Yield Increases with Lo-Solids® Cooking

Bertil Strömberg
Director of Technology
Andritz Inc.
Glens Falls, N.Y., USA

Keywords

Cooking Hardwood Yield Xylan

Summary

Fourteen Lo-Solids® digesters operating on hardwood report a yield advantage from using this cooking process. The measured benefit is 1-4 % on wood. Pulp strength and paper machine performance have also improved.

The experiences at different mills will be discussed, together with lab work proposing the mechanisms behind the improvements.

SUMÁRIO

Quatorze digestores operando com hardwood relataram vantagens no uso deste processo de cozimento. Os benefícios medidos sobre madeira são de 1 – 4%. A resistência da polpa e a performance de máquinas de papel também melhoraram.

As experiências em diferentes fábricas serão discutidas, junto com o trabalho em laboratório que propõe os mecanismos envolvidos nas melhorias.

Palavras chave: Cozimento, Hardwood, Rendimento, Xilana.

Introduction

Lo-Solids Cooking is a family of cooking technology, in which the bulk delignification zone is more dilute than with conventional cooking technology. This can be arranged in many different ways, depending on each individual digester. Since the introduction of Lo-Solids cooking in 1993, there are now over 60 digesters around the world, using this innovative cooking process. Of these, 12 digesters are new. Many benefits have been reported from these mills, as better digester runability, better pulp strength and better pulp dryer and paper machine performance. After gaining experience with the operation, hardwood mills started to report a yield increase as a result of using the Lo-Solids cooking process.

Figure 1. *Summary of Mil Experience with Measured Yield Increases on Lo-Solids Cooking*

Mill	Wood	Yield Increase	Method of Determination
A	Mixed So. US	4%	Wood Consumption Decrease (4years) M-P Equation (4 studies)
B	Mixed No. US	4%	Wood Consumption Decrease (3 years)
C	Mixed So. US	2%	M-P Equation (3 studies)
D	Mixed So. US	1%	M-P Equation (2 studies)
E	Euca. So. America	2-3%	Black Liquor Solids M-P Equation (2 Studies)
F	Mixed Ea. Canada	1.6%	Wood Consumption Decearse (2 years)
G	Birch Finland	1-2%	M-P Equation
H	Mixed So. US	2.4%	M-P equation Production Data
I	Mixed No. US	1.5%	Pulp Consumption Data
J	Euca. So. America	1.5%	Wood Consumption Data (2 years)
K	Birch Finland	3%	M-P Equation Wood Consumption Data (2 years)
L	Mixed Japan	2-3%	Short term trials
M	Euca. Spain	2-3%	Wood Consumption data 9 3 years)
N	Mixed Japan	1.5-2.5%	Black Liquor Solids

Yield Determination Methods

There are many more or less accepted ways to indirectly determine the pulp yield in a mill. The most common methods are measurements of wood consumption, black liquor solids, recovery boiler steam generation and pulp composition.

Measurement of wood consumption takes a long time. Black liquor solids and boiler steam generation are affected by the inorganic load, and as alkali consumption is typically lower with Lo-Solids cooking, this measurement does not correctly reflect the yield improvement.

Pulp composition has been used as an indicator of yield, but as we change the alkali profiles, this method can no longer be used. **Figure 2** shows that despite very small variations in hemi content in the pulps, the yield can vary by as much as 2 %. The yield difference is mainly due to a difference in cellulose yield. This was first reported by Achrén et. al. (1).

Figure 2. *Yield and Carbohydrate Composition for Lab Eucalyptus Pulps Cooked with Different Alkali Profiles*

Kappa	Lignin Free Yield	Glucan	Xylan
14.8	54.8 %	79.2	17.2
14.7	54.3 %	79.6	17.1
14.6	54.0 %	79.6	17.6
13.2	52.8 %	81.3	17.4

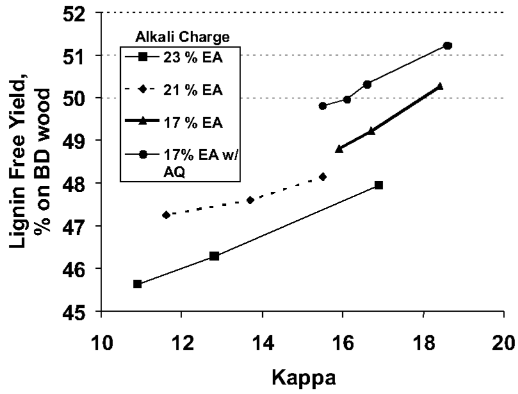

Figure 3. *Lignin-free Yield versus Kappa Number for HW Lab Pulps Cooked with Different Conditions*

