# Typical strength properties for different bleached pulps

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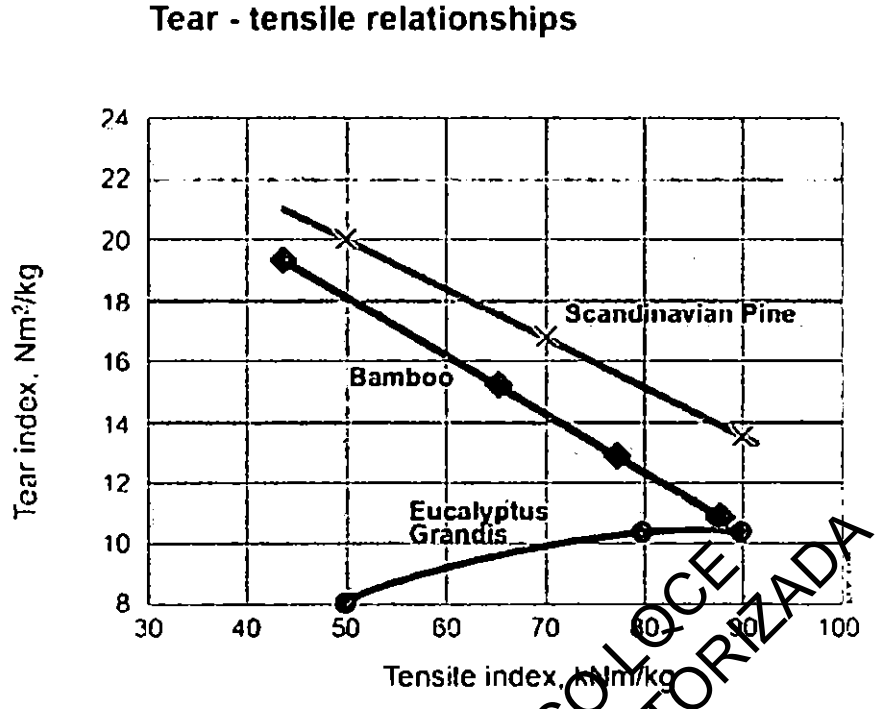


*Figure 2*

The fibre length for bamboo is much longer than for hardwood and this also results in a stronger pulp. However, pulping conditions are very similar to eucalyptus (figure 3). This means that bamboo can be pulped together with hardwood. This mixed cooking also gives a stronger pulp than if the hardwood is pulped separately. Bamboo can also be cooked together with acacia.

## Some cooking characteristics for Bamboo and Eucalyptus

| | | Bamboo | Eucalyptus Grandis/Urophylla |
|---|---|---|---|
| Cooking yield (at kappa 16-18) | % | 50-54 | 52-55 |
| Alkali charge in cooking | % EA as NaOH on BD wood | 19-20 | ~18-19 |
| Max. cooking temperature (Compact Cooking™) | °C | 142-144 | 142-145 |
| Steam consumption in cooking (Compact Cooking™) | kg/ADT | 400 | 300-400 |

*Figure 3*

An important characteristic of bamboo in comparison with other annual plants is that proper chips can be produced, which makes it possible to pulp bamboo in a continuous digester (figure 4). Length and thickness distribution is, for this sample anyhow, very similar to normal wood chips. The chip weight corresponds to the chip weight for eucalyptus, which also is important if mixed cooking is done.

