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Alkaline Pulping with Additives of Southern Cattail Stems from Sudan

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Abstracts: Soda-anthraquinone (soda-AQ) alkaline sulfite- anthraquinone (AS-AQ) and ASAM (alkaline sulfite-anthraquinone- methanol) cooking of southern cattail whole stem and bark from Sudan was carried out under different conditions and pulps with acceptable to good screened yields and very good mechanical properties were attained. The southern cattail whole stems gave satisfactory mechanical properties with ASAM process with good yields while the bark was best pulped with the AS-AQ with acceptable yield, but good strength properties.

Key words: Typha domingensis · Southern cattail stem · Papermaking · Fiber morphology · Chemical composition · Alkaline pulping with additives

INTRODUCTION

Typha domingensis known as southern cattail or cumbungi is a perennial herbaceous plant; it is found throughout temperate and tropical regions worldwide [1]. Growth height up to 3-4 m, reproduction spreads rapidly by vegetative reproduction and generative reproduction [2] In southern Sudan the centre core of the Sudd swamps is dominated by papyrus sedge and bordered by southern cattail(*Typha domingensis*), the dominant vegetation covers about 75% of the total area of the swamps [3]. All parts of southern cattail are edible, can be used as wild life wetland restoration, stems and leaves can be woven into mats, chairs and hats, as well as good source of biomass [4] Female flower inflorescence are used externally for burns and wound healing in Turkish folk medicine [5] It has the potential to be used in phytoremediation purposes to remove metals pollutants from contaminated wastewaters [6]. Typha *domingensis* is highly salt-tolerant and considered as potential source of pulp and fiber [7] The purpose of the present work concerns the suitability of Sudanese southern cattail for papermaking by soda and alkaline sulfite methods with additives.

MATERIALS AND METHODS

Southern cattail stems were collected at White Nile riverbank in Khartoum area. The stem length was 2-3 m and with 5-7 cm in diameter, the stems were chopped to 3-5 cm and Southern cattail bark and core were manually separated and a part was ground in a star mill. The 40-60 mesh fraction was analyzed by [8], except the Kurschner- Hoffer cellulose [9] and the carbohydrate composition that was determined by hydrolysis with H_2SO_4 and borate complex ion exchange chromatography [10]. Fiber dimensions were measured microscopically at x300 and x400 magnification after staining with 1% aqueous safranine [11].

The Southern cattail stems were cut to 3-5 cm size and pulped (Typha bark and Typha whole separately with Soda-AQ [12], AS-AQ and ASAM [13] methods against Soda cooking as reference with different levels of alkali in 7 electrically heated rotary digester, pulp characteristics and strength properties were determined by [8].

RESULTS AND DISCUSSIONS

The average basic density of *Typha domingensis* (southern cattail) was in the range of non-woody plants and agricultural residues 113 kg m^{-3}, low density means low digester capacity per unit space and low yield but it will facilitate the impregnation and penetration with cooking liquor. Bark to whole ratio by volume and mass were 16% and 96% respectively were in acceptable range for commercial pulping [14]. The southern cattail fibers average length (1.6 mm) was medium-long, while fiber

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Table 1: Chemical Composition of *Typha domingensis* (southern cattail)from Sudan, As Typha bark and Typha whole (all values expressed as percent oven-dry soluble or component on oven dry raw material)

Component in %	Typha bark	Typha whole
Ash content	4.3	10.5
Silica content	0.1	0.1
Cold water solubility	6.0	18.7
Hot water solubility	7.5	24.7
Alcohol	5.1	13.6
Alcohol cyclohexane (1/2)	2.6	5.3
1% Sodium hydroxide	24.9	32.8
Holocellulose	75.4	67.6
Pentosan	18.7	32.8
Cellulose, Kurschner- Hoffer	49.0	38.7
Acid insoluble Lignin	21.5	17.5
Cellulose / lignin ratio	2.1	2.1

Table 2: *Typha domingensis*- Southern Cattail Bark (TB): pulping conditions and unbleached pulp evaluation

