Effects of fermentation substrate conditions on corn–soy co-fermentation for fuel ethanol production

Linxing Yao, Show-Ling Lee, Tong Wang *, Juliana M.L.N. de Moura, Lawrence A. Johnson

Department of Food Science and Human Nutrition, Center for Crops Utilization Research, Iowa State University, Ames, IA 50011, United States

**Highlights**

- A successful integration of soy and corn biorefineries is shown.
- Soy skim from soybean aqueous extraction processing was shown to have rate promotion effect on corn-ethanol fermentation without affecting the ethanol yield.
- The soy skim provided all nutrients needed for the yeast.
- Such corn–soy co-fermentation benefits soybean aqueous extraction processing and ethanol fermentation.
- Soy-enhanced whole stillage had high protein and lysine contents and can provide feed with improved quality.

**Abstract**

Soy skim, a protein-rich liquid co-product from the aqueous extraction of soybeans, was co-fermented with corn to produce ethanol. Effects of soy skim addition level, type of skim, corn particle size, water-to-solids ratio, and urea on co-fermentation were determined. The addition of 20–100% skim increased the fermentation rate by 18–27% and shortened the fermentation time by 5–7 h without affecting ethanol yield. Finely ground corn or high water-to-solids ratio (P<3.0) in the mash gave higher fermentation rates, but did not increase the ethanol yield. When the water was completely replaced with soy skim, the addition of urea became unnecessary. Soy skim retentate that was concentrated by nanofiltration increased fermentation rate by 25%. The highest level of skim addition resulted in a finished beer with 16% solids, 47% protein (dwb) containing 3.6% lysine, and an ethanol yield of 39 g/100 g dry corn.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

The continuous growing demand on fuel ethanol encourages the exploration of new and improved technologies to increase the efficiency of traditional alcohol fermentation and co-product utilization. Fermentation rate and final ethanol concentration are usually limited by nutrient deficiencies and ethanol intolerance of yeast cells. Supplementing fermentation media with nutrients such as soy flour (Ju et al., 1983; Damiano and Wang, 1985; Viegas et al., 1985; Maia and Nelson, 1994), oryzemin (a rice protein), albumin, and koji mold mycelia (Hayashida et al., 1974), and finger millet flour (Reddy and Reddy, 2006) in fuel ethanol production has achieved notable enhancement on fermentation performance. Although the mechanism of the promoting effect from these proteins or protein–lipid complexes is not fully understood, the major contribution may be the remediation of nutrient deficiencies in the media (Viegas et al., 1985); however, inexpensive sources of supplements are needed to maintain or reduce the total production cost of fuel ethanol.

An integrated biorefinery concept with corn–soy co-fermentation was proposed by Yao et al. (2011) to utilize the co-product of the enzyme-assisted aqueous extraction of soybeans (EAEP), soy skim, in dry-grind corn fermentation. The authors found that soy skim increased the fermentation rate and thus shortened fermentation time. The co-fermentation, which uses the liquid EAEP co-product rich in hydrolyzed soy protein, not only benefits soybean EAEP by utilizing and adding value to its dilute protein stream (skim), but also introduces an inexpensive protein source to supplement alcohol fermentation. The study conducted by Yao et al. (2011) compared the performance of co-fermentation with...