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## Chip quality - Bamboo

### Basic density 590 kg BD wood/m³, chip weight 180 kg BD chips/m³

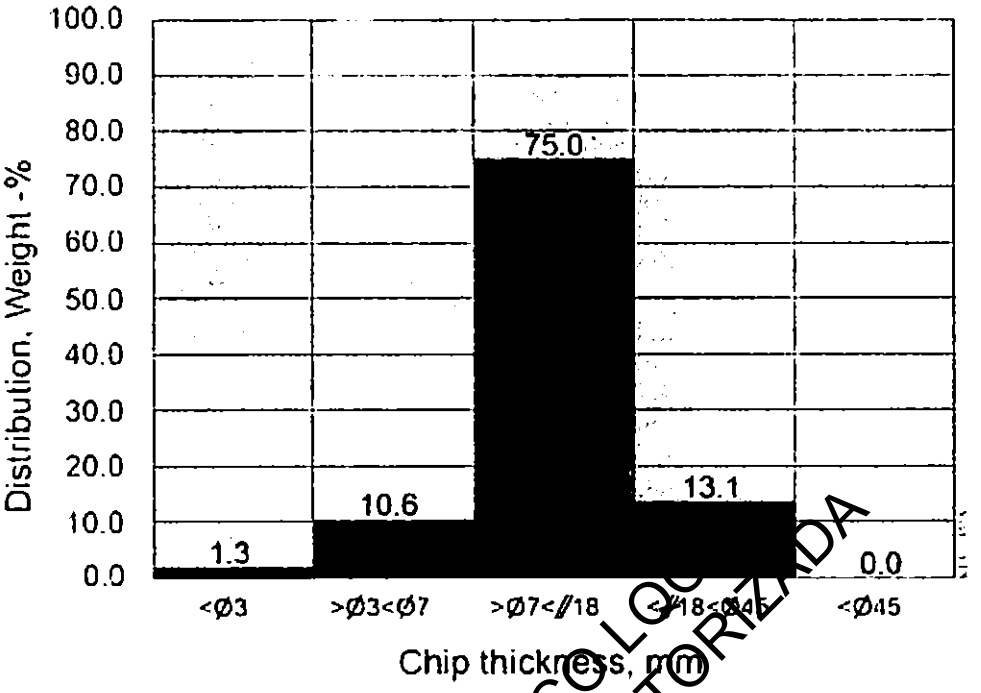


*Figure 4*

Bamboo is a grass and one consequence of this is that the silica content is much higher than for wood plants (figure 5). The presence of silica is the way that the plant is protecting itself from the environment. Trees use bark for protection while annual plants have high silica content, which acts as a "skin" for the plant.



## Ash and silica content in different raw materials

| Type | $SiO_2$ % | Ash % |
|---|---|---|
| Pine | Traces | < 1 |
| Birch | Traces | < 1 |
| Bagasse | 1.5 - 2 | 2 - 3 |
| Kenaf | 3 - 4 | 1.5 - 2.5 |
| Bamboo | 1.5 - 2 | 2 - 3 |

*Figure 5*

When a bamboo mill is designed the high silica content must be taken into consideration. The high silica content gives scaling problems in the cooking plant and in black liquor evaporation and also difficulties in lime reburning. The silica balance in figure 6 shows that if the silica content in bamboo is 2 %, approximately 65 % of the lime must be purged to maintain an equilibrium SiO2 content of 650 mg/l in the white liquor.

## Silica balance for a bamboo pulp mill

Basis for silica balance

- 100 % bamboo, 2 % silica as SiO2 in bamboo
- Washing of bamboo removes ~30 % of free silica
- Lime kiln included
- Silica balance based on unit of SiO2/ADT
- Lime mud purge (~65 %) to maintain:
  - equilibrium SiO2 content in white liquor, 650 mg/l (both soluble and insoluble)
  - maximum allowable SiO2 content in kiln input, 2 % wt
  - maximum allowable SiO2 content in kiln output, 5 % wt

*Figure 6*

For minimizing scaling problems in the cooking plant a continuous digester with few or no circulations for heating is recommended. COMPACT COOKING™ is in this case a very suitable solution. In figure 7 some characteristics for bamboo pulping are summarized.

# Chemical Pulping of Bamboo

## Situation

- Very fast growing raw material
- Cooking and bleaching conditions similar to hardwood
- Compact Cooking™ very suitable
- Paper properties almost as softwood
- Very suitable for campaign operations with hardwood
- The silica content can be handled in modern fiberlines and recovery systems

## Consideration

- Requires dumping of part of the lime mud

*Figure 7*

A reference list for continuous digesters operating on bamboo is shown in figure 8. The Chitianhua digester shown in the list is designed for COMPACT COOKING™.



## Digesters for Bamboo - References

| Customer | Country | Production ADMT/24 h | Raw material | Year of start-up |
|---|---|---|---|---|
| The Titaghur Paper Mills | India | 150 | Bamboo / Jutestick | 1966 |
| The Bengal Paper Mill | India | 150 | Bamboo / HW | 1966 |
| Hindustan Paper, Nowgong Mill | India | 410 | Bamboo | 1980 |
| Hindustan Paper, Cachar Mill | India | 410 | Bamboo | 1981 |
| Phoenix Pulp and Paper Co. | Thailand | 250 | Bamboo and Kenaf | 1981 |
| Yibin Paper Mill | China | 122 | Bamboo | 1992 |
| Panjapol Paper Industry Co. Ltd. | Thailand | 310 | Bamboo / SW | 1992 |
| Siam Cellulose | Thailand | 192 | Bamboo / HW | 1992 |
| Chitianhua | China | 850 | Bamboo | 2007 |

**Total: 9**

*Figure 8*

**Compact Cooking™**

The first Kamyr digester was started in 1949. However it took eight years before a real breakthrough for continuous cooking was made. This came when the so called "cold blow" system was introduced. Different development steps are shown in figure 9.