	Pulping conditions				pulp yield			pulp evaluation					
					Total screen			kappa	viscosity		B/L analysis		
Pulping Process	% of active Alkali as Na_2O	Temp°c	time-max temp/ min	time at max-temp	%	%	reject %	No	ness	Brightness	pH	RAA	Total solid
Soda													
TBS_4	17	165	90	120	40.6	40.6	nil	24.5	961	19.5	13.0	1.3	12.0
TBS_5	20	165	90	120	38.5	38.5	nil	19.4	924	26.4	13.3	1.4	12.8
Soda AQ													
TBQ5 $_{0.1\%}$	15	165	90	120	43.8	43.8	nil	18.0	901	28.0	3 11.	12.4	0.3
TBQ6	16.3	165	90	120	38.9	38.9	nil	15.9	904	28.8	13.1	0.6	11.3
ASAQ													
TBSq2 $_{(70:30)}$	15.5	165	90	120	47.6	47.5	0.1	39.5	923	16.6	10.7	0.3	10.8
TBSq3	18	165	90	120	41.4	41.3	0.1	22.8	891	24.3	11.5	0.4	11.2
ASAM													
Tbsm2	12.4	165	90	120	49.1	48.9	0.1	36.7	689	18.2	9.3	0.3	8.1
Tbsm3	15.5	165	90	120	44.2	44.2	0.1	22.5	916	23.2	10.9	0.8	10.5
Tbsm4	18	165	90	120	41.7	41.7	nil	13.4	904	30.6	12.1	1.9	11.6

B/ L : Black liquor

RRA: Residual Active Alkali

width was medium- narrow (20.6μm) and in the hardwoods ranges (10-35μm), with a medium thick cell wall (4.3μm) as well as lumen width (12μm). The flexibility index was 58 [15] positively correlated to the tensile strength, burst factor and double fold endurance, however felting power 75 was lower than that of banana stems 116 [16] and higher than doum rachis 57 [17] On the other hand Runkel (flatness) ratio (0.7) was favorable for pulping material with wall fraction was 21.

The ash contents were high 4.3% and 10.5% for Typha bark and Typha whole respectively (Table 1) typical for tropical non- woody plants and in the range of pulpable straws; however the silica contents were both 0.1%. The cold water extractives were 6% and 18.7% for Typha bark and Typha whole respectively, hot water were 7.5% and 24.7%. Organic solvents alcohols and alcohol cyclohexane (1/2) were 5.1-13.6% and 2.6-5.3% respectively all were rather high, suggesting an open anatomical structure easily accessible for chemicals. 1% NaOH extractives were 24.9% and 32.8% for Typha bark and Typha whole respectively and were high due to presence of many soluble polysaccharides and phenolic compounds. The cellulose Kurschner- Hoffer contents were 49% and 38.7% for Typha bark and Typha whole respectively implied good pulp yields to be expected from Typha bark, in addition the cellulose/ lignin ratios were both 2.1 suggested normal alkaline pulping [18].

Pulping of Southern Cattail Bark: In soda pulping of southern cattail bark (TBS4 and TBS5) were carried out as reference cooks with an active alkali levels of 17-20% a kappa numbers of 24.5 and 19.4 respectively were attained (Table 2). The addition of 0.1% anthraquinone to cooking liquors (TBSQ5 andTBSQ6) at lower effective alkali charge (15-16.3% respectively) gave a much higher degree of delignification (kappa numbers 18.0 and 15.9 respectively) at maximum temperature 165 C^0at screened yields between 38.9 - 43.8 %. The increase of the alkali charge from 15% to 16.3% at the same maximum temperature resulted in lower screened yield, with pulp had more or less the same

