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CHARACTERISTICS OF PAPER FROM SECONDARY FIBERS MIXED WITH REFINED AND UNREFINED REINFORCEMENT PINUS FIBERS

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Keywords: Kraft pulp, newspaper secondary fiber, OCC, paper properties, refining

ABSTRACT

Fibers from OCC (Old Corrugated Container) and newsprint paper are very suitable for packaging board, but they include a high content of mechanical pulp. Aiming to test properties of paper produced with reinforcement fibers, two sets of fibers mixtures were prepared. The first one with unrefined kraft pulp mixed with OCC/newsprint fibers. The second one with the kraft pulp refined previously to its mixing with the secondary fibers. The kraft pulp was produced from a mixture of 86% pinus wood (softwood) and 24% eucalyptus wood (hardwood). Therefore, the present work is not a co-refining study between pulp and secondary fibers. Each of the fibers blends was refined before its mixing for forming handsheets. However, since the kraft pulping was performed with a mix of softwood and hardwood chips, the work denotes some co-refining aspects indeed. Several properties results from the refined state of these mixed pulps are evaluated as per properties of the papers reinforced with secondary fiber mixtures.

INTRODUCTION

The *Pinus* genus was seen in Brazil as an alternative supply for the softwood pulping, since the native Parana pine (*Araucária angustifólia*) is much more difficult and costly to plant and manage. The main pinus specimen introduced in the country - with government incentives -, was the *Pinus elliottii* var. *elliotii*. However, this specimen was soon replaced by plantations of *Pinus taeda,* mainly because of its less extractives content, around 2.3% - 3% in weight. Government ended tax incentives in 1973 and, thereafter, pinus plantations decreased, although an increasing competition for pinus wood due to demand from furniture, building products and packaging industries. Costs and also some shortage of supply have been the main reason to induce a number of pulping strategies to take up a mix of pinus with 20% - 30% eucalyptus woodchips.

Worthwhile to mention that with the addition of recycled fibers (LUMIANEM, 1994), the decreasing in bonding ability among secondary fibers has been usually compensated by the addition of chemical agents and the intensity of mechanical refining.

In the present work it is verified the impact of the refining on kraft pulp and secondary fiber, with aim at the use of more OCC and newsprint recycled fibers.

MATERIAILS AND METHODS

The kraft pulp was obtained from a mix of 86% pinus and 24% eucalyptus chips, supplied by a Brazilian mill. The kraft batch cooking was carried out with an active alkali charge of 18% on dry wood weight - NaOH basis - and a dilution factor of 1:4. The cooking temperature was increased up to 170°C in 1 hour, and the operation kept in this temperature for 25 minutes. The Kappa number obtained for the washed pulp was 120. Papers made with this sort of pulp are considered in the market as of high quality products. This kraft pulp presented a drainage rate of 13°SR (Schopper Riegler) and was named ‘point 0’ for testing a first group of mixtures. This pulp was refined in a PFI mill to obtain stock with 18°SR, and named ‘point 1’ for a second group of tests.

OCC material, **Figure 1**, source of the OCC secondary fibers, was cut in small pieces and kept in water for one day at 25°C temperature. Fibers were then pulped for fibers separation on a laboratory hydrapulper, **Figure 2**. Afterward, fibers were centrifuged in a 380 mesh nylon bag and subsequently air dried. Resulting OCC fibers presented a 20°SR drainage degree – labeled point 0 - and used for the first group of tests. A portion of this pulp was refined in a PFI mill to obtain stock with 33°SR – named ‘point 1’ – for using for the second series of tests of mixtures. Another portion of pulp was refined to 45ºSR, and labeled as ‘point 2’.

Figure 1. The OCC fibers source material

Figure 2. The laboratory hydrapulper

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The secondary fibers from newsprint papers were kept in water during the night, and referred fibers dispersed in the hydrapulper. Then, the stock was centrifuged in a 380 mesh nylon bag and air dried. This stock - named 'point 0' -, presented 52°SR in its unrefined state.

The design of the experiments in this work applies two-level factorial with three repetitions in the central point, and three points to estimate the response-surface (BARROS NETO e coll., 1995).

In the first group, all the fibers from the kraft pulp, the OCC and the newsprint were in unrefined state. In the second group, the fibers from kraft pulp were refined to 18°SR, the OCC fibers were refined to 33°SR, and the newsprint fibers presented 52°SR without refining.

The handsheet papers were formed with 60 g/m^2 grammage according to ABNT NBR 14345:2004 method. The PFI mill refining was performed as per ABNT 29:003-01-014/97; the Schopper Riegler according ABNT NBR 14031:2004, and the handsheets formation procedure in agreement with ABNT NBR ISO 5269-1:1980.

The methods for physical testing were: ABNT NBR NM ISO 536 :2000; ABNT NBR NM ISO 534:2006; ABNT NBR NM ISO 1924:2001; ABNT NBR NM ISO 1974:2001; ABNT NBR NM ISO 2758:2007 .

RESULTS

Characteristics of fibers mixtures of the first group are shown in **Table 1**, while **Table 2** shows those of the second group. In **Table 3** are exhibited characteristics of the OCC n.° 6 fibers mixture, the one that owns the higher refining level, plus some data from the literature.

