Fungi-Based Biorefinery: Valorization of industrial residuals and techno-economic evaluation

Gülru Bulkan

Thesis for the degree of Doctor of Philosophy at the University of Borås to be publicly defended on November 18th 2022, 10:00 a.m. in room C203, University of Borås, Allégatan 1, Borås, Sweden.

Language: English

Faculty Opponent is:

Dr. Mats Galbe
Associate Professor
Lund University, Sweden

PhD thesis is available at
Swedish Centre for Resource Recovery
University of Borås
SE-501 90 Borås, Sweden. +46(0) 33 435 4000

UNIVERSITY
OF BORÅS

Abstract

Sustainable development of society and industry is necessary for a safer future that is being challenged by environmental pollution, climate change, and scarcity of food and nutrition. Materials considered as waste can be converted into value-added products and energy, hence regained to the economy. Filamentous fungi are saprophytic microorganisms that show great potential for bioconversion of organic waste materials into a wide range of products, including ethanol, enzymes, fungal biomass, and organic acids. In this study, industrial residuals from bioethanol plants (thin stillage), agro-industrial residuals (oat husks), and fruit-processing residuals were considered as potential substrates for filamentous fungi. Different filamentous fungi species were investigated due to their edibility and ability to produce ethanol. The aim of this study was to investigate 1) the feasibility of a biorefinery concept and contribution of fungal products to the process economy, 2) the valorization of oat husks in the fungal biorefinery and its contribution to the process economy, and 3) the effect of bioactive compounds existing in fruit residuals on filamentous fungi in a synthetic medium.

Bioconversion of thin stillage into value-added products, e.g., additional ethanol produced by filamentous fungi and edible fungal biomass for various feed/food markets, improved the process economy of a conventional bioethanol plant. Techno-economic analysis was carried out with Aspen Plus® and Aspen Process Economic Analyzer®. The economy of the conventional bioethanol plant was improved to 76% and 5.6-fold higher net present value when the fungal product was sold as fish feed and human food, respectively. When the fungal product was sold as human food, *Aspergillus oryzae* was more advantageous than *Neurospora intermedia.* It is possible to integrate lignocellulosic material into the fungi-based biorefinery and produce additional products, e.g., lignin and fungal biomass as feed/food products. Several scenarios for integrating organosolv pretreatment into the biorefinery were investigated. When protein-rich biomass was sold as feed and food, 71% and 7.9-fold higher net present value was obtained, respectively, compared to the conventional ethanol plant. Similarly, other materials, e.g., fruit residuals, can be valorized through the fungal biorefinery. However, bioactive compounds in fruit residuals have antimicrobial effects; therefore, it is essential to assess the sensitivity of fungi toward them for efficient processes. In addition to the fungi species utilized in thin stillage and oat husk valorization, two other industrially important fungi, *Rhizopus oligosporus* and *A. niger,* were tested against 10 bioactive compounds with antimicrobial properties (octanol, ellagic acid, (-)-epicatechin, quercetin, betanin, ascorbic acid, limonene, hexanal, car-3-ene, and myrcene). The bioactive compounds were added to a synthetic medium to reach final concentrations of 2.4, 24 and 240 mg/L, within their natural concentration in fruit/fruit residuals. *A. oryzae*, *A. niger* and *N. intermedia* were inhibited by octanol, while the latter fungus was also inhibited by D-Limonene at 240 mg/L. On the other hand, *R. oligosporus* was resistant to inhibitory compounds and increased the biomass yield. The highest change in biomass yield was in the presence of ellagic acid with up to a 4-fold increase. Ethanol and lactic acid yields were increased 38% and 30% in the presence of ellagic acid and betanin, respectively. Similarly, the existence of quercetin and ellagic acid, ascorbic acid, and hexanal increased the biomass yield of *A. niger* up to 28%.

These studies can contribute to developing efficient and feasible biorefineries, in which filamentous fungi convert the industrial residuals into value-added products.

Keywords: Techno-economic analysis, Organosolv, bioethanol, filamentous fungi, food, lignin, fruit, bioactive compounds