Evaluation of Refining Strategies for Combined use of Softwood and Eucalyptus Pulps in Papermaking

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ABSTRACT

The paper discusses the combined use of softwood and eucalyptus kraft pulps in the production of printing and writing papers. Looking for process and paper quality optimization, refining pilot plant trails were carried to identify the effects of refining type (mixed or separate) and intensities (specific edge load), and also furnish composition (amount of each pulp in mixture) on final paper quality and process costs.

The basic effects on pulp fibers were evaluated against paper quality properties, such as physical strengths, bulk, vessel picking, opacity and porosity, as well as the interactions with papermaking process, such as estimates of paper machine runnability, paper breaks and industrial refining control.

The results show that the furnish composition and the type of refining has a significant effect on properties related with both final paper quality and total costs. The best alternative for printing and writing papers was identified for mixed refining, under the lowest refining intensity, and with the highest dosage of eucalyptus pulp.

1. INTRODUCTION

Pulp mixtures have been used from long time to give same specific characteristics to final paper that cannot be achieved by just one type fiber [1-11]. As an example, different optical properties relationships can be obtained using different proportions of pulp fibers [12-13], and more sophisticated papers, such as security papers, low heavy and more opaque papers, and low basis weight wrapping papers can be produced from pulp mixtures [14].

Normally long fiber pulps are used to improve both wet and dried strengths in paper, allowing increases in paper machine runnability, while short fibers pulps are added to improve paper printability, formation and optical properties [5, 15-25]. In this case, the eucalypt pulp became one of the preferred pulps worldwide. The positive effect of short fibers addition is due to the higher number of fibers per gram of pulp suspension. The shorter fibers fill empty spaces between the long ones, spacing then and increasing the internal free surface for light dispersion [14, 26].

When using pulp mixtures there are three possibilities: a) mixture pulps prior to refining, b) mixture of separate refined pulps, and c) refining part of mixture (one or more pulps) and then add the other part of mixture to the refined part and follow the process. Of course the last option requires refiners in series (sequential refining).

The mixture of separated refined pulps is a general concept. It is believed that it promotes the best use of energy in pulp/paper properties development because in each refining treatment it would be possible to use the best operational conditions to meet the target result.

Nevertheless the literature shows positive results from both separated and mixed refining [3, 17-19, 22, 28-37]. The mainly cause of these differences is the flocculation tendency of fibers in suspension [17-20, 37-42].

This tendency, as well the anatomic characteristics of formed flocks, is controlled by fibers anatomy and superficial chemistry [17-20]. So, results obtained from specific furnish will vary according to the proportion of pulps in mixture or, of course, if one or more pulps were changed. Due to this, results obtained under one specific set of operational conditions can not be understood as a general rule. The evaluation of case-to-case is recommended, in special if one or more elements in mixture (pulps) was replaced.

This paper discusses the combined use of softwood (tropical pine) and eucalypt kraft pulps in the production of printing and writing papers. The mixture refining strategies were compared according to the refining energy consumption to meet a target property value in the final paper.

2. EXPERIMENTAL

Commercial samples (bales) of eucalypt (BEKP) and softwood (tropical pine - BSKP) pulps were used. Refining curves were performed in a pilot plant equipped with a single disk refiner (12 inch diameter) with an automatic system to assure a positive pressure inside the refiner. Refiner can be operated at different rotational speeds. Pulp flow through the refiner is controlled by a positive displacement pump, and can be changed to allow different of net energy application. It is possible to run both single and multiple-passes under nominal consistencies from 2.0 up to 6.0 %. The refining pilot plant characteristics are shown on Fig. 1.