Table 1. Formulations and characteristics of fibers mixtures - first group

Pulp mixture	Fibers contents (% weight basis)			Drainage	Grammage	Density	Tensile index	Stretch	Tear index	Burst index
Nº	Kraft	OCC	Newsprint	°SR	g/m^2	kg/m^3	N.m/g	%	mN.m^2/g	kPa.m^2/g
1	100	0	0	13	66.72	354.89	26.99	2.21	16.19	1.71
2	0	100	0	20	64.78	423.40	18.50	1.69	7.75	1.12
3	0	0	100	52	70.41	320.77	20.16	1.84	5.89	1.26
7	50	50	0	16	73.44	405.07	21.77	2.01	11.46	1.23
8	50	0	50	22	67.46	341.92	19.14	2.12	8.56	1.24
9	0	50	50	31	66.76	363.22	17.36	2.13	6.40	1.03
13	33.3	33.3	33.3	26	70.88	386.69	19.73	2.07	8.86	1.19
14	33.3	33.3	33.3	26	70.37	358.48	17.91	2.83	9.01	1.19
15	33.3	33.3	33.3	22	72.46	381.77	20.05	2.13	9.70	1.27
16	20	20	60	31	68.02	350.62	16.86	1.49	6.56	1.40
17	20	60	20	20	66.35	388.01	17.95	1.79	7.30	1.10
18	60	20	20	17	71.67	385.32	20.13	2.16	8.36	1.40

Table 1. Formulations and characteristics of fibers mixtures - first group (continuation)

Pulp mixture	Fibers contents (% weight basis)			Elasticity module	Tensile stiffness	Tensile work	Tensile energy	Air permeance Gurley (300 mL)	Bulk
Nº	Kraft	OCC	Newsprint	MPa	kNm/kg	J	kJ/kg	10^{-6} m/Pa.s	dm^3/kg
1	100	0	0	122.21	344.37	0.040	0.40	430.0	2.80
2	0	100	0	106.45	251.42	0.020	0.21	54.4	2.36
3	0	0	100	115.47	359.97	0.025	0.24	11.1	3.12
7	50	50	0	119.47	294.94	0.033	0.30	215.4	2.47
8	50	0	50	91.58	267.83	0.028	0.27	83.7	2.92
9	0	50	50	81.55	224.52	0.026	0.25	30.1	2.75
13	33.3	33.3	33.3	101.60	262.74	0.029	0.28	65.6	2.59
14	33.3	33.3	33.3	66.71	186.09	0.037	0.35	95.1	2.79
15	33.3	33.3	33.3	102.58	268.69	0.032	0.29	82.4	2.62
16	20	20	60	115.56	329.59	0.017	0.17	54.9	2.85
17	20	60	20	99.95	257.60	0.021	0.21	83.3	2.58
18	60	20	20	100.08	259.74	0.033	0.30	231.7	2.60

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Table 2. Formulations and characteristics of fibers mixtures - second group

Pulp mixture	Fibers contents (% weight basis)			Drainage	Grammage	Density	Tensile index	Stretch	Tear index	Burst index
Nº	Kraft	OCC	Newsprint	°SR	g/m^2	kg/m^3	N.m/g	%	mN.m^2/g	kPa.m^2/g
4	100	0	0	18	65.29	444.15	34.14	3.52	17.69	2.60
5	0	100	0	33	60.41	470.12	23.49	2.54	8.11	1.48
3	0	0	100	52	70.41	320.77	20.16	1.84	5.89	1.26
10	50	50	0	19	64.34	402.12	17.96	2.13	12.20	1.72
11	50	0	50	27	70.14	385.38	26.01	2.57	11.37	1.60
12	0	50	50	34	63.30	396.87	21.63	1.88	6.45	1.28
19	33.3	33.3	33.3	29	67.64	414.21	24.31	2.48	7.63	1.70
20	33.3	33.3	33.3	26	62.91	392.45	22.05	2.16	8.27	1.70
21	33.3	33.3	33.3	27	66.20	389.41	20.88	2.21	8.38	1.60
22	20	20	60	28	64.36	436.93	17.29	1.78	7.52	1.50
23	20	60	20	33	65.17	371.34	16.56	1.90	6.50	1.20
24	60	20	20	22	69.74	398.97	24.11	2.43	10.24	1.70

Table 2. Formulations and characteristics of fibers mixtures - second group (continuation)

Pulp mixture	Fibers contents (% weight basis)			Elasticity module	Tensile stiffness	Tensile work	Tensile energy	Air permeance Gurley (300 mL)	Bulk
Nº	Kraft	OCC	Newsprint	MPa	kNm/kg	J	kJ/kg	10^{-6} m/Pa.s	dm^3/kg
4	100	0	0	94.89	213.64	0.084	0.86	94.9	2.25
5	0	100	0	83.98	178.64	0.039	0.43	17.5	2.13
3	0	0	100	115.47	359.97	0.025	0.24	11.1	3.12
10	50	50	0	81.39	202.40	0.025	0.26	23.0	2.49
11	50	0	50	106.52	276.4	0.049	0.47	31.3	2.59
12	0	50	50	109.03	274.73	0.026	0.27	17.5	2.52
19	33.3	33.3	33.3	99.62	240.51	0.043	0.42	25.9	2.41
20	33.3	33.3	33.3	96.26	245.27	0.031	0.32	42.3	2.55
21	33.3	33.3	33.3	93.89	241.10	0.032	0.32	32.9	2.57
22	20	20	60	96.67	214.37	0.020	0.21	39.3	2.29
23	20	60	20	85.42	230.05	0.021	0.22	47.2	2.69
24	60	20	20	103.84	260.27	0.043	0.41	63.7	2.51

