Fuel 214 (2018) 623–633

Contents lists available at ScienceDirect

Fuel

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

Review article

Innovative developments in biofuels production from organic waste materials: A review

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ARTICLE INFO

Keywords:
Organic wastes
Biofuels
Technology development
Process intensification
Transesterification
Coalescer reactor

ABSTRACT

Several organic wastes into energy conversion technologies were successful in addressing global challenges such as fossil fuel dependency, production cost optimization, waste management and emission control issues. The utilization of organic wastes for biofuels production is considered as a plausible approach for achieving better energy security, pollution control, process economics, sustainable production, and societal improvements. This work intends to comprehensively review all available technologies for producing biofuels from organic wastes. Besides, it presents a synoptic analysis of the status, prospects and challenges pertinent to each technology. Globally, liquid biofuels are gaining prominence because of their potential to reduce the consumption of fossil fuels in transportation and industrial sectors with comparable performance efficiencies. This review work demonstrates the superiority of biodiesel over other liquid biofuels through a comparative assessment of relevant factors. Some of the main constraints for commercial deployment of biodiesel production using organic wastes include higher production costs, higher energy consumption, longer reaction residence times, and unsystematic feedstock accumulation procedures. The process intensification methods implemented by various researchers to circumvent these biodiesel production challenges are also presented. Moreover, this article recommends a novel concept for intensification of biodiesel production from waste cooking oil using coalescer reactor along with a preliminary scrutiny for justifying further research potential of the approach.

1. Introduction

The globally growing urge to reduce the dependency on fossil fuels, and to achieve better pollution control requires the development of alternate energy resources such as biofuels [1]. As the traditional energy resources are negatively impacting on the environment as well as climate patterns, the need to focus on developing alternate energy is indispensable in a modern society [2]. The usage of organic waste materials as feedstocks for biofuels production is the innovative approach towards the resolution of issues pertinent to waste management, fossil fuel dependency and harmful greenhouse gases (GHG) emissions. Apart from economical feedstock agglomeration, the utilization of organic wastes for biofuels production plays a vital role in decreasing the CO_2 emissions. This implies that the emissions involved in resource cultivation, and waste disposal can be either minimized or eliminated from the net life-cycle CO_2 emissions of biofuels production plant. Thus, this process minimizes the climate change impacts, contribute to air pollution control, ensure energy security, promote local development, and provide independence from fluctuations in the crude oil market situation [2].

A well-established biomass waste accumulation and storage system is indispensable for deployment of a full-scale biofuel plant for processing of organic wastes. To circumvent this challenge, strong legislative policies for improving waste collection and storage system should be enacted [1,3]. Besides, government subsidies for the development of organic wastes based biofuel plants, and incentives for utilization must be useful for waste derived biofuels in consistently maintaining their presence in the energy market [1,2]. Moreover, industry driven initiatives provide a vital role in endorsing biofuels process development using organic wastes. For instance, in the aviation industry, numerous strategic ventures were established between major biofuels makers, and aircraft builders with a sole objective to accelerate commercial deployment. These initiatives are mainly in agreement with the regulatory objectives such as emission reduction, fuel security improvement and most importantly prevent the nation from being victimized by oil price fluctuations. Furthermore, improved technologies result in higher value addition in the context of process optimization and cost control [2].

Recently, Stafford et al. [1] presented the most well-established and commercially operational wastes into biofuels conversion technologies. The technologies are: (i) ethanol production from agricultural residues

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https://doi.org/10.1016/j.fuel.2017.11.042
Received 3 September 2017; Received in revised form 10 November 2017; Accepted 14 November 2017
0016-2361/

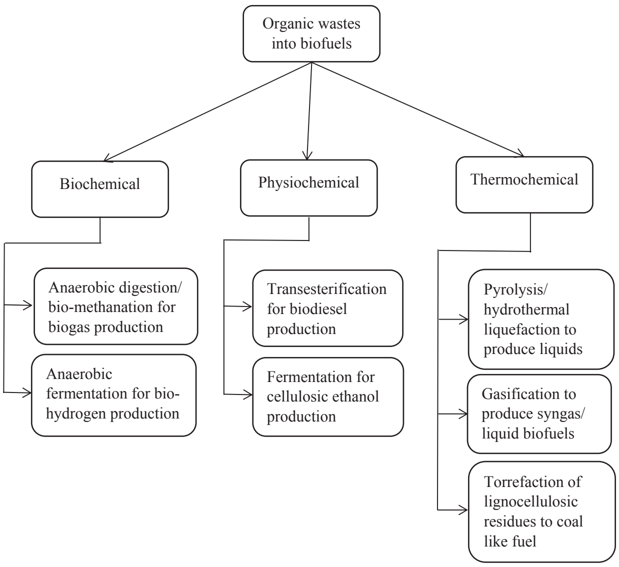

Fig. 1. Organic wastes into biofuels conversion processes.

by hydrolysis and fermentation, (ii) biogas production through anaerobic fermentation, and (iii) biodiesel production via transesterification process. Fig. 1 depicts the classification of three pathways for conversion of organic wastes into biofuels [1,4], and are: (i) biochemical, (ii) physiochemical, and (iii) thermo-chemical methods. The evolution of biofuels production over the three generations [1,3,5] is shown in Fig. 2. Besides, it highlights the competitiveness and sustainability traits of second-generation biofuels using organic wastes as feedstocks [1,3].

