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Influence of temperature, time, liquid/solid ratio and sulfuric acid concentration on the hydrolysis of palm empty fruit bunches

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HIGHLIGHTS

- Hydrolysis process of empty fruit bunches.
- Use of polynomial models to reproduce the experimental results.
- Optimization of hydrolysis operating conditions for EFB using polynomial models.
- Comparison of pulp properties of EFB and hydrolyzed EFB solid fraction.

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ABSTRACT

The influence of temperature (150–190 °C), time (0–20 min), liquid/solid ratio (6–8) and sulfuric acid concentration (0.1–0.5%), on the hydrolysis of palm empty fruit bunches (EFBs) was studied and the liquid and solid fractions were analyzed. Polynomial models were found to reproduce the experimental results with errors less than 15% in most of the cases (except for xylose concentration).

Operating conditions of 190 °C for 15 min at a liquid/solid ratio of 6 and a sulfuric acid concentration of 0.1% resulted in the production of 3.12, 4.0, 2.35 and 2.28 g/L of glucose, xylose, arabinose and acetic acid, respectively, starting with 1000 g of EFBs. The yield was 67.96%.

Soda-anthraquinone, ethanol and ethanolamine pulping of the solid fraction provided pulps with brightness values (63.24%, 28.78%, 48.76%), but with poor resistance properties (6.57–8.54 Nm/g for tensile index, 0.38–0.44 k N/g for burst index and 0.96–1.02 mN m^2/g for tear index). Therefore it is advisable to use the pulps for speciality papers or for bioethanol-production.

1. Introduction

Non-wood plants constitute an effective alternative to wood for production of cellulose derivatives (pulp for paper, dissolving pulp, sugars by hydrolysis, bioethanol by hydrolysis of cellulose and later fermentation) in countries with limited forest resources.

A promising non-wood raw material are empty fruit bunches (EFBs), a residue of the palm oil industry (Jiménez et al., 2009a,b; Rodríguez et al., 2008; Ferrer et al., 2011).

Conventional methods for producing cellulose also remove hemicelluloses and lignin. Such components can be recovered by using various procedures commonly associated with the concept of "bio-refinery" (Pan et al., 2005; Garrote et al., 2007a; Kadam et al., 2008; Requejo et al., 2012). The bio-refinery or fractionation of lignocellulosic materials as agri-food residues is especially interesting since it endows an added value and provides an environmental benefit (Sasaki et al., 2003; Sakaki et al., 2006; Garrote et al., 2007a; Kadam et al., 2008; Sánchez et al., 2011; Requejo et al., 2012).

One fractionation procedure involves the hydrolysis of lignocellulosic material and pulping of the resulting solid fraction. Hydrolysis with water at a high temperature produces an aqueous fraction essentially containing hemicellulosic sugars consisting of monosaccharides (xylose, glucose, arabinose) and xylo-oligosaccharides (Caparrós et al., 2007, 2008a,b; Alfaro et al., 2009; Yáñez et al., 2009), which can be further hydrolyzed and fermented to obtain various products (Boussarsar et al., 2009; Dogaris et al., 2009; Sakaki et al., 2006; Vázquez et al., 2007). The solid fraction composed largely of lignin and cellulose is potentially amenable to pulping for paper production (Caparrós et al., 2007, 2008a,b; Sánchez et al., 2011; Requejo et al., 2012), or for other uses such as the production of bioethanol by hydrolysis of the pulp and subsequent fermentation of glucose (Zhang and Lynd, 2010; Qing and Wyman, 2011; Requejo et al., 2011, 2012).

Hydrolysis can be conducted over wide ranges of operating conditions (Garrote et al., 2007b; Vegas et al., 2008; Sundqvist et al.,

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