Bioresource Technology 241 (2017) 1101–1117

Contents lists available at ScienceDirect

Bioresource Technology

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

Review

Waste biorefineries: Enabling circular economies in developing countries

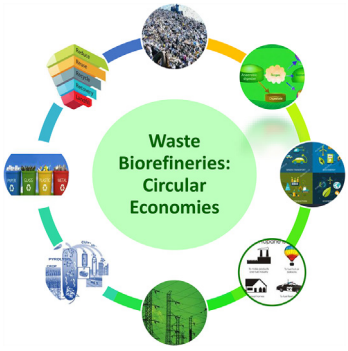
A.S. Nizami [a,*], M. Rehan [a], M. Waqas [a], M. Naqvi [b], O.K.M Ouda [c], K. Shahzad [a], R. Miandad [a], M.Z. Khan [d], M. Syamsiro [e], I.M.I. Ismail [a], Deepak Pant [f]

[a] Centre of Excellence in Environmental Studies (CEES), King Abdulaziz University, Jeddah, Saudi Arabia
[b] Future Energy Center, Department of Energy, Building and Environment, Mälardalen University, Sweden
[c] Department of Civil Engineering, Prince Mohamed Bin Fahd University, Al Khobar, Saudi Arabia
[d] Environmental Research Laboratory, Department of Chemistry, Aligarh Muslim University, Aligarh, India
[e] Department of Mechanical Engineering, Janabadra University, Yogyakarta, Indonesia
[f] Separation & Conversion Technology, Flemish Institute for Technological Research (VITO), Boeretang 200, 2400 Mol, Belgium

HIGHLIGHTS

- This study examined the potential of waste biorefineries in developing countries.
- Waste biorefineries can achieve circular economy, especially in developing countries.
- Waste in developing countries is a promising source of energy and value-added products.
- Selection of waste to energy technologies depend on regional waste characterization.
- Decision to select among the types of waste biorefineries requires LCA study.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 1 April 2017
Received in revised form 15 May 2017
Accepted 16 May 2017
Available online 18 May 2017

Keywords:
Waste biorefinery
Non-food feedstocks
Fuels
Circular economy
Value-added products

ABSTRACT

This paper aims to examine the potential of waste biorefineries in developing countries as a solution to current waste disposal problems and as facilities to produce fuels, power, heat, and value-added products. The waste in developing countries represents a significant source of biomass, recycled materials, chemicals, energy, and revenue if wisely managed and used as a potential feedstock in various biorefinery technologies such as fermentation, anaerobic digestion (AD), pyrolysis, incineration, and gasification. However, the selection or integration of biorefinery technologies in any developing country should be based on its waste characterization. Waste biorefineries if developed in developing countries could provide energy generation, land savings, new businesses and consequent job creation, savings of landfills costs, GHG emissions reduction, and savings of natural resources of land, soil, and groundwater. The challenges in route to successful implementation of biorefinery concept in the developing countries are also presented using life cycle assessment (LCA) studies.

* Corresponding author.
E-mail addresses: nizami_pk@yahoo.com, anizami@kau.edu.sa (A.S. Nizami).

http://dx.doi.org/10.1016/j.biortech.2017.05.097
0960-8524/

Contents

1. Introduction

Today, the world is facing many serious challenges, including ever-growing human population and the consequent security for food, energy, and water (Amulya et al., 2016). In addition, the greenhouse gas (GHG) emissions and various other pollutants are posing a serious threat to mankind due to anthropogenic climate change (Ouda et al., 2016). As a result, the gap between environmental sustainability and economic growth is increasing (Nizami et al., 2017). Therefore, the need for sustainable technologies, mandates, and policies to mitigate climatic change and provide a constant supply of energy and feed has become critical for enabling circular economies in the developing countries (Guerrero et al., 2013; Sadef et al., 2016a).

The sustainable disposal of waste is still in infancy in most of the developing countries due to limited allocated budgets, infrastructure and maintenance facilities (Tozlu et al., 2016; Tan et al., 2015; Nizami et al., 2016a). The high generation rates of organic waste and its disposal to open dumpsites or non-sanitary landfills are resulting in adverse environmental, economic and social problems (Sharholy et al., 2008; Nizami et al., 2016b). The actual collection of waste from most cities in developing countries like India, Pakistan and Bangladesh is only around 60%, while the remaining waste lies in the empty plots, street sides, along with the road, railway lines, drains, and low-lying areas (Hoornweg and Bhada-Tata, 2012; Sadef et al., 2016a). In poor regions, the unplanned growth of new cities is making the situation even worse (Miandad et al., 2016a, 2017). The municipalities dealing with municipal waste are unable to upgrade the facilities to international standards, as in most cases the waste management is the city's largest budgetary item (Brunner and Rechberger, 2015). The solid waste management costs will increase from current annual US $205.4 billion to around US $375.5 billion by 2025 worldwide (Hoornweg and Bhada-Tata, 2012).

The efficient treatment of waste is critical not only from a sanitation point of view but also due to associated economic and environmental benefits (Rathi, 2006). Similarly, the fuels if produced from feedstocks that are cultivated on a good agriculture land are blamed for high prices of food and animal feed in some parts of the world (Sims et al., 2010). Therefore, the strategic deployment of biofuels is required from such non-food feedstocks that reduce the land use impacts and GHG emissions in comparison to conventional fuels (Singh et al., 2010; Ouda et al., 2015). The biorefinery technologies such as pyrolysis, fermentation, gasification, anaerobic digestion (AD), incineration, refuse derived fuel (RDF) and plasma arc gasification have emerged as promising methods to produce fuels from non-food feedstocks such as cereal straw, sugarcane bagasse, perennial grasses, corn stover, agricultural and forest biomass waste, and municipal and industrial organic waste (Naik et al., 2010; Miandad et al., 2016b). However, each biorefinery technology can produce a specific fuel depending on the type and availability of feedstock (Sanaei et al., 2012; Mohan et al., 2016a). Therefore, if such technologies could be combined under an integrated waste biorefinery concept, mixed and multiple feedstocks could be treated to produce various products in the form of food, feed, fuel, power, and heat along with value-added chemicals (Posada et al., 2013).

In most of the developing countries, the concept of waste biorefineries is very relevant and imperative due to the environmental and economic overburden caused by the current waste disposal practices and for fulfilling the increasing energy demands along with the creation of new businesses, job markets and improvements in the public health and local environment (Ismail and Nizami, 2016). It is estimated that around US $410 billion can be generated only from the world market of municipal waste recycling. However, only a quarter of this waste is recovered or recycled for the beneficial purposes (Guerrero et al., 2013; Hossain et al., 2014).

This study aims to examine the potential of waste biorefineries in developing countries as a solution to their current waste disposal issues and as facilities to produce fuels, power, heat, value-added materials and chemicals in order to enable circular economies. In addition, the challenges and barriers, including the technical and regional issues in route to successful implementation of biorefinery concept in developing countries are also presented. Furthermore, a detailed technical, economic and environmental analysis of waste biorefineries is included using life cycle assessment (LCA). The study concludes with recommendations in order to address the relevant challenges in most of the developing countries.