Correlation between chemical characteristics of cellulosic pulp with optical and physical-mechanical properties of paper

Antonio J. V. Zanuncio: master candidate, UFLA, Brazil,ajvzanuncio@yahoo.com.br
Regina Maria Gomes,master candidate, UFV, Brazil, reginamgones@hotmail.com
Jorge L. Colodette : Full Professor, UFV, Brazil, colodett@ufv.br
Rubens Chaves de Oliveira, Full Professor, UFV, Brazil, rchaves@ufv.br

Abstract

The pulp and paper is an important socioeconomic sector for Brazilian development. In 2007, it contributed with US$ 2.1 billion in taxes compared to R$ 1.7 billion in 2003 and with an export of US$4.7 billion (about 4% of the Brazilian exports) compared to US$556 million in the early 90's and US$2.5 billion in 2003, besides exports of pulp equal to US$ 3 billion, an increase of 60% over 2003. It is essential to develop studies about production process and the factors that affect this sector to maintain its growing pattern. This study aimed to correlate the chemical characteristics of pulp with optical and physical-mechanical properties of paper. The determination of these properties paper were made with TAPPI rules (1992); the carbohydrate composition of the bleached pulps was adapted from the TAPPI T249 cm-85 procedure and hexenuronic acids were determined by the Vuorinen (1996) method. The content of xylan showed an r= -0.3411 for the tensile index; r= 0.3307 for the tear index; r= 0.5587 for resistance to air flow and r= 0.4504 for opacity of paper. The content of glycans showed r= 0.2534 for the tensile index; r= -0.3950 for the tear index; r= -0.078 and for the resistance to air flow and r= 0.5870 for opacity. The hexenuronic acids showed r= -0.2517 for the tensile index; r= -0.2433 for the tear index; r= 0.2028 for the resistance to air flow and r= -0.7245 for opacity of paper. The samples showed no significance difference with the F test. This indicates that the chemical characteristics of the pulp do not influence the optical and physical-mechanical properties of paper.
Keywords: Celulosic, xylan, glycan, hexenuronic acids.

INTRODUCTION

The growth of the pulp and paper production makes necessary to obtain high quality of raw materials and strict control of its production chain. Therefore, several tests are applied to evaluate the chemical properties of wood.

Associated with xylan, uronic acids are present mostly in the form of acid 4-O-metilglicuronic (MaGlcA`s). The structure of the uronic acid is converted into acid by hexenuronic via β-elimination during the pulping process. The latter does not react in an alkaline medium, which adversely affects the performance of pre-O2 (Dahlman et al., 1996), yet protect against xylan depolymerization reactions of terminal (JIANG et al., 2000).

Main component of the plant cell wall, the cellulose appears mostly in the form of fibers, being a polysaccharide composed of monomeric units of D-glucose linked by type (1-4) (Sjostrom 1993) and shared with amorphous aprts and carbons 2, 4, 6 and crystalline 1,3,5 carbons in its structure. The structure of cellulose molecules form microfibrils aggregate regions where organized (crystalline) regions change with disorganized areas (amorphous). Microfibrils joined to form fibrils and they provide tensile strength and solubility of cellulose to most solvents.
The polyoses (hemicellulose) are low molecular weight polysaccharides associated with cellulose in plant tissues and consisting of pentoses, hexoses, uronic acids and deoxy-hexoses (Fengel and Wegner, 1989).

Several tests are applied to evaluate the chemical properties of wood and the objective was to investigate how the chemical characteristics of pulp influence the physico-mechanical and optical properties of paper.

Experimental

The bleached pulp samples were obtained from the Laboratory of Pulp and Paper of the Federal University of Viçosa (UFV) in Viçosa, Minas Gerais State, Brazil. The carbohydrate composition of the bleached pulps was carried out by HPLC according to procedure adapted from Tappi T 249 cm-85. Acid content was determined by hexenuronic (Vuorinen 1996). The experimental analysis of the paper were performed according to standardized procedures and methodologies with the technical requirements of "Technical Association of Pulp and Paper Industry - TAPPI (1992) (Table 1).

The F test was used to determine significant correlations.