A new method for yield determination has been developed by the Andritz R&D lab. The method is described in detail in (2). **Figure 3** shows yield versus kappa number for lab hardwood pulps cooked with different alkali charges. By analyzing the lab pulps for TAPPI viscosity (V), and cellulose content (G'), and creating the parameter log(V)/G'^{2}, we get a straight line correlation with the lignin-free yield, **Figure 4.** We can now analyze the mill pulp made from the same chips as the lab pulps, determine the log(V)/G'^{2} value and read the yield of the mill pulp, **Figure 5.**

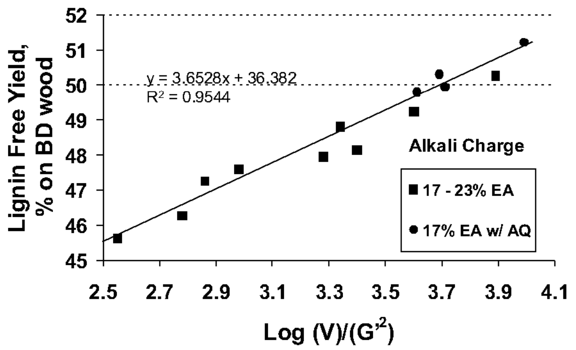

Figure 4. *The same pulps as in Figure 3, but the Lignin-Free Yield is plotted against the parameter log(V)/(G'^{2}). See the text for definitions of V and G'*

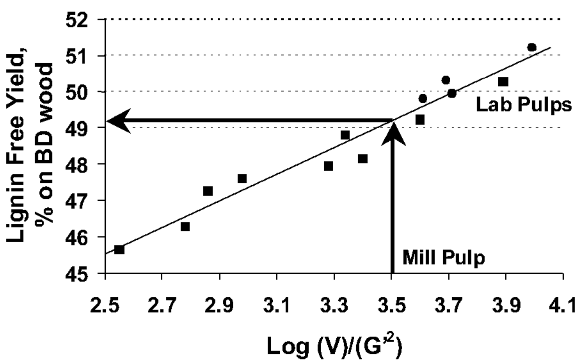

Figure 5. *Knowing the log(V)/(G'^{2}) for a Mill Pulp gives the Ability to Determine its Yield*

The log(V)/G'[2] value for different pulps plotted versus lignin-free yield show a very reliable slope of about 3.6, **Figure 6.** The intercept with the Y-axis is interpreted to be a function of differences in cellulose content of the native fiber, and differences in primary peeling. The validity of this method for yield determination has been verified by van Heiningen et. al.(3).

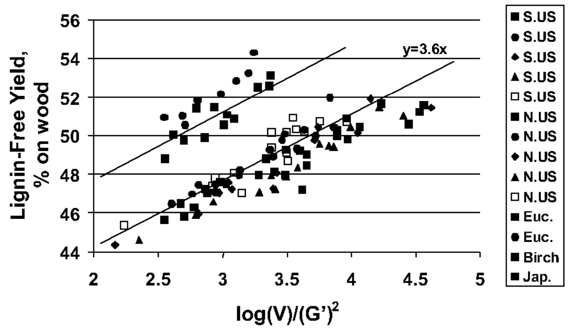

Figure 6. Lignin-free Yield versus log(V)/(G'[2]) for Several Different Hardwoods

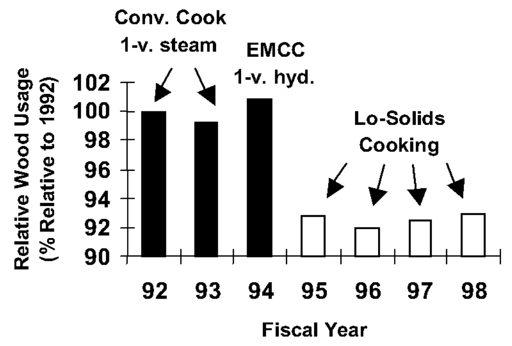

Figure 7. Yearly Average Hardwood Consumption at Gulf States Paper Co

Mill Experiences with Yield Improvements

Mill A, Gulf States Paper Co in Demopolis, Alabama, was one if the first mills to use Lo-Solids Cooking on a hardwood digester, and was also the first mill to recognize the yield increase, **Figure 6**. (4) The yield increase for bleached pulp is about 4 % on wood, compared to what was achieved in the old single-vessel steam phase digester, and also compared to the EMCC® operation in the new digester. Data from using M-P equation to determine the yield for Gulf States is presented in Figure 7. It confirms a 2.5% yield increase on unbleached pulp.

