PULPING WITH ADDITIVES OF *TYPHA DOMINGENSIS* STEMS FROM SUDAN

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Received: Oct 22, 2011; Revised: Feb 17, 2012; Accepted: Feb 20, 2012

Abstract

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.

Keywords: ***Typha Domingensis*, Southern cattail stem, Papermaking, Fiber morphology, Chemical composition, Alkaline pulping with additives**

Introduction

Typhadomingensis, known as southern cattail or cumbungi, is a perennial herbaceous plant. It is found throughout temperate and tropical regions worldwide (Mark McGinley *et al.*, 2010). In southern Sudan, the centre core of the Sudd swamps is dominated by papyrus sedge and bordered by southern cattail *(Typhadomingensis)*. The dominant vegetation covers about 75% of the total area of the swamps (USAID, 2007). All parts of southern cattail are edible and can be used as wild life wetland restoration. Besides, stems and leaves can be woven into mats, chairs and hats, and they can be a good source of biomass (USDA-NRCS, 2011). Female flower inflorescence(S) are used externally for burns and wound healing in Turkish folk medicine (Akkol *et al.*, 2011). It (THEY: referring to inflorescences above) has the potential to be used in phytoremediation purposes to remove metal pollutants from contaminated wastewaters (Hegazy *et al.*, 2011). *Typhadomingensis* is highly salt-tolerant and considered as a potential source of pulp and fiber (Alsharhan, 2000). The purpose of the present work is concerned with the suitability of Sudanese southern cattail for papermaking by soda and alkaline sulfite methods with additives.

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Materials and Methods

Typhadomingensis (southern cattail) stems were collected at White Nile riverbank in Khartoum area. The stem length was 2-3 m and 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 TAPPI (1996) methods, except the Kurschner-Hoffer cellulose (Obolenskaya *et al*., 1965) and the carbohydrate composition that were determined by hydrolysis with H_2SO_4 and borate complex ion exchange chromatography (Puls, 1984). Fiber dimensions were measured microscopically at ×300 and ×400 magnification after staining with 1% aqueous safranine (Horn, 1978).

The *Typhadomingensis* stems were cut to 3-5 cm size and pulped (*Typhabark* and *Typhawhole* separately) with Soda–AQ with alkali charge 15-16.3% as Na_2O (Holton, 1977), 15.5-18% as Na_2O for AS-AQ and 12.4-18% as Na_2O for ASAM (Kordsachia and Patt, 1988) methods against Soda cooking as reference with 17-20% as Na_2O with time to maximum temperature 90 min, at maximum temperature 165°C. The time at maximum temperature 120 min with liquor to raw material ratio 4:1 in 7 electrically heated rotary digester, (No verb here in this clause, Please make it a complete sentence.) pulp characteristics and strength properties were determined by TAPPI (1996).

Results and Discussions

The average basic density of *Typhadomingensis* (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 ratios by volume and mass were 16% and 96%, respectively and were in acceptable range for commercial pulping (Palmer *et al*., 1989). The Typhadomingensis fibers' average length (1.6 mm) was medium-

Table 1. Chemical Composition of *Typhadomingensis* (southern cattail) from Sudan, AsTyphabark 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

long, while fiber width was medium-narrow (20.6 μm) and in the hardwoods ranges (10-35 μm), with a medium thick cell wall (4.3 μm) as well as lumen width (12 μm). The flexibility index was 58 (2^{nd} group of Istas classification 1965), positively correlated to the tensile strength, burst factor and double fold endurance. However, felting power 75 was lower than that of banana stems 116 (Khristova *et al.*, 2001) and higher than doum rachis 57 (Khristova *et al.*, 2003). On the other hand, Runkel (flatness) ratio (0.7) was favorable for pulping material with wall fraction of 21.

The ash contents were high 4.3% and 10.5% for Typha bark and Typha whole, respectively (Table 1), which is typical for tropical non-woody plants and in the range of pulpable straws; however the silica contents for both were 0.1%. The cold water extractives were 6% and 18.7% for *Typha* bark and *Typhawhole*, respectively, and hot water extractives? 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 of which 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 *Typhawhole*, respectively, which implied good pulp yields to be expected from *Typha* bark. In addition, the cellulose/ lignin ratios were both 2.1, suggesting normal alkaline pulping (Simionescu, 1977).

