

Ethanol-kraft pulping and papermaking properties of aspen and spruce

SUNG-HOON YOON, PETER LABOSKY JR., AND PAUL R. BLANKENHORN

THE KRAFT PULPING PROCESS IS the major chemical pulping method used today, accounting for over 70% of the total world pulp production. One major drawback of the kraft pulping process, however, is that a high pulping temperature and an alkaline environment are required for delignification to occur. These conditions cause appreciable reductions in kraft pulp yields, mainly due to the low delignification selectivity (1). The paper industry has constantly searched for alternatives or a modified kraft pulping process that results in improvements in pulp yields and paper quality and economic processing advantages.

One potential way to improve the kraft process is to add a solvent to the chemical makeup (2). At present, however, very limited information is available on the use of a solvent in combination with the kraft pulping process. Previous studies have primarily focused on a neat organosolv pulping process (3, 4). Only a few studies have been conducted on the use of an organic solvent in combination with the soda or the kraft pulping process. Marton and Granzo (5) studied the effects of ethanol addition to soda cooks of spruce using 20% NaOH in a 50:50 volume ratio of ethanol-NaOH solution and 2.5 hours at pulping temperatures of 150, 160, and 170°C. Results showed that delignification was more rapid and more selective with the ethanol-soda than with the soda process. Higher pulp yields at a

given kappa number and higher-brightness pulps were obtained from the ethanol-alkali pulps compared to the soda pulps. More recently, Norman *et al.* (6) conducted studies on a methanol-reinforced kraft pulping process. In their pulping studies using a Scandinavian softwood, a 16% methanol addition to a conventional softwood kraft cook at 40% sulfidity and 18% effective alkali (EA) was found to increase the delignification rate and selectivity.

This paper reports on the results obtained using a solvent-kraft pulping process spruce in a laboratory-scale digester. Aspen (*Populus tremuloides*) and Norway spruce (*Picea exelsa*) were subjected to solvent-kraft pulping and compared to conventional kraft cooks. The effects of ethanol concentration in the cooking liquor on the delignification rate, selectivity, pulp yield, and papermaking properties were examined.

RESULTS AND DISCUSSION

Ethanol-kraft delignification at 150°C

Solvent-kraft pulping experiments were conducted at 150°C using a 2-hour digestion time for each cook to determine the effects of lower pulping temperature on pulp yields. Ethanol addition to the kraft cooking liquor was varied from 0 to 0.4 mole fraction to evaluate the influence of ethanol composition in the kraft cooking liquor on the resultant pulp kappa number. **Figure 1** shows a

PULPING

ABSTRACT

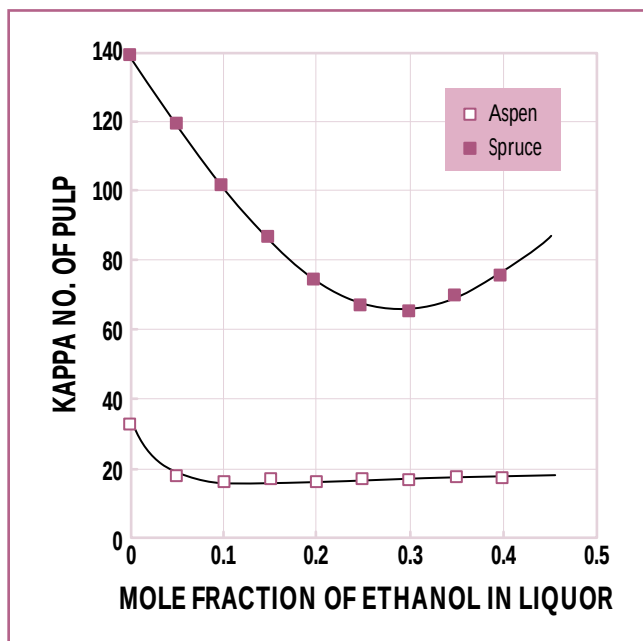
A study was undertaken to investigate the effect of ethanol addition to the kraft cooking liquor on the delignification of aspen and spruce wood chips and papermaking properties of the resulting pulps. Ethanol addition to the kraft pulping process had a significant impact on delignification and the resultant carbohydrate yields for both wood species. Maximum delignification selectivity was observed at the 0.1 and 0.3 ethanol mole fraction level for aspen and spruce, respectively. Remarkably faster delignification and about 30–50% lower residual lignin content of pulps was found in the solvent-kraft pulping process compared to the kraft process. A 4% gain in pulp yield and a 30% reduction in pulping time were achieved using the solvent-kraft pulping process. An increase in fiber shortening occurred during beating in solvent-kraft pulps, whereas no significant differences in beatability and water retention values were observed between the kraft and solvent-kraft pulps for both species. Solvent-kraft pulp handsheets exhibited higher bulk and comparable strength properties compared to the kraft samples, with the possible exception of tear.

