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Opportunities for Market Pulp Differentiation via Fractionation

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ABSTRACT

This study has focused on the different responses of three fractionation technologies, named as "Radiclone", "Radiscreen" and "Spraydisc", of an eucalypt market ECF pulp. Pilot trials were carried out to verify the real possibility to differentiate the narrow morphology of eucalypt pulps into two fractions (fines and coarse ones), and thus to modify significant combinations of important paper properties.

The results from the three fractionation set-ups showed different trends of paper properties development with refining, and additionally demonstrated that the "Radiclone" fractionation introduced the most significant differentiation in the paper properties.

It is believed that the specific surface area and also the fiber swelling, enhanced by the amount of fines, number of fibres per gram, pentosans, and carboxyl content, may provide a more fundamental explanation for the behaviours of properties development. It was confirmed that fractionation may be able to modify these fundamental properties of eucalypt pulp fractions, relatively to the original pulp, hence increasing the potential to optimize refining and allowing the production of unique paper properties, such as stronger paper with much higher opacity and surface smoothness.

INTRODUCTION

The development of alternatives to introduce changes in fiber morphology at the market pulp end are very interesting because: a) fiber size distribution is of a particular interest as a basic descriptor of fiber source for papermakers (1,2); and b) fiber morphology clearly impacts paper properties, as has been demonstrated by several studies (3-15). Changes in fiber morphology can be obtained through different strategies, such as tree breeding, chip quality, a number of processes throughout pulpmaking, as well as fiber fractionation. The decision to use one or another or a combination of them depends on an evaluation of several aspects, including timing and economics.

While tree breeding / forest management is a much longer term strategy, and could involve lower costs, process modification seems to allow faster changes, although apparently being more expensive. Some pulp producers are dealing with both strategies, aiming to differentiate the pulp properties. In this study the results from one process alternative are highlighted.

Extensive research has already demonstrated that fiber fractionation introduces significant changes in fiber morphology. As the market has been increasingly demanding better quality, pulpmakers and papermakers have been considering fractionation as one important alternative to obtain fiber differentiation. This paper presents results of an eucalypt market pulp fractionated in pilot trials, using three different equipment set-ups.

BACKGROUND

Market Demands

Reduced process energy consumption and improved fiber quality continue to be demanded by papermakers. Market pressures for higher quality grades, and trends to produce thinner sheets are clearly noticeable (16).

It is well recognized that eucalypt pulps have short and thin fibers, which translate into a large number of fibers per gram. They are also very uniform and stiff. As a consequence of these unique properties, papermakers have preferred eucalypt fibres in their furnishes, in order to reach uniform paper properties in those paper grades where good formation and printability, high bulk, opacity, and even softness are required.

Despite the fact that eucalypt pulp fibres are short and uniform, it was expected that a cost-effective fractionation could produce additional alternatives, via two different fibre fractions (fines and coarse), which might meet some market requirements more easily.

Fractionation and Fibre Morphology

The separation of pulp fibers into two or more fractions with different properties by fractionation allows the selective processing of these fractions. This idea has been used for many years. Many different purposes have motivated fractionation studies, such as: strength improvement; refining energy savings; the refining of long and short fibres separately, using long and short fibres for different end-uses; improving brightness, etc. as presented by several works (16-30).

Many studies on fractionation have been carried out on softwoods, including chemical, mechanical and thermo-mechanical pulps (17-22) and also for wastepaper (20,23-26). However, few fractionation works have been performed on hardwoods, including eucalypts (1,20). Thus, while much information about required fractionation configurations, optimized process variables, and process efficiency are well defined for softwoods and wastepaper (1,17,21,23-25,30-33), there is a gap of such information for eucalypts. As a consequence, many important questions on eucalypt fractionation are still to be answered, such as: Can fractionation really differentiate the narrow eucalypt fibre morphology in two fractions? If so, how significant are the differences? Can the differences really impact the refining of eucalypts pulps? Could a cost-effective fractionation help pulpmakers to meet some market requirements more easily, in terms of paper properties combinations? The present study is an attempt to bring more information, which may help to clarify this matter.

EXPERIMENTAL

An eucalypt ECF market pulp was fractionated in three different pilot systems:

A) Trade name "Spraydisc", by GL&V / Celleco AB Company (Former Celleco Hedemora AB)

B) Trade name "Radiscreen", by Noss Company

C) Trade name "Radiclone", by Noss Company

These systems are described in more detail, below:

A) "Spraydisc" technology principle: The pulp slurry is fed centrally to the stator housing, from where it is sprayed against two rotating mesh discs, through a number of spray nozzles. The coarse fraction is retained on the discs, while the fines fraction passes through it. As the discs rotate, the centrifugal forces causes the retained fibres to move radially on the discs and to be thrown off at the periphery. Continuous sprays of clean water keep the discs clean. The coarse fraction is drained by gravity. The fines fraction, which has passed through the discs, is collected in two separate chambers and is discharged from the filter, also by gravity.

Trials in the "Spraydisc" filter, equipped with 5 nozzles, were performed in different process conditions, however the pulps considered for analysis were obtained with the following process parameters: filter clothes openings of 290 micra, flow rate of 537 L/min., pressure of 180 kPa, filter speed of 60 rpm, and suspension consistency of 0.78%. Around 50 kg o.d. of pulp were used, each time. The trial configurations are presented in the figure 1.