Pulping of TyphaDomingensis Bark

Soda pulping of *Typha domingensis* bark (TBS4 and TBS5) was 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 and TBSQ6) 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^{o} C at 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 having more or less the same viscosity and initial brightness with lower kappa number. The soda reference pulps had higher viscosity and lower initial brightness. In the initial period of cooking, huge amount of alkali was 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 *Typhadomingensis* 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 (WHAT?) 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 effect of anthraquinone and addition of 15% v/v methanol to liquor decreased the screened yield, which gave better Kappa number and initial brightness at constant alkali charge of 15.5% as Na_2O and other pulping conditions as shown in (TBSq370:30 and TBSm3), increased the rate of delignification and improved the selectivity of reactions. The total solid and residual active alkali were similar in both AS-AQ and ASAM cooks.

The strength properties of the unbleached *Typhadomingensisbark* (Table 3 and Figures 1-3) 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.

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

	Pulping conditions				pulp yield			pulp evaluation			B/L analysis		
Pulping Process	**% of active Alkali as Na_2O**	**Temp °C**	**Time-max temp/min**	**Time at max-temp**	**Total %**	**Screen %**	**Reject %**	**Kappa no**	**Viscosity**	**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													
$BQ5_{0.1\%}$	15	165	90	120	43.8	43.8	nil	18.0	901	28.0	13.1	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

Table 3. ***Typhadomingensis*** **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	0.82	0.79	0.84	0.86	0.64	0.71	0.78	0.82	0.70	0.82	0.89	0.90
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			

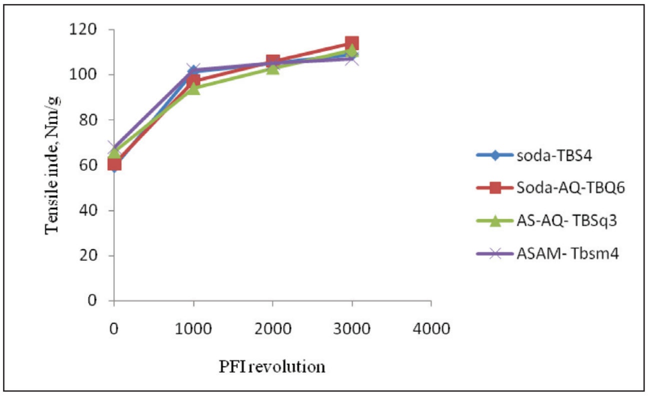

Figure 1. Tensile index vs. PFI revolution of *Typhadomingensis* bark unbleached pulps

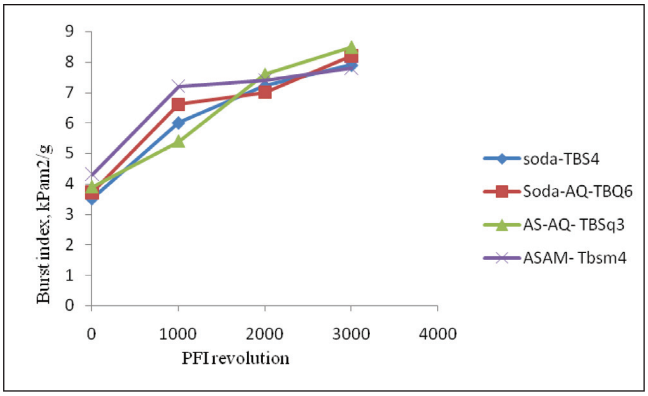

Figure 2. Burst index vs. PFI revolution of *Typhadomingensis* bark unbleached pulps

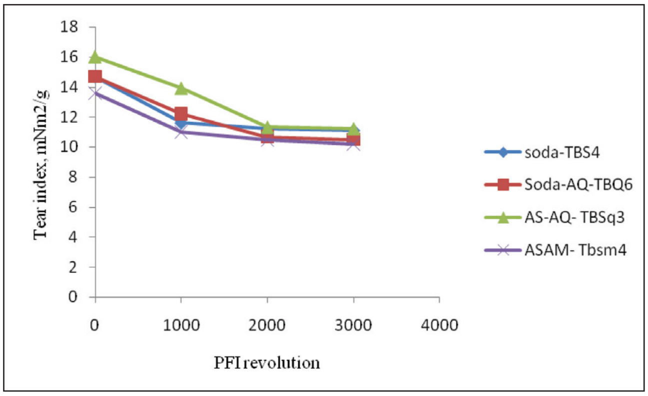

Figure 3. Tear index vs. PFI revolution of *Typhadomingensis* bark unbleached pulps

