sativa	Ipomea Carnea	Cannabis Sativa hemp Ribbon	Bamboo (16)	Pinus Kesiya (17)	Picca Abies (18)
1.	Density, g/cm^3	0.32	0.29	0.33	0.52	-	-
2.	Fiber length (L), mm	1.76	0.62	21.00	1.70	2.25	2.32
3.	Fiber width (D), μ	29.00	33.18	22.00	23.60	41.70	40.70
4.	Lumen width (d), μ	15.21	30.34	8.50	9.50	35.70	34.75
5.	Cellwall thickness (w) μ	7.05	1.47	6.7	7.00	6.00	5.85
6.	Flexibility coefficient d/D x100	51.50	91.46	40.56	-	85.54	85.62
7.	Ratio of length to width L/D	60.09	18.68	95.45	72.03	53.96	57.00
8.	Ratio of twice cell wall thickness to fiber width, 2w/D	0.478	0.089	-	0.59	0.29	0.29
9.	Wall fraction, 2w/D x 100	92.76	8.89	-	59.30	29.0	29.0
10.	Runkel ratio 2w/d	0.93	0.97	-	1.47	0.34	0.51
11.	Ratio of wall thickness to lumen width w/d	0.46	0.05	-	0.74	0.17	0.25

carnea, Cannabis sativa and hemp ribbon of Cannabis sativa separately were subjected to chemico mechanical maceration to separate the individual cellular elements from each other without damage. It involves the use of hot acetic acid and sodium chlorite solution to remove most of the lignin and other cementing materials without appreciable degradation of the cellulosic tissue. The microscope slides of cellular materials were prepared as per BIS : 5285-1969. The microscope slides were projected at a magnification of 40X and fiber lengths were measured, while the fiber width and cellwall thickness were measured by measuring the projected images at a magnification of 160X. The results are reported in Table - I.

PREPARATION OF PULPS AND BLENDS

Blending of long fibered raw material pulps with short fibered raw material pulps were made in three sets.

Set (i) Chips blending of chips in different proportion followed by pulping.

Set (ii) Blending the unbeaten pulps in different proportions before beating and

Set (iii) Blending of beaten pulp in different proportions, before sheet formation.

PULPING OF INDIVIDUAL RAW MATERIALS

The screened chips of ipomea carnea, Cannabis sativa,Cannabis sativa hemp ribbon and Bamboo were cooked separately in a rotargy WEVERK make electrically heated laboratory digester of 0.02 m^3 capacity. Cooking was done by soda as well as kraft processes. The cooking conditions and results are reported in Tables - 2 and 3.

PULPING OF BLENDED CHIPS

The short fibered Ipomea carnea chips were blended with Cannabis sativa, Cannabis sativa hemp ribbon and Bamboo chips in different proportions i.e. 100:00, 90:10, 80:20, 70:30, 60:40 50:50, 40:60, 30:70, 20:80, 10:90, and 00:100. The above blends were cooked by soda and kraft processes under cooking conditions mentioned in Tables - 4 & 5. The pulps obtained from above blends were washed, crumbled and screened. These pulps were beaten in a PFI mill upto a freeness level of 45 ± 1° SR.

BLENDING OF PULPS

The Ipomea carnea pulp was blended in different proportions with Cannabis sativa, Cannabis sativa hemp ribbon and Bamboo pulps separately and mixed pulps were beaten to a freeness level of 45 ± 1°SR.

Table-2

Kraft Pulping of Ipomea Carnea, Cannabis sativa, Cannabis sativa hemp Ribbon and Bamboo.