Mill B is the Weyerhaeuser mill in Johnsonburg, Pennsylvania (5). This mill also saw an increased yield for bleached pulp by about 4 %, compared to the previous batch and EMCC cooking methods, **Figure 8.** The M-P Equation shows a yield increase on unbleached pulp of about 2.7 %.

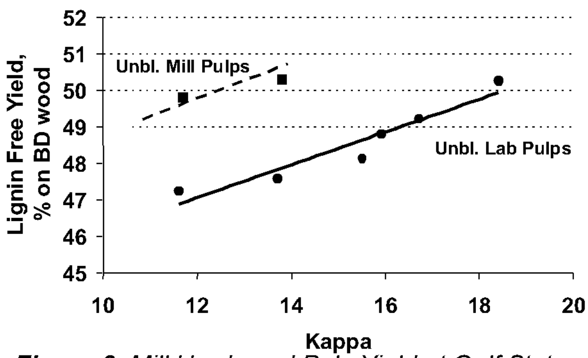

Figure 8. Mill Hardwood Pulp Yield at Gulf States as Determined by the M-P Equation. Comparison is made to Lab Pulps Cooked From the Same Wood as the Mill Pulp.

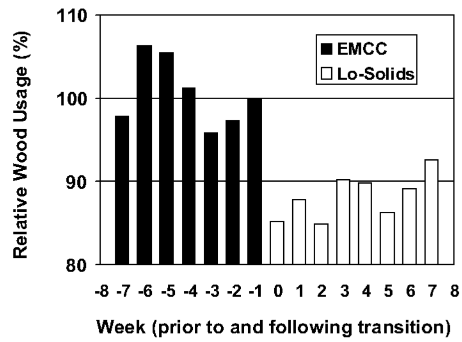

Figure 9. Weekly Average Hardwood Consumption at Weyerhaeuser, Johnsonburg Mill

For Mill C, a Southern US mill, the M-P Equation shows a yield increase of about 2 %, compared to the old batch cooking system.

Mill D, another Southern US mill, saw a 1 % yield increase after switching to Lo-Solids from EMCC, as evidenced by the M-P Equation.

Black liquor solids and pulp composition data indicate 2-3 % yield increase on Eucalyptus in a South American mill, Mill E, compared to data from other mills in the region. The other mills use single-vessel steam phase digesters.

Mill F, has a two-vessel hydraulic digester with Lo-Solids. Long-term production data show a 1.6 % yield increase for Lo-Solids, compared to MCC™ cooking.

Mill G, operates a two-vessel steam phase digester, which was converted from conventional cooking to Lo-Solids cooking. The digester swings between softwood and hardwood. The M-P equation shows a yield increase on hardwood of 1-2 %. There is no yield effect on softwood.

Mill H has a single-vessel hydraulic digester, which has operated on Lo-Solids mode for about six months. A yield increase is reported, but the mill has declined any further comments.

Mill I has a single vessel hydraulic digester in which the kappa number has been lowered 4-5 units on Lo-Solids cooking, compared to conventional cooking. Two years of operation show the wood consumption to be the same, despite the lower kappa number.

Mill J, has a two-vessel steam phase digester with one of the highest digester wash zone loadings in the world, 64 ADMT/D, m^2. Short-term data suggest that Lo-Solids cooking decreased wood consumption by about 3 %,

Mill K, UPM-Kymmene in Kuusanniemi replaced two single-vessel hydraulic digesters with one new Lo-Solids digester. Start-up took place in September 1999. Long term production data and lab measurements using the MP equation confirm about 3 % yield increase. This digester is also equipped with a Lo-Level® Feed system. A detailed description of this digester can be found in (6).

Mill L, has done preliminary studies showing yield increases of 2-3 % on hardwood with Lo-Solids cooking. The studies are continuing. This digester also has a Lo-Level feed system.

Most of these mills also report better pulp quality and performance on pulp and paper machines.

