Evaluation of sisal (Agave Cantala) and Sisal Hemp (Agave Sisalana) for paper making

Dr. BHARGAVA G.G.*, JOSHI R.C.*, ALOK KHARE*,
MAHESHWARI G.D.* MISHRA B.P.*,
MISHRA R. P.*,

ABSTRACT

Two species of Sisal namely *Agave Cantala* and *Agave Sisalana* were grown in Amlai region. The leaves were cut when plant has attained the age of eight years. The average length of *Agave Cantala* was more than *Agave Sisalana* but reverse was the trend with the width of the leaves. The average moisture content in both the species was around 85%. The fibre content in green leaves of *Agave Cantala* was 5.1% whereas for *Agave Sisalana* it was 4.8%. The pith percentage in *Agave Cantala* and *Agave Sisalata* was 3.0% and 2.8% respectively. Proximate chemical analysis of both the species show that Cold water, hot water, 1% NaOH and alcohol/Benzene solubilities were high.

Several methods were invesigated to separate fibers from sisal leaves but most convenient method was to convert leaves into chips, heating them in a digester at 100° C with water and refining the chips in a Sprout Waldron discrefiner followed by a washing stage over a flat screen to separate fibers.

Unbleached and bleached pulp yield of *Agave Cantala* was lower than *Agave Sisalana.* Bleach consumption in both the pulps was low to produce pulp of over 80% P. V. brightness. The bleached pulp yield in *Agave Sisalana* was higher (61.8%) than *Agave Cantala* (59.33%). The physical strength properties of unbleached and bleached pulps from both the species were excellent and were suitable for different grades of papers.

INTRODUCTION :

Sisal is a non wood plant of Amarillydacea family. It is a native of Mexico (Yucatan) and has successfully thrived in Semi-arid regions of Brazil, where it has been cultivated over 30 years Brazil is the largest producer of Sisal in the world followed by Tanzania and Kenya.

Agave fiber is obtained from various species of genous Agave. Different species are commercially important viz Manila Hemp (*Mussa Textilis*), True Hemp (*Cannabis Sativa*), Sisal Hemp (*Agave Sisalana*), Mexican Sisal (*Agave Foureroydes*), Benares Hemp (*Crotolaria Juncea*), Newzealand Hemp (*Phormium tenax)* and Mauritius Hemp (*Flucrseagigantea*). Manila Hemp is available for direct use in pulp manufacture in Philippines and in Central and South America.

Isolation of Sisal Fibres :

Leaves from both the Sisal species were cut into small chips of average size 6 cm x 6 cms. Following processes were adopted on Lab. Scale to extract fibers from Sisal chips.

1. Sisal chips were beaten with a hammer and finally washed over a flat screen to remove pith

*Research Division
Orient Paper Mills, Amlai
District Shahdol (M.P.)

from fibers. This process of fiber extraction was difficult and uneconomical.

2. Sisal chips were directly refined in Sprout Waldron disc refiner in two stages keeping clearance between the plates 2500 and 750 microns respectively. The chips got slipped away and made refining difficult due to wax content in leaves.

3. Sisal leaves were put in a cemented tank covered with water to allow the material to decompose. It took 25 days to decompose the material in January Unpleasant smell started eminating out since it started decomposing. This process was not followed for extraction of fibers due to unhygienic point of view.

4. Sisal chips were heated in a digester with water at 100°C (60 mts. hold time) keeping bath ratio 1 : 8. Softened chips were refined through Sprout Waldron Disc. refiner using refiner plate No. D-2A, 501. Adhering pith from fibers was removed by washing it over a flat screen. This process was followed for extraction of fibers.

Proximate Chemical analysis :

Dust of Sisal species retained on —40, +60 mesh was taken for proximate chemical analysis. Analysis data of both the species is compared with wheat straw 3, Rice Straw 3, Bagasse and Bamboo in Table-1.