Application:

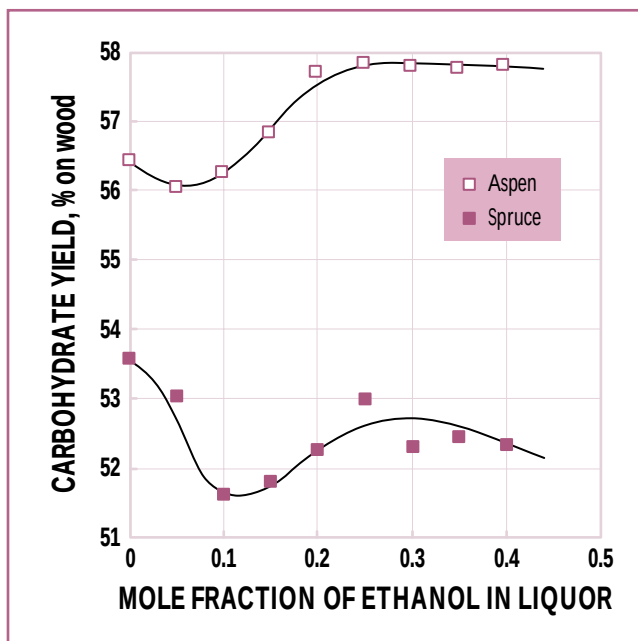
These results showed that marked improvements in the pulp yields can be achieved with ethanol additions to the kraft cooking liquor. Additional studies are needed to determine the effects of solvent additives to chemical recovery, black liquor heat value, and solvent recovery before commercial application can be considered.

plot of pulp kappa number as a function of ethanol mole fraction in the solvent-kraft cooking liquor.

At the 0.1 ethanol mole fraction level, approximately 45% of the



1. Kappa number of aspen and spruce pulps prepared at 150°C pulping as a function of ethanol mole fraction in the solvent-kraft cooking liquor



2. Carbohydrate yield of aspen and spruce pulps prepared from 150°C digestions as a function of ethanol mole fraction in the solvent-kraft cooking liquor

lignin of aspen kraft pulp was removed. The rapid reduction of lignin content upon the initial addition of ethanol to the kraft cooking liquor could be attributed to the improved reactivity of kraft chemicals with wood lignin in ethanol-added reaction media. Beyond 0.1 mole fraction of ethanol, however, an increase in the ethanol composition in the kraft cooking liquor appeared to have little or no effect in lignin removal from aspen wood chips. No statistical differences in mean kappa number of aspen pulps were observed beyond the 0.1 ethanol mole fraction level.

In the softwood solvent-kraft pulping with spruce wood chips, the lignin content of pulps also decreased, with a minima at about 0.3 mole fraction of ethanol. Approximately 50% of lignin in the kraft pulps was removed with an addition of 0.3 mole fraction of ethanol to the kraft cooking liquor. Significant differences in mean kappa number of solvent-kraft pulps were observed between the two wood species (p -value < 0.05). A slightly higher kappa

number observed in spruce pulp is apparently due to the higher initial lignin content of spruce wood chips compared to the aspen wood.

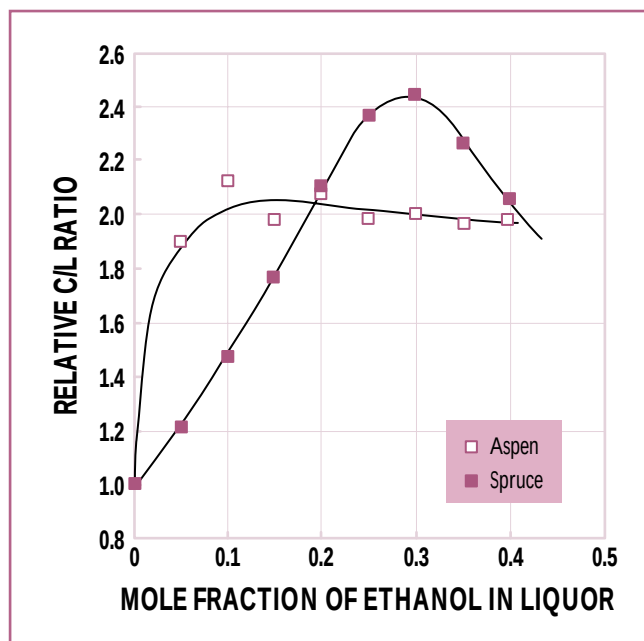
Carbohydrate yield

The carbohydrate yield or the lignin-free yield of pulp was estimated by subtracting the lignin content from the pulp yield (Fig. 2). Figures 1 and 2 demonstrate the different patterns between the carbohydrate reduction and lignin removal as a function of ethanol mole fraction for both wood species. The alkaline degradation of carbohydrates was significantly accelerated at the water-rich region of aqueous ethanol binary liquor. The carbohydrate retention on fibers, however, increased as the mole fraction of ethanol was increased and appeared to level off at about 0.25 ethanol mole fraction level. No significant differences in mean carbohydrate yield was observed for both wood species above the 0.25 ethanol mole fraction level (p -value > 0.05). The higher carbohydrate yield observed in aspen pulp suggests that the hemicellulose components in aspen

