Biobutanol production from coffee silverskin

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Abstract

- Coffee silverskin was evaluated as a feedstock for biobutanol production (ABE fermentation).
- The biomass was subjected to autohydrolysis at 170 ºC during 20 min, with a solid load of 20% and a subsequent enzymatic treatment to complete the hydrolysis.
- The obtained hydrolysate contained 34.39 ± 2.61 g/L total sugars (34 ± 3% sugar recovery).
- The fermentability of the hydrolysate was assessed with four solventogenic strains from genus *Clostridium* without the need of a detoxification stage.
- The best fermentation results were obtained by *Clostridium beijerinckii* CECT 508, attaining 7.02 g/L butanol, 11.41 g/L ABE, 0.269 g_B/g_S.
- Coffee silverskin could be a suitable feedstock for biobutanol production.

Introduction

Coffee silverskin is a thin tegument obtained as a by-product after the roasting process and it constitutes about 4.2% (w/w) of coffee beans[1]. It contains important amounts of cellulose and hemicellulose, which makes this by-product an interesting feedstock for microbial fermentation.
The objective of this research is to hydrolyze coffee silverskin into simple fermentable sugars to obtain a broth which could be directly fermentable by solventogenic *Clostridium* strains to produce butanol.

Material and methods

Biomass description
Dry coffee silverskin was ground and sieved to a size of 0.5-1.0 mm (Fig. 1).

Pretreatment
An autohydrolysis pretreatment was performed in a high-presure 2-L reactor made of alloy Carpenter-20 (Fig. 1) at 170 ºC for 20 min, with a solid load of 20% (w/w).

Enzymatic hydrolysis
The whole slurry obtained in the pretreatment was subjected to hydrolysis with the enzymatic cocktail Cellic CTec2 (pH 5.0, 50 ºC, 180 rpm, 72 h) (Fig. 1).

Fermentation and strain selection
The hydrolysate was filtered and supplemented with nutrients (1 or 5 g/L yeast extract, 2.1 g/L NH_4Cl, 0.5 g/L K_2HPO_4, 0.5 g/L KH_2PO_4, 0.01 g/L $FeSO_4{\cdot}7H_2O$, 0.2 g/L $MgSO_4{\cdot}7H_2O$, and 0.5 g/L cysteine) to perform ABE fermentation with *C. beijerinckii* CECT 508, *C. beijerinckii* DSM 6423, *C. saccharobutylicum* DSM 13864 and *C. saccharoperbutylacetonicum* DSM 2152, at 35 ºC, 100 rpm, initial pH of 6.0 (controlled by $CaCO_3$) and anaerobic conditions during 96 h, to select the best butanol-producing strain.

Optimization of fermentation conditions
The strain selected was subjected to a Box-Behnken design linked to the response surface methodology (RSM) to improve butanol concentrations obtained, determining the most adequate values for temperature, initial pH and $CaCO_3$ concentration during the fermentation.

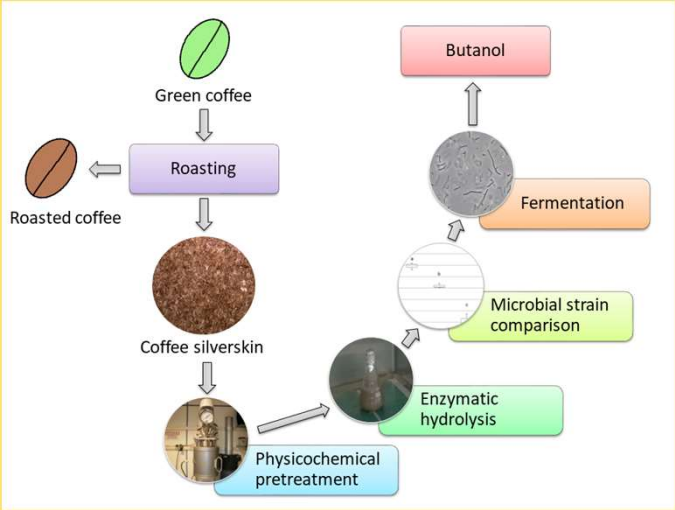

Fig. 1. Bio-butanol production process from coffee silverskin.

Results

Coffee silverskin hydrolysis
The obtained hydrolysate contained 34.39 g/L total sugars (33.74 ± 3.49% sugar recovery).

Coffee silverskin fermentation
C. beijerinckii CECT 508 was the most efficient strain to produce butanol. No significant differences ($p<0.05$) were observed between coffee silverskin hydrolysates containing 1 or 5 g/L yeast extract for any of the four strains (Fig. 2).

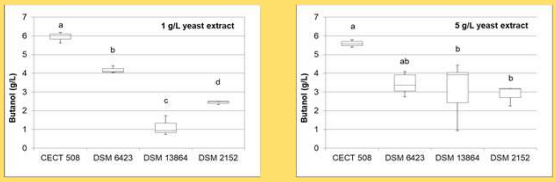

Fig. 2. Butanol production from coffee silverskin hydrolysates by the four tested strains under two yeast extract concentrations: a) yeast extract 1 g/L, b) yeast extract 5 g/L.

Optimization of fermentation conditions with the selected strain
The optimal values of temperature, initial pH and $CaCO_3$ concentration to produce the highest butanol concentration from coffee silverskin hydrolysate with *C. beijerinckii* CECT 508 were: 33.9 ºC, initial pH 5.59 and 7.55 g/L $CaCO_3$ (Fig. 3). The validation of these optimal conditions produced 7.02 ± 0.27 g/L butanol, 4.14 ± 0.21 g/L acetone and 0.25 ± 0.01 g/L ethanol.

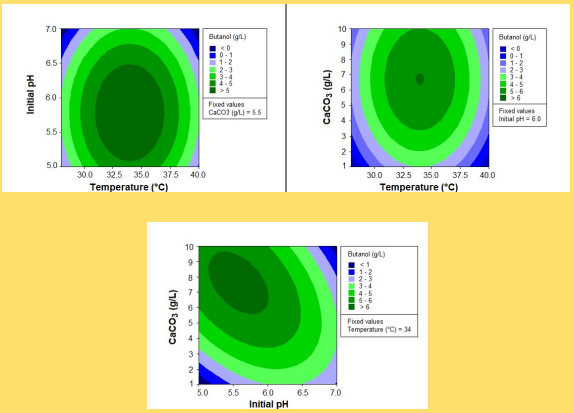

Fig. 3. Contour plots for the estimation of butanol concentration as a function of fermentation conditions (temperature, initial pH and $CaCO_3$ concentration), according to the mathematical RSM model.

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