Table 3: Typha domingensis southern cattail bark unbleached pulp properties

Pulping process	Soda				Soda-AQ				AS-AQ				ASAM			
Pulp Code	TBS4				TBQ6				TBSq3				Tbsm4			
Properties																
Beating degree (SR)	25	34	41	47	18	32	39	43	22	32	39	45	22	31	39	44
PFI revolution	0	1000	2000	3000	0	1000	2000	3000	0	1000	2000	3000	0	1000	2000	3000
Apparent density g/cm^3	0.66	0.77	0.78	0.82	0.73	0.79	0.84	0.86	0.64	0.71	0.78	0.82	0.70	0.82	0.89	0.90
Tensile index, Nm/g	59.5	101.5	105	109	60.5	97	106	114	66	94	103	111	68	102	105	107
Burst index, $kPam^2/g$	3.5	6.0	7.2	7.9	3.7	6.6	7.0	8.2	3.9	5.4	7.6	8.5	4.3	7.2	7.4	7.8
Tear index, mNm^2/g	14.7	11.6	11.2	11.1	14.7	12.2	10.7	10.5	16	13.9	11.3	11.2	13.6	11.0	10.5	10.2
Fold Kohler (log)	1.88	2.42	2.71	2.78	2.30	3.10	3.14	3.15	2.28	2.72	2.74	2.94	2.44	2.92	3.07	3.08
Porosity Bendsten, ml/min	811	212	122	86.5	685	126	86.4	62.4	1130	441	147	86.5	864	135	86.4	67.2
Opacity %	99.4	99.7	99.8	98.1	99.2	98.1	99	98	98	98.6	98.8	97.2	98.9	97.7	99.6	98.8
Kappa number	24.6				15.96				22.83				13.4			
ISO brightness	26.4				28.8				24.3				30.6			
CED viscosity	924				904				891				904			

Table 4: *Typha domingensis* southern cattail whole stems (TW): pulping conditions and unbleached pulp evaluation

	Pulping conditions				pulp yield			pulp evaluation			B/L analysis		
					Total screen			kappa viscosity					
Pulping Process	% of active Alkali as Na_2O	Temp°c	time-max temp/ min	time at max-temp	%	%	reject %	No	ness	Brightness	pH	RAA	Total solid
Soda													
TWS_1	17	165	90	120	40.8	40.7	0.1	22.7	836	25.1	13.0	3.2	11.9
TWS_2	17	170	90	120	41.2	41.0	0.1	22.7	746	24.1	13.1	2.7	-
TWS_3	20	165	90	120	38.5	38.5	nil	16.9	830	27.4	13.3	6.6	12.8
Soda AQ													
$TWQ5_{0.1\%}$	15	165	90	120	43.8	43.8	nil	17.0	898	24.2	12.3	1.1	10.7
TWQ6	16	165	90	120	42.1	42.1	nil	14.4	885	26.6	12.8	2.1	11.7
ASAQ													
$TWSq1_{(70:30)}$	15.5	165	90	120	44.2	44.1	0.1	36.1	891	18.1	10.5	0.6	11.59
TWSq2	18	165	90	120	41.1	41.1	nil	15.9	861	27.6	11.4	2.2	12.4
ASAM													
TWsm2	13	165	90	120	44.6	44.6	nil	22.1	991	21.9	10.3	0.3	11.4

B/L : Black liquor

RAA: Residual Active Alkali

Table 5: Typha *domingensis* southern cattail whole stem unbleached pulp properties