Pulping of Sisal Species :

Agave Cantala was digested with 15% alkali as Na_2O, keeping bath ratio 1 : 8 and total cooking time 4 hrs. under pulping condition No. 1 where as under pulping condition No. 2 cooking alkali used was 12%, and bath ratio was kept 1 : 6 and total cooking time maintained was 6 hrs. Cooking condition No. 2 was found more suitable to get higher pulp yield and satisfactory quality of pulp hence *Agave Sisalana* digestions were carried out uuder pulping condition No 2. The cooking conditions and results are recorded in Table-2.

Table-1

Proximate chemical analysis of Sisal (Agave Cantala), Sisal Hemp (Agave Sisalana) and its comparison/Wheat straw, Rice straw, Bagasse and Bamboo.

S. No.	Particulars	Sisal Hemp (Agave Cantala)	Sisal Hemp (Agave Sisalana)	Wheat straw	Rice straw	Bagasse*	Bamboo*
1.	Ash (%)	7.30	8.00	7-8	13-15	6.05	3.0
2.	Lignin (%)	13.80	12.00	16-18	11-15	20.60	26-28
3.	Pentosan (%)	11.97	10.20	26-30	19-20	22.20	15.0-16.0
4.	Hot water solubility (%)	41.50	30.80	10-15	13-14	8.87	4.5-5.0
5	Cold water solubility (%)	35.70	26.60	—	—	7 58	—
6	1% NaOH solubility (%)	39.55	35.70	41-45	43-44	44.6	22-23
7.	Alcohol/Benzene solubility (%)	11.50	11.44	3-4	5-6	3.76	2-3
8.	Hollocellulose (%)	65.60	69.00	67-70	55-57	68.9	60-62

*Proximate chemical analysis was cartied out in Research Lab. O. P. Mills, Amlai.

Fibre morphology and Fibre classification studies.

Fibre dimensions (Fibre length and diameter) of *Agave Cantala* and *Agave Sisalana* kraft pulps were measured under a Projectina Projection Microscope. The results are compared in Table-3 with wheat straw, Rice Straw, Bagasse and Bamboo.

Fibre classification of *Agave Cantala* and *Agave Sisalana* kraft pulps carried out in a Bauer Mcnett classifier shows maximum fibres were retained on + 20 mesh (Table - 4).

Bleaching of Sisal pulps.

Agave Cantala and *Agave Sisalana* unbleached kraft pulps were bleached under C/E/H Sequence to attain pulp brightness around 78-80% P.V. Bleaching conditions and results are recorded in Table-6. The bleach consumption in both Sisal species was low to attain pulp brightness more than 80% P. V.

Comparison of physical strength properties.

Unbleached and bleached *Agave Cantala* and *Sisalana* pulps were beaten in a P.F.I. mill and evaluated for physical strength properties. The unbleached and bleached *Agave Sisalana* pulp has better strength properties than *Agave Cantala* and strength properties are recorded in Table 5 and 7 respectively.

Table-2

Kraft pulping of Depithed Sisal Species

S.No.	Particulars	Agava Cantala		Agava Sisalana	
		Pulping condition No. 1	Pulping condition No. 2	Pulping condition No. 2	
				Expt No. 1	Expt No. 2
1.	Moisture in Sisal fibres(%)	65.0	65,0	65.6	65.6
2.	Alkali used (%) Na_2O	15 0	12.0	12.0	11.0
3.	Sulphidity (%)	16.5	16.5	16.5	16.5
4.	Bath ratio	1:8	1:6	1:6	1·6
5.	**Cooking Schedule (mts.)**				
	(i) Upto 150°C	60	120	120	120
	(ii) At 150°C	180	240	240	240
	(iii) Total cooking time (hrs.)	4.0	6.0	6.0	6.0
6.	Permangnate No (25 ml) of Unbleached Pulp	9.30	9.93	9.84	11.34
7.	Unbleached yield(%) on O.D. Sisal fibre	62.0	63.80	65.60	67.56
8.	**Black liquor analysis**				
	(i) °TW at 60°C	5.5	5.0	6.5	5.5
	(ii) R-A.A. (g/L) as Na_2O	9.0	10.80	9.3	7.75

Table-3

Fibre morphological studies of Agave Cantala, Agave Sisalana and its comparison with wheat straw and Rice straw