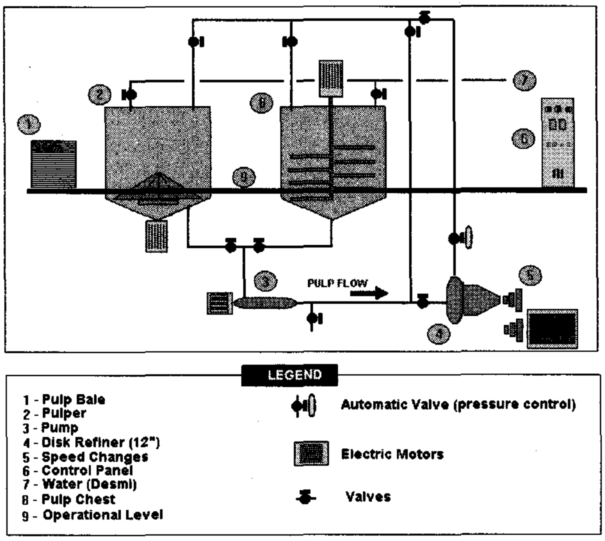

Figure 1 – The refining pilot plant.

Pulp sheets from commercial bales (1) were charged in pulper (2) filled with the necessary volume of water to give the target consistency. After dispersion, pulp suspension was circulated through the installation (2→3→4→2) and, during this time, the refiner "no load" power was measured. For each refining curve, different levels of "net refining energy" were obtained by changing the flow through refiner keeping the "total power" constant according to the refining intensity required for the trial.

Exception in pure softwood pulp - when disk configuration 5.0x5.0/5° was used - refining curves were performed with disks 3.0x3.0/5°. All refining curves were running at 1185 rpm (rotational speed) and 4.5 % consistency.

In sequential refining simulation the long fibers was prepared as a single pass operation (constant net energy input). Refined suspension was collected in the auxiliary tank where eucalypt pulp was added to meet the target mixture proportion. The consistency was adjusted and pulp suspension transferred to pulper (2). A new refining curve was done in single pass operation using the mixed pulp suspension. The total energy applied was estimated adding the energy used for the softwood pulp plus the energy used by the mixed pulp taking account the pulp proportions in the final mixture.

All refining curves were repeated at least three times. TAPPI or SCAN Standards were used in the handsheets characterization. Anatomical evaluation were performed by optical microscopy or using the Kajaani Fiber Analyzer, according to supplier standards.

3. RESULTS AND DISCUSSION

The refining behavior depends on pulp flocculation tendency [17-20, 37-42] that is controlled by both fiber anatomical and surface chemistry characteristics [17-20]. Final paper quality and paper machine runnability are related with fiber properties (collapsibility and specific surface area - bonding ability). Table 1 shows pulp and fibers characteristics for the samples used in this study.

Table 1 – Pulp Characteristics.

Commercial Pulp Characteristics		Samples	
		Eucalypt	Softwood
Brightness (% ISO)		90.6	88.7
Viscosity (dm^3/kg)		752	737
Pentosan Content (%)		15.4	8.5
Sedimentation – 12 hours (mL)		1370	1860
Kajaani FS 200	Fiber Length (mm)	0.72	2.73
	Coarseness (mg/100m)	9.0	29.8
	Fibers per Gram ($x10^6$)	18.8	2.2
	Fines Content (%)	6.7	20.4
Optical Micro-scopy	Cell Wall Width (μm)	7.43	11.16
	Lumen Diameter (μm)	1.92	15.51
	Fiber Wall Relation (%)	44.3	29.5

There are, of course, significant differences between the two pulps. In addition to higher fiber length the softwood fibers shows higher values for fiber diameter and cell wall thickness, given higher coarseness and lower wall proportions than eucalypt fibers.

Due to their high coarseness values it is usual relate high fiber intrinsic strength for softwood pulps and, as a consequence, higher tear strength also. As they have lower cell wall proportion in diameter, the long fibers collapses easily then the eucalypt fibers (lower fiber rigidity in softwood fibers). Nevertheless the higher collapsibility is not related with more open paper structure because the fiber diameter is higher in softwood fibers than in eucalypt.

3.1. Refining Energy Consumption

Fiber collapsing and the increase on surface area are the most important modifications of refining on fibers. The wet conformability is an important fiber property and one of the reasons to refine pulps. Other fiber properties can be modified in positive or negative effects depending upon the paper grade to be produced [43].