B) "Radiscreen" technology principle: According to the manufacture, it is based on fiber length. The stiff undeveloped fibers are rejected by the screen and the developed fibers are accepted. The test equipment used was a full size commercial type "Radiscreen 1000D". Fractionation was performed at 1,3% of feed consistency, and in two steps, where the coarse fraction from step one was forwarded to step two, while the fines fractions from both stages were combined. The test arrangement is presented in the figure 2. Around 150 kg o.d. of pulp were used, in each repetition.

C) "Radiclone" fractionation principle: According to the manufacture, it is based on the fiber characteristic, mainly the specific area of the fiber. The stiff undeveloped fibers are rejected by the hydrocyclone and the developed fibers are accepted. The test equipment used was full size commercial type "Radiclone AM80" system equipped with special "AM80-F" fractionation hydrocyclones.

Fractionation was made at 0,5% of consistency, and in a two-stage system, where the coarse fraction from the stage one was fed to stage two, while the fines fractions from both stages were combined. The test arrangement is presented in figure 3. Around 150 kg o.d. of pulp were used, in each repetition.

Pulps Considered for Analysis:

Original pulp; "Spraydisc" fines fraction (30% flow); "Spraydisc" coarse fraction (70% flow); "Radiscreen" fines fraction (30% flow); "Radiscreen" coarse fraction (70% flow); "Radiclone" fines fraction (30% flow); and "Radiclone" coarse fraction (70% flow).

At least 3 samples from each trial were taken. Handsheets and tests were performed using SCAN standards. The following measurements were also performed, with the corresponding methodology: Fines content (Britt Jar)-Tappi T261 cm-94. Water retention value-Tappi UM 256. Dynamic Drainage Time (8). Weighted Average Fiber length-Tappi T233 cm-95, Fiber coarseness (Kajaani FS-100)-Tappi T234 cm 84. Pentosans Content-Tappi T223 ts-84. Carboxyl content-Tappi 237 om-93. At least 2 repetitions were performed for each analysis.