Mill M, Papelera Guipuzcoana de Zicunaga in Spain, experienced a yield increase of 2-3 % compared to conventional cooking, based on long-term wood consumption numbers. Zicunaga operates a single-vessel hydraulic digester, which is also equipped with a Lo-Level feed system.

Possible Reasons for the Yield Improvement

The digesters experiencing this yield improvement have many parameters in common:

1. Post-Impregnation Extraction
2. Slow heat-up in liquor phase
3. Low and even alkali concentrations
4. Low liquor-to-wood ratios
5. No black liquor impregnation
6. High sulfidity at beginning of bulk delignification
7. Lower concentration of dissolved wood substances in cook zone
8. Lower ion strength in cook zone
9. Lower temperatures

The post-impregnation extraction takes place at temperatures lower than about 130°C. At this low temperature, a very low alkali concentration can be maintained. A typical target is about 3 g/l EA as NaOH. About 40 % of the total extraction flow from the digester is withdrawn after the impregnation zone. The low volume, combined with a low temperature and low alkali concentration ensures that no hemicellulose is removed at this point.

Due to the slow heat-up in counter-current fashion, there is no problem with these low residuals. A fast heat-up would cause large amounts of rejects. The counter-current heat-up also ensures that the alkali concentration stays low. This is particularly good for cellulose yield retention (1,7).

The alkali concentration in the digester never exceeds about 15 g/l, except for at the very beginning of the impregnation zone, **Figure 11.** This, in combination with low cooking temperatures, decreases random chain scission and secondary peeling reactions.

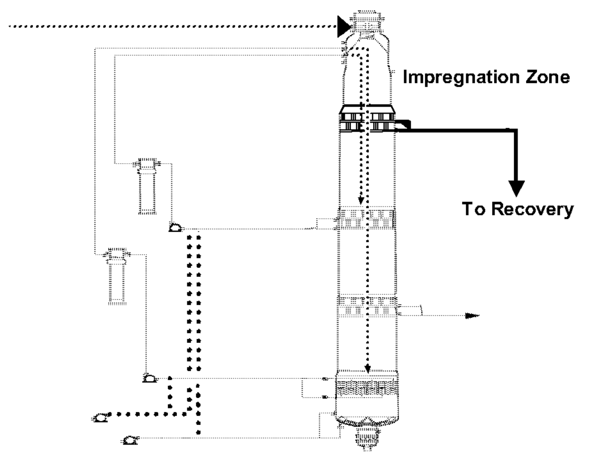

Figure 10. *Post-Impregnation Extraction is used in every Digester Showing a Yield Increase*

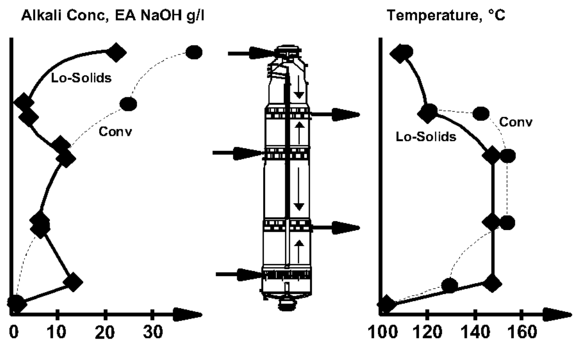

Figure 11. *Alkali and Temperature Profiles for Lo-Solids and Conventional Cooking*

Supporting Lab Studies

Achrén compared the effects of different alkali and temperature profiles on the yield of birch pulps (1).

He found that hardwoods are much more sensitive than softwoods to the impact of alkali concentrations on yield. By cooking at low and even alkali concentrations, the yield could be increased from a normal 52 % to close to 56 %. Having low alkali concentrations at the beginning of the bulk delignification is of particular importance.

Figure 12 shows three different alkali concentration profiles in the bulk delignification zones used in Achren's work. The alkali concentration in the residual phase was the same for the three tests. The resulting yields in **Figure 13** show the low alkali profile (C) having a yield that is about 4% higher than that for the more normal alkali profile (A).