# Continuous Cooking Development

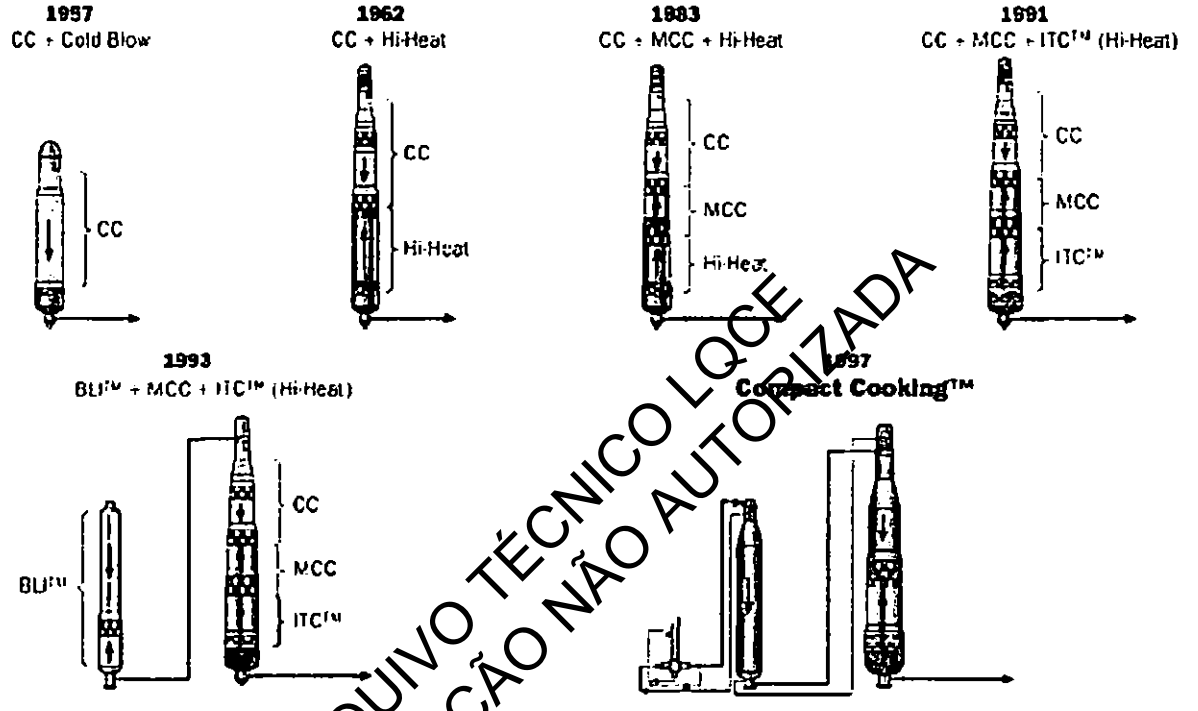


*Figure 9*



Today Kvaerner Pulping is promoting COMPACT COOKING™, for which the process significants, mill results and benefits have been shown and can be summarized as follows:

- Liquor/wood ratio completely flexible between impregnation and cooking
- Optimal chemical profile
- Low cooking temperature and low steam consumption
- Strong pulp
- Good bleachability
- Easy to operate and high availability
- Reduced investment and operational costs
- Possibilities to tailor-make different pulp qualities

The total world production of chemical pulp is today approx. 140 million tons/year of which 65-70 % is produced in continuous digesters (figure 10).