S. No.	Particulars	Agave Cantala	Agave Sisalana	Wheat straw	Rice straw	Bagasse	Bamboo
1.	**Fibre length (m.m)**						
	(i) Minimum	1.60	2.2	—	—	0.6	1 2
	(ii) Maximum	3.20	6.4	—	—	4.2	3.0
	(iii) Average	2.56	3.37	1.1-1.5	0.5	1.47	2.1
2.	**Fibre diameter (microns)**						
	(i) Minimum	10.0	10.0	—	—	12	7
	(ii) Maximum	32.50	27.5	—	—	30	15
	(iii) Average	18.32	20.0	9-13	8.5	18	11

Table-4

Fibre classification of Agave Cantala and Agave Sisalana unbleached pulps

S. No.	Mesh size	Agave Cantala		Agave Sisalana	
		Pulp from pulping condition No. 1	Pulp from pulping condition No. 2	Pulp from pulping condition No. 2 Expt. No. 1	Expt No. 2
1.	+20	81.42	77.98	90.41	92 00
2.	—20, +40	3.89	4.72	2.01	3.41
3.	—40, +70	0.16	1.92	0.64	0.71
4.	—70, +100	0.25	0.53	0.12	0.91
5.	—100, +140	0.11	0.12	0 10	0.20
6.	—140	14.17	18.73	6.72	2.77
7.	Total	100.00	100.00	100.00	100.00

Table-5

Physical strength properties of unbleached Sisal Kraft pulps

S.No.	Particulars	Agave Cantala		Agave Sisalana	
		Pulp from pulping condition No.1	Pulp from pulping condition No. 2	Pulp from pulping condition No. 2 Expt No. 1	Expt No. 2
1.	Final freeness of beaten pulp °SR	45.0	45.0	45.0	45.0
2.	Beating revolution in P.F.I. mill	10,000	9,000	9,000	10,000
3.	Bulk (c c/gram)	1.46	1.45	1.42	1.50
4.	Breaking length (meters)	9,663	10,000	10,322	9,784
5.	Burst factor	88.30	91.60	95.90	87.30
6.	Tear factor	168.60	180.60	187.00	194.50
7.	Double fold	2193	2537	2256	2352
8.	Tensile Index (N m/g)	94.73	98.04	101.20	95.92
9.	Burst Index (K. Pa.m²/g)	8.66	8.98	9.40	8.56
10.	Tear Index (mN.m²/g)	16.52	17.71	18.33	19.07

Table-6

Bleaching of Sisal kraft pulps under C/E/H Sequence

S.No.	Particulars	Agave Cantala		Agave Sisalana	
		Pulp from pulping condition No. 1 K. No. =9.30	Pulp from pulping condition No. 2 K.No. =9.93	Pulp from pulping condition No.2 Expt No. 1 K. No. =9.84	Expt No. 2 K.No. =11.34
1.	**Chlorination Stage**				
	(i) Chlorine applied (%) on O D. Pulp	3.0	3.0	3.0	4.0
	(ii) Chlorine consumed(%) on O.D. Pulp	2.60	2.88	2.55	3.76
	(iii) End pH	2.0	1.9	2.0	1.9
2.	**Alkali extraction stage**				
	(i) Alkali applied(%)	2.0	2.0	2.0	2.0
	(ii) End pH	10.3	10.2	10.1	10.2
3.	**Hypochlorite stage**				
	(i) Hypo applied (%) as available chlorine	1.5	2.0	1.5	2.0
	(ii) Hypo consumed (%)	1.25	1.78	1.30	1.66
	(iii) pH during bleaching	8.5—9.0	8.5—9.0	8.5—9.0	8.5—9.0
	(iv) End pH	8.0	8.2	8.1	8.0
	(v) Buffer added (%)	0.4	0.5	0.5	0.5

Table—6 (Contd)