Sl. No.	Particulars	Units	Ipomea carnea	Cannabis sativa	Cannabis sativa hemp ribbon	Bamboo
1.	Active alkali, As Na_2O	%	16	16	08	17
2.	Sulphidity	%	20	20	20	20
3.	Time to maximum temp.	min.	90	90	90	90
4.	Time to maximum temp.	min.	120	120	120	120
5.	Maximum temp.	°C	165±2	165±2	165±2	165±2
6.	Liquor to wood ratio		4.0:1	3.5:1	5.0:1	2.7:1
7.	Unbleached pulp yield	%	46.40	53.86	66.25	45.00
8.	Rejects	%	3.50	1.12	2.20	2.80
9.	Kappa No.		29	29	11	17

Table-3

Soda Pulping of Ipomea carnea, Cannabis sativa and Cannabis sativa Hemp Ribbons.

Sl. No.	Particulars	Units	Ipomea carnea	Cannabis sativa	Cannabis sativa hemp ribbon
1.	Active alkali, As Na_2O	%	16	16	09
2.	Time to maximum temp.	min.	90	90	90
3.	Time to maximum temp.	min.	180	180	180
4.	Maximum temp.	°C	165±2	165±2	165±2
5.	Liquor to wood ratio		4.0:1	3.5:1	5.0:1
6.	Unbleached pulp yield	%	45.40	49.50	64.00
7.	Rejects	%	2.44	1.00	--
8.	Kappa No.		31	31	15

Table-4

Pulp Yield and Kappa No. of Soda Pulps of Chips Blends* of Ipomea carnea with Cannabis sativa and Cannabis sativa Hemp Ribbon.

Ipomea carnea : Cannabis sativa	Pulp Yield %	Kappa No.	Ipomea carnea : Cannabis sativa Hemp. Riboon	Pulp Yield %	Kappa No.
100:00	42.56	34	100:00	42.56	34
90:10	42.70	34	90:10	43.50	33
80:20	43.00	33	80:20	44.80	31
70:30	43.50	33	70:30	46.50	30
60:40	44.00	32	60:40	48.50	29
50:50	45.50	32	50:50	51.00	27
40:60	46.50	32	40:60	53.50	26
30:70	47.50	31	30:70	56.25	25
20:80	48.50	31	20:80	59.50	24
10:90	49.50	31	10:90	62.00	23
00:100	49.50	31	00:100	64.00	22

* Cooking conditions : Active alkali = 16 % (as Na_2O)
Maximum cooking temp. = 165±2°C
Time to temp. = 90 minutes
Time at temp. = 180 minutes

Table-5

Pulp Yield and Kappa No. of Sulphate Pulps of Ipomea carnea with Cannabis sativa and Cannabis sativa Hemp Ribbon and Bamboo.

I. Carnea : C. sativa	Pulp Yield %	Kappa No.	I. Carnea : Hemp. Ribbon	Pulp Yield %	Kappa No.	I. carnea : C. Sativa	Pulp Yield %	Kappa No
100:00	46.40	29	100:00	46.40	30	100:00	46.40	29
90:10	46.90	29	90:10	48.40	30	90:10	46.40	27
80:20	47.10	29	80:20	51.50	30	80:20	46.00	26
70:30	47.90	29	70:30	54.50	30	70:30	46.00	26
60:40	48.25	29	60:40	56.50	29	60:40	45:90	25
50:50	49.50	29	50:50	58.00	29	50:50	45.70	25
40:60	51.50	29	40:60	60.50	29	40:60	45.50	24
30:70	52.50	29	30:70	61.00	29	30:70	45.25	24
20:80	52.50	29	20:80	63.60	29	20:80	45.20	23
10:90	43.10	29	10:90	65.40	26	10:90	45.00	23
00:100	53.86	29	00:100	67.25	28	00.100	45.00	22

* Cooking conditions :			
	Active alkali	=	16 % (as Na_2O)
	Sulphidity	=	20%
	Maximum cooking temp.	=	165±2°C
	Time to temp.	=	90 minutes
	Time at temp.	=	180 Minutes

In another set, the pulps of ipomea carnea, Cannabis sativa, Cannabis sativa hemp ribbon and Bamboo were beaten separately to a freeness level of 45 ± 1° SR. Beaten Ipomea carnea pulp was blended with Cannabis sativa, Cannabis sativa hemp ribbon and Bamboo pulps in different proportions as mentioned above.