Table 1. Physical-mechanical tests made with cellulosic pulp of eucalyptus

Tests	Norm
Training of laboratory sheets	T 205 sp-95
Weight of paper	T 220 sp-96
Physical testing of paper	T 220 sp-96
Resistance to bursting	T 403 om-97
Thickness of sheets of paper	T 411 om-97
Tear resistance (Elmendorf)	T 414 om-98
Tensile	T 494 om-96
Resistance to air flow	T 536 om-96

Results and Discussion

The chemical analysis of wood showed values from 83.2 to 85.2% for the content of glycans, 13.6 to 14.1% for xylans and 2.9 to 11.2% and mmol/kg for Hexas (Table 2).

Table 2. Polysaccharides characterization and levels of hexenuronic acids (HexA's) of bleaching pulp by the sequence of DualDEopDP expressed in percentage of dry weight of the pulp

Samples	Glycan	Xilanas	Mannans, galactans, arabinans,raminanas	HexAs, mmol/kg
1M	83,3	14,1	n.d.*	9,0
2M	84,2	13,7	n.d.	9,3
3M	84,1	13,8	n.d.	11,2
4M	84,7	13,9	n.d.	5,6
5M	85,1	13,8	n.d.	10,6
6M	84,5	14,0	n.d.	10,1
7M	83,9	14,1	n.d.	3,3
8M	84,0	14,0	n.d.	5,1
9M	84,5	13,9	n.d.	7,9
10M	83,9	14,1	n.d.	8,2
11M	85,2	13,6	n.d.	2,9

*non detectable

The physico-mechanical and optical tests showed results from 16.54 to 24.28 Nm/g for the tensile; 1.02 and 5.33 mN.m ^{2}/g for the tear; 0.40 and 0.77 s/100cm^3 for the resistance to air flow and 78.85 and 82.18% for the opacity (Table 3).

Table 3. Characterization of optical and physical-mechanical properties of the paper

Samples	Tensile index (N.m/g)	Tear index (mN.m²/g)	Opacity (%)	Resistance to airflow (s/100cm³)
1M	20,46	4,06	79,78	0,73
2M	17,98	2,48	80,04	0,59
3M	22,9	2,67	78,85	0,77
4M	17,29	1,02	81,39	0,53
5M	24,28	2,2	81,65	0,67
6M	17,45	3,73	79,65	0,43
7M	19,29	3,71	81,39	0,55
8M	19,58	5,33	81,17	0,58
9M	19,49	4,47	81,09	0,52
10M	16,54	4,08	80,23	0,4
11M	20,81	3,79	82,18	0,63

Carbohydrates content ranged from 83.3 to 85.2%. The test of correlation between the content of glycans and the main physical-mechanical and optical tests showed r= 0.2534 and r^2= 0.06622 for the tensile index; r= -0.3950 and r^2= 0.1560 for rip; r= -0.078 and r^2 = 0.0061 for resistance to air flow and r= 0.5870 and r^2= 0.3445 for opacity (Figure 1).