# World chemical woodpulp capacity vs Kvaerner Pulping continuous digester capacity

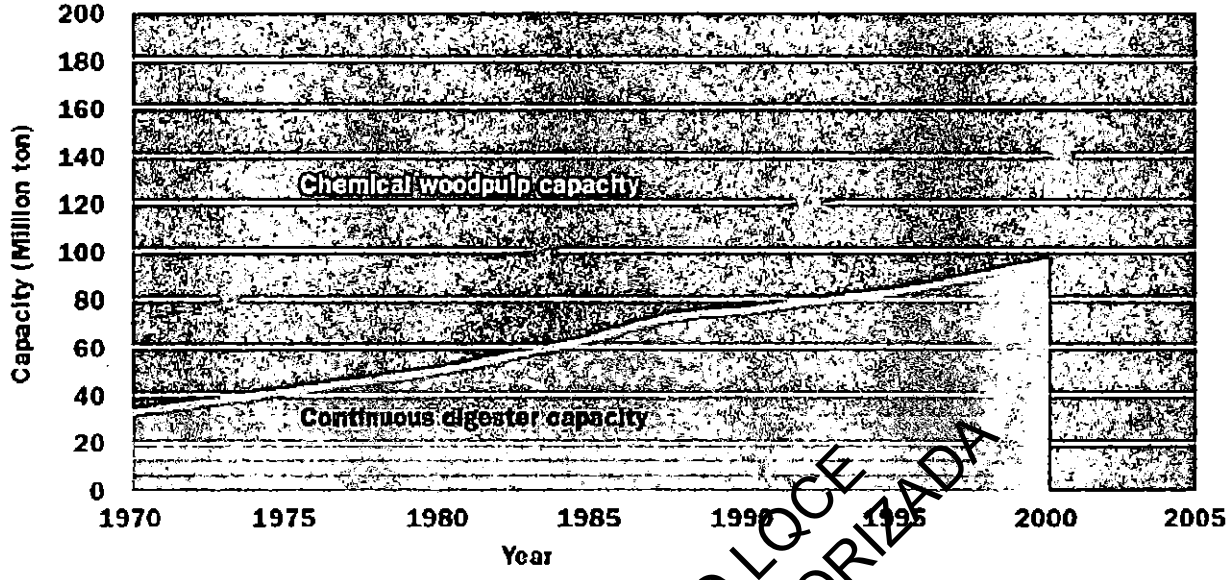


*Figure 10*

**Results from lab study on bamboo**

Kvaerner Pulping has done several comprehensive lab studies on bamboo. Figure 11 shows some cooking results. Bamboo pulp is rather easy to bleach. It will also be noticed that the hexaneuronic acid content is on the same level as for softwood pulp. The HexA concentration is 0.01 - 0.015 mM HexA/g BD pulp. In an ECF sequence a conventional D0 stage can be used and neither an A nor a DualD™ stage is necessary.



# Lab study - Cooking

| | Chinese Bamboo 100% | Bamboo 30% (Vietnam) Acacia 70% |
|---|---|---|
| Kappa number | 18 | 18 |
| Alkali charge, % EA as NaOH | 19 | 18 |
| Cooking temperature, °C (Compact Cooking™) | 142 | 142 |
| Cooking yield, % | 51 | 53 |
| Total reject content, % | 1 | 0.5 |

*Figure 11*

Bamboo pulp with an ingoing kappa number of 8 after oxygen delignification can be bleached to full brightness, 90 % ISO, with the three-stage sequence D0(EOP)D. The total chlorine consumption is around 30 kg/ADT. Peroxide charge in the pressurized EOP stage is 4 kg/ADT, figure 12. If a lower brightness, 85-87 % ISO, can be accepted the two-stage sequence (DQ )(PO) can be used, figure 13. The peroxide consumption is 20-25 kg/ADT and active chlorine charge 12 kg/ADT, figure 14.