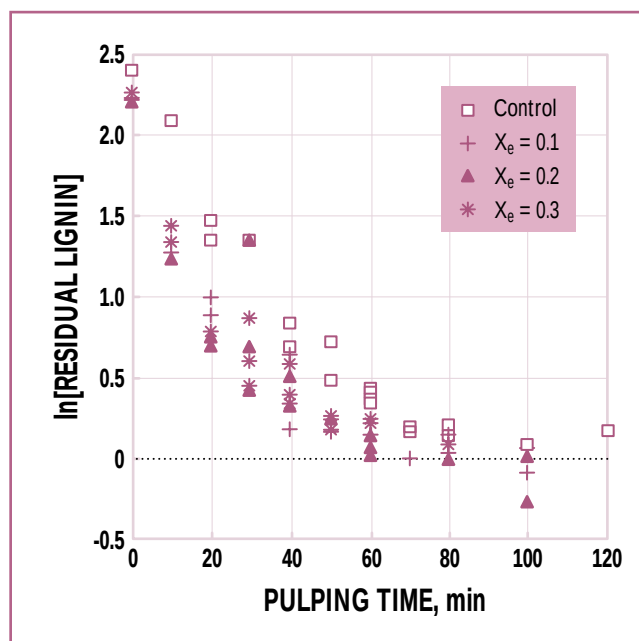
appeared to have a higher resistance to alkaline degradation in solvent-kraft pulping compared to those in spruce wood.

Delignification selectivity

The delignification selectivity can be expressed as the ratio of carbohydrate yield to lignin content of pulp (7); hereafter it will be designated as the C/L ratio. The relative C/L ratio can also be defined as the ratio between the C/L ratio of solvent-kraft pulps and the C/L ratio of control pulps. Figure 3 shows a plot of the relative C/L ratio of solvent-kraft pulps as a function of the mole fraction of ethanol in aqueous ethanol kraft cooking liquor. The result clearly indicates that the addition of ethanol to the kraft cooking liquor significantly affected the delignification selectivity for both wood species. In aspen pulp, the selectivity was increased drastically upon the initial addition of ethanol to the cooking liquor to about 0.1 mole fraction of ethanol. However, the delignification selectivity expressed as the relative C/L ratio progressively increased as ethanol addition in-



3. Relative C/L ratio in aspen and spruce pulps prepared from 150°C solvent-kraft digestions as a function of ethanol mole fraction in the cooking liquor



4. Natural logarithm of residual lignin contents of aspen pulps obtained from 170°C solvent-kraft digestions as a function of pulping time (min)

creased to about 0.3 mole fraction of ethanol and then decreased. These results suggest that the delignification selectivity of the kraft pulping process could be increased by a factor of 2.0–2.5 with the addition of the appropriate amount of ethanol to the kraft cooking liquor. Higher ethanol additions should be required in softwood than in hardwood solvent-kraft pulping.

Delignification rate

Aspen and spruce wood chips were subjected to the 170°C isothermal solvent-kraft pulping. The natural logarithm of residual lignin content was plotted as a function of pulping time (Figs. 4 and 5). Significantly lower residual lignin contents occurred for pulps obtained from the solvent-kraft pulping process in which the ethanol mole fraction varied from 0 to 0.3. However, no discernable differences in residual lignin content were observed with respect to ethanol addition levels. The ethanol addition to the kraft cooking liquor reduced the kappa number by about 5 and by about 22 units for 60-min pulping of aspen and for 100-min

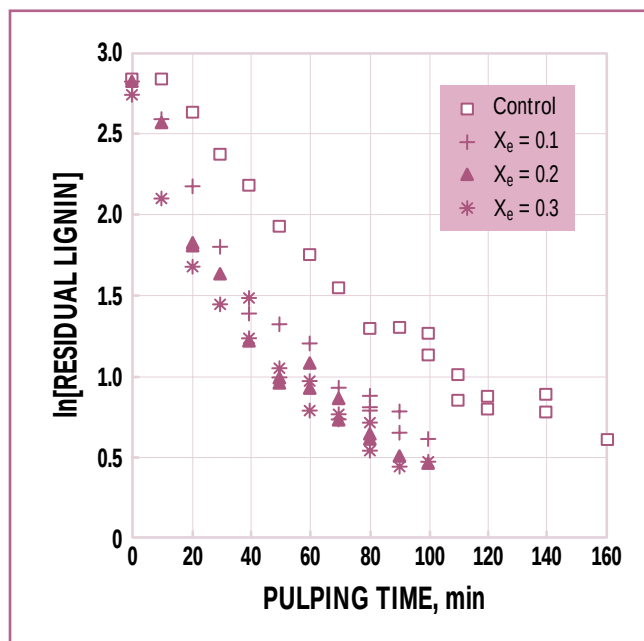
pulping of spruce, respectively. The low lignin content of solvent-kraft pulps could have a beneficial effect in reducing the consumption of bleaching agents, especially chlorine.