Collapsed fibers conform themselves over other fiber surfaces creating higher bonding contact areas between fibers in the paper structure. Paper strength (tensile, folding, burst, and wet strength) is improved [28, 44-48, 51, 53-55]. Optical properties and paper density are also modified by the fiber collapsibility [28, 45-52].

In this study the refining strategies were evaluated according to their net refining energy consumption to meet a target paper property. Tensile index was considered as target property because it is closely related with the fiber bonding ability. Table 2 shows the amount of net refining energy required in each refining treatment to meet tensile indexes from 35 to 55 Nm/g. The results are also illustrated on Fig. 2.

Table 2 – Refining net energy consumption to meet the target tensile resistance.

Refining Type	Pulp Proportion (%)		Refining Intensity (Ws/m)				Net Refining Energy (kWh/t) to Meet target Tensile Index values (Nm/g)				
	SW	HW	SW	HW	First Pass	Mixed	35	40	45	50	55
Pure pulps	100	-	1.25	-	-	-	36.5	48.6	61.1	74.0	87.3
	-	100	-	0.75	-	-	64.3	117.6	186.2	-	-
				0.50	-	-	34.3	47.8	59.9	10.6	87.8
Mixed pulps	25	75	-	-	-	0.50	24.6	33.9	43.5	53.3	63.4
						0.75	31.0	43.2	56.1	69.7	83.9
						1.25	41.8	66.4	96.4	131.6	172.2
	50	50	-	-	-	0.50	23.7	31.7	39.8	48.1	56.6
						0.75	25.8	36.4	48.2	61.1	75.2
						1.25	35.4	53.0	73.7	97.4	124.1
	75	25	-	-	-	0.50	23.9	31.4	39.1	46.9	55.0
						0.75	25.2	36.5	49.5	64.2	80.5
						1.25	29.8	45.1	63.4	84.8	109.3
Mixture after refining	25	75	1.25	0.50	-	-	45.3	60.7	75.9	90.9	105.7
				0.75	-	-	94.9	154.8	228.6	-	-
	50	50	1.25	0.50	-	-	43.1	59.8	78.0	97.7	119.0
				0.75	-	-	54.8	73.4	92.9	113.1	134.1
	75	25	1.25	0.50	-	-	44.3	59.3	75.2	92.0	109.7
				0.75	-	-	53.2	70.3	87.9	106.1	124.7
Sequential Refining (First pass only with poftwood pulp)	25	75	-	-	1.25 (5 m^3/h)	0.50	36.5	48.6	61.7	75.7	90.7
						0.75	43.8	58.4	71.9	84.3	95.7
					1.25 (3 m^3/h)	0.50	41.8	53.6	66.5	80.5	95.5
						0.75	43.8	56.6	72.1	90.3	111.3
	50	50	-	-	1.25 (5 m^3/h)	0.50	39.1	49.3	60.7	73.3	87.0
						0.75	43.8	57.1	71.0	85.6	101.0
					1.25 (3 m^3/h)	0.50	50.0	58.7	68.8	80.4	93.4
						0.75	61.6	67.3	76.1	88.2	103.5