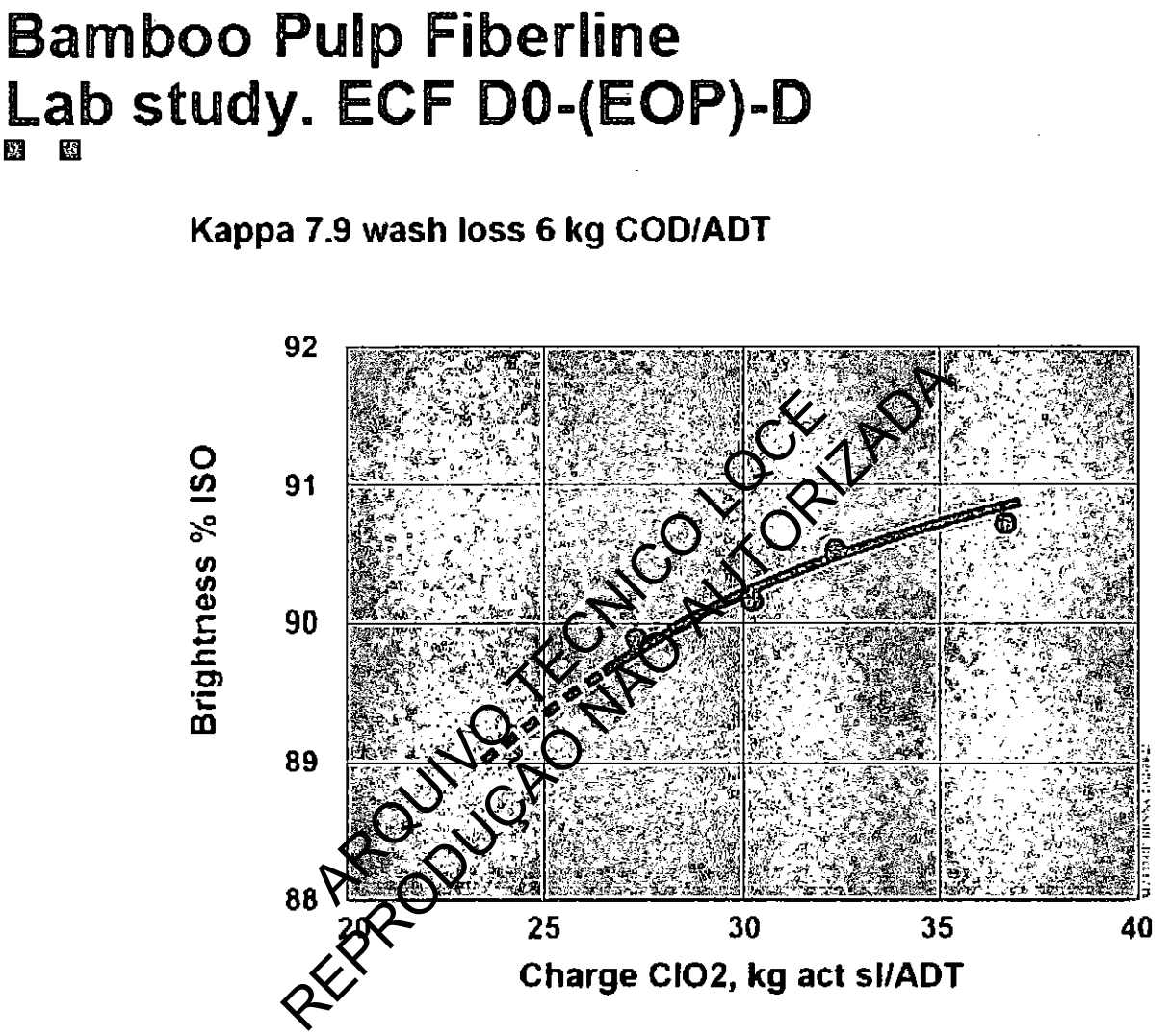




*Figure 12*

# Short sequence ECF
## Bleaching (DQ)(PO)

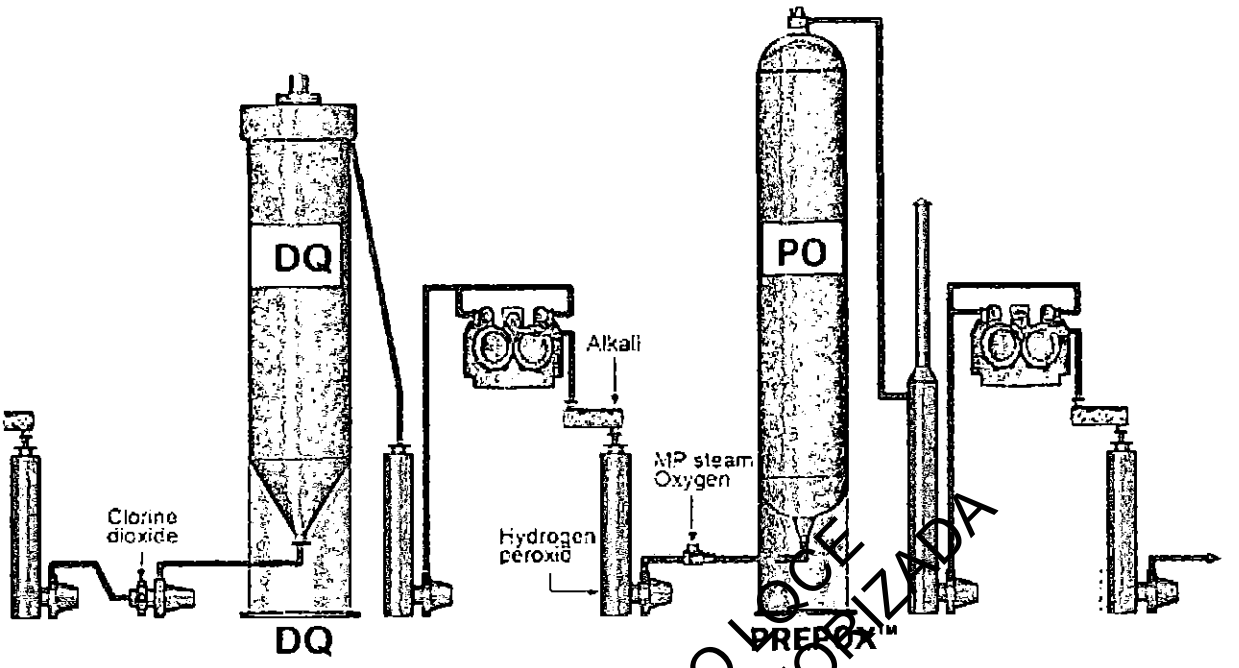


*Figure 13*

# Bamboo Pulp Fiberline Lab study. ECF (DQ)(PO)

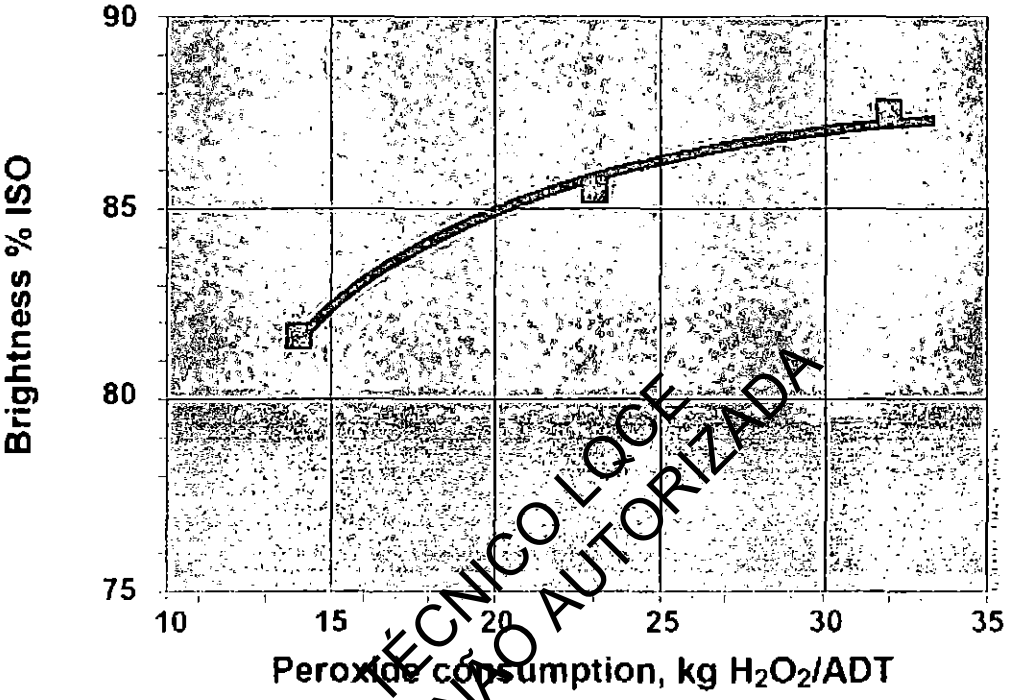




*Figure 14*

Results for the four-stage ECF sequence D0(EOP)-D-PO is shown in figure 15. For bleaching to brightness 90 % ISO, total active chlorine charge is 24 kg/ADT and $H_2O_2$ consumption 10-12 kg/ADT. Bleaching to brightness 89-90 % ISO is also possible with the four-stage TCF sequence Q(EOP)Q(PO). Total peroxide consumption for bleaching to 89 % ISO is 30-35 kg/ADT, figure 16. With the short TCF sequence Q(PO) brightness 80 % ISO can be obtained, figure 17. The PO stage is in all shown sequences pressurized (PREPOX™) with a retention time of two hours and a temperature of 105°C. Peroxide consumption for bleaching to brightness 80 % ISO is approx. 30 kg/ADT. These were only some examples of modern bleaching sequences for bamboo. Other alternatives are of course also possible.