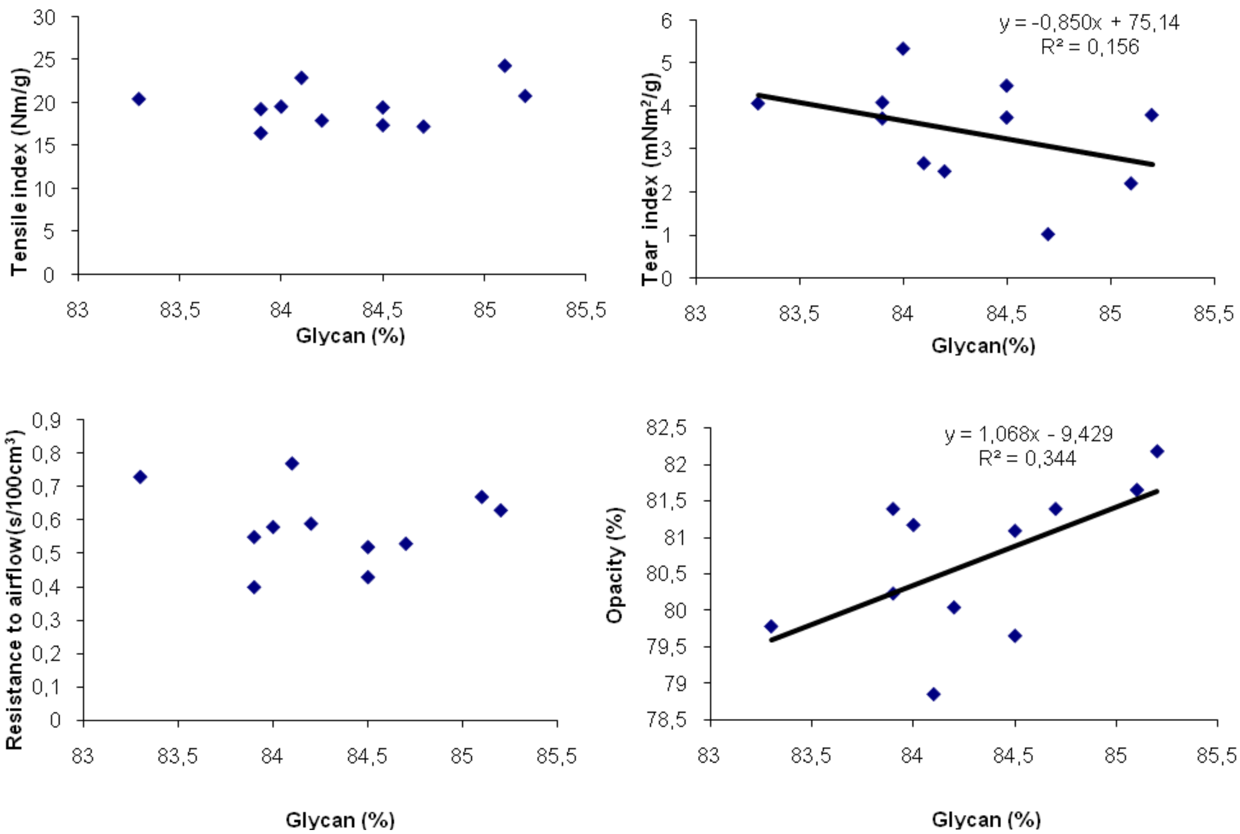

Figure 1. Correlation between the percentage of glycans and the main physical and mechanical properties of paper.

The xylan content ranged from 13.6 to 14.1. The test correlation showed a r= -0.3411 and r^2= 0.1163 for the tensile index; r= 0.3307 and r^2= 0.1163 for the index of tear; r= 0.5587 and r^2= 0, 3121 for the resistance to air flow and r=0.4504 and r^2= 0.2029 for opacity (Figure 2).

