Effect of ultrasound and cellulase application on physical and mechanical properties of handsheets

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Abstract

Modifications of eucalyptus fiber structure in the chemical industry to produce derivatives are widely known, however, with specific purpose of manufacturing high-value paper have been little explored. Therefore, in this paper the main objective is to modify the bleached eucalyptus Kraft pulp by ultrasonic and cellulose treatment in order to obtain improvements on physical and mechanical properties of handsheets. It could be observed that both ultrasonic and cellulase provided improvements in tensile index, specific elastic modulus and tensile energy absorption and a decrease of tear index on the mechanical properties of handsheets. In opacity the action of ultrasound and cellulase did not influence.

Keywords: ultrasonic; cellulase; physical properties; mechanical properties

Introduction

The modification of eucalyptus bleached fiber is a very attractive alternative when improvements are required in properties of the paper produced. To manufacture paper is to create superficies. Different surface treatments are used in the process, aiming improvements in its properties [1]. The action of cellulases on the fiber components can result in improved inter-fiber bonding and decreased fiber-water interactions [2]. It has been reported that the fiber treatment with cellulase modifies the interfacial properties of fibers, increasing the affinity for water, which in turn promotes changes in the technical properties of the pulp and paper, such as pulp drainability and paper strength [3-5].

The ultrasonic is defined with a sound of frequency beyond response of human hearing, this is, higher than 16kHz (1600 cycles per second) [6]. This may produce morphological changes in the fiber which can contribute for a best conformability, flexibility and consolidation of the fibers during paper formation [7]. The effects of ultrasonic on the enzymes aren´t very known and contradictory results are observed when they are treated at high intensities. Only some enzymes are inactivated by application of ultrasound systems at high intensities, since the sonification don't denature all proteins, unlike of heat denaturation, which could explain the contradictions with respect to deactivation of the enzymes by sonification [8]. The low intensities of ultrasonics in some cases may increase the activity of free enzymes [9].

Therefore, the fiber treatment by ultrasound and cellulase has considerable influence in the paper production process and can improve the performance of fiber-fiber and fiber-water interactions. It also contributes to the consolidation of product properties. So, this work aims to modify the physical-chemistry, structural and surface nature of eucalyptus bleached fiber for the production of paper by ultrasound and cellulase treatments.

Experimental

The equipment model used to generate ultrasonic waves in this work was the VIRSONIC 475 with a frequency of 20 kHz using the maximum power of the equipment (190 W). The applied dosage of cellulase was 0.10 Kg/ton. Two treatments were performed: (I) treatment of eucalyptus kraft pulp by ultrasound and subsequent cellulase treatment; (II) treatment of eucalyptus kraft pulp by cellulase only. For all the treatments it was used pulp with consistency of 3% and pH range of 7 to 7.5. After the treatments, the cellulose pulps were refined in PFI mill laboratory. For the realization of physico-mechanical and optical tests it was formed laboratory sheets, which are stored in an environment with relative humidity of 50 ± 2% and 23 ± 1 ºC temperature. All procedures and tests were realized according to TAPPI procedures [10]. The treatments were compared statistically.

The adjusted equations were compared by F test, using the models identity test and adopting a significance level of up to 5% probability according to the methodology presented by Regazzi [11] for linear

models. The equations were compared in order to check equality between them. If so, the equations were reduced to a single equation. If it had confirmed a significant difference between the equations, it was not tested which differed. The tested hypotheses were: H0: all equations are equal and they may be represented by a common reduced equation, and H1: the equations are different statistically and they can't be reduced to a common equation

Results and Discussion

The nomenclatures of the samples (REF, UCE and CE) are equivalent to the following treatments:

REF: initial pulp, in other words, without ultrasonic treatment and enzyme treatment;
UCE: pulp relating to treatment (I);
CE: pulp relating to treatment (II).

Refining PFI

The choice of the number of revolutions is indicated by the degree of drainability of an aqueous suspension of fibers [12]. The equipment used in the Pulp and Paper Laboratory for measuring the degree of drainability is the Schopper-Riegler. This expresses the degree of refining as Schopper-Riegler degree (°SR).

Four points of refining were made . In order to obtain a curve to analyze how the properties of paper formed "react" to refining,trying to achieve a value close to 50 °SR. The maximum degree Schopper used was 60 °SR. These values are used because many companies that produce paper derived from bleached Kraft pulp employ them. During the refining it is also obtained the energy needed to refine the pulp. In a company the consumption is very important, because it is directly tied to production costs. To study the effect of enzyme treatment and ultrassonification on the consumption energy a graphic was done which relates this with the degree Schopper-Riegler (Fig 1).