# Bamboo Pulp Fiberline
# Lab study. ECF D0-(EOP)-D-(PO)

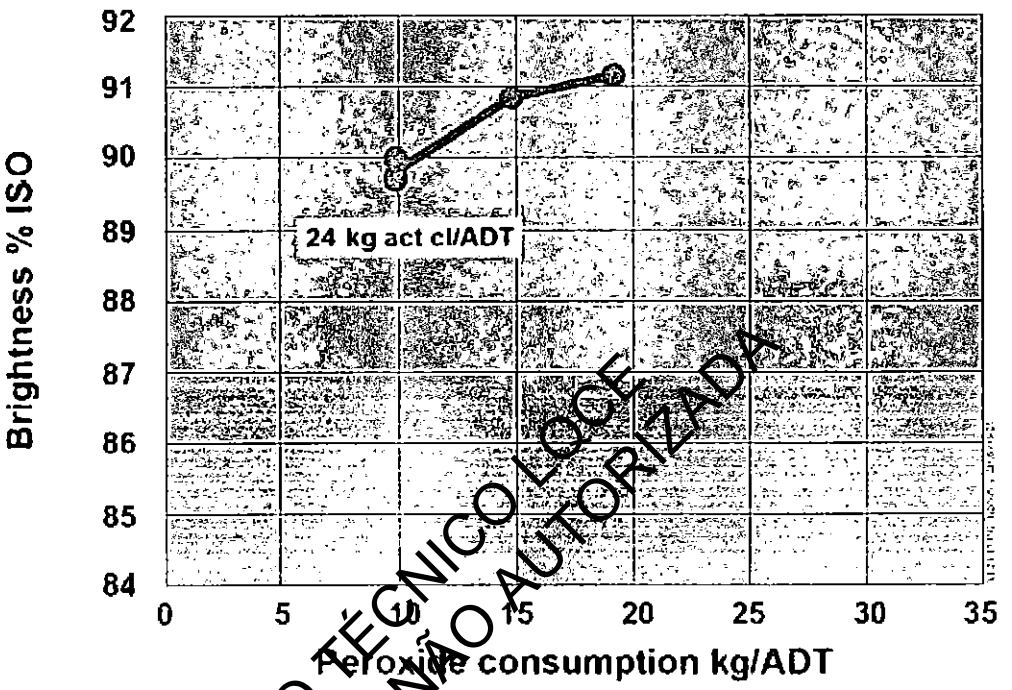


*Figure 15*

# Bamboo Pulp Fiberline Lab study. TCF Q-(EOP)-Q-(PO)

## Kappa 7.9 Wash loss 6 kg COD/ADT

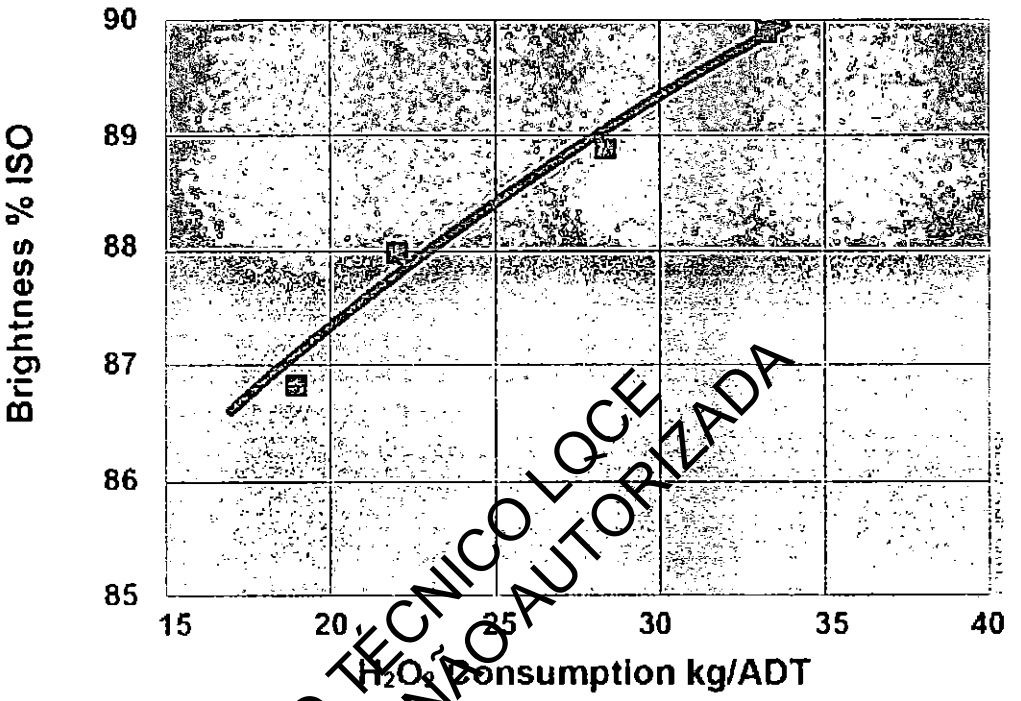


*Figure 16*

# Bamboo Pulp Fiberline Lab study. TCF Q-(PO)

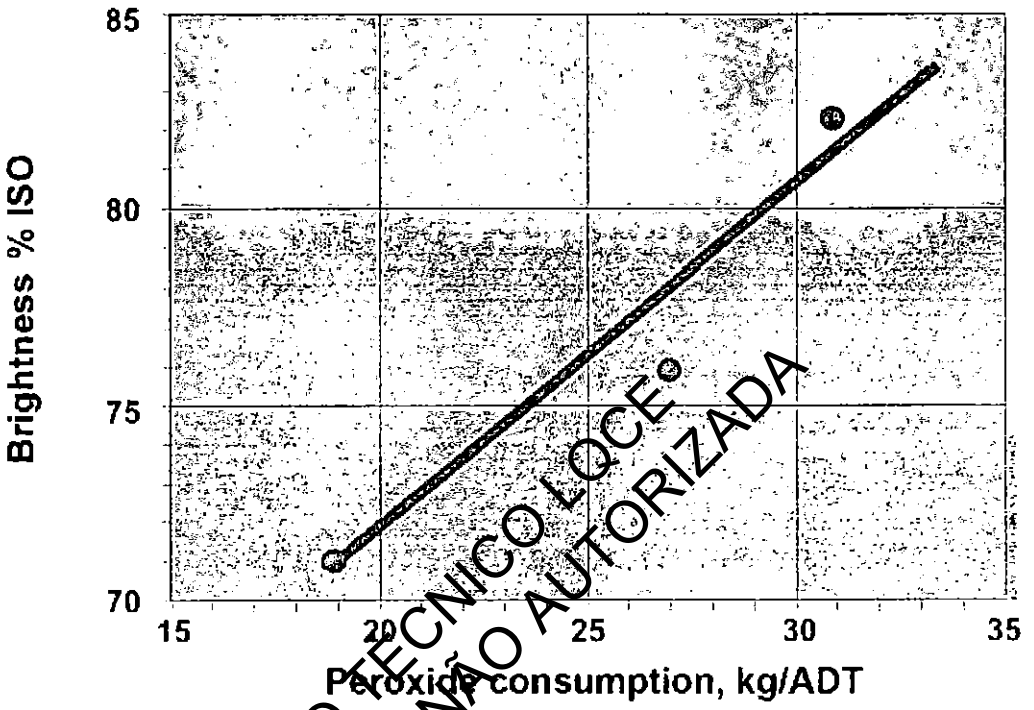




*Figure 17*

**Kvaerner Pulping proposal for a bamboo fibreline**

For cooking we recommend COMPACT COOKING™ of the so called second generation (G2). This digester has very few liquor circulations for heating and is therefore less sensitive for scaling than other continuous digesters. Cooking is