Table 3. Formulations and characteristics of fibers mixtures - third group

Pulp mixture	Fibers contents (% weight basis)			Drainage	Grammage	Density	Tensile index	Stretch	Tear index	Burst index
Nº	Kraft	OCC	Newsprint	°SR	g/m^2	kg/m^3	N.m/g	%	mN.m^2/g	kPa.m^2/g
6	0	100	0	45	75.07	462.54	24.77	3	8.53	1.86
Lu-OCC1*		100		19			24.10		8.00	1.36
Lu-OCC2*		100		18			24.00		8.50	1.30
Lu-DIP1*				47		487.80	26.20		7.38	1.30
Lu-DIP2*				62		549.40	39.30		8.05	2.34

* LUMIANEN (1994)

Table 3. Formulations and characteristics of fibers mixtures - third group (continuation)

Pulp mixture	Fibers contents (% weight basis)			Elasticity module	Tensile stiffness	Tensile work	Tensile energy	Air permeance Gurley (300 mL)	Bulk
Nº	Kraft	OCC	Newsprint	MPa	kNm/kg	J	kJ/kg	10^{-6} m/Pa.s	dm^3/kg
6	0	100	0	93.09	201.3	0.062	0.55	7.1	2.16
Lu-OCC1*		100							
Lu-OCC2*		100			333.0				
Lu-DIP1*									
Lu-DIP2*									

* LUMIANEN (1994)

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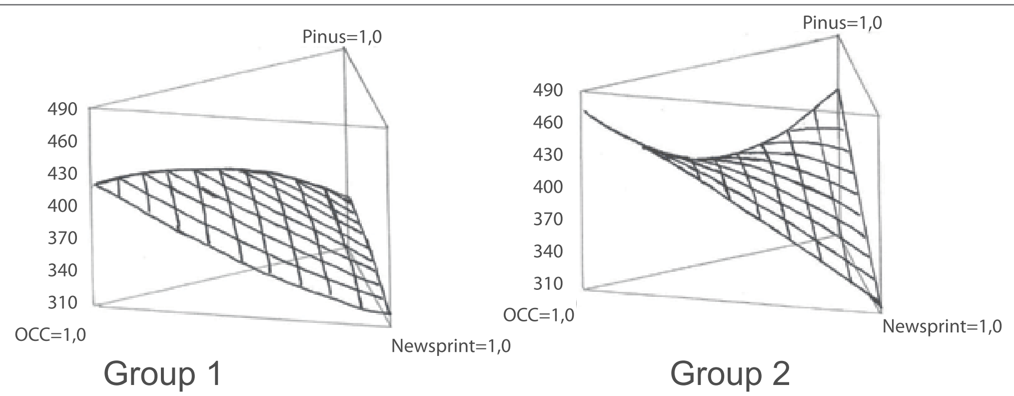
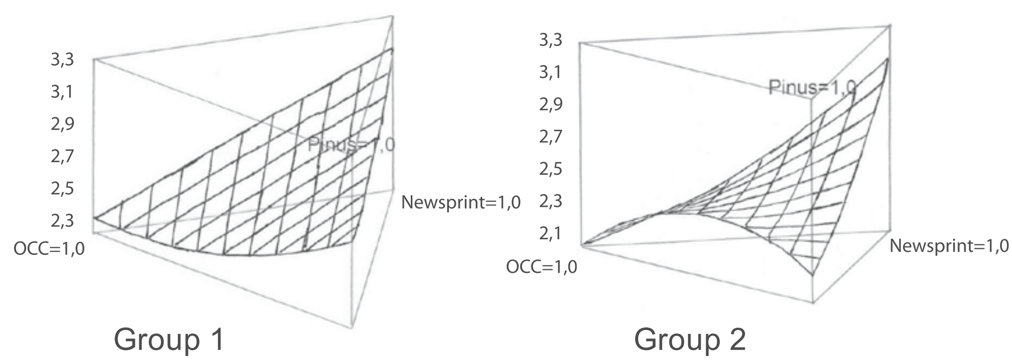
According to data of Tables 1 and 2, results as response-surfaces are presented in **Figures 3** to **13**, aiming to analyze the impacts of each sort of fiber on the properties of the fibers mixture of the paper. In these figures, where we read "pinus" actually is the kraft pulp from the mix of pinus/eucalyptus woods.



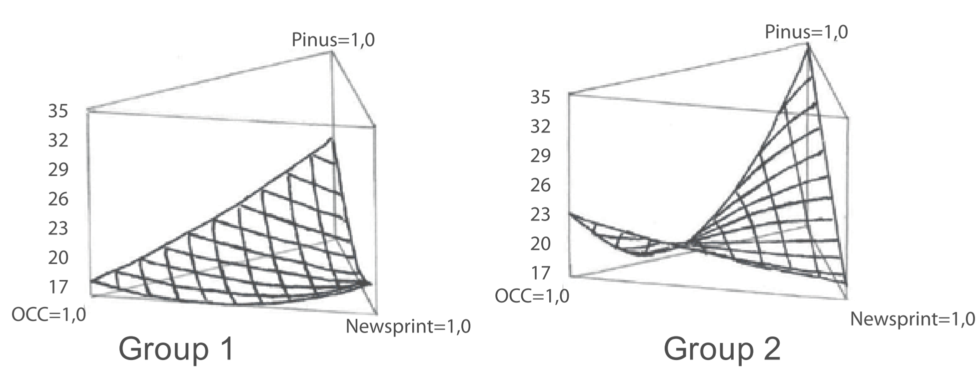
DS(Group 1) = 357,28*Pinus+421,54*OCC+320,45*Newsprint+65,46*Pinus*OCC+23,26*Pinus*Newsprint - 42,75*OCC*Newsprint +134,28*Pinus*OCC*Newsprint (R^2 = 92,87)
DS(Group 2) = 442,17*Pinus+473,94*OCC+319,95*Newsprint-213,92*Pinus*OCC+1,0*Pinus*Newsprint+14,36*OCC*Newsprint +287,93*Pinus*OCC*Newsprint (R^2 = 95,1) DS