In the kraft pulping process, delignification occurs in three stages: the initial delignification, the bulk delignification, and the residual delignification (8). Figures 4 and 5 show the bulk and residual delignification stages in the kraft and solvent-kraft pulping processes. In both types of delignification process, a turning point exists between the bulk and residual delignification stages; this is referred to as the *phase transition point* of delignification (9, 10). Clearly, the addition of ethanol to kraft pulping shifted the phase transition point to a shorter cooking time. In producing bleachable-grade pulps, a 30–50% reduction in pulping time was observed using solvent-kraft pulping for both wood species.

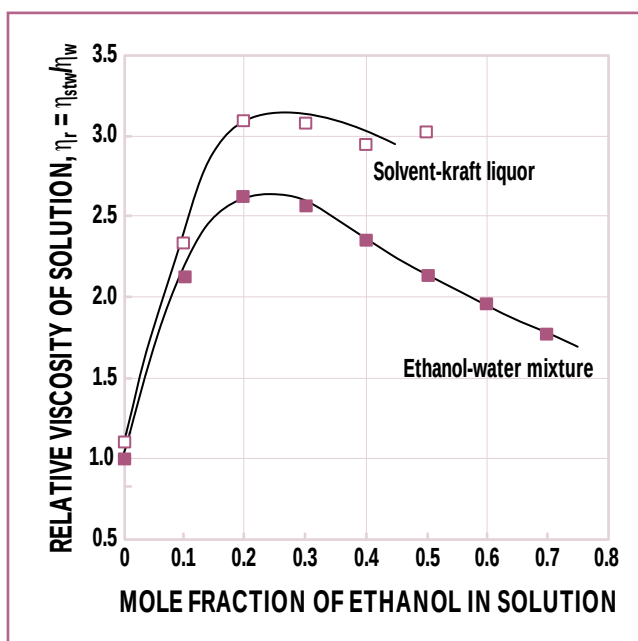
Either or both of two factors could occur to account for the accelerated delignification in the aqueous ethanol binary cooking liquor. One

factor could be that kraft ions present in an ethanol-water binary mixture may have a modified solvation structure and may exist in a higher free energy state (11). Higher mobilities of kraft ions and higher basicity in ethanol-added reaction media were observed compared to water media. The increased mobilities of kraft ions in the cooking liquor by addition of ethanol could result in a higher reactivity with lignin polymers in wood; this could explain the increased delignification rates observed in this study (Figs. 6 through 8).

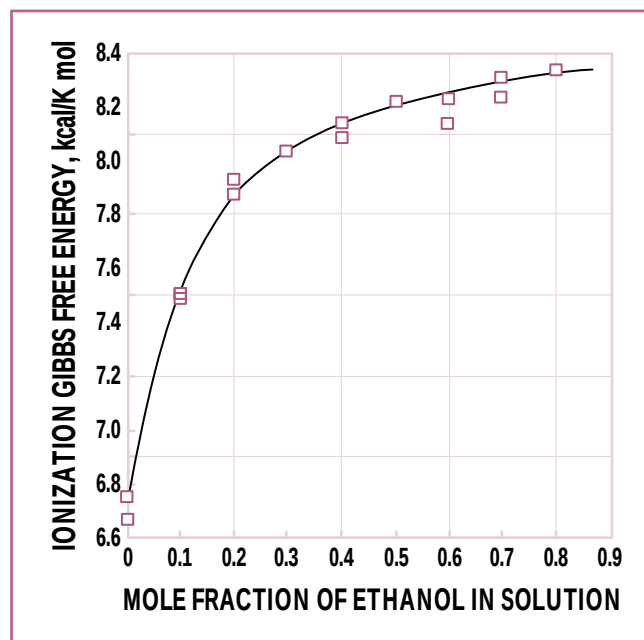
A second factor for the observed increased delignification rate with ethanol addition to the kraft cooking liquor may be the improved solubility of lignin in the liquor. In the kraft delignification process, the size of the pores in the wood cell walls may limit the depolymerized lignin fragments that can be removed from their location in the cell wall (12). Depolymerized lignin fragments that are larger than the pore size should be solubilized in the cooking liquor before removal through the cell wall.



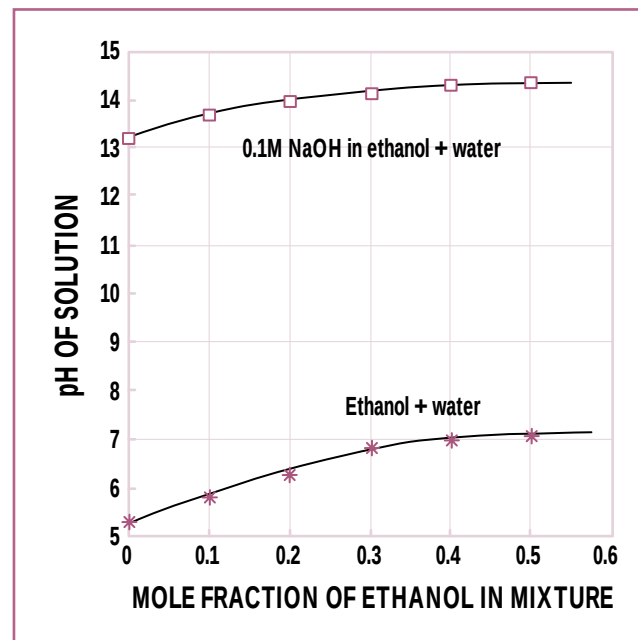
5. Natural logarithm of residual lignin contents of spruce pulps obtained from 170°C solvent-kraft digestions as a function of pulping time (min)



