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Comparative characterization of eucalyptus fibers and softwood fibers for tissue papers applications

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ABSTRACT

Significative growth and demanding for premium tissue products, in which softness and absorbency are key consumer requests, pointed out the need for the establishment of relations between fiber properties and tissue paper properties. For this purpose, an experimental plan was designed using a representative group of pulp fibers, six hardwood, and six softwood, for the production and characterization of low basis weight paper structures (20 g/m^2). The pulp fibers morphology and chemical content were evaluated, and hardwoods showed lower fiber length (0.70–0.84 vs 1.57–1.96 mm), coarseness (6.71–9.56 vs 16.77–19.66 mg/100 m) and higher pentosan content (6.3–21.1 vs 7.6–10.3%). Even though the paper structures were produced with the same basis weight, they presented a broad range for bulk (3.46–8.04 cm^3/g), tensile index (2.00–11.45 N.m/g), softness (65.7–86.9) and absorption capacity (8.08–9.48 g/g). The results indicated that softness was directly influenced by structural properties, increasing with bulk, while tensile strength correlated inversely. Therefore, the correlations obtained were used to identify the most suitable pulp fibers properties for each type of tissue paper.

1. Introduction

Today's cellulose industry offers a growing range of pulps produced by different delignification processes. Each pulp has unique characteristics, depending on the fiber's wood original properties and fiber modifications that are introduced by the pulping and bleaching processes. A combination of lignin removal, oxidation, and extraction unit operations will originate different pulps [1]. The correlations between key pulp fibers properties and end-use specifications constitute a novelty, that will be applied to select the most suitable pulps to obtain premium quality tissue papers. Tissue products are produced predominantly with hardwoods eucalyptus fibers [2] with a percentage of softwoods to confer strength and runnability in the paper machine process [3]. Depending on the type of tissue paper, there will be a specific formulation with specific percentages of hardwood and softwood. Higher percentages of hardwood fibers will improve softness and the addition of softwoods will increase wet and dry strength, lowering softness [4]. The main goal of the present study is to analyze and compare different pulp properties, relating them with tissue paper performance. For this purpose, hardwoods and softwoods pulps were characterized in terms of morphological and chemical properties. The pulps drainability and water retention value were also evaluated. Tissue isotropic 20 g/m^2 handsheets were produced and their structural, mechanical, absorption and softness properties were measured.

2. Experimental

Six eucalyptus kraft pulps (hardwoods named from H_A to H_F) and six softwood kraft pulps (S_A to S_F) with different bleaching sequences (Table S1 in supplementary data) were selected for being representative market pulps. The morphological properties of pulp fibers were evaluated in MorFi® (TECHPAP, Grenoble, France) equipment, in triplicate. The pulps were characterized through viscosity (SCAN-CM 15:88), pentosan content (TAPPI T 223 cm-10), and carboxyl group content (TAPPI T 237 om-97). The drainability of the pulps suspension (°SR) was determined by Schöpper-Riegler methodology according to ISO 5267/1. The water retention value (WRV) index of pulp fibers was determined

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according to the method described by Jayme [5], in triplicate. To evaluated tissue paper properties, handsheets were produced with a basis weight of 20 g/m2, according to an adaptation of ISO 5269-1, i.e. unpressed handsheets, to be representative of the low basis weight industrial tissue paper. The handsheets produced were characterized by measuring the thickness and bulk (ISO 12625-3), basis weight (ISO 12625-6), tensile index (ISO 12625-4), water absorption capacity (ISO 12625-8), capillary rise (ISO 8787) and softness using a TSA - Tissue Softness Analyzer (Emtec) equipment.

