Optimum Kappa Cooking – a Versatile Tool to Improve the Financial Performance of an Eucalyptus Mill

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SUMMARY

The Optimum Kappa Level Concept which has previously been implemented in some softwood and hardwood mills is here adapted for the processing of Eucalyptus. Laboratory trials to increase the cooking kappa number show a higher pulp yield throughout the fiber line and an improvement in some properties of the bleached pulps. A higher pulp kappa number prior to bleaching gives higher bleaching chemical costs and higher levels of AOX and COD in the bleaching effluents prior to effluent treatment. As with the softwood bleaching effluents, the increase in these levels after effluent treatment will be rather small and usually manageable.

Simulations of an "Imaginary Eucalyptus Mill" show a significant potential to boost pulp production (over 10% increase) as a result of increasing the pulp yield and lowering the content of dry solids to the recovery when the cooking kappa number is increased by four kappa number units.

INTRODUCTION

Over the last decade, there have been significant changes in cooking technologies directed mainly to lowering the kappa number after cooking. However, these extended pulping procedures may result in substantial yield losses (1,2). The benefits of optimizing the cooking kappa number as a means of increasing the pulp yield have been identified (3-9) and realized on a commercial scale (8,9). There also seems to be a trend to use the Optimum Kappa Level Concept to improve the financial performance of the mills (10). Norrsundet Mill in Sweden reports that it is financially attractive to cook to a higher cooking kappa numbers level. In this softwood kraft mill, this concept has been practiced for a period of over one year (8).

The present paper, which is one of a series of papers dealing with the Optimum Kappa Level Concept, presents laboratory results of trials in which Eucalyptus chips *(Grandis/ Saligna)* were cooked to different kappa numbers, O_2 pre-bleached and D (EOP) DnD bleached to a final ISO brightness of above 90 %.The effects of the change in cooking kappa number were evaluated in terms of pulp yield and quality, bleaching chemicals consumption, and COD and AOX levels in the bleaching effluents. In addition, simulations have been carried out at Helsinki University of Technology / SciTech, Finland to evaluate the potential and the consequences of boosting pulp production when raising the cooking kappa number in an "Imaginary Eucalyptus Pulp Mill".

EXPERIMENTAL

Raw material:

Industrial Eucalyptus chips (*Grandis* 60%, *Saligna* 40%)

Cooking:

The hand-sorted chips were cooked in a circulation digester under conditions similar to the ITC conditions in the mill. The kappa numbers after cooking, 14.3 and 18.2, were achieved by selecting a suitable combination of cooking time / temperature and alkali level during the cooking. The residual alkali levels were the same (about 7 g/l as NaOH) regardless of the cooking kappa number.

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	Cooking		O_2 delig		ECF bleaching	
Kappa Nº	14.3	18.2	9.6	11.6	n.d.	n.d.
Total yield, %	52.0	53.5	50.4	52.3	50.0	51.0
HexA, µmol/g	83	77	76	74	28	<5
Hemicellulose, rel.%	19.5	20.5	19.0	19.9	17.1	18.0
Fibre charge, µEq/g	154	180	154	178	116	121

n.d. = não determinado

Table I Pulp yield and properties throughout the fiber line

Cooking kappa nº	14.3	18.2
O_2 kappa nº	9.6	11.6
Brightness, % ISO	90.5	90.2
Brightness rev., % ISO units	3.2	2.1
Viscosity, dm^3/kg	1069	1161
Total ClO_2, aCl kg/t	20	28

Table II. Basic pulp properties after bleaching and ClO_2. consuption

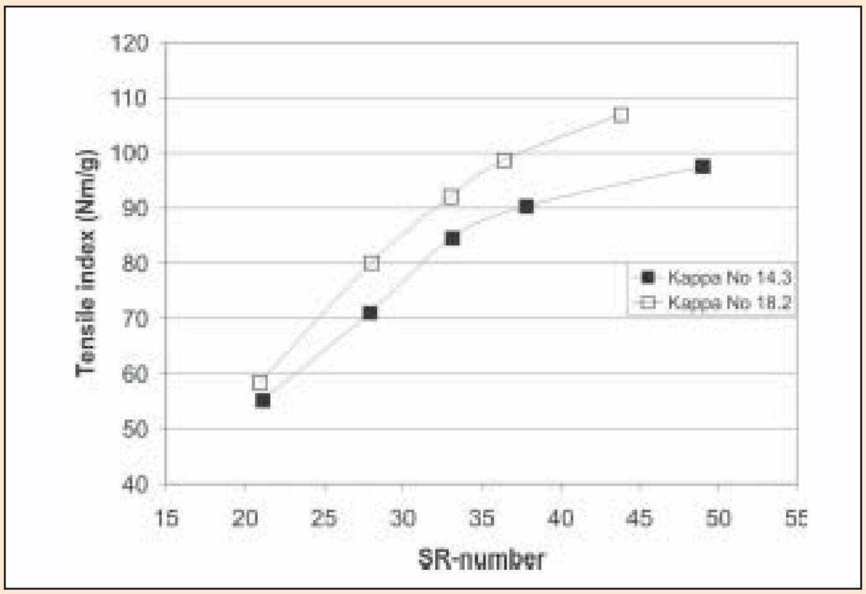

Figure 1 ***Tensile index vs SR for pulps with different cooking kappa numbers***