Figure 3. Response-surface for density (kg/m^3)



VA(Group 1) = 2,81*Pinus+2,38*OCC+3,12*Newsprint-0,56*Pinus*OCC-0,32*Pinus*Newsprint+0,02*OCC*Newsprint (R^2=93,0)
VA(Group 2) = 2,27*Pinus+2,11*OCC+3,13*Newsprint+1,08*Pinus*OCC-0,41*Pinus*Newsprint-0,56*OCC*Newsprint (R^2=95,0)

Figure 4. Response-surface for bulk (dm^3/kg)



IT(Group 1) = 26,90*Pinus+18,5*OCC+20,02*Newsprint-4,23*Pinus*OCC-18,51*Pinus*Newsprint-8,36*OCC*Newsprint +9,76*Pinus*OCC*Newsprint (R^2=92,6)
IT(Group 2) = 34,50*Pinus+23,25*OCC+19,41*Newsprint-43,02*Pinus*OCC-5,89*Pinus*Newsprint-4,08*OCC*Newsprint+31,44*Pinus*OCC*Newsprint (R^2=83,6)

Figure 5. Response-surface for tensile strength index (kN.m/kg)

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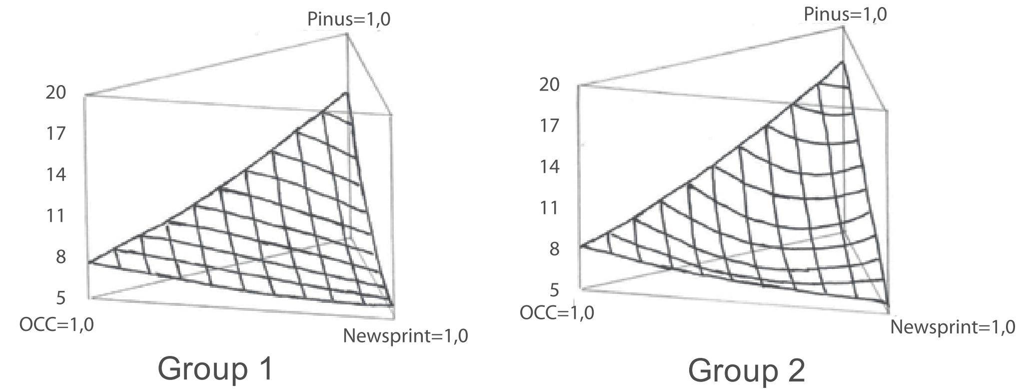
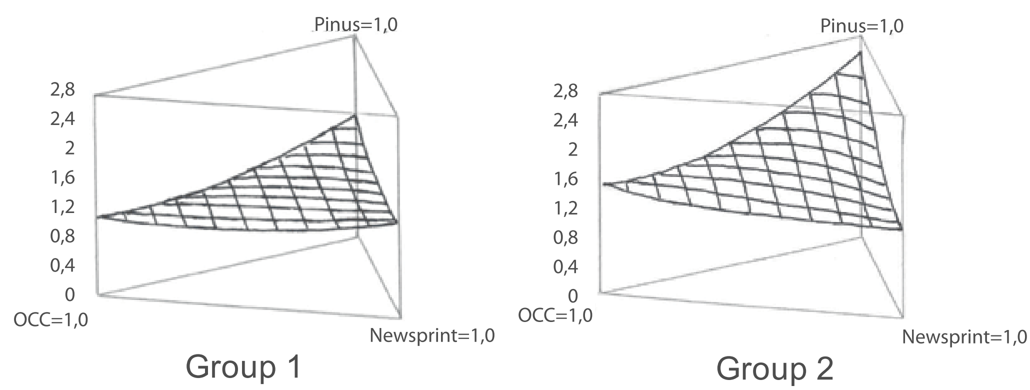


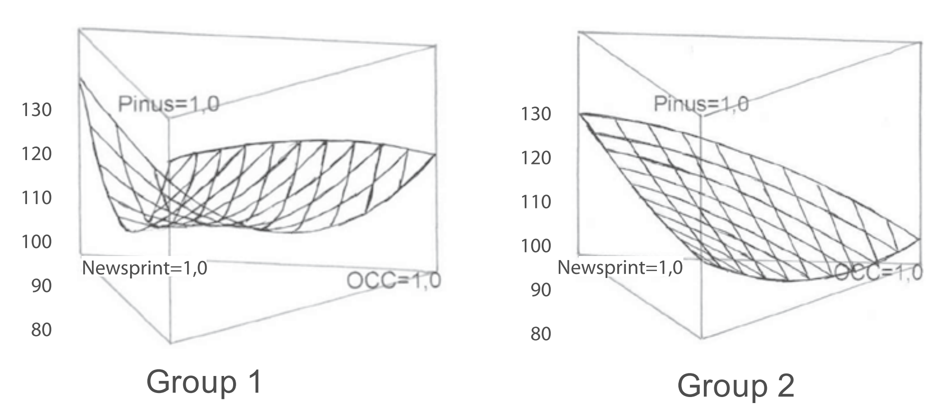
IR(Group 1) = 15,80*Pinus+7,71*OCC+5,98*Newsprint-3,47*Pinus*OCC-10,91*Pinus*Newsprint-1,53*OCC*Newsprint+10,07*Pinus*OCC*Newsprint (R^2=89,4)
IR(Group 2) = 17,50*Pinus+8,16*OCC+5,89*Newsprint-3,26*Pinus*OCC-2,30*Pinus*Newsprint-2,02*OCC*Newsprint-52,25*Pinus*OCC*Newsprint (R^2=96,4)