Figure 1 -"Spraydisc" trial Diagram

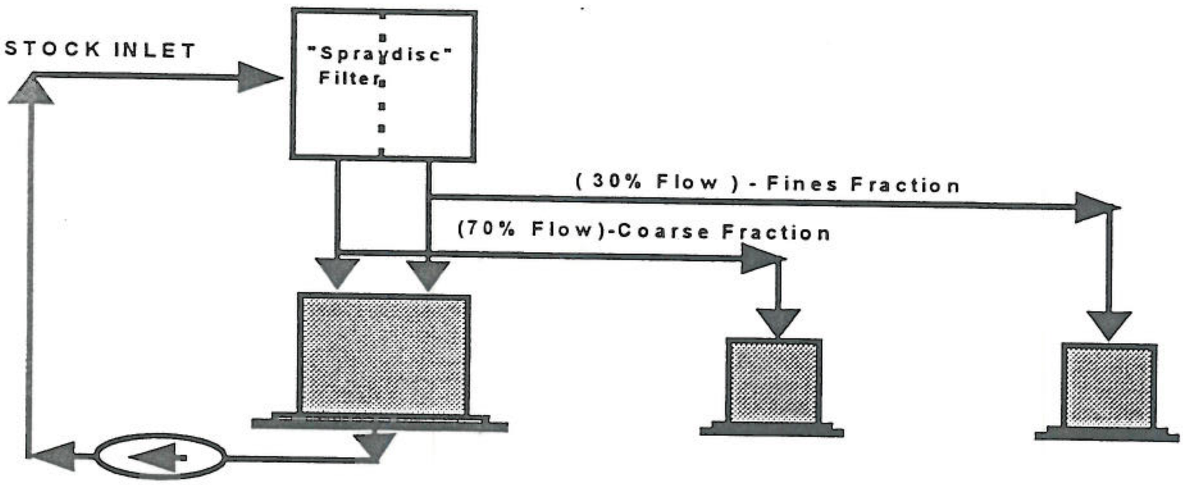


Figure 2 - "Radiscreen" Trial Configuration

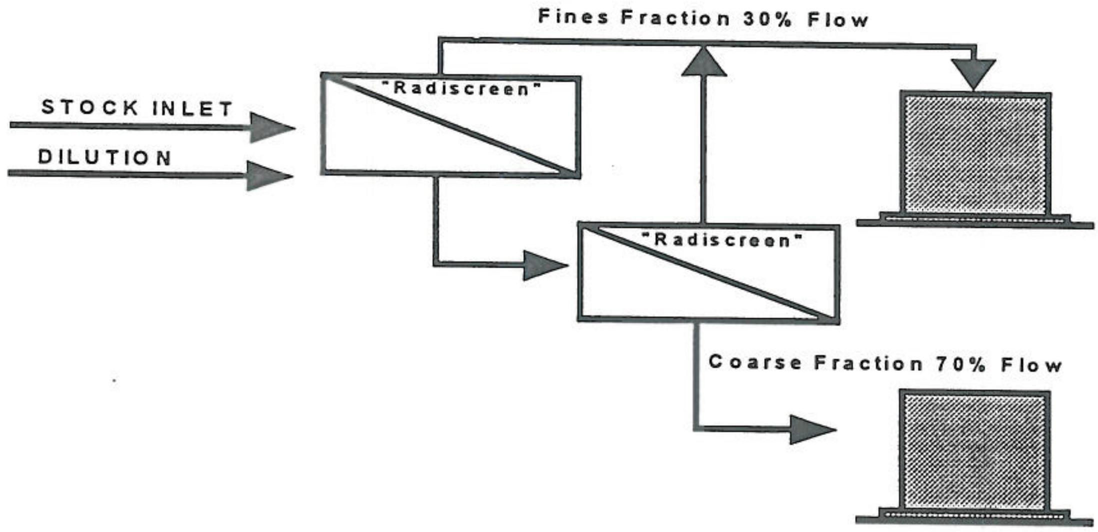
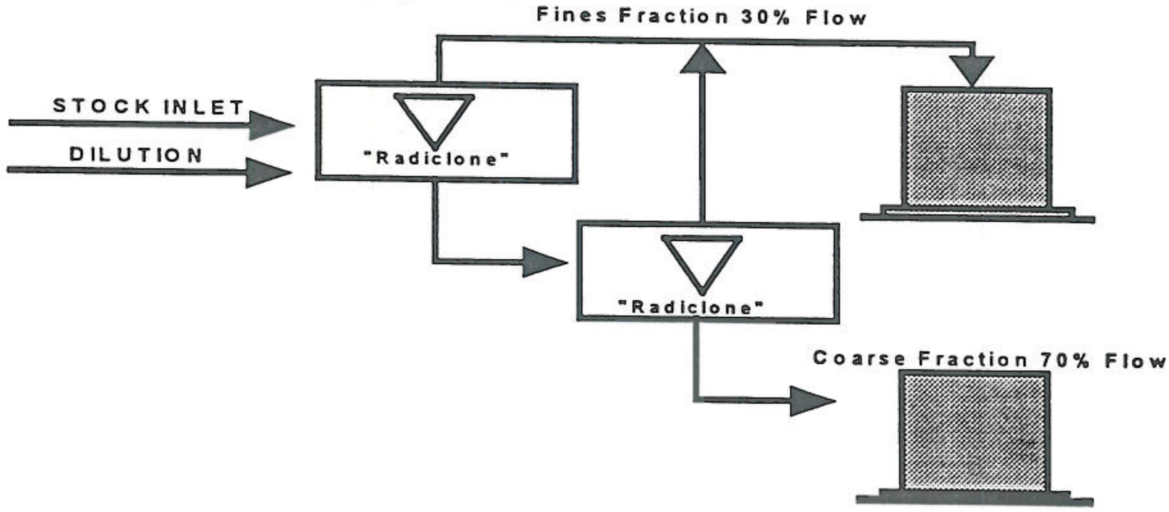


Figure 3 - "Radiclone" Trial Configuration



RESULTS AND DISCUSSION

a) Impact of Fractionation on Fibre Characteristics - Unbeaten Pulp

The results presented in tables 1 to 3 show that all pilot trials introduced significant (although not so big) changes in fiber morphology, which were expected to impact important paper properties. As anticipated, a larger number of fibres per gram (because of lower fiber length) and higher fines content were observed for the fractions named as "fines fraction", for all types of technologies tested. Conversely, the "coarse fractions" always showed a lower number of fibres per gram (larger fiber length) and lower fines content than the whole pulp.

The "Radiclone" technology introduced the most significant impact on the number of fibres per gram and also on the fines content when compared to "Radiscreen". These results seem to be in accordance with those obtained by MAKKONEN et al (20), who observed that the centricleaner principle has a considerable potential for separation of the eucalypt pulp.

The results presented in tables 1 and 2 also show that fractionation has a tendency to impact the chemical characteristics of the fractions. Although the differences are small, the amount of pentosans and carboxyl content tend to be higher for the fines fractions from the "Radiclone" set-up, as compared to the coarse ones.

Table 1 - Fibre Characteristics for Original and Pulps Fractionated by "Radiscreen"

Fiber Characteristics	Original Pulp	Fines Fraction	Coarse Fraction
Weighted Av. Fiber length, mm	0.67	0.66	0.68
Fiber Coarseness, mg/100m	7.8	7.9	8.0
Nº Fibers per Gram, Million	22.7	23.2	21.7
Fines Content (Britt Jar), %	10.9	14.6	8.9
Pentosans content, %	16.6	16.6	16.4
Carboxyl Content, meq/100g	5.8	5.9	5.6

Table 2 - Fibre Characteristics for Original and Pulps Fractionated by "Radiclone"

Fiber Characteristics	Original Pulp	Fines Fraction	Coarse Fraction
Weighted Av. Fiber length, mm	0.67	0.64	0.69
Fiber Coarseness, mg/100m	7.8	7.8	7.9
Nº Fibers per Gram, Million	22.7	24.2	21.6
Fines Content (Britt Jar), %	10.9	19.5	7.1
Pentosans content, %	16.6	16.8	15.3
Carboxyl Content, meq/100g	5.8	5.9	5.7