• Equipment and procedures, O_2 pre-bleaching and D(EOP)D bleaching

The equipment and the standard procedures used at Eka Chemicals laboratory for O_2 pre-bleaching and D(EOP)DnD bleaching are described elsewhere (11,12).

• O_2 pre-bleaching conditions

The washed pulps with kappa numbers 14.3 and 18.2 were O_2 pre-bleached using conditions which achieved 35 % kappa number reduction at a final pH of about 11.5. The conditions used for the 14.3 kappa pulp were 60 min; 110 ºC; 13 kg/tp NaOH and for the 18.2 kappa pulp 50 min; 107 ºC; 19 kg/tp NaOH. In all cases, the O_2 partial pressure was 0.5 MPa and 0.5 kg Mg 2' /tp were added.

• Bleaching conditions D(EOP)DnD

For both pulps the charge of peroxide in the (EOP) stage was 3 kg/tp. For the pulp with O_2 kappa number 9.6, the chlorine dioxide charges (active chlorine) in the D0, D1 and D2 stages were 14; 4 and 2 kg/tp. For the pulp with O_2 kappa number 11.6 the charges were 17; 8 and 3 kg/tp respectively.

• Analyses

Pulp brightness, kappa number, viscosity and AOX in the effluents were determined using SCAN-test methods. The COD levels in the effluents were determined according to the Dr. Lange method. The TAPPI standard method was used to determine the heat-induced brightness reversion. The pulp properties, the content of hexeneuronic acids and the carbohydrate composition of pulps were determined at STFI, Sweden, using SCAN, ISO or internal methods.

RESULTS AND DISCUSSION

Laboratory results

In general terms, cooking to a higher kappa number gives a higher pulp yield. This higher pulp yield can then be used to save wood. Moreover, the higher pulp yield after cooking means less dry solids to the recovery boiler and a higher pulp production if the intention is to fully load the recover boiler. Table I shows that the yield increase of about 1.5%, associated with the increase in kappa number after cooking from 14 to 18, is more or less retained during the O_2 pre-bleaching (35 % kappa number reduction) and during a subsequent D(EOP) DnD bleaching to about 90% ISO brightness.

This yield increase corresponds to a higher pulp hemicellulose content (mostly xylan) which gives a higher fiber charge. It can also be seen that the pulp with the higher kappa number after cooking contains less hexenuronic acids (HexA). This is particularly relevant after bleaching, when the pulp with the higher incoming kappa number shows a very low HexA content.

Table II shows some basic pulp properties and the consumption of

Cooking kappa nº	14.3	18.2
Kappa nº after O_2	9.6	11.6
Beating revolutions, nº	500	250
Tear index, mNm^2/g	10	11
Bulk, dm^3/kg	1.41	1.40
Opacity, %	72.7	73.4
Light scattering coeff., kg/m^2	32	32
Air permeance, µm/mPa s	21	23

Table III ***Properties of bleached pulps after beating to a Tensile Index of 70 Nm/g***

Kappa cooking	14.3	18.2
Kappa O_2	9.6	11.6
AOX, bleaching, kg/t	0.40	0.65
Estimated AOX levels after effluent treatment, kg/t	0.08	0.11
COD, bleaching, kg/t	16.2	23.7
Estimated COD levels after effluent treatment, kg/t	4.8	7.1

Table IV ***Levels of AOX and COD in total bleaching effluents***

Kappa nº after cooking	12	16	20
Alkali charge on b.d. wood, % NaOH (EA)	19.4	18.8	16.0
Total yield in cooking, %	51.3	53.5	55.1
Dry solids to recovery, t/d	1999	2000	1999
Dry solids to recovery, t/b.d.t pulp	1.67	1.34	1.23
Pulp production b.d.t/d	1198	1497	1626

Table V ***Simulated process data, pulp production and dry solids to recovery at different cooking kappa numbers***

Kappa nº after cooking	12	16	20
Dry solids to recovery, kg/h	83294	83335	83295
CBHV, Mcal/kg	3.583	4.040	4.188
Total heat production, Gcal/h	298	337	349
Steam consumption, 3 bar, t/h	104	112	113
Steam consumption, 3.5 bar, t/h	17	22	24
Steam consumption, 7 bar, t/h	60	74	79

