Bioresource Technology 258 (2018) 270–278

Contents lists available at ScienceDirect

Bioresource Technology

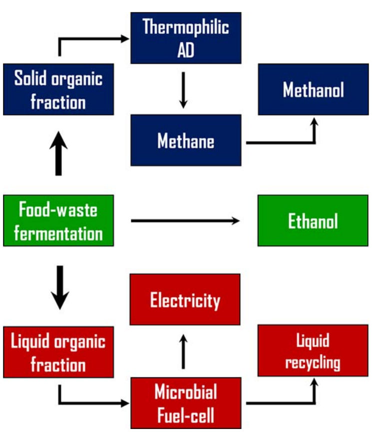
journal homepage: www.elsevier.com/locate/biortech

Producing methane, methanol and electricity from organic waste of fermentation reaction using novel microbes

Saurabh Sudha Dhiman[a,b,c], Namita Shrestha[d], Aditi David[a], Neha Basotra[a,e], Glenn R. Johnson[f], Bhupinder S. Chadha[e], Venkataramana Gadhamshetty[b,d,g], Rajesh K. Sani[a,b,c,*]

[a] Department of Chemical and Biological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701, USA
[b] BuG ReMeDEE Consortium, South Dakota School of Mines and Technology, Rapid City, SD 57701, USA
[c] Composite and Nanocomposite Advanced Manufacturing Centre – Biomaterials (CNAM/Bio), Rapid City, SD 57701, USA
[d] Department of Civil and Environmental Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701, USA
[e] Department of Microbiology, Guru Nanak Dev University, Amritsar, Punjab 143005, India
[f] Hexpoint Technologies Inc. PO Box 1159, Panama City, FL 32402, USA
[g] Surface Engineering Research Centre, South Dakota School of Mines and Technology, Rapid City, SD 57701, USA

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Food waste
Methane oxidation
Methyloferula stellata
Microbial fuel cell
Thermophilic anaerobic digestion

ABSTRACT

Residual solid and liquid streams from the one-pot CRUDE (Conversion of Raw and Untreated Disposal into Ethanol) process were treated with two separate biochemical routes for renewable energy transformation. The solid residual stream was subjected to thermophilic anaerobic digestion (TAD), which produced 95 ± 7 L methane kg^{-1} volatile solid with an overall energy efficiency of 12.9 ± 1.7%. A methanotroph, *Methyloferula* sp., was deployed for oxidation of mixed TAD biogas into methanol. The residual liquid stream from CRUDE process was used in a Microbial Fuel Cell (MFC) to produce electricity. Material balance calculations confirmed the integration of biochemical routes (i.e. CRUDE, TAD, and MFC) for developing a sustainable approach of energy regeneration. The current work demonstrates the utilization of different residual streams originated after food waste processing to release minimal organic load to the environment.

* Corresponding author at: Department of Chemical and Biological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701, USA.
E-mail address: Rajesh.sani@sdsmt.edu (R.K. Sani).

https://doi.org/10.1016/j.biortech.2018.02.128
Received 3 January 2018; Received in revised form 27 February 2018; Accepted 28 February 2018
0960-8524/

1. Introduction

The US Energy Security and Independence Act of 2007 (Department of Energy and Department of Agriculture) mandates the use of biomass to supply 5% of heat and electricity sources, 20% of transportation fuel, and 25% of value-added products by 2022 (Perlack et al., 2015). Currently, 13% of the renewable energy portfolio in the US is covered by liquid biofuels including ethanol and diesel. Results from a series of recent studies support the use of biorefinery concepts to convert renewable feedstocks into liquid transportation fuels (Dhiman et al., 2016). Transformative biorefinery technologies can yield innovative solutions for challenges related to energy security, the environment, and rural development (Dhiman et al., 2015).

A criticism of crop-based biofuel production is that it requires land and water that could otherwise be used for production of typical agricultural food products, special commodities, and fiber (Michel, 2012). Another negative aspect of energy-crop based biorefinery is the lower values for photosynthetic efficiency and their carbon-neutral capacity compared to food-crops (Lin et al., 2013). Food waste (FW), a nutrient rich and abundant feedstock (up to 43.6 million tons per year in US), is an alternative to agricultural commodities as feedstocks for renewable energy production (Gustavsson et al., 2011). The FW contains soluble sugars and polymers (FAO, 2015), which can act as precursors for high-value commercial compounds as well as energy source, thus making FW as valuable feedstock in the biorefinery (Rosentrater, 2006).

The goal of a biorefinery is to produce renewable energy and value-added products from a given feedstock in a timely and energy-efficient manner (Dhiman et al., 2017a). In order to be cost-effective, commercial biofuel production must overcome several economic and technical challenges. The majority energy requirements for an integrated biorefinery process emerge from the five core steps: feedstock collection, pretreatment of the feedstock, hydrolysis of the bulk feedstock, fermentation, and product separation (Koutinas et al., 2014). Some of the limitations in the biorefinery approach can be resolved by using the extremophilic microorganisms that thrive in high temperatures and other challenging operational conditions (Rahayu et al., 2017). In our previous exploration of microbes from the deep-biosphere of Sanford Underground Research Facility (SURF) (Lead, SD), several unique microbes including thermophiles have been isolated and characterized. We extended those discoveries and applied them to the development a novel biorefinery approach (CRUDE process) that uses thermophilic microbes to consolidate the core steps of waste treatment and biofuel production into a single bioprocess (Dhiman et al., 2017b).