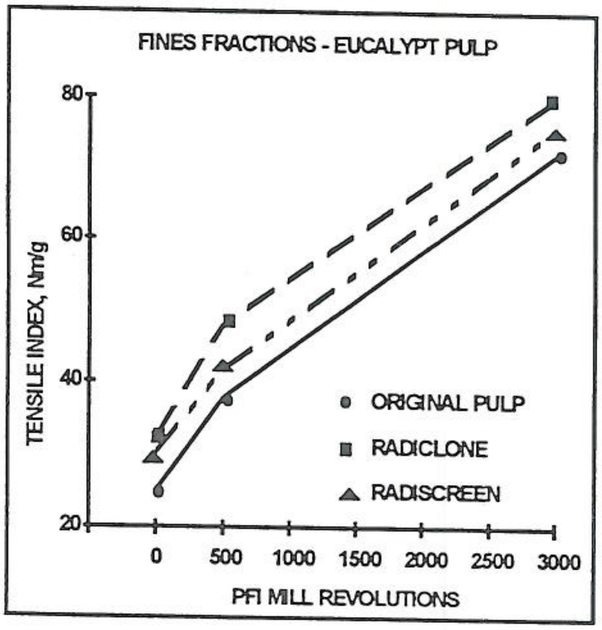
Table 3 - Results of Bauer McNett Classification for Original and Pulps Fractionated by "Spraydisc"

Bauer McNett Screen (Mesh)	Original Pulp %	Fines Fraction %	Coarse Fraction %
30	10	Nil	14
50	65	30	67
100	12	22	11
200	2	3	1
<200	11	45	7

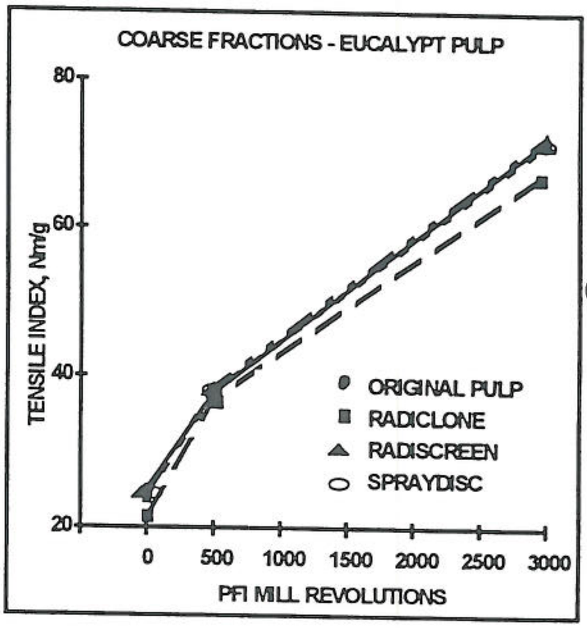
b) Impacts of Fractionation Technologies on Refining and on Paper Properties

As indicated in Figure 4, the fractionation technologies had pronounced effects on the rate of tensile strength development (when beaten in the PFI Mill). The "Radiclone" fractions presented the largest change in tensile (Figure 4a), when compared to the other fractionation technologies. Differently of "Radiclone" results observed for the fines fractions, the coarse fractions obtained from "Radiscreen" and "Spraydisc" were shown to follow the same curve of the original pulp, as visualized in Figure 4b. These results indicate a great potential to optimize the refining energy consumption to reach a tensile strength target, specially when applying "Radiclone" fractionation.

Figure 4 - Impact of Fractionation on Tensile Index



(4a)



(4b)

In Figures 5 and 6, it can be observed that while the fines fractions obtained from the "Radiclone" set-up produced paper with lower porosity (5a) and bulk (6a) than the original pulp, at a given tensile strength, the same fraction obtained from the "Radiscreen" set-up presented a very similar bulk/strength relationship as to the original pulp. This has been interpreted as an indication that strength development has been obtained through different combinations of effects.

Other important paper properties, such light scattering (Figure 7) and smoothness (Figure 8), apparently follow the same tendencies that were showed for the porosity (Figure 5). In all cases, "Radiclone" fines fractions presented the highest light scattering coefficient (7a) and paper smoothness (8a) at a given tensile index. The opposite tendencies can be observed for the coarse fractions (7b and 8b).