1	2	3	4	5	6
4.	**Final results**				
	(i) Total chlorine applied (%)	4.5	5.0	4.5	6.0
	(ii) Total chlorine consumed (%)	3.85	4.66	3.85	5.42
	(iii) Brightness of pulp % P.V.	82.0	82.0	81 0	82.0
	(iv) Viscosity (0.5%, C. E. D.) Cps	11.78	12.6	13.0	12.2
	(v) Copper No.	1.1	1.0	0 82	0.91
	(vi) Shrinkage of pulp (%) on O. D. Sisal pulp	6.40	6.50	5.8	6.6
	(vii) Bleached yield (%) on O. D. Sisal fiber	58.03	59.33	61.80	63.10

Bleaching Conditions

Sequence	Consistency (%)	Temperature °C	Time (minutes)
C	3.0	Room	60
E	5.0	55±1	60
H	5.0	40±1	120

Table-7

Physical strength properties of bleached Sisal kraft pulp

S. No.	Particulars	Agave Cantala		Agave Sisalana	
		Pulp from pulping condition No. 1	Pulp from pulping conditions No. 2	Pulp from pulping condition No. 2 Expt No. 1	Expt No. 2
1.	Final freeness of beaten pulp °SR	45	45	45	45
2.	Beating revolution in P.F.I. mill	9,500	8,500	9,000	9,500
3.	Bulk (c. c/gram) .	1.44	1.38	1.38	1.44
4.	Breaking length (meters)	9163	9431	9777	9584
5.	Burst factor	83.33	86.60	93 00	88.3
6.	Tear factor	158.60	174.60	176.00	180.00
7.	Double fold	1503	1896	1300	1470
8.	Tensile Index (N. m/g)	89.83	92.46	95.85	93.96
9.	Burst Index (K Pa. m^2/g)	8.17	8.49	9.10	8.66
10.	Tear Index (mN. m^2/g)	15.55	17.12	17.25	17.64

Discussions of Results and Conclusion.

The leaves of *Agave Cantala* and *Agave Sisalena* were cut from the plant after attaining 8 years of age. The average length of *Agave Cantala* was 1.2 meter and width 5.6 cms whereas in *Agave Sisalana* it was 0.79 meter and 6.0 cms respectively. The average fibre and pith percentage in *Agave Sisalana* was 4.83% and 2.8% respectively whereas in *Agave Cantala* it was 5.1% and 3.0% respectively.

Proximate chemical analysis reported in Table-1 shows that in Sisal species Cold water, hot water, 1% NaOH and alcohol/Benzene solubilities were higher than wheat straw 3, Rice Straw3 Bagasse and Bamboo. Lignin content in both Sisal species is lower than Bagasse, wheat straw and bamboo.

Sisal species under pulping condition No.2 (Table--2) requires 12% alkali as Na_2O, bath ratio (1:6) and total cooking time 6 hrs. to produce unbleached pulp. The unbleached pulp yield in *Agave Sisalana* was higher (65.6%) than *Agave Cantala* 62.0%).

Fibre morphology of Sisal species (table-3) shows that fibre length and diameter of *Agave Sisalana* was higher(3.37 m. m., 20 microns respctively) than *Agave Cantala* (2.56 m. m. 18.32 microns respectively). Fibre classification data recorded in Table-4 indicates that fibers retained on + 20 mesh was over 90% in *Agave Sisalana* where as in *Agave Cantala* it was 81.42%. The fines content was more in Agave Cantala as compared to *Agave Sisalana.*

Unbleached pulp strength properties reported in Table-5 confirm that physical strength properties of *Agave Sisalana* was higher than *Agave Cantala* Tear factor was exceptionally high in both the Sisal species.

Sisal pulps bleached under C/E/H Sequence (Table 6) shows that bleach consumption was low to produce high brightness of pulp (over 80% P.V.). The bleached pulp yield in *Agave Sisalana* was (61.88%) higher than *Agave Cantala* (59.33%). The bleached pulps evaluated for physical strength properties (Table-7) confirm that *Agave Sisalana* has better strength properties.

It can be concluded from experimental data that pulp produced from *Agave Cantala* and Agave Sisalana is of excellent quality with low alkali and bleach consumption but the main bottle neck for its commercial utilization is the need of suitable technology to extract fibres from the leaves.

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