3. Results and discussion

Regarding the hardwood eucalyptus pulp fibers biometry, it showed a range in length (0.70–0.84 mm) and in width (18.0–19.1 μm) lower than softwoods. These properties may be related to each other by the felting power, since is expected that the papers produced from these fibers will have relatively good mechanical properties. For instance, H_F and S_F pulps had the lowest slenderness ratio values (fiber length/fiber width), namely 38.0 and 52.7. Eucalyptus fibers coarseness presents the highest percentage of variation (6.71–9.56 mg/100 m), where H_D pulp had the highest coarseness and S_D pulp registered the lower coarseness. This parameter is related to the fiber wall thickness and influences the fiber collapse degree and development of bulk [6]. A more open fibrous network structure, with lesser interfiber bonds, will influence positively the softness and negatively the tensile strength [2]. Generally, eucalyptus pulps showed a low coarseness, but a high number of fibers per gram and may point to a larger bonded area. H_F pulp had the highest values of curl and kinks. Curl and kinks are fiber deformations that contribute to a more developed network, generating less inter-fiber bonds and leading to a potential develop bulk, porosity, and smoothness in the final product. The high fines content may correspond to the fibers that are more flexible (H_A and S_A pulps).

Viscosity is related to the cellulose polymerization degree. H_E pulp presented the lower viscosity value (453 mL/g), possibly related with the use of oxygen and ozone in the bleaching stage. This bleaching process is not selective because the high oxidation potential of these reagents induces the depolymerization and pulp polysaccharides degradation [6]. Pentosans are hydrophilic and contribute positively to fiber water absorption capacity. H_E pulp presented the higher pentosan content (21.1%), while H_F pulp presented the lower pentosan content (6.3%). The value for the H_F pulp is justified since it is a pulp from an acid sulfite cooking process.

The hardwood pulps presented a drainability resistance (°SR) higher than softwoods, which could be related to the fines content. Regarding WRV, the H_B and S_A pulps presented higher values for this property (76.9 and 75.0%) and higher carboxyl groups content values (9.61 and 10.60 mmol/g). The pulps chemical composition is one of the factors that influence WRV since it influences the fibers binding to water [6]. This ratio was also observable, for example, for H_F pulp because it had low carboxyl groups content (4.36 mmol/g) and, in addition, little presence of pentosans, and consequently a low WRV value (63.1%). It was possible to verify that the main parameter responsible for the differences in °SR may be the fibers length, while in WRV, higher fibers coarseness may explain the results obtained for the H_B, H_D and S_A pulps.

Hardwood and softwood fibers showed different bulk values (3.55–5.83 vs 3.46–8.04 cm^3/g). H_D and H_F pulps presented the same bulk values, but high differences in tensile index properties (Fig. 1). This may be because of differences in flexibility and morphological properties. While H_D pulp had the highest coarseness, H_F pulp showed low coarseness. H_D and S_D pulps had higher values of the tensile index (9.96 and 11.45 N.m/g). H_F pulp

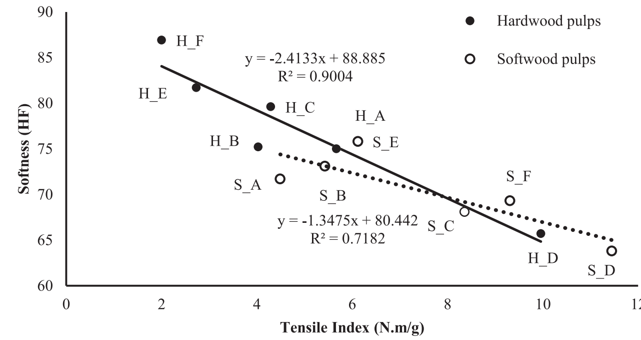

Fig. 1. Correlation of tensile index and softness for hardwood and softwood pulps.