Figure 5 - Air Resistance vs. Tensile Index

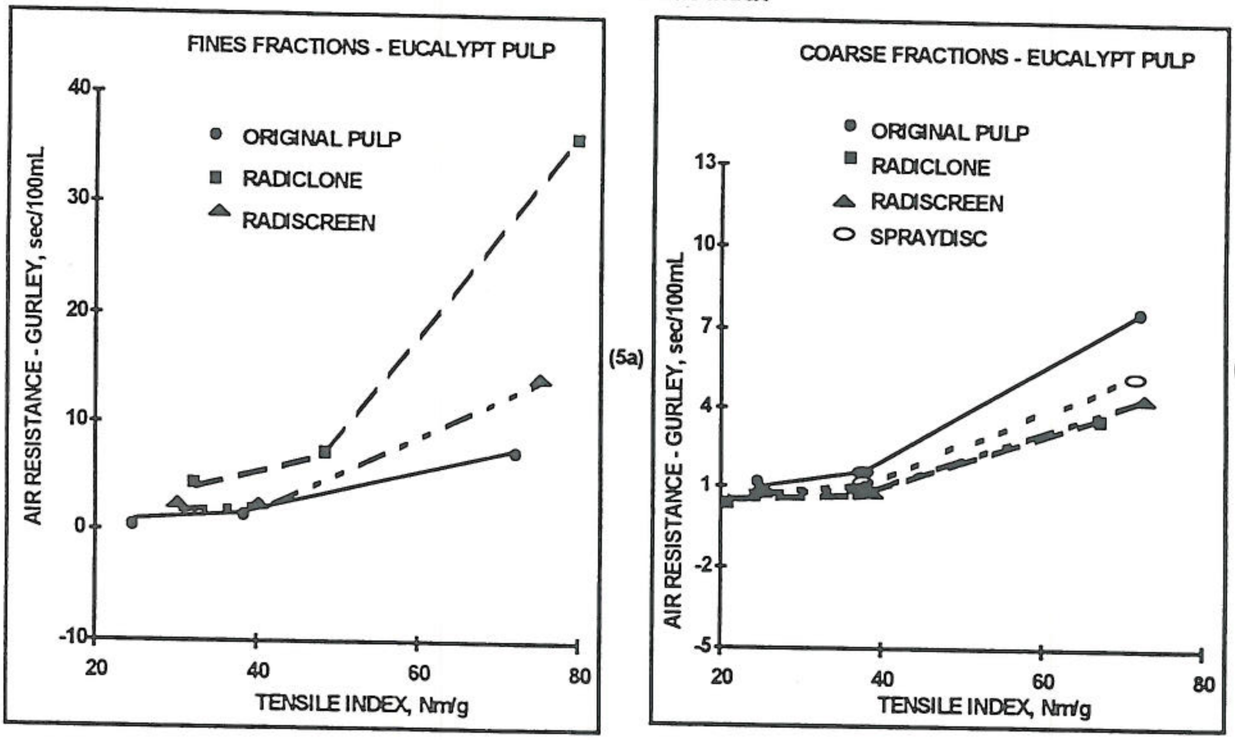


Figure 6 - Sheet Apparent Density vs. Tensile Index

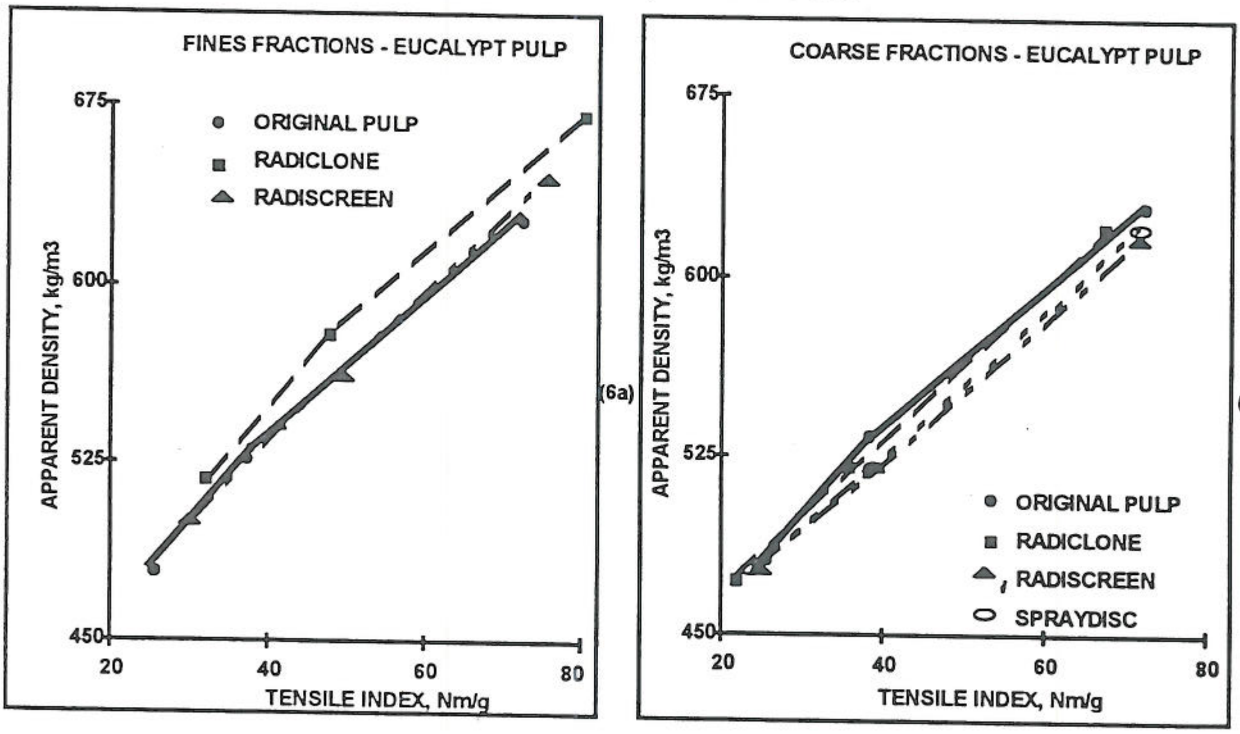