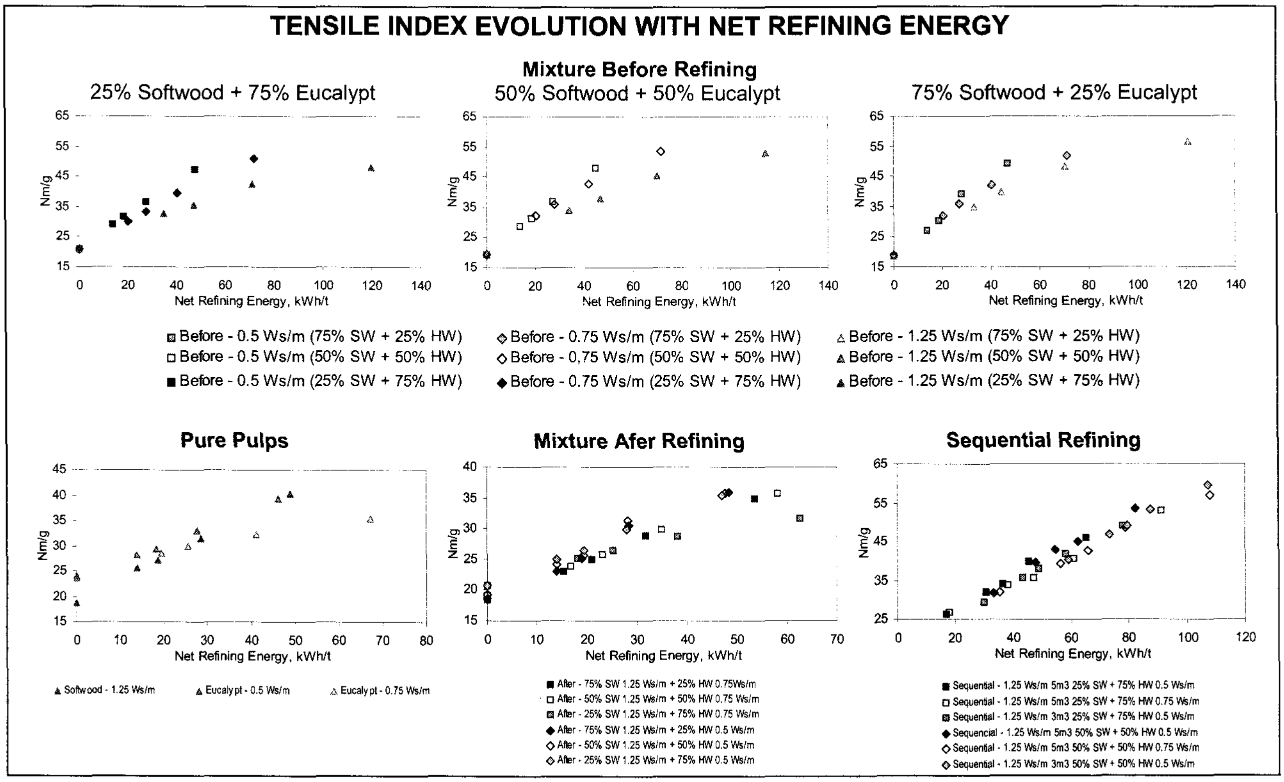

Fig. 2 – Tensile strength evolution during refining (Net refining energy. kWh/t)

Confirming previous results [55-58], in eucalypt refining the lower net refining energy requirements was observed for the lowest refining intensity operation. To meet 35 Nm/g the difference was 46 % that increases for higher tensile strength levels.

Mixing pulp before refining was the lowest energy consumer strategy evaluated. Within a specific refining strategy the lowest energy requirements were observed for refining under the lowest intensity (Table 2). In all cases, the refining intensity had higher effect than the proportion of fibers in mixture, and comparing pulp proportions the mixtures with 75 % eucalypt were the highest energy consumer (3 to 12 % more) than the others. Similar results were observer for 25 % or 50 % eucalypt pulp in furnish (Table 2).

These results differ from some presented by literature where a reduction on energy requirement is reported for separated refining [3, 27, 59]. The separated refining is also elected [20] as the most appropriated if the proportion of short fibers exceeds 50 %. To understand these differences the flocculation tendency must be addressed [17-19, 33, 37-42, 60].

For the same type of study it was concluded [42] that mixing before refining is advantageous when the addition of long fibers improves the flocculation tendency of short fibers component. This was the tendency observed here (Fig. 3).

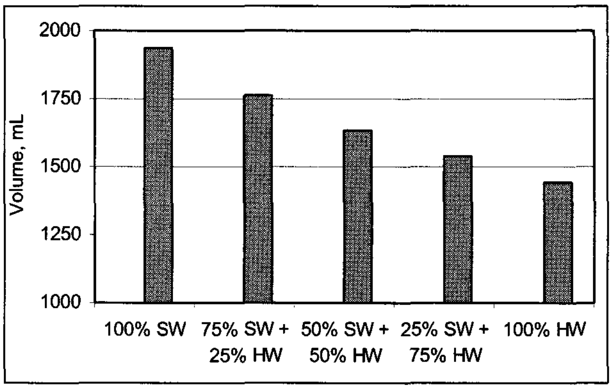

Fig. 3 – Volumes after 12 hours sedimentation.