Table VI ***Calorimetric bomb heating value (CBHV) of black liquor, heat energy production and steam consumption at different cooking kappa levels (Modern Eucalyptus Mill)***

chlorine dioxide (as active chlorine) when O_2 pre-bleached pulps of kappa numbers 9.6 and 11.6 were bleached to a final ISO brightness of about 90%. The pulp with the higher O_2 kappa number showed a higher pulp viscosity and a significantly lower brightness reversion. The lower brightness reversion can be related at least in part to the very low HexA content in this pulp. Simultaneously, the higher brightness reversion of the bleached pulp which had been cooked and O_2 pre-bleached to a lower kappa number can be related to its high HexA content, which is in turn a consequence of the lower ClO_2 charge needed to achieve the target final brightness (Table I). It has recently been shown that ClO_2 is an efficient and selective tool for removing HexA from pulps not only by acid hydrolysis but also by an oxidative action (13).

It can be expected that the bleached pulp with a higher hemicellulose content (higher cooking kappa number) will be more easy to refine and will show a higher tensile index at a given SR value (2,4,6-8,14). Figure 1 shows that this was indeed the case with this Eucalyptus pulp.

The results in Table III, which shows pulp properties at a tensile index of 70 Nm/g, reveal that the tear index is slightly improved whereas some other properties such as opacity, density and light scattering coefficient are hardly affected by the changes in cooking and O_2 pre-bleaching kappa numbers.

Table IV shows that the AOX and COD levels in the bleaching effluent increase with increasing cooking kappa number. The reduction achieved by effluent treatment may vary considerably, depending on the type of Eucalyptus pulp, on the equipment available and on the chemical composition of the bleaching effluent (15). The estimated values after external treatment shown in Table IV were calculated using maximum reduction values of 80 % for AOX and 70% for COD, as reported in the literature (16). Although the estimated increase after external treatment can be considered rather small and usually manageable, Eka Chemicals is putting a significant scientific effort into improving the biological treatability of these high kappa effluents.

SIMULATION RESULTS

A higher pulp yield after cooking means less dry solids to the recovery boiler. Simulation results on Scandinavian softwood pulps (4) show that, at a constant pulp production level (increase in pulp yield is balanced by less intake of chips), the cooking to a higher kappa number means that less white liquor is needed for cooking, and this leads to a lower liquor flow rate to the evaporators and a lower load of solids to the recovery boiler, with a noticeable decrease in energy production in the recovery boiler as a consequence.

In our approach, the benefits of a higher pulp yield were used to increase the pulp production rate while fully loading the recovery boiler. The simulation tool used was the PulpSim simulation system developed by Gullichsen (17).

Table V shows the simulation results achieved in an "Imaginary Eucalyptus Mill". Since there was no particular reference mill available, the relevant initial process data were taken from the literature (2,6,18 -19).

Table V shows that an increase in cooking kappa number leads to less white liquor in the cooking, a higher pulp yield and a lower concentration of dry solids to the recovery. To fully load the recovery boiler (2000 t/d of dry solids), the pulp production can be substantially increased. The potential production increase for a eucalyptus mill, if the cooking kappa number is increased by four units, is above 10% i.e. much higher than the simulated and partly verified production increase for a softwood mill (8).

If the cooking kappa number and pulp production are increased, both the calorimetric bomb heat value (CBHV) and the total heat production increase as shown in Table VI. On the other hand, more production in the fiber line means more steam consumption in the cooking, bleaching and drying stages.

As in the "real" production increase, the energy balance has to be evaluated specifically for each mill, taking into consideration the mill conditions and the equipment available. Other specific production parameters which are difficult to simulate, such as content of rejects etc., has to be included in the simulation particularly where hardwoods are considered.

Nevertheless, the results in Tables V and VI show that there is a potential for improving the financial performance of a eucalyptus mill by optimizing the kappa numbers after cooking and O_2 pre-bleaching. This has already been proven for a softwood mill during a period of over one year (8).

CONCLUSIONS

• Cooking of Eucalyptus chips *(Grandis/Saligna)* to higher kappa numbers will give, after O_2 pre-bleaching and D(EOP)DnD bleaching to 90% ISO, a higher pulp yield and improved pulp strength properties.

• Simulation results show that there is a significant potential (above 10% increase) for boosting pulp production if the cooking kappa number is increased by four units in a Eucalyptus pulp mill.

• A higher pulp kappa number prior to bleaching will lead to higher bleaching chemical costs and higher levels of COD and AOX in the bleaching effluents prior to effluent treatment.

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