Pulping process	Soda			Soda-AQ			AS-AQ				ASAM			
Pulp Code	TBS4			TBQ6			TBSq3				Tbsm4			
Properties														
Beating degree (SR)	26	44	48	32	41	48	27	37	41	49	31	41	45	53
PFI revolution	0	1000	2000	0	1000	2000	0	500	1000	2000	0	500	1000	2000
Apparent density g/cm^3	0.63	0.74	0.76	0.71	0.77	0.83	0.68	0.75	0.77	0.78	0.74	0.74	0.77	0.80
Tensile index, Nm/g	82	118	123	98.5	116	119	88.5	106	120	125	95	108.5	115	129
Burst index, $kPam^2/g$	5.0	8.0	9.0	6.1	8.0	9.0	5.5	7.7	9.0	9.2	5.0	7.3	8.4	9.0
Tear index, mNm^2/g	17.0	13.9	12.2	15.4	11.6	11.4	15.4	12.6	12.1	11.2	15.0	13.7	11.9	10.5
Fold Kohler (log)	2.71	2.61	2.87	2.9	2.91	2.93	2.62	2.10	3.13	3.15	2.71	2.18	2.92	2.95
Porosity Bendsten,ml/min	453	86.5	85.7	156	86.5	54.4	293	86.5	86.5	54.6	134	80.5	75.2	43.1
Opacity %	99.7	99.3	99.5	99.1	97.9	98.5	98.7	98.8	98.2	98.4	99.1	98.4	99.7	97.2
Kappa number	22.7			14.4			15.96				10.6			
ISO brightness	25.1			26.6			27.6				31.4			
CED viscosity	836			885			861				946			

viscosity and initial brightness with lower kappa number. Although the soda reference pulps had higher viscosity and lower initial brightness. In the initial period of cooking huge amount of alkali are consumed for neutralization of acid derived from the polysaccharides and for neutralizing lignin degradation products. Nevertheless, too high alkali concentrations must be avoided, otherwise over proportional degradation and dissolution of hemicelluloses and cellulose might take place, resulting in reduced yield and viscosity.

The alkaline sulfite-anthraquinone (AS-AQ) (TBSq2 and TBSq3) pulping of southern cattail seemed attractive, a higher screened yield 41.3-47.5% at same viscosity and initial brightness with higher kappa numbers compared to cooks of soda and soda-AQ. On the other hand AS-AQ cooks gave astonishingly similar to those of alkaline sulfite anthraquinone with methanol (ASAM) Screened yields 44.2% and 41.7% of (TBsm3 and TBsm4 respectively) under the same cooking conditions with addition of 15% v/v methanol, with higher initial brightness and more or less similar viscosity of 904-916 mlg^{-1}. The total solid and residual active alkali were similar in both AS-AQ and ASAM cooks.

The strength properties of the unbleached southern cattail bark (Table 3) indicated superior strength of ASAM pulps to those of the soda and soda-AQ pulps at low PFI revolution. However the development of tensile index during beating was remarkable. Moreover, the AS-AQ pulps (TBSq3) had a higher tear resistance. The unusually high tensile and burst strength of AS-AQ pulps at high revolution reflected selectivity of this process in preserving the hemicelluloses to a great extent. In general the morphological characteristics and chemical constituents of southern cattail bark were reflected in high tear resistance and bonding strength.

Pulping of the Whole Stem Southern Cattail: ASAM, AS-AQ and soda pulping of Typha domingensis (southern cattail) whole stem carried out with and without AQ addition (Table 4) with 13-20% active alkali gave acceptable to good screened yields (38.5-44.6%) and good to excellent kappa numbers (10.5-36.1). Use of high maximum temperature 170 C^0 in soda pulping reduced the viscosity and initial brightness. However use of 0.1% AQ in soda cooking substantially enhanced the delignification, reduced the level of rejects with better viscosity than reference soda pulping (17% active alkali).AS-AQ and ASAM cooks, at the same conditions had the same low rejects and almost screened yields but ASAM pulping gave higher viscosity, excellent kappa numbers with inferior initial brightness.

The mechanical properties of the unbleached southern cattail whole stem (Table 5) were quite high and satisfactory especially the tensile strength and tear resistance of ASAM and AS-AQ pulps, the very good papermaking properties suggested the southern cattail pulps could be used in manufacture of high strength papers or as blender for the short fiber pulps.

CONCLUSIONS

The fiber of southern cattail stems is close to that of hardwoods. The removal of pith improved the chemical constituents and the open anatomical structure easy to penetrate by chemicals, makes it possible to have strong pulp with soda process, while AS-AQ and ASAM processes well suited for pulping of southern cattail. Due to satisfactory papermaking properties of whole stem it is preferable to be used without separation of bark and thus reduce the cost of preparation.

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