In sequential refining intermediary energy consumptions where observed. They were higher when the first pass – 100 % long fibers – was conduct at the lowest flow through the refiner (3.0 m^3/h) and for second passes conducted under the highest refining intensity (0.75 Ws/m). The lower energy consumption for sequential refining comparing to mixture after refining agrees with literature results [18, 27].

3.2. Effects on paper quality

Pulp properties relationships are shown on fig. 4 where evolutions of traditional pulp properties are plotted against "paper consolidation" (tensile index) during refining. In this case it is important to note that, according to the refining strategy, different levels of net refining energy were need to reach same tensile index.

All pulp properties - except internal strength that is dependent upon the same factors controlling tensile strength – presented variation related with the proportion of each type of pulp in the mixture.

Opacity and vessel picking (direct effect) as tear strength (inverse effect) were the properties with the highest influence of eucalypt pulp content in mixture.

These effects were expected because increasing the eucalypt pulp proportion the number of fibers per gram in mixture also increases. This allows higher specific surface of fibers, increasing opacity and adding vessel elements. With higher eucalypt content in mixture the tear strength is reduced due to the reduction on average fiber intrinsic strength. Nevertheless tear strength is no an important property for printing and writing papers.

The same tendency, but at lower intensity, was also observed for Schopper-Riegler and air resistance, with higher values for higher eucalypt pulp content. The variation on apparent density and stretch values – at same tensile index - were not proportional with eucalypt pulp content in mixture. Only in mixtures with 75 % of eucalypt pulp it was observed a small (5 %) difference from mixtures with 50 % and 25 % of this pulp.

Probably this is caused by the flocculation tendency of these pulps in mixture. Fig 3 shows higher volumes for softwood pulp, and the eucalypt fibers can fill empty spaces these large flocks. In this situation, the long fibers will protect the short fibers against mechanical impacts during refining [3, 20, 17, 18, 22, 34, 35, 37, 61].

4. CONCLUSION

The paper discusses the combined use of softwood and eucalypt kraft pulps in the production of printing and writing papers. Looking for process and paper quality optimization, refining pilot plant trails were carried to identify the effects of refining type (mixed or separate) and intensities (specific edge load), and also furnish composition (amount of each pulp in mixture) on final paper quality and process costs.

Refining energy consumption to reach a target property (tensile index) in refined mixture was controlled by pulp proportion, by the refining strategy (if the pulps are blended after or before refining), and also by the refining intensity.

For the commercial pulps used in this study the lower energy consumption was determined in blended refining (mixture before refining) and under lowest refining intensity.

At same tensile index increasing the eucalypt content in mixture significantly increases the paper opacity and smoothness. Small differences on apparent density (bulk) and stretch were observed only for mixtures with the highest eucalypt pulp content. No difference was observed for internal paper strength. These results confirm that increasing eucalypt pulp content in mixture allows improvements in paper quality for printing and writing papers.

Negative effects from higher amounts of eucalypt pulp were observed in tear index and, of course, for vessel picking. Both situations are related with the anatomical pulp characteristics. Reduction on tear strength occurs due to the reduction on average intrinsic fiber strength when eucalypt pulp is added in mixture. Nevertheless this is a not critical property for printing and writhing papers.

Vessel picking, in special for low refined papers, tend to increase due to the addition of vessel elements (not presented in softwood pulps). This disadvantage can be managed by refining operational procedure, such as increasing on refining consistency.

In pure eucalypt pulp refining the energy requirement is controlled by the refining operational parameters. The lower refining intensity is the best situation allowing lower energy amounts to produce the target quality paper.

