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Hot water extraction and steam explosion as pretreatments for ethanol production from spruce bark

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HIGHLIGHTS

- ▶ Hot water extraction (80 °C) and steam explosion were studied as pretreatments.
- ▶ Steam explosion of spruce bark should be carried out without acid catalyst.
- ▶ Hot water extraction is a suitable pretreatment for spruce bark with right enzymes.
- ▶ Ethanol production from pretreated enzymatically hydrolysed barks was efficient.
- ▶ Spruce bark is a potential feedstock for the production of lignocellulosic ethanol.

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ABSTRACT

Spruce bark is a source of interesting polyphenolic compounds and also a potential but little studied feedstock for sugar route biorefinery processes. Enzymatic hydrolysis and fermentation of spruce bark sugars to ethanol were studied after three different pretreatments: steam explosion (SE), hot water extraction (HWE) at 80 °C, and sequential hot water extraction and steam explosion (HWE + SE), and the recovery of different components was determined during the pretreatments. The best steam explosion conditions were 5 min at 190 °C without acid catalyst based on the efficiency of enzymatic hydrolysis of the material. However, when pectinase was included in the enzyme mixture, the hydrolysis rate and yield of HWE bark was as good as that of SE and HWE + SE barks. Ethanol was produced efficiently with the yeast *Saccharomyces cerevisiae* from the pretreated and hydrolysed materials suggesting the suitability of spruce bark to various lignocellulosic ethanol process concepts.

1. Introduction

The utilization of biomass for the production of transport fuels, chemicals and materials is increasing because of fluctuating price and limited availability of oil, and the need to reduce greenhouse gas emissions. Upgrading of biomass to value-added products may also provide additional profits when compared to its combustion to heat and electricity.

Bark, which constitutes of ca. 12% of the total weight of a tree (Surminski, 2007), is an abundantly available biomass feedstock that is already efficiently collected at pulp, paper, and sawmill sites. With annual industrial wood consumption of 70 Mm^3 (ca. 35 Mt), approximately 3–5 Mt of industrial bark is produced per annum alone in Finland (Finnish Forest Industries Federation, 2011). Most of this bark is combusted for electricity and heat at mill site. In addition to debarking lines producing mixed bark varieties, also pure streams of e.g. spruce and birch bark are available.

Spruce bark and bark in general have been surprisingly little studied recently as a lignocellulosic feedstock for 2nd generation biorefinery processes. The composition of spruce bark is very complex and not well understood as it contains several compounds such as polyphenols and extractives which are not found in wood (Laks, 1991). Bark is not generally considered as a very good source of fermentable sugars because of the high amount of lignin and extractives in the material (Kim et al., 2005; Robinson et al., 2002; Torget et al., 1991; Vazquez et al., 1987). In fact, some non-lignin derived compounds condense and precipitate in sulphuric acid showing up as Klason lignin and making the analysis of true bark lignin difficult (Laks, 1991). Spruce bark contains ca. 19% cellulose and a varying amount of non-cellulosic sugars that are present as free sugars and bound in hemicellulose, pectin and glycosides (Laks, 1991). Most abundant non-cellulosic monosaccharides are glucose, arabinose, galacturonic acid, mannose, xylose and galactose (Le Normand et al., 2011). Additional challenges come from

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