Figure 6. Response-surface for tear index (mN.m^2 /g)



IA(Group 1) = 1,71*Pinus+1,10*OCC+1,30*Newsprint-0,81*Pinus*OCC-0,86*Pinus*Newsprint-0,59*OCC*Newsprint +3,66*Pinus*OCC*Newsprint (R^2=86,2)
IA(Group 2) = 2,56*Pinus+1,49*OCC+1,23*Newsprint-1,30*Pinus*OCC-1,45*Pinus*Newsprint-0,41*OCC*Newsprint +4,77*Pinus*OCC*Newsprint (R^2 =93,7)

Figure 7. Response-surface for burst index (kPa.m^2/g)



ME(Group 1) = 120,40*Pinus+106,06*OCC+119,71*Newsprint+13,24*Pinus*OCC-100,93*Pinus*Newsprint-104,80*OCC*Newsprint+26,95*Pinus*OCC*Newsprint (R^2=49,1)
ME(Group 2) = 97,35*Pinus+85,33*OCC+111,26*Newsprint-19,50*Pinus*OCC-0,48*Pinus*Newsprint+27,69*OCC*Newsprint - 82,82*Pinus*OCC*Newsprint (R^2=54,8)

Figure 8. Response-surface for elasticity module (MPa)

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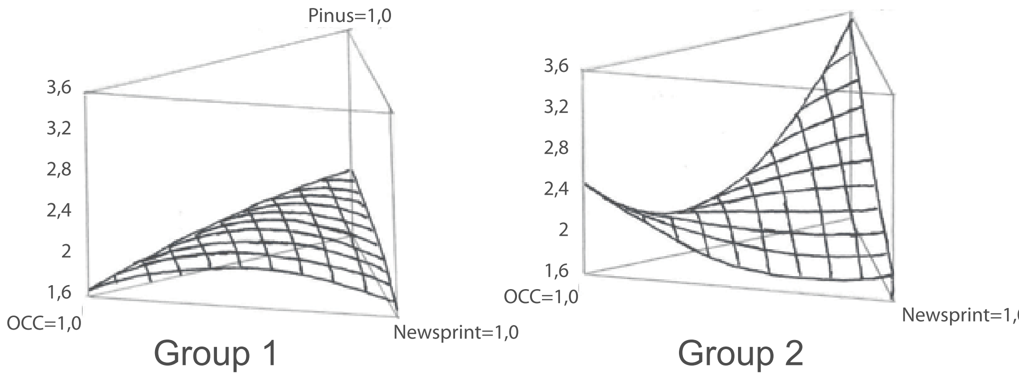
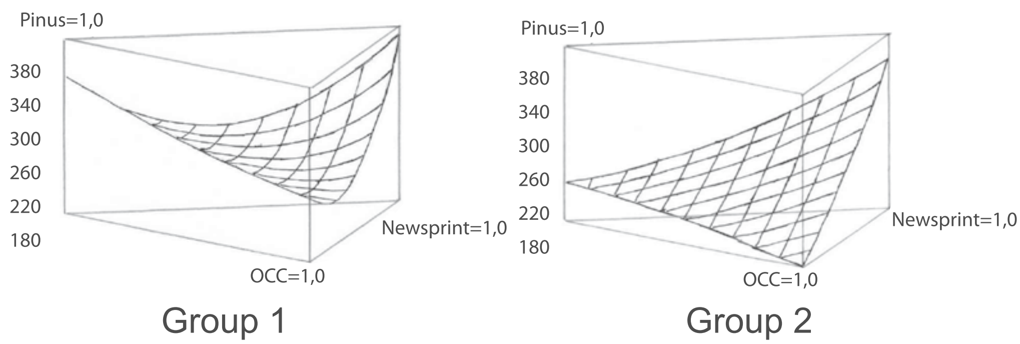