PULP EVALUATION

The standard handsheets of 60 g/m² from above admixtures were made on British sheet forming machine. The sheets were pressed and dried as per Tappi standard methods, T-205, cm-80. These sheets were conditioned at 25±2 °C and relative humidity of 65 ± 2% and evaluated for various physical strength properties. The results are reported in Tables 6, 7 and 8.

RESULTS AND DISCUSSION

Table - 1 shows the morphological characteristics of Ipomea carnea, Cannabis sativa, Cannabis sativa hemp ribbons, Bamboo, pinus kesiya and Picca abies. The Ipomea carnea fibers are tapering at one end and slightly less tapering an another end. The cellwall cavity is wide and nearly empty. The cellwall thickness is very low, thus giving a low wall fraction. The fibers having lower wall fractions and Runkel ratio give stronger paper. The fiber width and lumen diameter of Ipomea carnea resembles, with softwood like Pinus kesiya and Picca abies. The thin walled & wide lumen fibres of Ipomea Carnea couapse easily to double walled ribbon structure on delignifacation and exhibit plastic deformation, thus offering more surface contact and fiber bonding. This gives good physical strength and less porosity. The Cannabis sativa bast fibers

Table-6
Strength Properties of Ipomea carnea and Bamboo Kraft Pulps

Furnish I.carnea: Bamboo	Blending after beating			Blending before beating			Chips blending		
	Burst index kPam²/g	Tear index mNm²/g	Tensile index Nm/g	Burst index kPam²/g	Tear index mNm²/g	Tensile index Nm/g	Burst index kPam²/g	Tear index mNm²/g	Tensile index Nm/g
100:10	3.82	3.72	70.42	3.92	3.72	70.42	3.82	3.72	70.42
90:10	4.05	3.92	70.01	3.52	3.82	69.23	3.74	3.72	68.41
80:20	4.28	4.28	69.98	3.60	4.11	68.60	3.76	3.87	66.79
70:30	4.31	4.58	69.52	3.92	4.23	67.38	3.82	3.92	65.34
60:40	4.62	4.80	69.32	4.12	4.32	65.99	3.94	4.05	64.95
50:50	4.92	4.90	69.03	4.25	4.64	66.00	4.02	4.32	64.05
40:60	5.12	5.36	68.75	4.32	5.06	65.84	4.11	4.83	63.72
30:70	5.30	5.46	68.45	4.85	5.12	64.62	4.15	5.21	63.24
20:80	5.51	5.75	68.21	5.20	5.45	64.42	4.16	5.42	64.23
10:90	5.85	6.09	67.92	5.35	5.62	64.12	4.21	5.38	65.90
00:100	6.34	6.37	67.52	5.35	5.62	64.12	4.21	5.38	65.90

Table-7
Strength Properties of Ipomea carnea and Cannabis sativa Hemp Ribbon Kraft Pulps

Furnish I.carnea: C.sativa Hemp Ribbon	Blending after beating			Blending before beating			Chips blending		
	Burst index kPam²/g	Tear index mNm²/g	Tensile index Nm/g	Burst index kPam²/g	Tear index mNm²/g	Tensile index Nm/g	Burst index Kpam²/g	Tear index mNm²/g	Tensile index Nm/g
100:10	3.82	3.72	70.42	3.81	3.72	70.42	3.81	4.65	70.42
90:10	3.87	4.82	70.40	3.70	4.33	68.54	3.52	4.23	69.11
80:20	4.10	5.21	70.24	3.98	4.98	68.03	3.74	4.23	69.50
70:30	4.48	5.69	70.61	4.13	6.02	67.40	3.79	5.80	68.98
60:40	4.50	6.59	70.62	4.22	6.23	67.41	3.85	6.01	68.98
50:50	4.91	7.43	70.73	4.56	6.98	68.21	4.11	6.72	68.98
40:60	5.12	8.23	70.80	4.88	7.85	68.89	4.47	7.44	67.25
30:70	5.62	8.92	70.90	5.22	8.73	69.03	4.89	8.11	66.24
20:80	5.72	9.52	70.91	5.49	9.17	69.12	5.69	8.84	67.23
10:90	6.14	10.19	71.00	5.94	9.92	70.30	5.84	9.72	68.61
00:100	6.34	11.10	71.50	6.34	11.10	71.50	6.34	11.10	71.50