Figure 7 - Light Scattering Coefficient vs Tensile Index

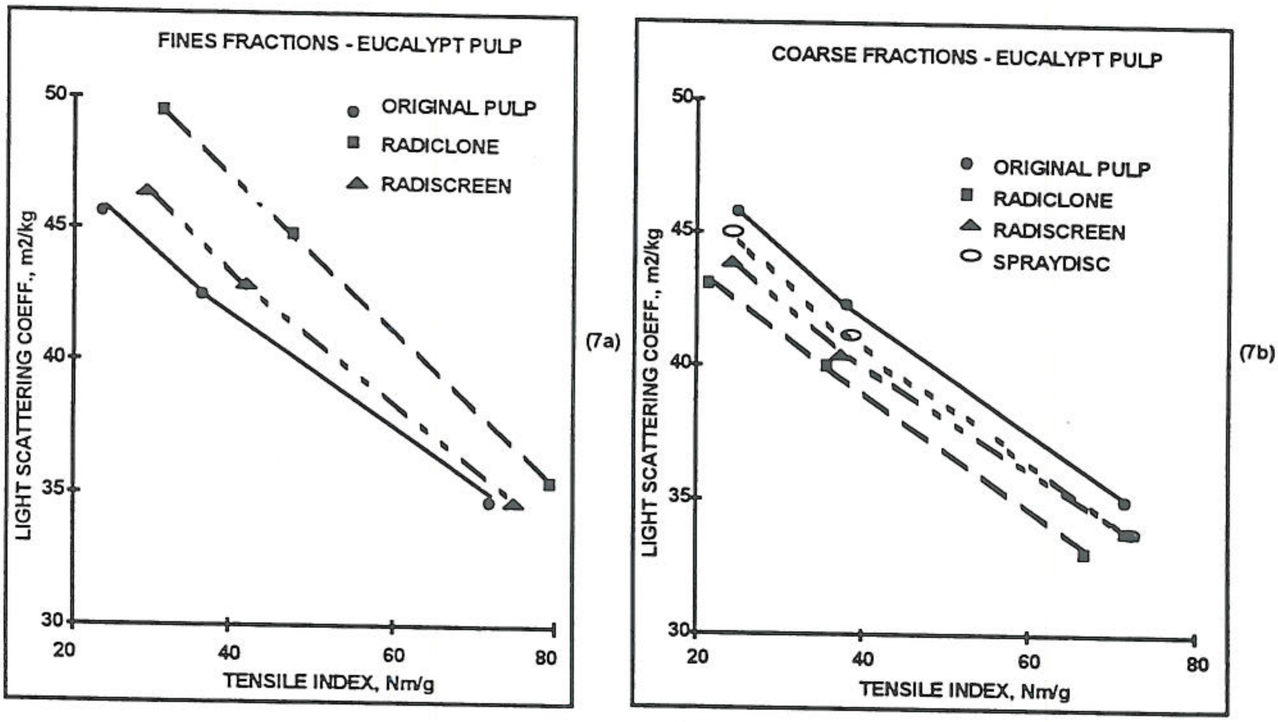
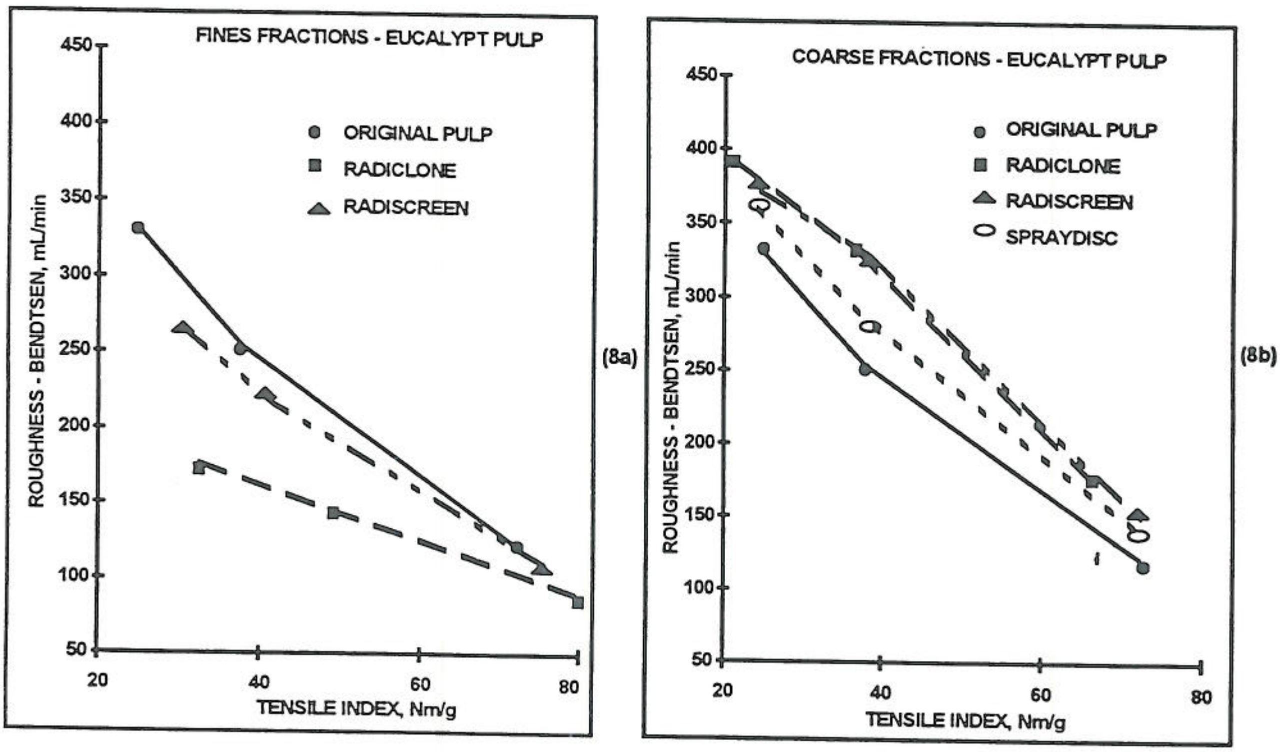