6. Change of relative viscosity of ethanol-water binary solvent and solvent-kraft cooking liquor (16% EA & 30% sulfidity) as a function of ethanol mole fraction in solution



7. Change of ionization Gibbs free energy of NaOH in ethanol-water binary solvent as a function of ethanol mole fraction



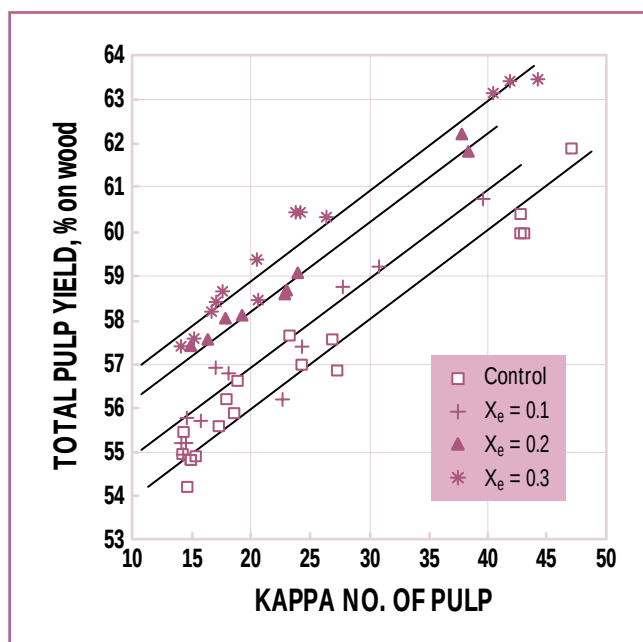
8. Effect of ethanol addition on the pH of pure water and 0.1 molar concentration of NaOH solution

The solvent property most important for polymer solubility is Hildebrand's solubility parameter (13). For excellent lignin solubility properties, the solvent should exhibit a

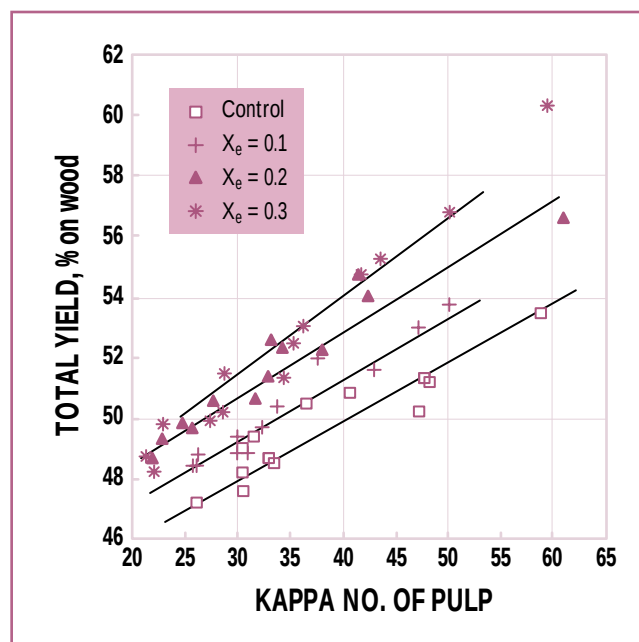
solubility parameter as close to 11 as possible (12).

As noted in an earlier experiment, the solubility parameter of ethanol is 12.7, whereas that of

water is 23.4 (14). Therefore, it is postulated that ethanol addition to the kraft cooking liquor may facilitate an enhanced lignin solubility and facilitate its removal from the



9. Total yields of solvent-kraft and control pulps obtained at 170°C cooking of aspen wood chips vs. kappa number of pulps



10. Total yields of solvent-kraft and control pulps obtained at 170°C cooking of spruce wood chips vs. kappa number of pulps

SPECIES	ASPEN		SPRUCE	
	0	0.3	0	0.3
X_e				
Beating, min	23 (a)	24 (a)	35 (c)	43 (d)
Fiber length, mm	1.34 (a)	1.32 (b)	1.46 (c)	1.35 (d)
WRV, %	127 (a)	123 (a)	138 (c)	137 (c)
Bulk, cm ³ /g	1.37 (a)	1.44 (b)	1.65 (c)	1.75 (d)
Tensile index, N/m ² /g	41 (a)	42 (a)	61 (c)	65 (c)
Burst index, kPa·m ² /g	3.7 (a)	4.0 (a)	7.7 (c)	7.8 (c)
Tear index, mN·m ² /g	0.7 (a)	0.6 (b)	1.4 (c)	1.4 (d)