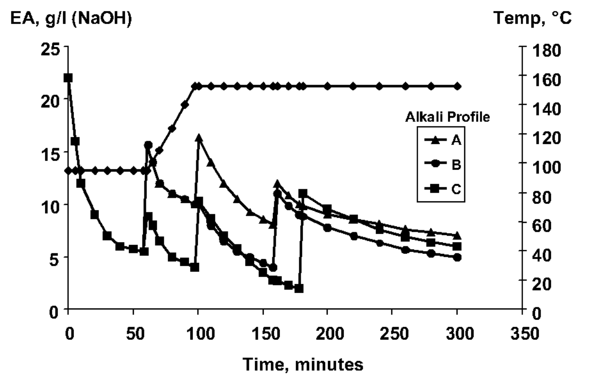

Figure 12*. Alkali and Temperature Profiles used by Achren (1)*

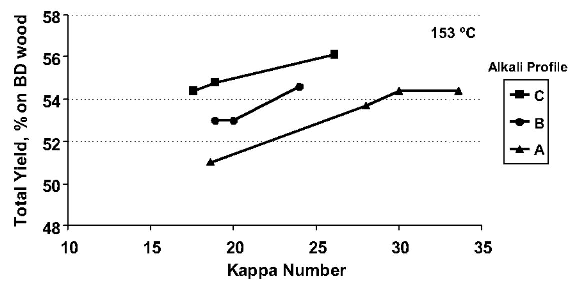

Figure 13. *Total Yield versus Kappa Number reported by Achren*

Figure 14 shows the alkali profiles when the alkali concentration in the residual phase was varied. For these tests, each of the other bulk delignification profiles was also used. **Figure 15** shows that even with extremely large changes in alkali concentration in the residual phase, the yield difference was smaller than with comparatively small alkali changes during bulk delignification. This emphasizes the need for low alkali concentration during bulk delignification.

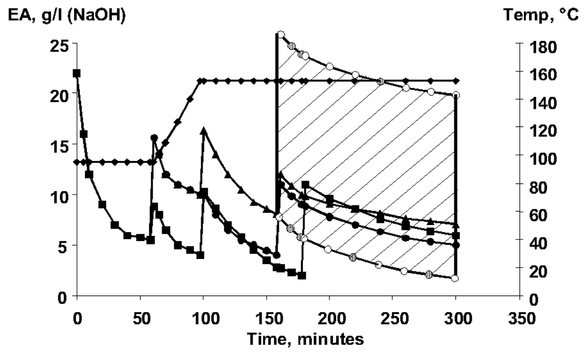

__Figure 14.__ Alkali Profiles Variations used by Achren in Residual Delignification. The same Bulk Delignification Profiles as in Figure 12 were used.

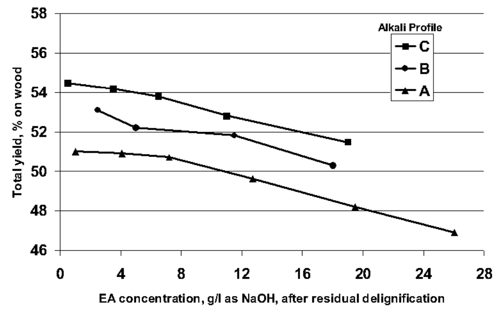

__Figure 15.__ Total Yield as a function of Alkali Concentration after Residual Delignification. Curves A, B and C refer to the Bulk Delignification Alkali Profiles shown in Figure 12.

Jiang et. al. showed that the alkali concentration at the beginning of the bulk delignification had a major effect on the cellulose yield, whereas the alkali concentration at the end of the cook affected mainly the hemicellulose yield (7). This explains why the pulp composition alone cannot be used to determine the yield of a particular pulp. The alkali profiles used in Jiang's work are shown in **Figure 16**, and the yield of the major pulp components in **Figure 17**.

