Bioresource Technology 130 (2013) 613–620

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Bio-conversion of apple pomace into ethanol and acetic acid: Enzymatic hydrolysis and fermentation

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HIGHLIGHTS

- Potential use of apple pomace to manufacture high value chemicals was explored.
- Enzymatic saccharification was optimized using cellulase, pectinase, β-glucosidase.
- Sugars were fermented into ethanol and acetic acid using yeast and bacteria.
- Enzymatic digestibility was enhanced by dilute acid and laccase pre-treatments.

ARTICLE INFO

Article history:
Received 1 November 2012
Received in revised form 10 December 2012
Accepted 11 December 2012
Available online 20 December 2012

Keywords:
Enzymatic saccharification
Cellulase
Pectinase
β-Glucosidase
Fermentation

ABSTRACT

Enzymatic hydrolysis of cellulose present in apple pomace was investigated using process variables such as enzyme activity of commercial cellulase, pectinase and β-glucosidase, temperature, pH, time, pre-treatments and end product separation. The interaction of enzyme activity, temperature, pH and time had a significant effect ($P < 0.05$) on release of glucose. Optimal conditions of enzymatic saccharification were: enzyme activity of cellulase, 43 units; pectinase, 183 units; β-glucosidase, 41 units/g dry matter (DM); temperature, 40 °C; pH 4.0 and time, 24 h. The sugars were fermented using *Saccharomyces cerevisae* yielding 19.0 g ethanol/100 g DM. Further bio-conversion using *Acetobacter aceti* resulted in the production of acetic acid at a concentration of 61.4 g/100 g DM. The present study demonstrates an improved process of enzymatic hydrolysis of apple pomace to yield sugars and concomitant bioconversion to produce ethanol and acetic acid.

1. Introduction

Valorization of waste coming out from food processing plants is becoming an important contributor to the food industry and bio-economy. Fruit processing industry generates large volumes of biological by-products that could be used for manufacture of value-added products. In lieu of this, several thousand tons of apple processing by-products generated by fresh-cut, juice, pie and sauce manufacturing plants seek attention due to reasons such as high disposal costs and associated environmental concerns. Nevertheless, these waste by-products, especially apple pomace, are rich in both soluble carbohydrates such as simple sugars (fructose, glucose, sucrose) and polysaccharides (cellulose, hemicellulose, pectin), representing a high potential for further bio-conversion purposes (Vendruscolo et al., 2008). In this context, bio-conversion of apple pomace into bio-ethanol and organic acids provides an excellent possibility to reduce the environmental challenge posed by its vicinity. Among polysaccharides in apple pomace, cellulose (23% DW) and pectin (10% DW) present a useful substrate for enzymatic hydrolysis to yield fermentable sugars (Parmar and Rupasinghe, 2012). Commercial cellulase, pectinase and β-glucosidase are generally used for hydrolysis of polysaccharides present in fruit by-products. Cellulose and pectin, when hydrolyzed into glucose and galacturonic acid, respectively, can be converted into bio-ethanol and/or organic acids through fermentation.

The polysaccharides present in apple are marked by interactions among themselves and other polymers, which pose limitations to access of hydrolyzing enzymes. High lignin to cellulose ratio (roughly 1:1) has been reported for apple pomace as a reason for its hampered bio-processing (Parmar and Rupasinghe, 2012). In addition, previous studies have shown that cell wall of apple contains a pectin matrix, which shields cellulose and hemicellulose, thereby decreasing its enzymatic digestibility (Oechslin et al., 2003). A study by Gullón et al. (2008) investigating the enzymatic digestibility of apple pomace used cellulase and cellobiase, for optimizing the hydrolysis conditions, following a factorial, incomplete, centered, second-order experimental design for kinetics of

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http://dx.doi.org/10.1016/j.biortech.2012.12.084