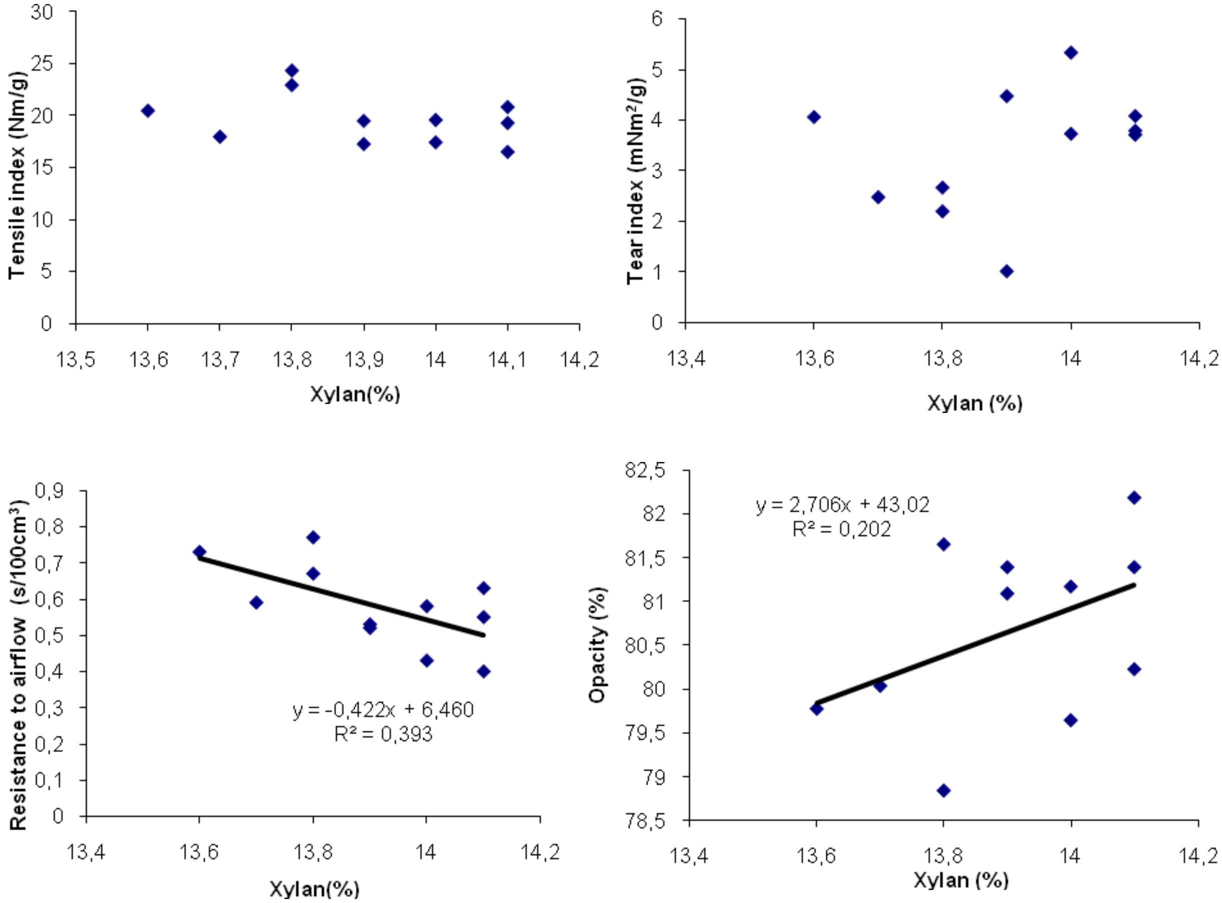

Figure 2. Correlation between the percentage of xylan and the main physical and mechanical properties of paper.

The hexenuronic varied from 2.9 to 11.2%. The correlation showed r= -0.2517 and r^2= 0.0634 for the tensile index; r= -0.2433 and r^2 = 0.0592 for the tear; r= 0.2028 and r^2= 0.0411 for resistance to air flow and r= -0.7245 and r^2 = 0.5250 for the opacity (Figure 3).