1. Summary of papermaking properties of pulps prepared from 170°C kraft and 0.3 mole fraction of ethanol-kraft pulping (at approx. 400 mL CSF); kappa no.=13.5 (aspen) and 30 (spruce). Mole fraction of ethanol in cooking liquor is designated as X_e . Each measurement is an average of eight replicates. Means showing (a)-(a) and (c)-(c) within a row indicate no significant differences were observed at 95% probability (2-sample t-test).

porous solid wood into the surrounding liquid phase during pulping. Kraft delignification undoubtedly involves a more complicated mechanism; however, these two factors could explain a possible mechanism for the enhanced delignification rate observed with the ethanol addition to the kraft cooking liquor.

Total pulp yield

Pulp yields obtained from 170°C isothermal solvent-kraft pulping of aspen and spruce were compared at

the same kappa number; the results are shown in Figs. 9 and 10. As expected, a linear relationship was observed between total pulp yields and kappa numbers of pulp. An analysis of covariance conducted on the data indicated that significant differences in total pulp yields were observed among treatment levels of ethanol (15). Total pulp yields appeared to increase as the ethanol composition in the solvent-kraft cooking liquor increased from 0 to 0.3 mole fraction for both wood

species. The highest gain in pulp yield was observed at the 0.3 mole fraction level for both species. Approximately a 4% gain in pulp yield could be predicted from each regression relationship at a bleachable-grade kappa number for both wood species. An increase in pulp yield as a function of ethanol addition could be attributed to the increased delignification selectivity using the solvent-kraft pulping media.

KEYWORDS

Delignification, ethanol, hand sheets, kraft pulping, paper properties, Picea, Populus tremuloides, selectivity, solvents, temperature, yield.

Papermaking properties

Solvent-kraft pulps were prepared from 170°C digestions with 30% sulfidity. The effective alkali charge was 16% for aspen and 18% for spruce, and the ethanol concentration in the cooking liquor was 0 and 0.3. The handsheets were then prepared after beating pulps with kappa numbers of 13.5 for aspen and 30 for spruce. Papermaking properties, including beatability, weight-averaged fiber length, water retention value, and specific volume and strength properties of handsheets, were evaluated at 400 mL CSF (Table I). For aspen pulps, no statistical difference in beatability was observed between kraft and 0.3 mole fraction ethanol-kraft pulps. However, the differences in beatability of spruce pulps were significant between kraft and solvent-kraft pulps (p -value < 0.05).

The higher beating response of spruce solvent-kraft pulps could be attributed to the higher glucomannan contents of the pulps compared to the kraft pulps. For both wood species, significantly lower weighted-average fiber lengths were observed in solvent-kraft pulps than in kraft pulps. An increase in the amount of fiber shortening during beating of solvent-kraft pulps could produce paper with a large reduction in tear properties. The water retention value (WRV) of refined pulps would correspond to the difficulty of water removal in the actual paper machine wet press section. No significant differences in WRV were found between kraft and solvent-kraft pulps for both wood species. Significantly higher specific volume of handsheets

was observed in solvent-kraft pulps compared to the kraft pulps. Bulky handsheets of solvent-kraft pulps may account for the lower relative bonding area, which is mainly influenced by the elasticity of fibers. If the fibers are stiffer, minimal contact area occurs during wet pressing, and a comparatively weak, soft, and bulky sheet results (16). One of the beneficial effects of bulky paper could include its high softness in tissue paper and its high degree of dimensional stability, which is of major importance in printing-paper quality (17).

Solvent-kraft pulp handsheets exhibited comparable tensile and burst properties to kraft pulp handsheets for both wood species. However, a significant loss in tear strength value was observed in handsheets prepared from solvent-kraft pulps compared to the control pulps. This trend in low tear properties has been encountered in early solvent-soda pulping studies (5) and in most high-yield processes (18). In a high-yield pulping process, further loading of the carbohydrates on the fibers with an increasing amount of hemicellulose would reduce the proportion of cellulose and the number of fibers in the sheet to critical levels, thereby lowering the tearing resistance (17).

In the case of solvent-kraft pulp, however, some improvement in the overall structural properties of the individual fibers might be expected, partly because of the gain in total pulp yield and partly because of the shorter cooking time or milder cooking conditions used in the solvent-kraft pulping.

Considerations on commercial application

Considering the low specific heat capacity (about 0.62 cal/g°C) and heat of vaporization (204.26 cal/g) of ethanol compared to that of pure water (specific heat $\approx$ 1 cal/g°C, heat of vaporization = 540 cal/g), a com-

bination of ethanol and water in the kraft pulping process may contribute to a substantial heat economy for both digester operations and the solvent recovery system (19). The solvent may be easily recovered by using a simple distillation method. Of course, the cost of installation and maintenance of the distillation equipment for the solvent recovery system (cost/benefit) should be taken into account.