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

	Pulping conditions				pulp yield			pulp evaluation			B/L analysis		
Pulping Process	**% of active Alkali as Na_2O**	**Temp °C**	**Time-max temp/min**	**Time at max-temp**	**Total %**	**Screen %**	**Reject %**	**Kappa no**	**Viscosity**	**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
TWsm3	15.5	165	90	120	41.9	41.8	0.1	12.6	974	27.4	10.9	1.1	12.2
TWsm4	18	165	90	120	41.1	41.1	nil	10.5	946	31.4	12.0	2.2	12.5

B/L : Black liquor
RAA: Residual Active Alkali

Table 5. ***Typhadomingensis*** **southern cattail whole stem unbleached pulp properties**

Pulping process	**Soda**			**Soda–AQ**			**AS-AQ**				**ASAM**			
Pulp code	**TWS1**			**TWQ6**			**TWSq6**				**TWSm4**			
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
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	

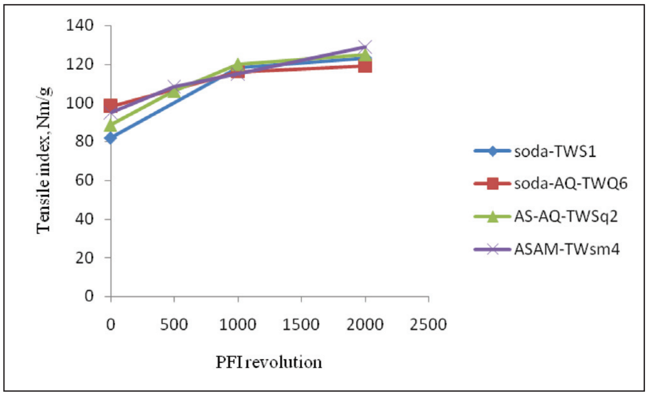

Figure 4. Tensile index vs. PFI revolution of *Typhadomingensis* whole stem unbleached pulps

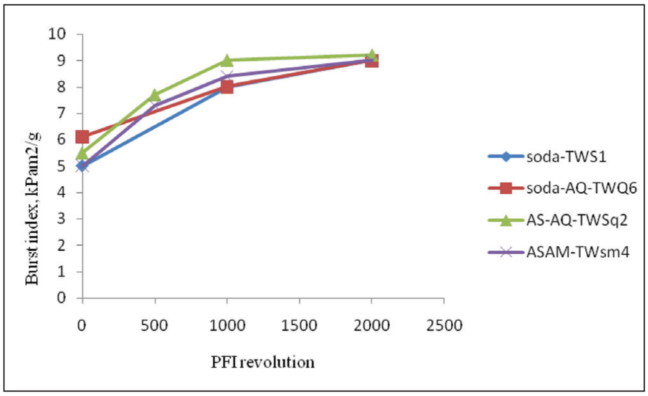

Figure 5. Burst index vs. PFI revolution of *Typhadomingensis* whole stem unbleached pulps

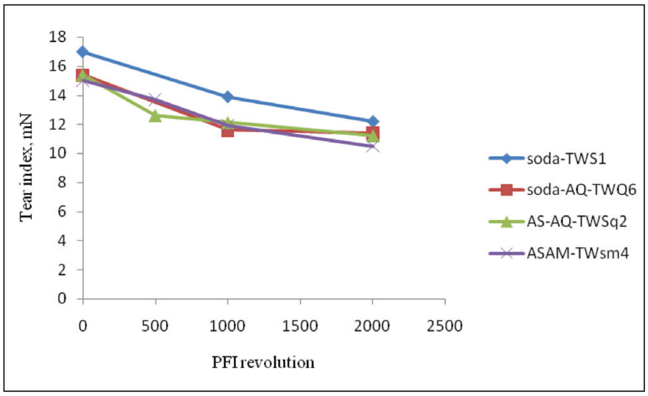

Figure 6. Tear index vs. PFI revolution of *Typhadomingensis* whole stem unbleached pulps

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 (Kordsachia and Patt, 1988). 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 TyphaD (d) omingensis

ASAM, AS-AQ and soda pulping of Typhadomingensis (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^{o}C 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 AND excellent kappa numbers with inferior initial brightness.

The mechanical properties of the unbleached *Typhadomingensis* whole stem (Table 5 and Figures 4-6) were quite high and satisfactory especially the tensile strength and tear resistance of Soda and AS-AQ pulps, which are very good papermaking properties this suggested that the southern cattail pulps could be used in manufacture of high strength papers or as blender for the short fiber pulps. The strength properties of *Typha* bark and whole stems (Tables 3 and 5) showed higher bonding strength (tensile and burst indices) and tear index of *Typha* whole stems (TWsm4) compared to *Typha* bark (Tbsm4).

Conclusions

The fiber of *Typha domingensis* 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. This removal provides 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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