A globally increasing trend in the use of renewable biofuels is being observed because of the need to replace the fossil fuels in transportation and power generation sectors [3,6]. However, there are many hindrances encountered for the commercial deployment and operation of large scale biofuels production plants [7]. The technological enhancements for efficient production of biofuels are highly indispensable for achieving future energy security, and decreasing the consumption of fossil fuels in global infrastructural and industrial applications. Therefore, an urgent progress in sustainable production of biofuels is highly essential to meet the global energy demand in future. Besides, the world is seeking an innovative approach to alleviate the persistent waste management issues which involve larger land and water use for handling and processing of wastes. The attractive option of transforming wastes into energy is the plausible solution to this concern [8]. However, the continuous improvement of these processes, and policy support for their market acceptance are crucial for ensuring the feasibility of biofuels production from organic wastes [2]. Therefore, this work is envisioned to review the technological progress for conversion of organic wastes into biofuels. Furthermore, biodiesel is evidently a superior biofuel with high eligibility for use as a standalone fuel in the transportation sector [9]. This work further describes the process intensification approaches attempted on biodiesel production technologies from organic wastes to realize sustainable and commercially feasible development. Additionally, efforts are focussed on recommending a novel concept for process intensification of biodiesel production from organic wastes.

2. Feedstock potential of organic wastes in biofuels production

An extensive range of organic wastes can be used for advanced biofuels production which indicates substantial opportunities for diverse production processes and biofuel potentials. The examples of organic wastes include kitchen, garden, forest, lignocellulosic, solid biogenic, farm, animal, paper, sewage sludge and municipal wastes containing mainly organic fractions [2,8]. The availability of organic wastes may vary with location. In urban areas, feedstocks comprising of organic fractions of municipal wastes which are economical and readily accessible choice while agricultural, pastoral, farming residues, and other green wastes are suitable for biofuel production in rural areas. Forest and other ligno-cellulosic residues are coherent options in regions where wood based product manufacturing are common owing to their easy accessibility and reasonable costs. Therefore, the feedstock availability and costs are major decisive factors for biofuels production in different regions of the world [1–3].

The number of commercial and demonstration units across the

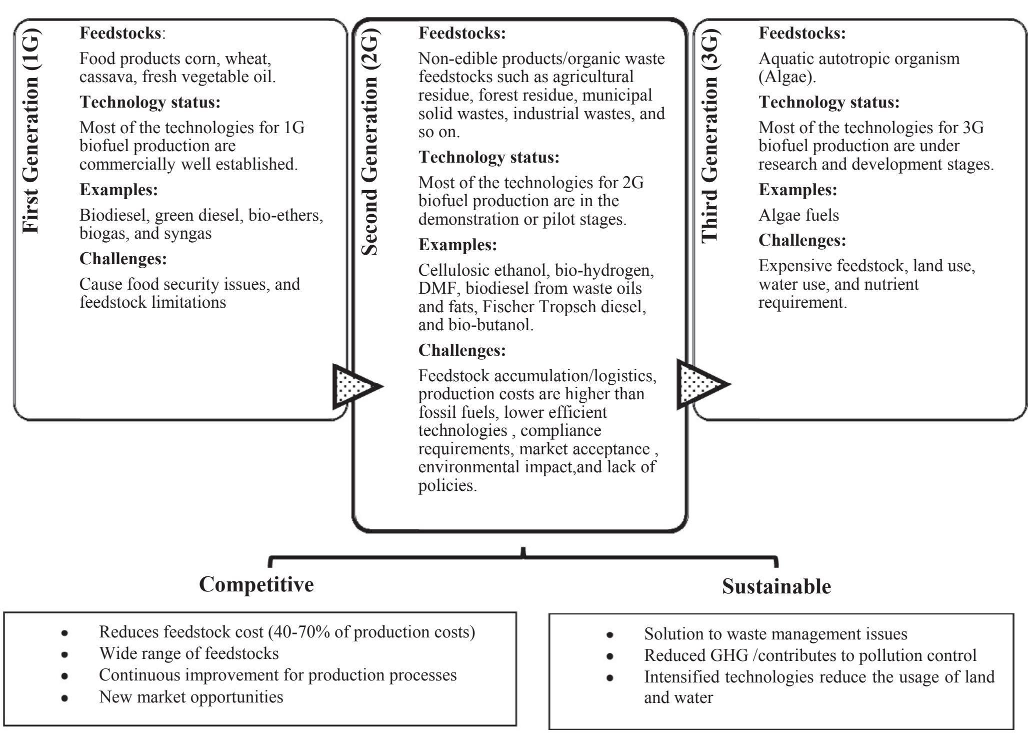

Fig. 2. Evolution of biofuels production stages over three generations.