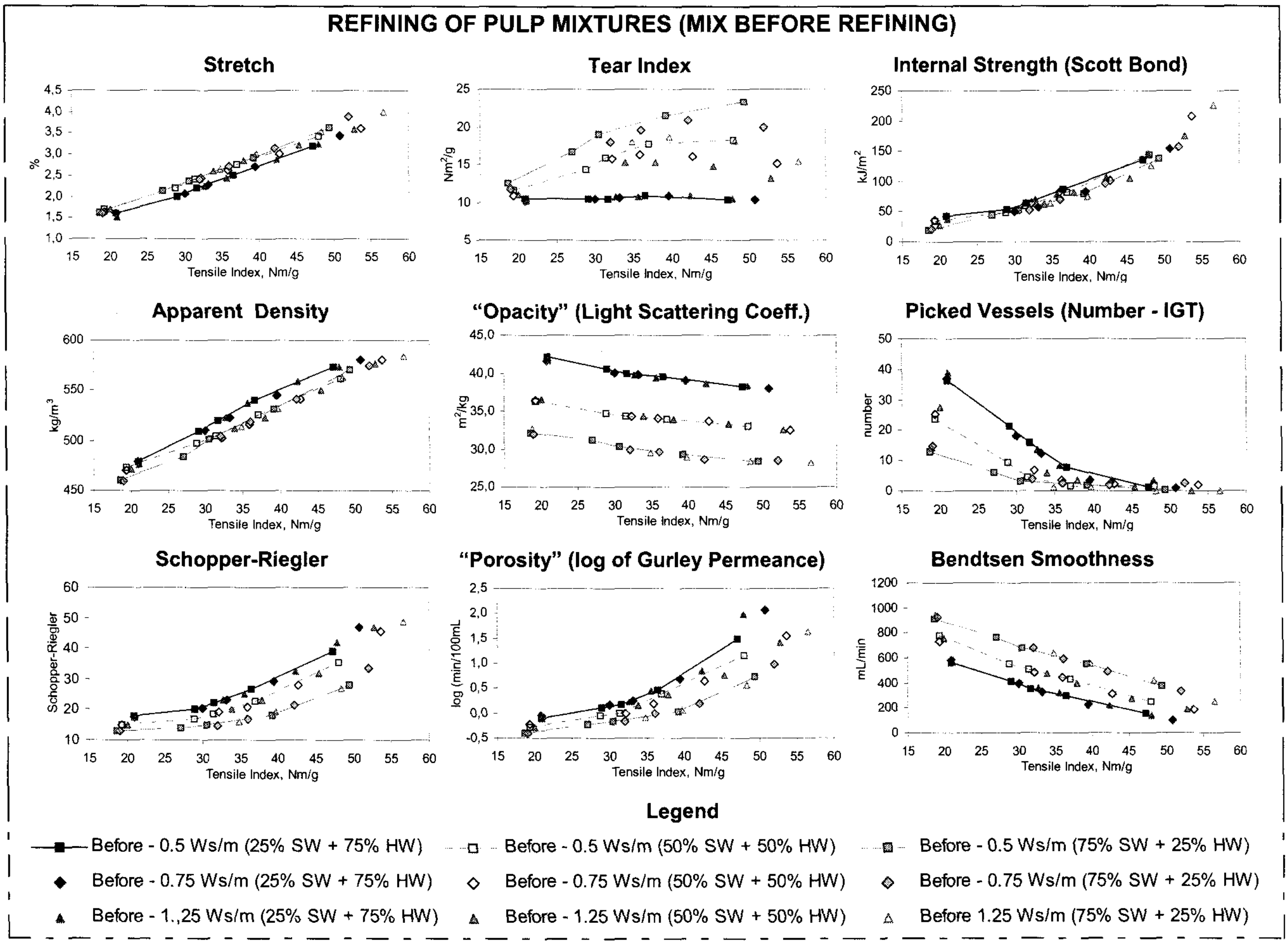

Fig. 4 – Properties relationships according to the pulp proportions in mixtures. Pulp mixture before refining.

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