Figure 8 - Roughness - Bendtsen vs. Tensile Index



It somewhat unexpected that such small differences in the eucalypt fiber characteristics, as introduced by fractionation, could express a big impact on paper properties, as earlier presented. At this point, it is very important to rise the following questions: Why did fractionation, specifically the "Radiclone" set-up, introduce such a big impact on important paper properties development? Is there a possible explanation for such behaviour?

In this discussion it is important to consider that the development of different combinations of paper properties through beating/refining can usually be better interpreted by examining the fundamental effects of the treatment. It is well known that fines formation and the internal and external fiber fibrillation are among the most important effects of refining. Both fines and fibrillation have a tremendous impact on pulp drainage resistance, and also on fibre swelling (here estimated by the water retention value).

In Figures 9 and 10 it is shown that among the three configurations tested, the "Radiclone" fractionation introduced much higher differentiation on the dynamic drainage time and also on the water retention value, than the two other set-ups. These results were, to a certain extent, expected, since it is known that dynamic drainage time presents a straight-line relationship with specific surface area of pulp slurries, which in turn is well correlated with fines content (8). Certainly the number of fibers per gram also impacts the specific surface area, and the larger number of fibers per gram (because the small particle size), the higher is the value of specific surface area. These results corroborate the indication that "Radiclone" fractionation showed the highest performance in separating fines and short fibers (Table 2).

In addition to all the possible morphology-related explanations, other phenomena were analyzed as possible explanations for the results obtained in this study. It is also well known that fibre surface chemistry may impact fibre swelling, and thus, it is possible that the changes in pentosans and carboxyl content introduced by fractionation (mostly by the "Radiclone" set-up), may have helped to enhance the effects of fibre swelling. However, the relative contributions of morphology and chemical mechanismis were not possible to measure, and could not be estimated in this investigation.