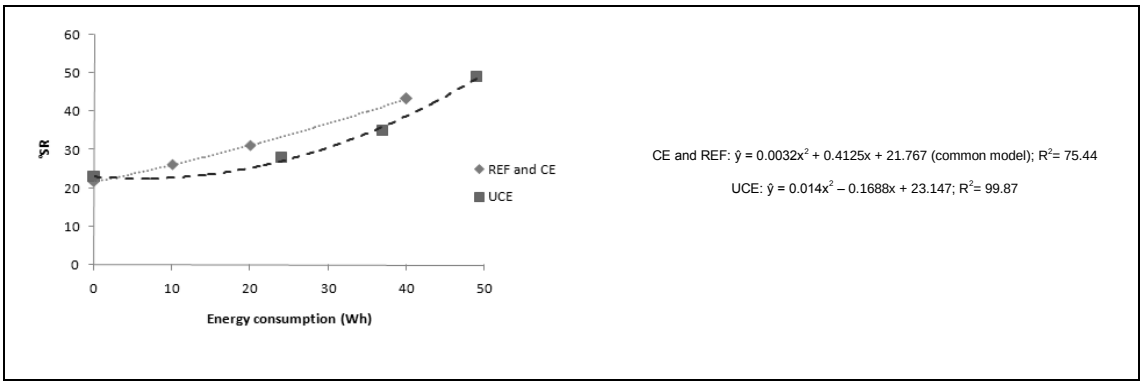

Figure 1: Schopper-Riegler degree versus Energy Consumption.

Based on the F test, the hypothesis of equality between equations relating at REF and CE in function of energy consumption was accepted ($P < 0.05$), and these can be represented by the common model estimated represented in Figure 1. Therefore REF and CE are statistically equal, thus cellulase only did not provide any effect on energy consumption of pulp.

The effects observed of ultrasonic treatment in the fibers are removing of the S1 layer, displacement of the S2 layer, swelling of the S2 layer and subsequent fibrillation of S2 layer [7]. This causes the celluloses to become more exposed which facilitates their removal. Because the cellulase promotes the break of cellulose chain reduces the number of possible hydrogen bonds between cellulose chains and water. This causes swelling of the fibers to become disadvantaged, which provides a more difficult refining; therefore higher energy consumption. Without the accessibility to the fibers produced by ultrasound, the cellulase being a macromolecule couldn't act to the point of breaking the chain of cellulose to increase energy consumption. Therefore, the energy consumption of treatment only with cellulase is the same to the initial pulp.

Physical and Mechanical Properties

Tensile Index

The tensile strength is related to the durability and utility of the paper, for example, packaging papers are subject to direct tension forces. This is favored by intensity of interfibrillar links occurred during the formation of the paper, the external fibrillation and the collapse of the fibers [12].

For the F test, the hypothesis of equality between equations relating at CE and UCE in function of energy consumption was accepted (P <0.05), and these can be represented by the common model estimated, represented in the Figure 2. Therefore UCE and CE are statistically equal, thus the ultrasound did not increased the accessibility of fiber for the cellulase to the point of to improving action for to raise the tensile index in relation to treatment with only enzyme (CE). Due to cellulase break the chains of cellulose, the fibers become more fragile. Thus, the collapse of fibers during the stages of drainage, pressing and drying the paper formation, is more likely, which will result in better interlacement between the fibers, providing a higher resistance.

During, the tensile tests force-deformation relations are produced and through these relations the properties of specific elastic modulus (MOE) and tensile energy absorption (TEA) will be derived. In this study, it was observed that the joint of enzymatic and ultrasonic treatments resulted in additional properties MOE and TEA in relation to initial pulp, it was found an increase 11.2% and 48.7% for MOE and TEA, respectively. MOE is an important property because they represent the capacity of the material to absorb force without, however, suffer substantial deformation. Already, the TEA represents the durability of paper when subjected to repetitive use, under conditions of tensile or impact.

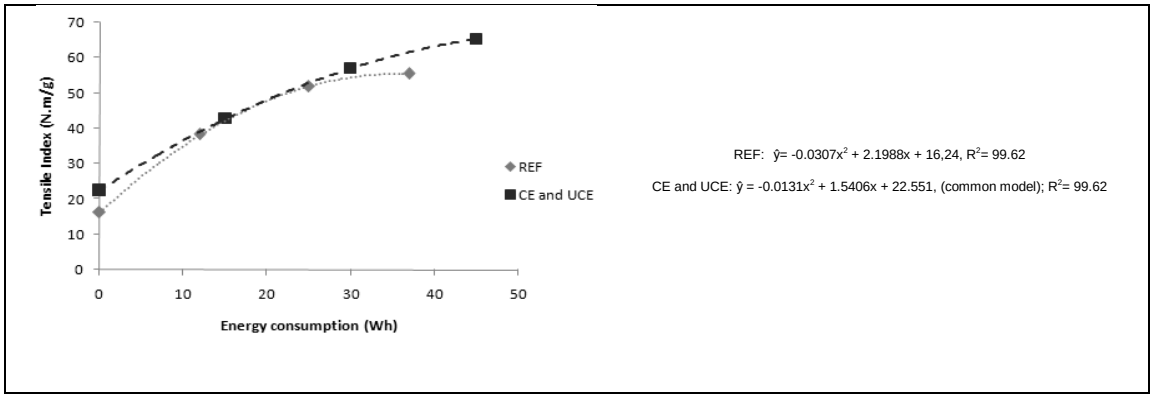

Figure 2: Tensile Index versus Energy Consumption.

