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Morphological and structural modifications introduced by xylanase-assisted bleaching on eucalypt pulp fibres

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INTRODUCTION

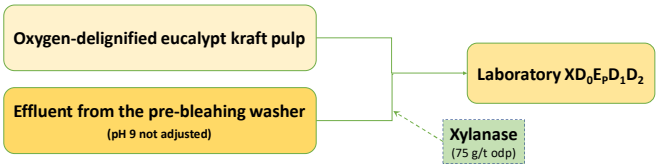
- The commercial application of xylanase-assisted bleaching has been shown to allow substantial savings of chlorine-based chemicals, and to decrease the amount of organochlorinated compounds (AOX) released to the process effluents.
- A laboratory pre-bleaching xylanase treatment (X) was applied on oxygen-delignified eucalypt kraft pulp, which was then subjected to an ECF bleaching sequence ($OXD_0E_PD_1D_2$ sequence).
- The aim was to confirm the efficacy of the optimised X treatment, and to assess its effect on fiber morphology and structure, as well as on bleached pulp quality.

OBJECTIVES

- To apply X-stage in industrial conditions (pulp and carryover)
- To achieve savings of chemical bleaching agents, thus decreasing environmental impacts;
- To evaluate morphological and structural changes in fibers;
- To maintain, or improve, bleached pulp quality.

METHODS

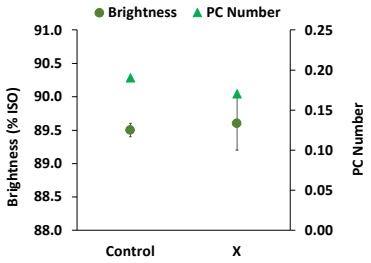
- Oxygen-delignified eucalypt kraft pulp (KN 10.3) was used as collected at a portuguese pulp mill.
- The xylanase pre-bleaching treatment was performed at 70 ºC and pH 9, using a commercial endo-xylanase product (Xylio Pre, Novozymes). Treatment duration was 30 min. Consistency adjustment (to 10 %) before the X stage was performed using the industrial effluent from the pre-bleaching washer.



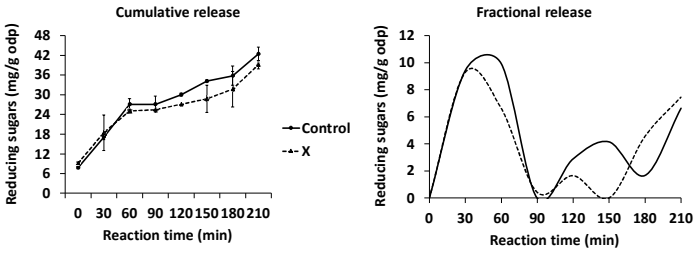
- ECF chemical bleaching consisted of a $D_0E_PD_1D_2$ sequence (D – chlorine dioxide, ClO_2; E_P – alkaline extraction with sodium hydroxide, NaOH, with addition of hydrogen peroxide, H_2O_2). Mill conditions were employed.
- When the X stage was employed, **20 % ClO_2 savings and 10 % NaOH savings** were applied during D_0 and E_P, respectively, comparing to the control sequence (without enzyme treatment).
- The enzymatic peeling technique consisted in treating X-treated and control pulps with a different endo-xylanase, under optimal enzymatic hydrolysis conditions.

RESULTS

Decreasing ClO_2 and NaOH doses following the X pre-treatment did not impair the brightness of bleached pulp. The X stage improved brightness stability.



The X stage reduced the amount of xylan in the fibres, and depolymerised the remaining xylan, leading to its redistribution inside the cell wall.



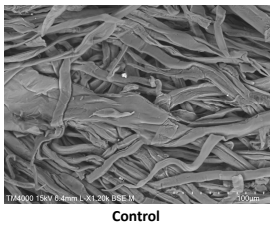
The X stage did not cause any significant effect on fibre morphology.

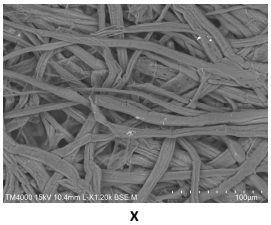
	Length (mm)	Width (µm)	Shape (%)	Coarseness (µg/m)	Fines content (%)
Control	0.763 ± 0.002	18.4 ± 0.0	89.4 ± 0.0	60.6 ± 1.1	23.3 ± 0.4
X	0.761 ± 0.002	18.3 ± 0.0	89.4 ± 0.0	63.9 ± 1.1	23.8 ± 0.7

Enzymatic pre-bleaching slightly reduced drainability and bulk of refined bleached pulp, and slightly increased tensile index. No significant impairments were identified concerning any of the papermaking properties analysed.

	Control	X
Drainability (ºSR)	26	25
Bulk (cm^3/g)	1.37	1.34
Burst index ($kPa.m^2/g$)	5.20	5.15
Tensile index (kN.m/kg)	72.0	73.0
Tear index ($mN.m^2/g$)	8.89	9.91
Internal bond strength (J/m^2)	394	405
Light scattering coefficient (m^2/kg)	28.2	28.0
Opacity (%)	70.2 ± 0.3	69.8 ± 0.2
Klemm capillary rise (mm)	4.5 ± 0.4	4.3 ± 0.2
Gurley air resistance (s/100mL)	9.2 ± 1.2	9.6 ± 1.0
Bendtsen roughness (mL/min)	91 ± 8	91 ± 6
Water retention value (%)	117 ± 5	124 ± 5

A slight fibrillation in xylanase-treated fibres is observable in the form of some external peeling.


Control


X

DISCUSSION

- The pre-bleaching treatment of oxygen-delignified eucalypt kraft pulp using a commercial endo-xylanase increased the efficiency of ECF bleaching.
- Xylanase action did not significantly affect fibre morphology, although some external fibrillation seems to have occurred.
- The xylanase treatment caused xylan removal, degradation and relocation within the cell walls of the fibres.
- Xylan removal and degradation may have contributed to slightly decrease pulp drainability.
- The external fibrillation caused by enzyme action may explain the slight tear index increase.

CONCLUSION

This work confirmed the effectiveness of the xylanase-assisted bleaching technology in reducing the amount of chemical bleaching agents, and in obtaining a high-quality paper-grade pulp product, even using industrial pulp (O-pulp, carryover, pH 9). Simultaneously, this study provided fundamental knowledge about the direct effects of this technology on fibers, which aids in explaining some of the observed features of the final product.

Acknowledgements

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More information in : Matos, J.M.S., Evtuguin, D.V., Sousa, A.P.M., Carvalho, M.G.V.S. (2023) Effect of Xylanase-Assisted Treatment of Oxygen-Delignified Eucalypt Kraft Pulp on ECF Bleaching. *Forests*, 14, 396. https://doi.org/10.3390/f14020396