A fundamental question associated with toxicity of solvents should also be addressed before the solvent-kraft pulping process can be commercialized. All organic solvents show varied physiological and toxicological properties influencing the human organism to some extent. The extent of this influence greatly depends on the type of solvent, the time of exposure, and the amounts of solvent absorbed through skin and respiratory organs. The threshold limit values (TL values) have been used as a measure of the inhalation toxicity of chronic interaction with solvent vapors (14). Comparing TL values for the most applicable types of alcohols in the solvent-kraft pulping process, ethanol (TL value = 1900 mg/m³) shows 5–7 times lower toxicity than methanol (TL value = 260 mg/m³). This factor alone leads one to investigate the use of ethanol as the most promising type of solvent in the commercialization of the solvent-kraft pulping process.

EXPERIMENTAL

Aspen (*Populus tremuloides*) and Norway spruce (*Picea exelsa*) were selected for the solvent-kraft pulping studies. Two sets of pulping experiments were conducted to evaluate the effect of ethanol addition to the kraft cooking liquor on the pulping and handsheet properties. For experiment 1, wood chips were subjected to 2-hour solvent-kraft cooks at 150°C pulping temperature with var-

ious ethanol mole fractions. For experiment 2, 170°C isothermal solvent-kraft pulping experiments were carried out with various pulping times and various ethanol mole fractions. In all cases, the effective alkali charge was 16% for aspen and 18% for spruce at a liquor-to-wood ratio of 5:1 and a sulfidity of 30%. In preparing the solvent-kraft cooking liquor, 95% ethanol was used. The concentration of ethanol in the cooking liquor is expressed in mole fraction, X_e . The calculation procedure used to determine the ethanol mole fraction in the liquor is described as follows:

- (95% ethanol volume) x (Specific gravity of 95% ethanol) = A
- $A \times 0.05 = B_1$ (Weight of water in 95% ethanol)
- $A - B_1 = C$ (Weight of pure ethanol)
- Number of moles of ethanol = $C / (\text{Mol. weight of ethanol})$
- Number of moles of water = $(B_1 + B_2) / (\text{Mol. weight of ethanol})$, where B_2 = volume of water added to the liquor.

Then,

$$X_e = D / (D + E) \quad (1)$$

The M/K laboratory digester used in this work was a 6-L stainless steel vessel equipped with an external heat exchanger and a forced liquor circulation system. For each cook, 120 g (o.d. basis) of wood chips were charged into the digester in addition to the prepared cooking liquor containing the desired amounts of chemical and solvent. Pre-evacuation of the digester prior to a run was not performed in this study to avoid any possible change in solvent composition of the liquor. After completion of the cook, the spent liquor was discharged as quickly as possible through a blow valve located at the

bottom of the digester. The softened chips obtained from each run were passed through an 8-in. Bauer Bros. single-disc refiner at a 0.06-in. clearance to enhance fiber separation and washing.

Approximately 50 gal of warm water were used as continuous dilutions for each pulp. All effluent from the wash tank was directed into a 200-mesh screen to minimize loss of fines, and entrained fibers were returned to the pulp mass. Hand-squeezed wet pulps were transferred to tared, dried kraft paper bags and oven dried. Pulp yields were determined based on the oven-dry weight of wood chips initially charged to the digester. Residual lignin contents of pulps were evaluated for kappa number (TAPPI Test Method T 236 om-85). Pulps with a kappa number of 13.5 for aspen and 30 for spruce were beaten in the laboratory Vally beater (TAPPI Test Methods T 227 om-85 and T 205 om-85). Beatability, weight-averaged fiber length, and water retention values were measured and evaluated at 400 mL CSF. Handsheets were conditioned and tested for basis weight, specific volume, tensile, burst, and tear properties.

CONCLUSIONS

The following conclusions were drawn from the results of this study:

- Ethanol-kraft pulping experiments performed at 150°C pulping temperature and 2 hours cooking time indicated that the ethanol mole fraction in the solvent-kraft pulping process had a significant impact on delignification and the resultant carbohydrate yields for aspen and spruce wood chips.
- Using a solvent-kraft pulping temperature of 150°C, maximum delignification selectivity was observed at 0.1 and 0.3 ethanol

mole fraction levels for aspen and spruce, respectively.

- Ethanol-kraft pulping of aspen and spruce wood chips at 170°C exhibited remarkably faster delignification and 30–50% lower residual lignin content of pulps compared to the conventional kraft pulping process.
- At comparable kappa numbers, about a 4% gain in pulp yield was obtained for both species as a result of the increased selectivity using the ethanol-kraft pulping process at 170°C.
- An increase in the amount of fiber shortening occurred during beating in solvent-kraft pulps compared to kraft pulps, whereas no significant differences in beatability and water retention value were observed between kraft and solvent-kraft pulps, with few exceptions, for both wood species.
- Solvent-kraft pulp handsheets of aspen and spruce exhibited higher bulk and comparable tensile and burst properties compared to kraft pulps, with the possible exception of tear.
- Based on the results observed in this study, a 4% gain in pulp yield and about a 30% reduction in pulping time was achieved using the solvent-kraft pulping process, with minimal changes in paper quality. **TJ**

Yoon is a doctoral candidate, Labosky is a professor, and Blankenhorn is a professor at The Pennsylvania State University, School of Forest Resources, University Park, PA 16802.

