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Enzymatic saccharification of sugar beet pulp for the production of galacturonic acid and arabinose; a study on the impact of the formation of recalcitrant oligosaccharides

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HIGHLIGHTS

- ▶ Production of monomeric galacturonic acid and arabinose from sugar beet pulp.
- ▶ Saccharification conditions are used that are feasible for industrial upscaling.
- ▶ Release of 79% galacturonic acid and 82% arabinose with 17% cellulose degradation.
- ▶ Recalcitrant oligosaccharides obtained after hydrolysis are characterized in detail.
- ▶ Lacking enzyme activities for further increase of yield are being discussed.

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ABSTRACT

Enzymatic saccharification of sugar beet pulp was optimized on kg-scale to release the maximum amounts of monomeric galacturonic acid and arabinose with limited concomitant degradation of cellulose, using conditions that are feasible for industrial upscaling. A selected mixture of pectinases released 79% of the galacturonic acid and 82% of the arabinose as monomers from sugar beet pulp while simultaneously degrading only 17% of the cellulose. The recalcitrant structures that were obtained after hydrolysis were characterized using mass spectrometry. The most abundant structures had an average degree of polymerization of 4–5. They were identified as partially acetylated rhamnogalacturonan-oligosaccharides, mostly containing a terminal galacturonosyl residue on both reducing and non-reducing end, partially methyl esterified/acetylated homogalacturonan-oligosaccharides, mostly containing methyl and acetyl esters at contiguous galacturonosyl residues and arabinan-oligosaccharides, hypothesized to be mainly branched. It could be concluded that especially rhamnogalacturonan-galacturonohydrolase, arabinofuranosidase and pectin acetylesterase are lacking for further degradation of recalcitrant oligosaccharides.

1. Introduction

The production of monosaccharides by hydrolysis of polymeric carbohydrates in sugar beet pulp is a promising step towards increasing the value of this by-product of the sugar industry. The main constituent monosaccharides in sugar beet pulp are glucose (from cellulose), galacturonic acid and arabinose (both present in pectin). They constitute 60–70% of the dry matter of sugar beet pulp (Oosterveld et al., 1996). A large number of earlier studies mainly focused on production of monosaccharides from sugar beet pulp for bioethanol or biogas production (e.g. Kühnel et al., 2011; Šantek et al., 2010; Zheng et al., 2012). However, instead of serving as carbon source for fermentation, galacturonic acid and arabinose are interesting molecules for further conversion into building blocks which can be subsequently transformed into high-value biobased chemicals or materials, like polyesters, polyamides or plasticizers (Werpy and Petersen, 2004). Moreover, the remaining cellulose after saccharification may be an interesting component for application as biobased fiber or nanocomposite material (Siró and Plackett, 2010). Therefore, it is desirable that cellulose degradation during hydrolysis is minimized, although some degradation will be beneficial to improve the physical accessibility of pectin to the enzymes (Panouillé et al., 2006). Optimal release of galacturonic acid and arabinose from sugar beet pulp, while leaving cellulose intact, is a promising biorefinery opportunity. However, not much effort has been directed towards this so far.

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