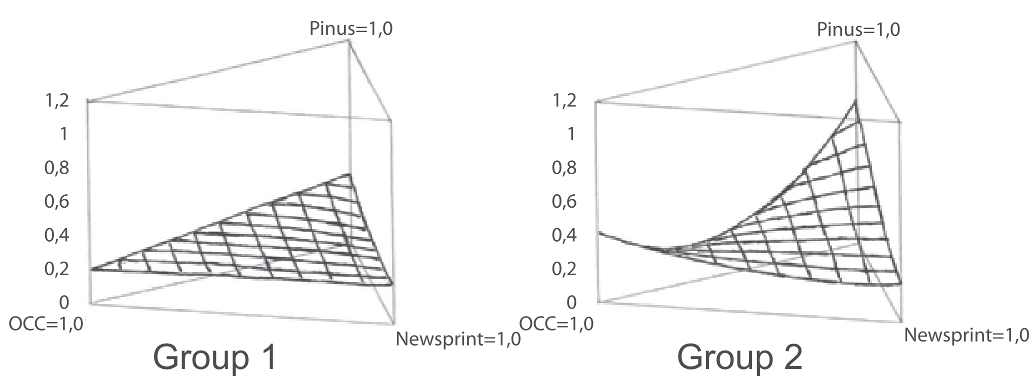
AL(Group 1) = 2,24*Pinus+1,67*OCC+1,74*Newsprint+0,29*Pinus*OCC+0,17*Pinus*Newsprint+0,08*OCC*Newsprint+2,82*Pinus*OCC*Newsprint (R^2 =27,3)
AL(Group 2) = 3,52*Pinus+2,5*OCC+1,83*Newsprint-3,73*Pinus*OCC-0,47*Pinus*Newsprint -1,41*OCC*Newsprint+4,65*Pinus*OCC*Newsprint (R^2 =91,7)

Figure 9. Response-surface for stretch index (%)



IRT(Group 1) = 337,79*Pinus+251,88*OCC+371,73*Newsprint-32,19*Pinus*OCC-320,07*Pinus*Newsprint-283,94*OCC*Newsprint+64,06*Pinus*OCC*Newsprint(R^2=65,3)
IRT(Group 2) = 221,61*Pinus+178,97*OCC+349,64*Newsprint+52,69*Pinus*OCC-49,50*Pinus*Newsprint-11,67*OCC*Newsprint-303,40*Pinus*OCC*Newsprint (R^2=84,6)

Figure 10. Response-surface for tensile stiffness index (kN.m/kg)



IET(Group 1) = 337,79*Pinus+251,88*OCC+371,73*Newsprint-32,19*Pinus*OCC-320,07*Pinus*Newsprint-283,94*OCC*Newsprint+64,06*Pinus*OCC*Newsprint (R^2 =65,3)
IET(Group 2) = 221,61*Pinus+178,97*OCC+349,64*Newsprint+52,69*Pinus*OCC-49,50*Pinus*Newsprint-11,67*OCC*Newsprint - 303,40*Pinus*OCC*Newsprint (R^2 =84,6)

Figure 11. Response-surface for tensile energy index (kJ/kg)

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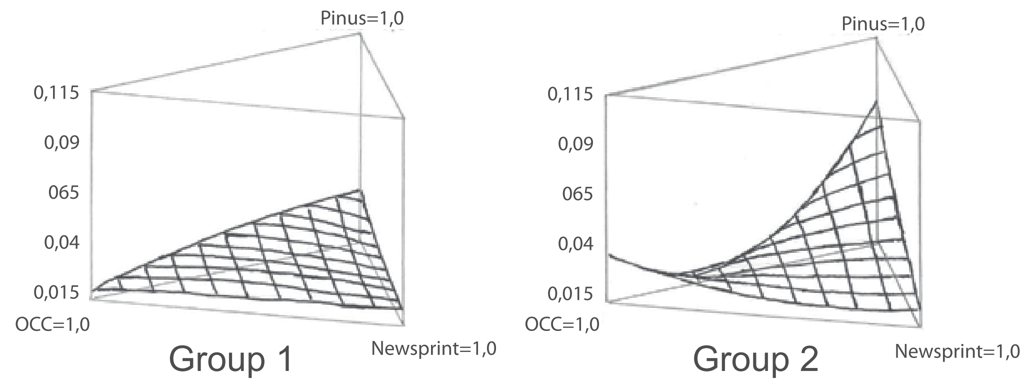
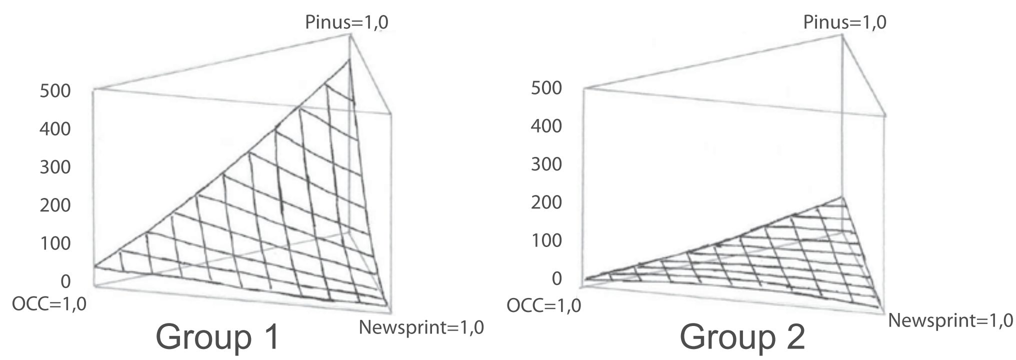