presented the lowest value for the tensile index (2.00 N.m/g). This result may be related to the low pentosan content and, consequently, to a lower establishment of interfiber bonds. Deformations (curl and kinks) contribute to the reduction of fiber strength. The pulps with the high tensile index also showed the lowest values of curls and kinks and vice versa. According to the estimated values for softness (handfeel-HF) (Fig. 1), H_E, H_F, and S_E pulps presented high values for this property (81.7, 86.9 and 75.8). The low hemicelluloses content in H_F pulp may have contributed significantly to the production of a structure with fibers less linked to each other and more open structure [6]. In addition, this pulp also showed the highest deformation values, which also contributed to the softness potential [6]. The tensile index and handfeel property are inversely proportional, and the factors that contribute to the increase of the resistance are the same that contribute negatively to the softness potential. Therefore, from result analysis for both properties, this relationship was easily verified (Fig. 1). H_D and S_D pulps had the highest values of tensile strength and the lowest softness values. For the hardwood and softwood pulps the relations were Tensile = −2.4133 Handfeel + 88.885 (R^2 = 0.9004) and Tensile = −1.3475 Handfeel + 80.442 (R^2 = 0.7182).

Water absorption is a key property of tissue products [7]. This property was analyzed by the total water absorption capacity and the capillary rise (Fig. 2). H_A and S_A pulps presented higher values for the total water absorption capacity (8.83 and 9.48 g/g). The high pentosans content and the high carboxyl groups content in these pulps, respectively, will promote more interaction points. H_D pulp showed the lowest values for this property (8.08 g/g) which may be related to a more closed fibrous network, having less space available to retain water. H_A and S_D pulps revealed better performance in the capillary rise. It is also important to note that the H_F pulp had an intermediate absorption capacity value (8.45 g/g). This pulp had a low pentosan content, which explains the capillary rise value. In contrast, H_F pulp had also a high bulk and an increase in pore volume. This means that there will be more space for water retention, hence increasing water absorption capacity.

4. Conclusions

The morphological properties and chemical composition of different hardwood and softwood pulps showed a distinctive influence on tissue paper properties. The eucalyptus pulps more suitable for tissue paper should have high coarseness (H_A or H_D), deformations (H_F), low fines content (H_C or H_E) and low pentosan content (H_F). Each tissue paper type has different specificities and the management of furnish supply will be optimized according to the information obtained in this study. Eucalyptus pulps with higher water absorption capacity and

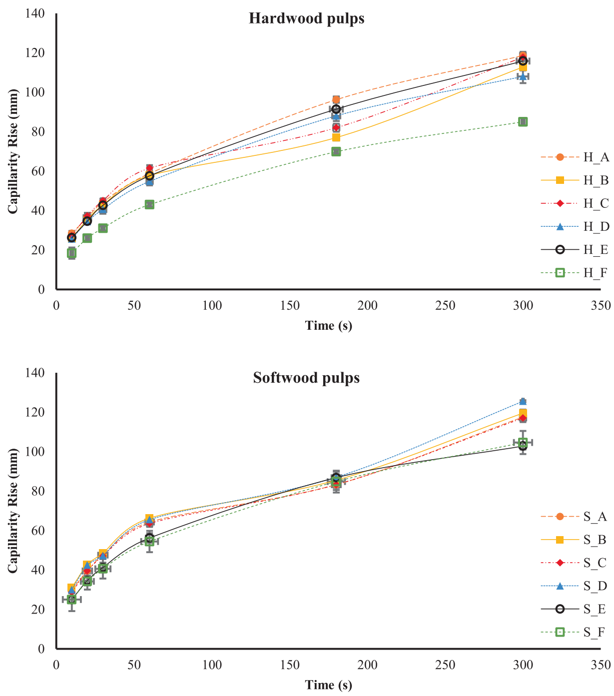

Fig. 2. Capillary rise as function of time for hardwood and softwood pulps.

softness (H_E and H_F) will be selected to be used in premium toilet and facial papers. Eucalyptus pulps with the highest tensile index (H_D) will be used in towel papers, where wet strength is essential. The addition of softwood S_D pulp proved to be the most suitable to promote paper machine runnability.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.mlblux.2019.100028.

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