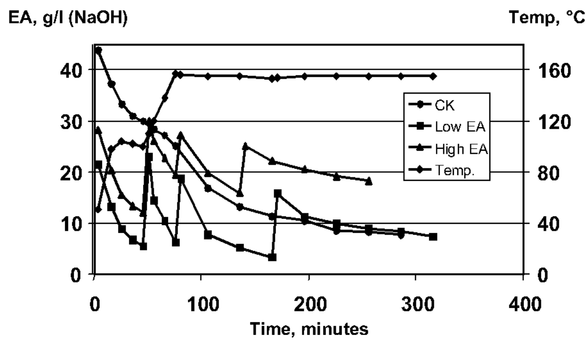

__Figure 16.__ Alkali and Temperature Profiles used by Jiang (7)

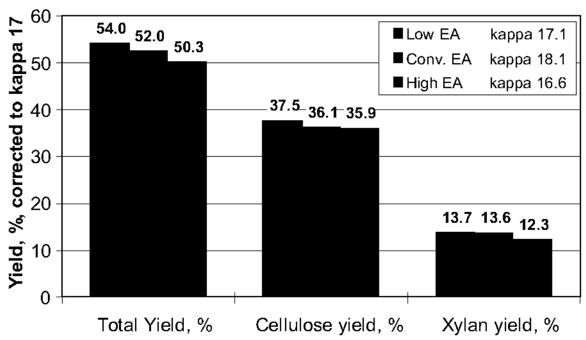

__Figure 17.__ Total Yield and Cellulose and Xylan Yields for the Pulps Produced using the Alkali Profiles in Figure 16. Cellulose Yield for the Low EA Cook is the highest.

For the High EA profile, the cellulose yield is the same as for the Conventional alkali profile, but the xylan yield is lower, as expected.

For the Low EA profile, the cellulose yield is about 1.5 % higher than for the Conventional EA profile, whereas the xylan yield is the same for both profiles. For the High EA profile, the cellulose yield is the same as for the Conventional, but the xylan yield is lower, as expected.

The xylan concentrations in the black liquor were analyzed throughout the cooks. The results are shown in **Figure 18**. The normal alkali profiles, starting at normal concentrations in the beginning of the cook, show the expected behavior of the xylan concentration first increasing to close to 15 g/l as it dissolves into the liquor. In typical manner, the xylan concentration first increases to close to 15 g/l as it dissolves into the liquor. The xylan concentration then decreases, as it reprecipitates back onto the fiber. However, at the lower alkali concentrations, the dissolved xylan concentration stays at a very low level, about 4 g/l. Thus, there is no worry about excessive removal xylan from the cook by extracting from several different points on the digester. It is interesting to note that the dissolved xylan concentration is exactly the same after the conventional cook as after the low alkali cook. At the same time, the xylan yield for the two cooks was shown to be the same.

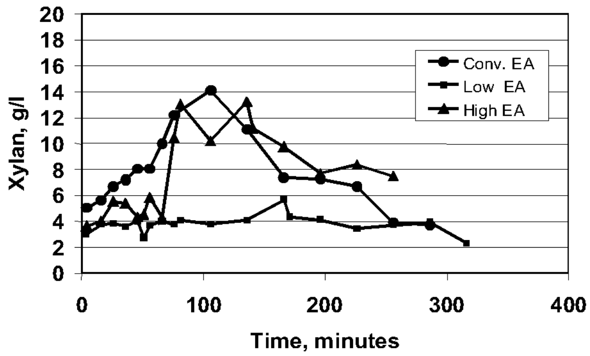

Figure 18. *Dissolved Xylan Concentration in the Cooking Liquor for the Cooks shown in Figure 16. Dissolved Xylan Concentration is the Lowest for the Low Alkali Cook.*

These lab studies show that the different components in the fiber react differently to the conditions in different parts of the cook. By knowing this behavior, we can optimize the chemical properties of the pulp to fit the desired properties of the paper maker.

Conclusions

All HW mills us Lo-Solids cooking with post-impregnation extraction show a yield increase of 1 - 4% compared to eailier operating methods.

The alkali concentration profile during the kraft cook affects the yields of both cellulose and hemicellulose.

Low alkali concentration at end of cook mainly affects hemicellulose (xylan) yield.

Low alkali concentration at the beginning of the cook is most important for high yield.
The knowledge of the impact of the chemical profiles on yield of the individual wood components makes us able to tailor the pulp properties to each customer's needs.

References

(1) Achrén, S. et. al. Tappi "Breaking the Pulp Yield Barrier" Symposium, Atlanta 1998

(2) Edmonds, J. and Wiley, W.E.
Proceedings, ASKK Tech. Symposium, Tokyo, Sept. 1997

(3) Marcoccia, B.,Prough, R.,Stromberg, B.
Proceedings, TAPPI Pulping Conference, Montreal, Oct. 1998

(4) Van Heiningen, Adriaan, Proceedings TAPPI Yield Workshop, Atlanta, March 2002

(5) Stanley, D. and Marcoccia, M.
Proceedings, TAPPI Pulping
Conference, Orlando, Oct. 1999

(6) Westin, C. et al, Paperi ja Puu, Vol. 84, No.1, January 2002

(7) Jiang, J. et. al. 10th International Symposium on Wood and Pulping Chemistry, Yokohama, Japan, June 7-10, 1999