The authors express their appreciation of Westvaco Corp., Tyrone, PA, for the use of its laboratory to test handsheets.

Received for review June 21, 1995.

Accepted June 30, 1996.

LITERATURE CITED

1. Rydholm, S. A., *Pulping Processes*, Vol. I, Interscience Publishers, John Wiley and Sons, New York, 1965, pp. 576-649.
2. Yoon, S.-H., "Solvent-kraft pulping and papermaking properties of aspen and spruce," Ph.D. dissertation, The Pennsylvania State University, University Park, PA, 1995.
3. Aziz, S. and Sarkanen, K. V., *Tappi J.* 72(3): 169(1989).
4. Aziz, S., McDonough, T., Thompson, N., et al., *Tappi J.* 71(2): 251(1988).
5. Marton, R. and Granzow, S., *Tappi* 65(6): 103(1982).
6. Norman, E., Olm, L., and Teder, A., *Tappi J.* 76(3): 125(1993).
7. Oriaran, T. P., Labosky Jr., P., and Blankenhorn, P. R., *Tappi J.* 73(7): 147(1990).
8. Sjostrom, E., *Wood Chemistry: Fundamentals and Applications*, Academic Press, New York, 1981, pp. 66-75, 124-141.
9. Lemon, S. and Teder, A., *Svensk Papperstid.* 11: 407(1973).
10. Kleinert, T. N., *Tappi* 57(8): 99(1974).
11. Amis, E. S., *Solvent Effects on Chemical Phenomena*, Vol. I, Academic Press, New York, 1973, pp. 62-74.
12. Sarkanen, K. V. and Ludwig, C. H., *Lignins: Occurrence, Formation, Structure and Reactions*, Wiley-Interscience, New York, 1971, pp. 639-689.
13. Krevelen, D. W. V. and Hoftyzer, P. J., *Properties of Polymers: Their Estimation and Correlation with Chemical Structure*, Elsevier, New York, 1976, pp. 447-449.
14. Reichardt, C., *Solvents and Solvent Effects in Organic Chemistry*, 2nd edn., VCH Publishers, New York, 1988, pp. 1-129.
15. Anon., *S.A.S. User's Guide*, S.A.S. Institute, Inc., Cary, NC, 1983.
16. Clark, J. d'A., *Pulp Technology and Treatment for Paper*, Miller Freeman, San Francisco, 1985, pp. 278-332.
17. Casey, J. P., *Pulp and Paper Chemistry and Chemical Technology*, Wiley-Interscience, New York, 1981, pp. 1766-1774.
18. Sanyer, N. and Laundrie, J. F., *Tappi* 47(10): 640(1964).
19. Perry, R. H. and Chilton, C. H., *Chemical Engineer's Handbook*, 5th edn., McGraw-Hill, New York, 1973, pp. 3-116.

..... Now Available From TAPPI PRESS



THE ISO 14000 HANDBOOK ISO 14000 QUESTIONS AND ANSWERS

Edited by Joseph Cascio

Edited by Caroline G. Hemenway and Mary McKiel

- The most comprehensive information sources for ISO 14000 available! The handbook
- contains the actual text of the ISO 14001 and ISO 14004 standards, as well as clause-
- by-clause explanations. It offers guidance for evaluating ISO 14001 Environmental Man-
- agement Systems requirements and for developing and executing an implementation
- plan. The handbook will help answer your questions about the certification process.
- Contents also include: ISO 14000 Overview, Different Approaches, Other ISO 14000
- Standards, Auditing, Conformity Assessment, Legal and Regulatory Considerations,
- Global Status, Related Initiatives, and EMS Resources. The ISO 14000 Questions and
- Answers book addresses more than 55 frequently asked questions about all aspects of
- ISO 14000. It also features a list of Environmental Acronyms, an Environmental Glossary,
- a listing of ISO 14001 Accreditation and Certification Bodies, a list of TC 207 Liaison
- Members and a references section.
- Both books published 1996 by CEEM with ASQC
- The ISO 14000 Handbook: 764 pgs., 7 1/2" x 9" soft cover; Item number: 08CEISOH
- Price: \$75 (members and nonmembers), plus shipping and handling
- ISO 14000 Questions and Answers: 56 pgs., 7" x 8 1/2" soft cover; Item number:
- 08CEISOQA
- Price: \$20 (members and nonmembers), plus shipping and handling

Call TAPPI's Service Line today to place your order! 1-800-332-8686 (US)
1-800-446-9431 (Canada) • (770) 446-1400 • fax (770) 446-6947