performed at a low cooking temperature, around 140-142°C. The pulp produced has good strength properties, figure 18, and good bleachability. The whole fibreline is shown in figure 19. In the digester blow line we recommend installing a pressure diffuser. With COMPACT COOKING™ the total reject content will be very low, 0.5 - 1 %. We therefore recommend taking out both knots and fine rejects from the screen room. After screening we install a COMPACT PRESS™ as final wash stage before oxygen delignification.

# Strength properties for lab. ECF bleached bamboo pulp

## Tear - tensile relationships

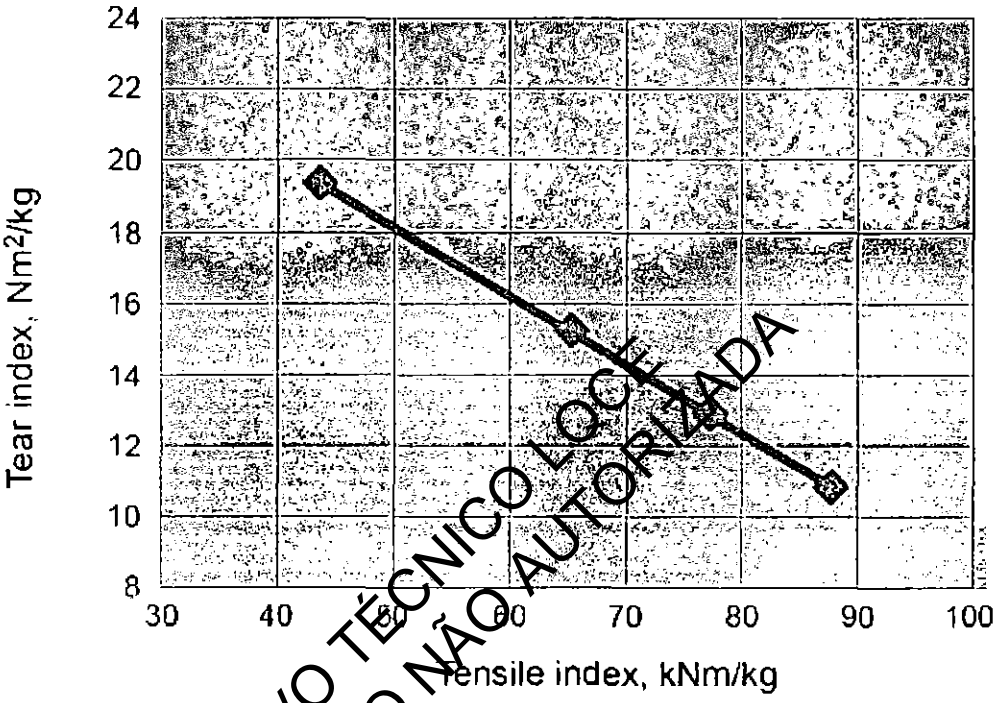


*Figure 18*