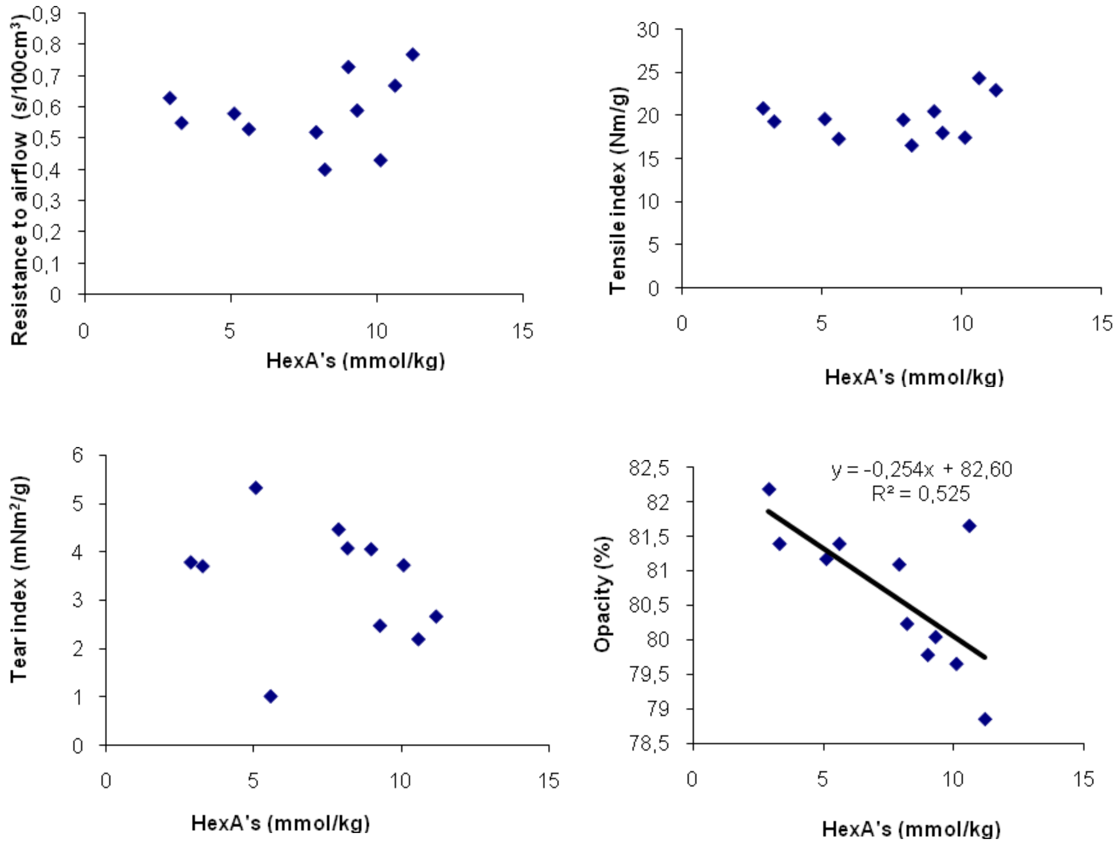

Figure 3. Correlation between hexenuronic acids (HexA's) and the main physical and mechanical properties of paper.

The tensile strength is related to the durability and utility of the paper for packaging and other uses subject to direct tensile strength. In the case of printing papers, the tensile strength indicates the likelihood of rupture when subjected to tension during the printing process. This property depends on the degree of bonding, generally showing higher levels in pulps with more fiber per gram. This shows that this characteristic provides a greater number of contacts, which increases those of connections. The index showed variation traction from 16.54 to 24.28 Nm/g for the pulp, lower than the variation of 22.4 to 39.8 for MOKFIENSKI et al., (2008).

The tear index values ranged between 1.02 and 5.33 mN.m²/g. Tear index is the work required to tear the paper at some distance after the tear has been initiated with a knife adapted to a machine.

The opacity was correlated positively with the content of glucans and xylans and negatively with that of HexA. Samples 4M, 5M and 6M had higher levels of glycans; the 1M, 6M, 7M, 8M and 10M higher content of xylans and the 4M, 7M, 8M and 9M lower content of HexA. Other factors may influence the opacity, since higher density wood have higher opacity when refined than those of low density. Opacity is the property related to the amount of light transmitted through the paper. The values for the pulps ranged from 78.85 to 82.18%, similar to 73.5 to 81.7 for those of eucalyptus (MOKFIENSKI et al., 2008)

The resistance to air flow ranged from 0.40 to 0.77 s/100cm2 for pulp, lower than the 0.2 to 4.2 for pulp bleaching sequence OD-(PO)-D (MOKFIENSKI et al. 2008), suggesting that resistance to airflow is higher in sequence as DualDEopDP han with the OD-(PO)-D.

Conclusions

No correlation was significant with the F test, which indicated that the chemical characteristics of the pulp do not influence the optical and physical-mechanical properties of the paper.

References

DAHLMAN, O.; MORCK, R.; LARSSON, P.T. Effects of TCF-bleaching on hemicelluloses. In: INTERNATIONAL PULP BLEACHING CONFERENCE, 1996, Washington. Proceedings. Washington: Tappi, 1996. p. 371-376.

FENGEL, D.; WEGENER, G. **Wood, chemistry, ultraestructure, reactions**. New York: Waster & Grugter, 1984, 613p.

JIANG, Z.; VAN LIEROP, B.V.; BERRY, R. Hexenuronic acid groups in pulping and bleaching chemistry. **Tappi Journal**, Atlanta, v.83, n.1, p.167-175, 2000.

MOKFIENSKI, A; COLODETTE, J.L.; GOMIDE , J.L.; CARVALHO, A.M.L. A importância relativa da densidade de madeira e do teor de carboidratos no rendimento de polpa e na qualidade do produto. **Ciência Florestal**, Santa Maria, v.18,n.3, p 407-419, jul-set, 2008.

SJÖSTRÖM, E. Wood chemistry: fundamentals and applications. New York, Academic Press, Inc., 2ª ed., 1993. 293p.

VOURINEN, T.; BUCHER, J.; TELEMAN, A.; TENKANEN, M.; FAGERSTROM, P. Selective hydrolysis of hexenuronic acid and its application in ECF and TCF bleaching kraft pulps. In: INTERNATIONAL PULP BLEACHING CONFERENCE, 1996, Washington. **Proceedings**…, Washington: Tappi, 1996. p. 43-51.

TAPPI - TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY-TAPPI. Tappi test methods*:* 1992-1993. Atlanta, 1992.

Acknowledgements

Financial support provided by the Minas Gerais State Research Foundation is greatly appreciated