ELUCIDATING THE BARRIERS FOR EXTENDED OXYGEN DELIGNIFICATION

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ABSTRACT

Research studies employed a low- and high-kappa SW kraft pulp and treated the pulp to an O and OO stage varying the charge of caustic and reaction temperature. Fiber properties and physical strength of low- and high-kappa kraft pulp subjected to O, OO stage and ECF bleaching have been measured. Analysis of residual lignin indicated that conjugated C-5 noncondensed phenolics play a key role in determining the overall extent of oxygen delignification. High-kappa pulp subjected to OO shows easier development upon beating. These results suggest that the kraft digester can be employed to prepare kraft pulps with residual lignin reactivity tailored for oxygen delignification.

EXPERIMENTAL

- Commercial SW kraft pulps (K#30.0, visco. 29.6 cP; K# 48.0, visco. 32.8 cP) and a laboratory conventionally cooked SW kraft pulp (K#50.0, visco. 36.8 cP) were employed in this study.
- All O and OO stages were conducted in a 1000-mL rotary autoclave. Conditions: 10% csc., 0.05% $MgSO_4$, 1.6-4.4% NaOH, 70-110°C temp., O_2 pressure 40.0 psi, time 1.0 h.

RESULTS

Table 1. O stage delignification conditions and results for low- and high-kappa pulps.

Pulp	NaOH, %	Temp., °C	Kappa	Viscosity, cP	Bleachability[a]	Selectivity[b]
K# 30	1.6	78	17.1	23.7	8.06	2.19
	4.4	78	16.4	20.7	3.09	1.53
	1.6	104	14.3	20.6	9.81	1.74
	4.4	104	12.4	15.6	4.00	1.26
K# 48	2.0	110	25.2	20.3	11.4	1.82
	3.3	94	27.2	21.2	6.30	1.79
	4.4	88	24.7	24.7	5.30	2.20

[a]Δ kappa/NaOH charge; [b]Δ kappa/Δ viscosity.

Table 2. O and OO delignification conditions and results for high kappa pulps.*

	NaOH, %	Temp., ˚C	Kappa	Viscosity, cP	Bleachability[a]	Selectivity[b]
O	3.0	90	30.0	27.0	6.67	2.04
OO1	3.0	72	23.0	25.2	2.33	2.39
OO2	1.6	78	24.2	25.2	3.63	2.22
OO3	4.4	78	22.0	23.0	1.82	2.03
OO7	1.6	105	19.3	20.2	6.69	1.85
OO8	4.4	105	14.9	15.4	3.43	1.64
OO9	3.0	110	14.3	15.7	5.23	1.69

*Kappa 50, viscosity 36.8; [a]Δ kappa/NaOH charge; [b]Δ kappa/Δ viscosity.

Table 3. 31P NMR analysis of kraft brownstock and post-O delignified residual lignins (mmol/g lignin).

Pulp	K# of O Stage	Aliphatic	C.OH : Nc.OH	p-Hydroxy-phenyl units	Acids
K# 30	brownstock	1.71	1.00	0.16	0.39
	17.1	2.13	1.13	0.18	0.68
	16.4	1.93	1.14	0.17	0.74
	14.3	2.15	1.18	0.18	0.75
	12.4	1.89	1.12	0.18	0.86
K# 48	brownstock	1.85	1.01	0.14	0.31
	25.2	2.27	1.21	0.14	0.67
	27.2	2.31	1.18	0.14	0.72
	24.7	2.28	1.10	0.14	0.65

C.OH : C-5 Condensed Phenolic OH; Nc.OH : C5 Noncondensed Phenolic OH.

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Figure 1. Changes in 5,5' biphenyl, C-5 condensed, and noncondensed phenolics in the residual lignin of brownstock (K #50) and post-O and OO delignified pulps.

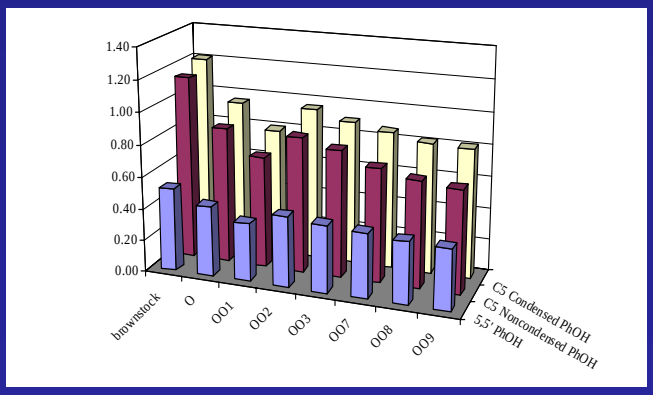

Table 4. Fiber properties of O, OO, and ECF treated pulps as analyzed by FQA.

Pulp	Percentage Fine, %*	Mean Length*, mm	Mean Curl Index*	Mean Kink Index, 1/mm
30-O	0.37	2.67	0.16	1.32
50-OO	0.33	2.67	0.14	1.31
30-O DEopD	0.28	2.50	0.20	1.86
50-OO D(Eop)D	0.35	2.42	0.23	1.92

* Length weighted.

Table 5. Physical strength properties of O, OO, and ECF* bleaching pulps.

Sample	PFI Rev.	Freeness	Bulk cm^3/g	Tear $mN.m^2/g$	Tensile N.m./g	Burst $kPa.m^2/g$	Zero-Span N.m./g
30-O	0	780	2.7	19.9	24.9	1.38	132.8
	1000	710	1.56	17.3	56.3	4.16	132.5
	3000	544	1.53	15.3	63.4	4.94	137.7
	6000	216	1.38	11.0	91.0	6.75	143.8
	7000	94	1.31	10.2	102.4	7.06	151.2
50-OO	0	744	1.92	21.3	33.2	2.03	127.8
	1000	677	1.51	12.5	60.6	4.34	136.1
	3000	432	1.38	9.3	80.3	6.00	140.0
	6000	173	1.32	8.2	84.2	6.77	144.5
30-O DEopD	0	758	2.43	19.4	20.9	1.0	119.6
	1000	684	1.57	14.4	58.7	4.17	129.7
	3000	386	1.4	10.6	79.6	5.15	139.4
	6000	104	1.28	9.0	87.7	7.25	136.7
50-OO D(Eop)D	0	751	1.84	20.8	28.9	1.73	120.6
	1000	663	1.52	13.0	57.5	4.43	128.6
	3000	365	1.39	10.0	76.7	6.28	139.3
	6000	111	1.3	9.3	77.7	6.53	140.8

* D: Csc 10%, 60 min, temp. 70ºC; Eop: Csc 10%, 60 min, temp. 70ºC, 0.5% H_2O_2; D: Csc 10%, 60 min, temp. 70ºC. Brightn. 88% ISO.

CONCLUSIONS

C-5 condensed phenolics and *p*-hydroxyphenols are enriched in the residual O and OO delignified lignin. C-5 condensed units are resistant to further degradation and most likely contribute to reduced O bleachability. C-5 noncondensed phenolics play a key role in determining the overall extent of oxygen delignification. The residual lignin in post oxygen delignified pulps is shown to be enriched with acid groups. The high-kappa kraft pulp shows comparable fiber properties after OO stage and ECF bleaching with low-kappa pulp after O stage and ECF bleaching. It is easier to develop the strength properties in high-kappa OO pulp upon beating, and both high-kappa OO and low-kappa O treated pulp are suitable for ECF bleaching, yielding acceptable strength properties.

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