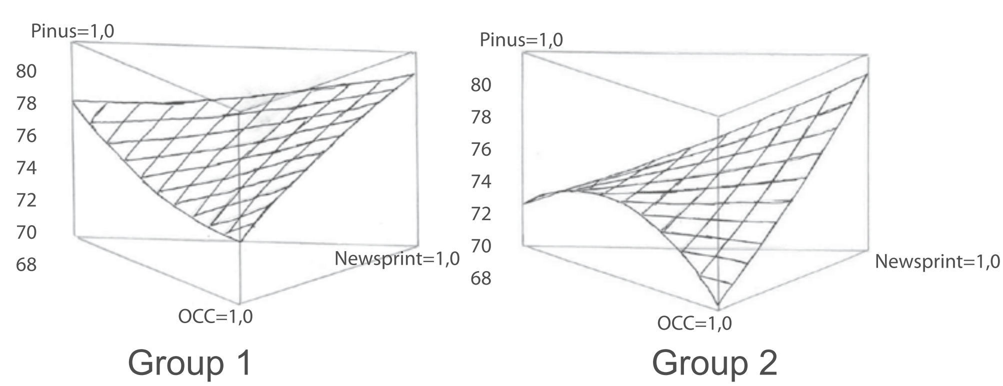
TR(Group 1) = 0,04*Pinus+0,02*OCC+0,02*Newsprint+0,01*Pinus*OCC-0,02*Pinus*Newsprint+0,01*OCC*Newsprint+0,05*Pinus*OCC*Newsprint (R^2 = 63,4)
TR(Group 2) = 0,08*Pinus+0,04*OCC+0,02*Newsprint-0,15*Pinus*OCC-0,03*Pinus*Newsprint-0,03*OCC*Newsprint+0,15*Pinus*OCC*Newsprint (R^2 = 92,7)

Figure 12. Response-surface for tensile work index (J)



PE(Group 1) = 436,17*Pinus+52,06*OCC+13,76*Newsprint-107,26*Pinus*OCC-530,81*Pinus*Newsprint-22,36*OCC*Newsprint (R^2 =98,3)
PE(Group 2) = 93,61*Pinus+15,92*OCC+10,92*Newsprint - 80,22*Pinus*OCC-29,54*Pinus*Newsprint+69,08*OCC*Newsprint (R^2 =79,5)

Figure 13. Response-surface for air permeance (10^{-6}m/Pa.s)



Estimates of response-surfaces

VP(Group 1) = 76,204*Pinus+71,917*OCC+78,666*Newsprint-4,979*Pinus*OCC-2,177*Pinus*Newsprint+2,228*OCC*Newsprint (R^2 =92,4)
PR(Group 2) = 70,585*Pinus+68,470*OCC+78,765*Newsprint+78,765*Pinus*OCC+12,719*Pinus*Newsprint-2,5112*OCC*Newsprint (R^2 =94,4)

Figure 14. Response-surface for pore volume (%)

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RESULTS AND DISCUSSION

In Figure 3, it is observed that fibers mixtures with OCC present the highest results of sheet density and, consequently, the lowest in bulk. The mixtures with more newsprint fibers content, richer in mechanical pulp, present the lowest density results (and highest bulk), as is shown in Figure 4. Results of Group 1 and 2, as seen in Figures 3 and 4, show that kraft pulp refining increases significantly the apparent paper density. When the OCC fibers are refined, the increasing in density (or the decreasing in bulk) is not significant.

For the paper mechanical properties, such as tensile index, burst and tear index, see Figures 5 - 7. As expected for the reinforcement fibers, more kraft pulp fibers impact positively. Also, more kraft pulp refining results in better paper mechanical properties. The refining of the OCC fibers does not impacts on mechanical properties, or decrease them in some cases such as in Group 2 of Figure 5. Obviously, the low quality of the newsprint secondary fibers is cause for the poor paper quality.

It may be observed that the results for elasticity module do not show significant difference among different fibers (see Group 1 in Figure 8), and that OCC fibers do not contribute to increase this property. Interesting to observe that do not occur a positive synergistic effect on elasticity module property, it has even been negative in mixtures with higher content of newsprint fibers (mechanical pulp).

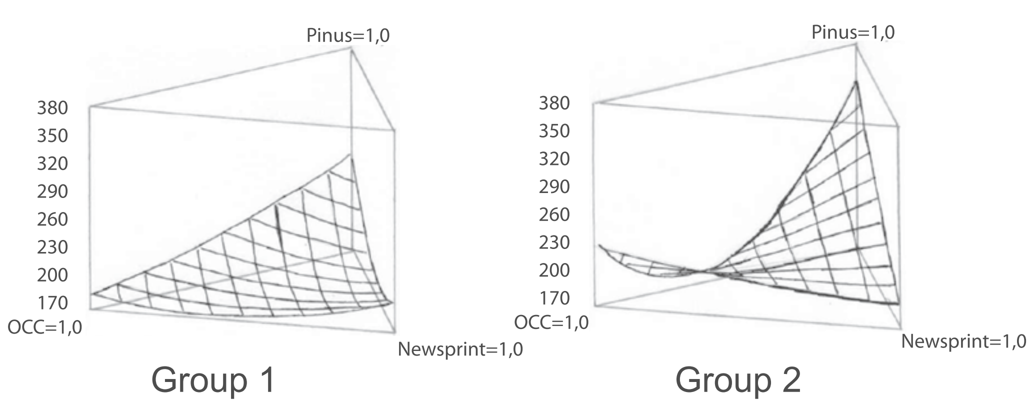
Several authors present estimation for the tear index, as illustrated in **Table 6.** Here, it is applied an equation similar to SUTTIGER (1979), but using tear index and tensile index, as shown in **Figure 15**.

Figure 15 shows again that more kraft pulp produces better resistance, but even OCC fibers reduce this potential. Newsprint fiber gives the poorest paper quality in resistance potential in both Figure 15 and Figure 9. The energy absorption, such as stiffness index, tensile energy and work are presented in Figures 10-12. Stiffness for mixture was worst when increasing kraft pulp and OCC fiber content in Figure 10. In general, properties increase when kraft pulp is applied as reinforcement fiber, as shown in Figures 11-12.