Table-8
Strength Properties of Ipomea carnea and Cannabis sativa Hemp Ribbon Soda Pulps

Furnish	Blending after beating			Blending before beating			Chips blending		
I.carnea: Bamboo C. sativa Hemp Ribbon	Burst index kPam²/g	Tear index mNm²/g	Tensile index Nm/g	Burst index kPam²/g	Tear index mNm²/g	Tensile index Nm/g	Burst index kPam²/g	Tear index mNm²/g	Tensile index Nm/g
100:00	3.82	3.72	70.42	3.81	3.72	70.42	3.81	4.65	70.42
90:10	3.87	4.82	70.40	3.70	4.33	68.54	3.52	4.23	69.11
80:20	4.10	5.21	70.24	3.98	4.98	68.03	3.74	4.23	69.50
70:30	4.48	5.69	70.61	4.13	6.02	67.40	3.79	5.80	69.49
60:40	4.50	6.59	70.62	4.22	6.23	67.41	3.85	6.01	68.98
50:50	4.91	7.43	70.73	4.56	6.98	68.21	4.11	6.72	68.98
40:60	5.12	8.23	70.80	4.48	7.85	68.89	4.47	7.44	63.25
30:70	5.62	8.92	70.90	5.22	8.73	69.03	4.89	8.11	66.24
20:80	5.72	9.52	70.91	5.49	9.17	69.12	5.69	8.84	67.23
10:90	6.14	10.19	71.00	5.94	9.92	70.30	5.84	9.72	68.61
00:100	6.34	11.10	71.50	6.34	11.10	71.50	6.34	11.10	71.50

have smooth thickwall narrower lumen filled with some solids known as libriform fibers. As a result of the inability of the fibers to collapse when dried after beating, papers made from thickwalled fiber have smooth thickwall marrower lumen filled with some solids known as libriform fibers. As a result of the inability of the fibers to collapse when dried after beating, papers made from thickwalled fibers have high bulk, stiffness and compressibility and in general higher opacity and resiliency than those utilizing thin walled fibres. Tear factor, however, is often greater. The purpose of blending of thinwalled fibers (Ipomea carnea and Cannabis sativa woody fibers) with thickwalled fibers (Cannabis sativa Hemp Ribbons and Bamboo) in suitable proportions is to produce papers whose over all properties may be considered to be suitable for fine paper manufacture.

Table -2 shows the kraft cooking conditions and results of Ipomea carnea, Cannabis sativa, Cannabis sativa Hemp Ribbon and bamboo by kraft pulping process. The unbleached pulp yield at optimum cooking condition is found to be 46.40% at Kappa number 29 for Ipomea carnea, 53.86% at Kappa number 29 for Cannabis sativa, 66.25% at Kappa number 11 for Cannabis sativa Hemp Ribbon pulp and 45.00% at Kappa number 17 for bamboo.