Tear Index

The tear resistance measures the work required to tear the paper. The length of the fiber and the link between them are factors that may affect the resistance for the tearing [12].

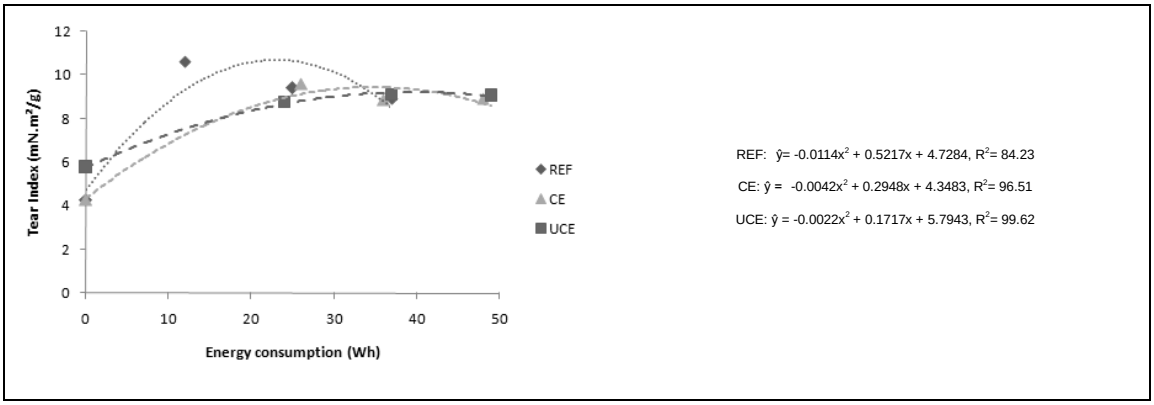

Figure 3: Tear Index versus Energy Consumption.

Based on the F test, the hypothesis of equality of the three equations for the consumption of energy was rejected and it may be conclude that there is significant difference (P <0.05) between the three equations and the common equation cannot be used for the three equations.

Because, the cellulase removes the most superficial layer of the fibers, it provides a weakening of

these same, consequently a reduction in tear index, as seen in Figure 3. This effect is observed only at lower levels of the refining, because when it is intensifies it the effect of fibrillation is increased and interfiber links exceed the effect of reduced intrinsic fibrillar resistance. The isolated effect of the ultrasound observed in the pulp UCE (0 Wh) suggests that the ultrasonification does not cause weakening of the fibers but promotes an increase in interfibrillar links.

Optical Property

Opacity

Opacity is an optical property that is related to the amount of light transmitted through the paper [12], therefore, with phenomena of refraction, dispersion and absorption. Thus, the greater the amount of void spaces, the greater the amount of surface refraction, dispersion and absorption, and the lower the amount of light transmitted to the opposite side of the paper and the greater the opacity of the paper. It was observed by the study of statistics of CE, UCE and REF treatments that these are equal. Therefore, these may be written with a common equation, as represented in Figure 4. So, neither ultrasound nor cellulase influence the opacity of the paper.

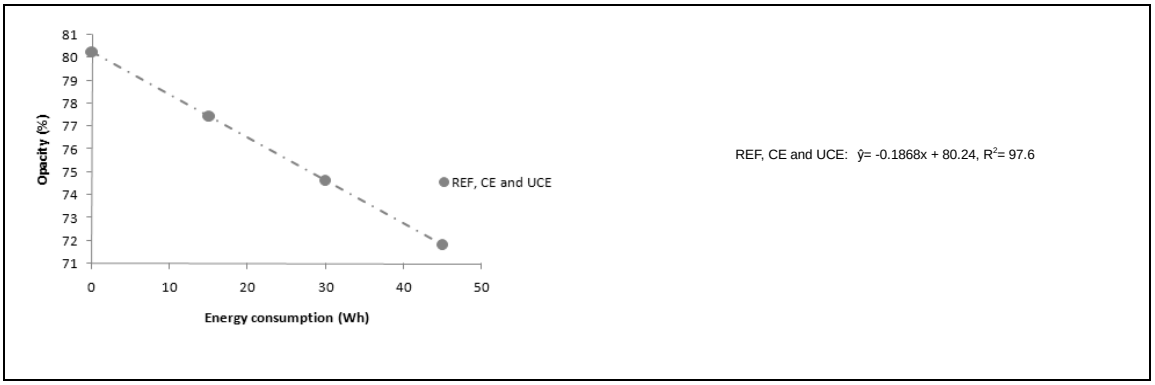

Figure 4: Opacity versus Energy Consumption.

Conclusions

This paper aimed to enhance the physical and mechanical properties of handsheets through ultrasound and cellulase treatments. It was observed that both ultrasonic and cellulase provided improvements in tensile index, specific elastic modulus and tensile energy absorption and a decrease of tear index on the mechanical properties of handsheets. In opacity the action of ultrasound and cellulase did not influence.

The idea of applying the ultrasound before cellulase was so that the ultrasound could facilitate the enzyme action by fibrillation, but in this study this can not be affirmed.

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