As expected, pore volume and air permeance show higher values when the paper presents higher content of newsprint fiber. Refining of kraft pulp and OCC fibers decreases these values. Results show that the synergy between kraft pulp and OCC fibers is better than other mixtures, including newsprint secondary fibers.

Table 6. Estimation of the potential for resistance

.	
Authors	
Seehofer and coll. (1983)	[(CAR*, N) * (RR, mJ/m)]/1000
Weidhaas (1979)	(RT, N) + 0,1* (RR, mJ/m)
Suttiger (1979)	10*(RT) + 0,1* (RR)
where: CAR: breaking length; RR: tear resistance; RT: tensile resistance.	



resistance potential, PR = 10*(tensile index, kNm/kg)+0,1*(tear index, mN.m²/g)

PR(Group 1) = 270,118*Pinus+185,341*OCC+200,426*Newsprint-39,935*Pinus*OCC-177,119*Pinus*Newsprint-75,043*OCC*Newsprint (R^2 = 92,4)
PR(Group 2) = 345,471*Pinus+232,09*OCC+193,399*Newsprint-492,833*Pinus*OCC-11,535*Pinus*Newsprint-13,338*OCC*Newsprint (R^2 = 83,2)

Figure 15. Estimated responce-surface for resistance potential

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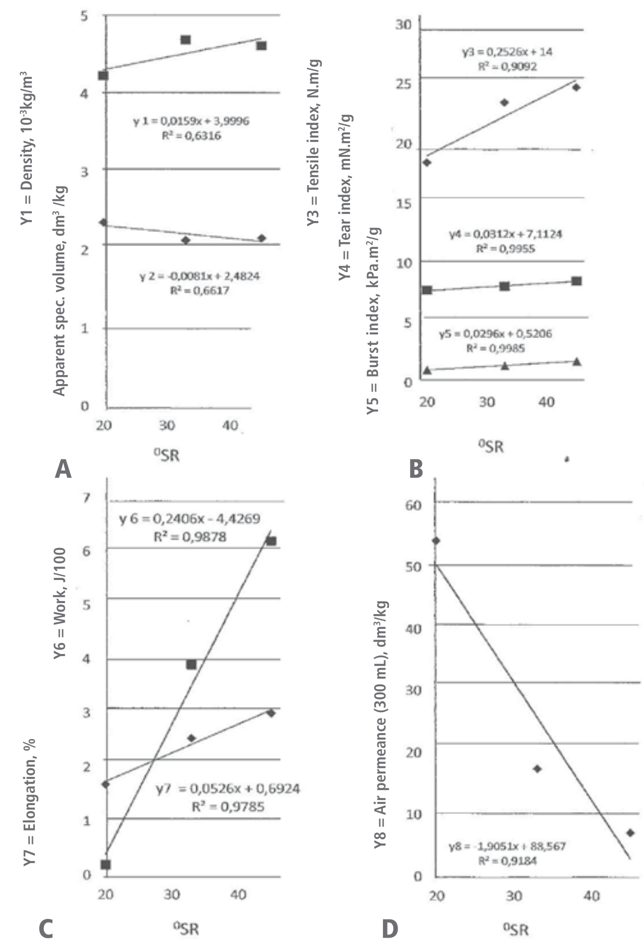

Figure 16. Impact of refining degree on OCC fiber properties

Figure 16 shows the refining degree impact on OCC fibers properties. More refining implies loss of bulk, increased elongation index and increased mechanical properties. Also, more refining is cause of loss in air permeance.

CONCLUSION

The potential of gains in mechanical properties of paper from mixture of fibers when the individual fibers are separately refined is presented in this paper. The loss in properties due to newsprint fibers is clearly compensated by the inclusion of reinforcement kraft pulps fibers.

This work presents a clear direction for industrial application when the feedstock includes significant amounts of OCC fibers and newsprint fibers, exposing how this condition impacts negatively in mechanical properties and positively in bulk. This study also presents how the amounts of reinforcement fibers and the refining levels can compensate these impacts. As here clearly shown, it is not worthy to refine the fibers after the mixture, because it negatively impacts on the newsprint fibers and is not significant for the OCC fibers. The main conclusion, therefore, is that kraft pulp refining prior to the mixture results in a more economical procedure. ■

REFERENCES

1. BARROS NETO, B. DE; SCARMINIO, I. S.; BRUNS, R.E. - *Planejamento e otimização de experimentos.* Campinas: Editora UNICAMP, 1995.
2. LEVLIN, J. - *Characterization of Papermaking Pulps*. Tappi, v. 58, n0 1, January, 1975. p.71 – 74.
3. LUMIANEN, J. - *Fibras recicladas precisam de refinação?* O Papel LV (2): 36-39 (1994).
4. SEEHOFER, J. CORNELL, H. STRITTMATTER, G. WEIDHAAS. A.G. - *An forderung an die Holzstoffe*. V. 37 (10A) : V-110 – 114 (1983).
5. WEIDHAAS. A.G. - *Umrustung einer RMP- auf eine TMP – Anlage*; Wochenblat fur Papierfabrication 107 (23/24) : 923 – 932 (1979).
6. SUTTIGER, R. - *Die Technologie des Hozschleifprozesses* . Voith Forschung und Konstruktion, Heft 26, dec. 1979. 78 pag. Alemanha. P. 23.