Table-3 shows the cooking conditions and results of Ipomea carnea, Cannabis sativa and Cannabis sativa Hemp Ribbon by soda pulping process. The unbleached pulp yield at optimum cooking condition is found to be 45% at Kappa number 31 for Ipomea carnea, 49.50% at Kappa number 31 for Cannabis sativa and 64% at Kappa number 15 for Cannabis sativa Hemp Ribbon pulp. Table-4 and 5 indicate that by increasing Cannabis sativa, Cannabis sativa Hemp Ribbon or bamboo in the chips blends of Ipomea carnea + Cannabis sativa, Ipomea carnea + Cannabis sativa Hemp Ribbon and Ipomea carnea + bamboo, the pulp yield increases and Kappa number decreases both in soda as well as in kraft pulping processes. The increase in pulp yield and decrease in Kappa number is due to variation in cellulose content, lignin and extractives in different materials. Morphological and anatomical characteristics of different chips also affect cooking by diffusion/penetrations of cooking liquor (13). In blends Cannabis sativa and Cannabis sativa Hemp Ribbon contain higher cellulose content and lower extractives and lignin content as compared to Ipomea carnea (14). Hence by increasing the proportions of Cannabis sativa and Cannabis sativa Hemp Ribbon in blends, the pulp yield increases and Kappa no, decreases. While bamboo contains lower cellulose and higher lignin content as compared to Ipomea carnea (15), so by increasing the proportions of bamboo in chips blends both pulp yield as well as Kappa number decreases.

Table - 6 shows the strength properties of Ipomea carnea and bamboo pulps obtained in the three sets of experiments stated above. The burst index, tear index and tensile index of Ipomea carnea pulp are 3.82 $kPam^2/g$, 3.72 mNm^2/g and 70.42 Nm/g respectively. The burst index, tear index and teusile index of bamboo kraft pulp are 6.34 $kPam^2/g$, 6.37 mN^2/g and 67.52 Nm/g respectively. When both the pulps are blended after beating. The burst index and tear index increases and tensile index decreases with increase in bamboo proportions in blends. The variation in strength properties in blends before beating is due to variation in morphological characteristics of Ipomea carnea and Cannabis sativa Hemp Ribbon. The beating time of Ipomea carnea pulp at freeness 45^0 SR was 22 minutes, whereas, the time for Cannabis sativa Hemp Ribbon pulp was 75 minutes. This gives under and over beating of one or other pulp affecting the strength properties adversely.

The strength properties of pulps obtained from chips blends beaten to a freeness of 45^0 SR show lower burst index, tear index and tensile index. The deterioration in strength properties is due to same treatment of both raw material though they require different treatment because of different composition. The strength properties further deteriorates during beating due to variation in morphological characteristics of Ipomea carnea and bamboo. Hence the strength properties of separately cooked pulp blends beaten together shows an improvement over strength properties of pulps obtained from chips blending. Excellent strength properties are obtained when pulps are blended after beating separately.

Tables - 7 and 8 show the strength properties of Ipomea carnea and Cannabis sativa Hemp Ribbon kraft pulps and Ipomea carnea and Cannabis sativa soda pulps obtained in the three sets of experiments. The burst index, tear index and tensile index of Ipomea carnea kraft pulp are 3.82 $kPam^2/g$, 3.72 mNm^2/g and 70.42 Nm/g respectively. These are 6.34 $kPam^2/g$, 11.10 mNm^2/g and 71.50 Nm/g respectively for cannabis sativa and 5.16 $kPam^2/g$ 9.31 mNm^2/g and 52.00 Nm/g respectively for Cannabis sativa soda pulp. Both the above Tables-7 and 8 follows the same pattern as in Table-6. The strength properties of separately cooked pulp blends beaten together shows an improvement over strength properties of pulp obtained from chips blending. Excellent strength properties are obtained, when pulps are blended after beating separately. The Bamboo and Cannabis sativa fibers gives porous sheet as they retain their shape even after beating [13], whereas beating characteristics of Ipomea carnea fibers are quite different from those of Bamboo and Cannabis sativa and the sheet formation of Ipomea Carnea is quite good.

CONCLUSION

Based on experimental observations, it can be concluded that

i) Blending of long fibered pulps with short fibered pulps after beating the pulps separately gives better strength properties when compared to the pulp obtained from mixed chips cooking and mixed pulp beating. Percentage of long fibered materials in the blend can be predicted based on the paper properties of desired final product.

ii) Separate cooking and beating the pulps together shows an improvement over cooking of mixed chips.

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