To improve the energy efficiency and broaden the product portfolio of the CRUDE or other similar bioprocesses, the current study investigates feasibility of generating additional forms of renewable fuels (methane and methanol) and electricity from the CRUDE process effluent. The study includes energy and mass balance calculations to evaluate the feasibility of the combined biorefinery framework for treating FW and its conversion to useable bioenergy. The additional

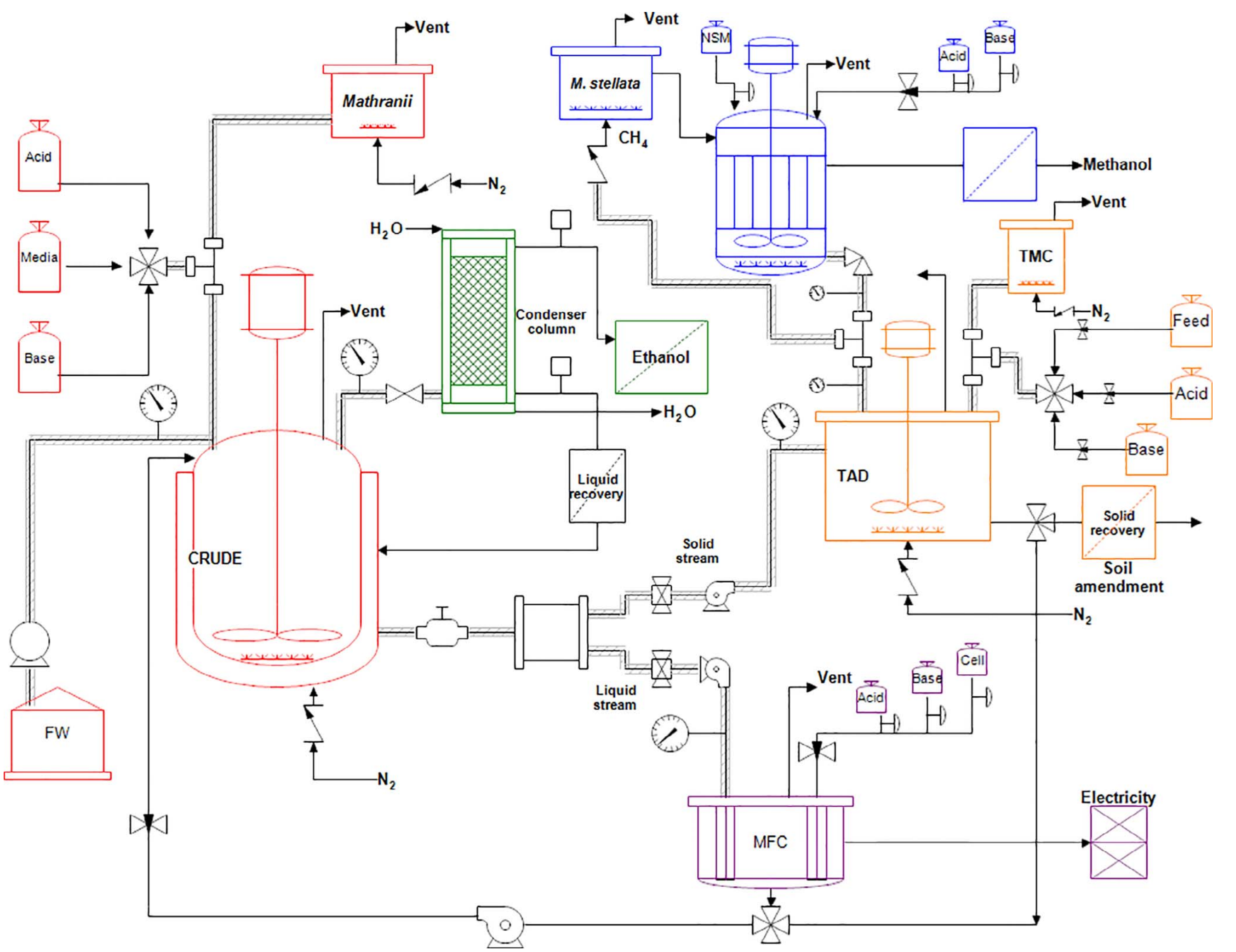


Fig. 1. Piping and instrumentation diagram (P&ID) of all interconnected biochemical processes. CRUDE reactor and related tanks (Red); Ethanol distillation process assembly (green); TAD (orange); MFC reactor (purple); and methane oxidation reactor (MOR) (blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)