Figure 9 - Dynamic Drainage Time vs. Tensile Index

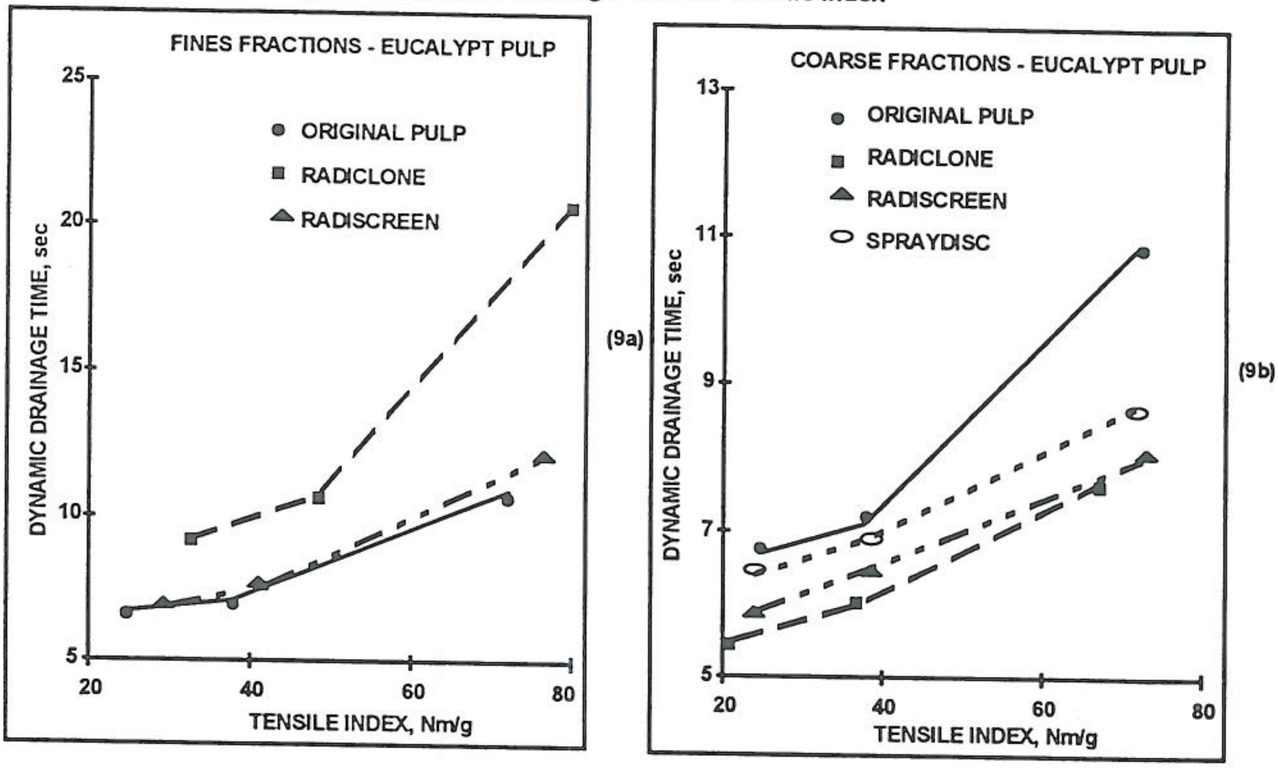
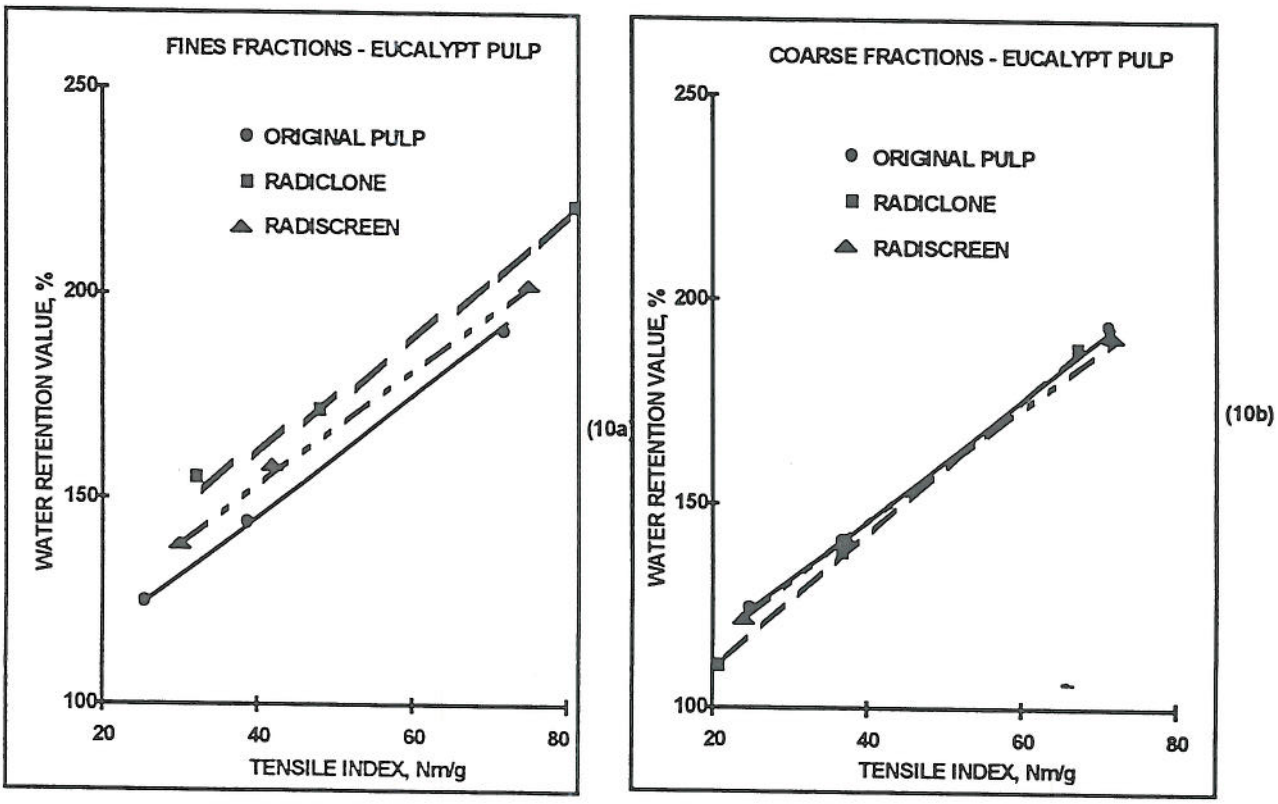


Figure 10 - Water Retention Value vs. Tensile Index



Obviously the results obtained through this study are far from being able to answer all questions related to eucalypt pulp fractionation. Further investigation seems to be necessary, aiming to provide both the pulp and papermakers with additional knowledge over this matter. The real impact of the pulp fractions on the paper machine, including refining, runnability, retention, and sizing to meet some paper grade specifications, appears to be a important step in this development.

CONCLUSIONS

This paper presents results of an eucalypt market ECF pulp, fractionated at pilot scale. The trials were carried out aiming at differentiating the original pulp in two fractions, named as "fines fraction" and "coarse fraction".

The results demonstrated that fractionation was able to separate the narrow eucalypt fibre morphology in two different fractions, which presented significant impact on the paper properties development. The most significant changes on fiber characteristics (morphology and surface chemistry) were introduced by the "Radiclone" fractionation technology.

It was confirmed that fractionation may be able to modify the specific surface area and also the fiber swelling of eucalypt pulp fractions, relatively to the original pulp, hence increasing the potential to optimize refining and also allowing the production of unique paper properties, such as stronger paper with much higher opacity and surface smoothness.

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