Bioresource Technology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Bioresource Technology

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

Review

Waste biorefinery in arid/semi-arid regions

Juan-Rodrigo Bastidas-Oyanedel, Chuanji Fang, Saleha Almardeai, Usama Javid, Ahasa Yousuf, Jens Ejbye Schmidt *

Institute Center for Energy – iEnergy, Masdar Institute of Science and Technology, PO Box 54224, Abu Dhabi, United Arab Emirates

HIGHLIGHTS

- The review discuss the water scarcity as main restriction of biorefinery in arid regions.
- The review focus on MENA region available biomass to be used in biorefinery processes.
- The review presents prices and market size of potential products from waste biorefinery in the MENA region.

ARTICLE INFO

Article history:
Received 3 February 2016
Received in revised form 1 April 2016
Accepted 2 April 2016
Available online xxxx

Keywords:
Waste biorefinery
Seawater biorefinery
Arid biorefinery
Water scarcity

ABSTRACT

The utilization of waste biorefineries in arid/semi-arid regions is advisable due to the reduced sustainable resources in arid/semi-arid regions, e.g. fresh water and biomass.

This review focuses on biomass residues available in arid/semi-arid regions, palm trees residues, seawater biomass based residues (coastal arid/semi-arid regions), and the organic fraction of municipal solid waste. The present review aims to describe and discuss the availability of these waste biomasses, their conversion to value chemicals by waste biorefinery processes. For the case of seawater biomass based residues it was reviewed and advise the use of seawater in the biorefinery processes, in order to decrease the use of fresh water.

Contents

* Corresponding author.
E-mail address: jschmidt@masdar.ac.ae (J.E. Schmidt).

http://dx.doi.org/10.1016/j.biortech.2016.04.010
0960-8524/© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Arid and semi-arid regions are defined by their water scarcity. A water scarcity indicator is the annual renewable freshwater (m^3/inhabitant/year) (FAO, 2012), where values below 500 are considered of Absolute water scarcity, values between 500 and 1000 are chronic water shortage, between 1000 and 1700 are regular water stress, and above 1700 are occasional or local water stress. As an example of arid region, the Middle East and north Africa (MENA) region is comprised of 20 countries (WB, 2015) with water scarcity concerns. From the 20 MENA countries, 14 are in absolute water scarcity, 4 in chronic water scarcity, and two in occasional of local water stress.

Biomass availability in arid regions can be obviously considered limited for the fresh water scarcity which constrains forestry, and limited amount of agricultural activities compared with not arid regions. Biomass residues available in arid/semi-arid regions may be derived from Palm trees related activities (El-Juhany, 2010), as the in the MENA region, fisheries and marine capture-farming-processing in coastal arid/semi-arid areas (FAO, 2013), and the organic fraction of municipal solid waste (Hoornweg and Bhada-Tata, 2012).

The biorefinery of such of biomass residues can produce valuable products, e.g. activated carbon, organic acids, biogas, that can contribute to the economy of the arid regions. Table 1 shows prices and market size of products that can be produce by waste biorefinery, and conventional products that can be alternatively produced by the biorefinery of residues (Alibaba, 2015; Bastidas-Oyanedel et al., 2015; BusinessWire, 2014; GlobeNewswire, 2015; IEA, 2014; Indexmundi, 2015).

Table 1
Bulk prices and market size of potential products from the valorization of solid organic waste in MENA region.

Compound	Price (USD/tonne)	Market size (tonne/year)
Activated Carbon	800–2000[a]	$1.37 \cdot 10^6$ (2013)[b]
Biochar	250-800[a]	10^5 (2013)[c]
Glass Fiber	800–1500[a]	$4 \cdot 10^6$ (2011)[c]
Acetic acid	400-800[d]	$3.5 \cdot 10^6$ (2013)[d]
Butyric acid	2000–2500[d]	$3 \cdot 10^4$ (2013)[d]
Propionic acid	1500–1700[d]	$1.8 \cdot 10^5$ (2013)[d]
Caproic acid	2000–2500[d]	$2.5 \cdot 10^4$ (2013)[d]
Lactic acid	1000–2100[d]	$1.2 \cdot 10^4$ (2013)[d]
Ethanol	800–2000[d]	$5.1 \cdot 10^7$ (2013)[d]
Butanol	1000–1800[d]	$3 \cdot 10^6$ (2011)[d]
Diesel	456[e]	$1.2 \cdot 10^9$ (2009)[d]
Jet Fuel	459[e]	$2.5 \cdot 10^8$ (2008)[d]
Natural Gas	0.05–0.12[e]	$2.9 \cdot 10^9$ (2013)[f]

[a] Alibaba (2015).
[b] GlobeNewswire (2015).
[c] BusinessWire (2014).
[d] Bastidas-Oyanedel et al. (2015).
[e] Indexmundi (2015)
[f] IEA (2014).

Therefore waste biorefineries in arid/semi-arid regions have a main challenge, to minimize the use of freshwater for their processes, and adapt to the available biomass residues. The present review aims to describe and discuss the availability of these waste biomasses, their conversion to value chemicals, minimizing the use of fresh water in some cases. The review is divided into: valorization of date palm residues, Saltwater-based biorefinery, and biorefinery of the organic fraction of municipal solid waste.

2. Valorization of palm residues

2.1. Biomass resource from dates waste and palm residues

The date palm (*Phoenix dactylifera* L.) is a major fruit crop in most MENA countries. It has historically been connected to sustaining human life and traditional heritage of the people in the old world as a major agricultural crop. MENA countries possess 70% of the 120 million world's date palms (El-Juhany, 2010). Dates fruits are the most important agricultural product of many countries in the MENA.

The culture of date palms involves the generation of leaf residues. Generally, each date palm tree produces 10–30 dried leaves annually. An average naturally dried leaf (includes leaflets and rachis) has a mass of 2–3 kg (Mallaki and Fatehi, 2014). Hence, each date palm is estimated to yield approximately 50 kg leaf residues per year. The annual global production of lignocellulosic feedstock from date palm leaf residues is estimated to be over 6 million tonnes.

Another biomass resource from date palm includes discarded dates fruits. Total global production of dates in 2013 was 7.6 million tonnes (FAO, 2015). However, 25% of the dates could be considered as a waste product due to the very low quality (Bassam, 2010), which means a production of 1.9 million tonnes waste biomass including around 1.7 million tons of flesh with high carbohydrate content (~70–80%) (Al-Farsi et al., 2005), and 0.2 million tons of date seed, also named as date pits, and date stone, and constitute about 10% of the date weight (Ahmad et al., 2012).

2.2. Current status of palm waste management

Date palm lignocellulosic residues, e.g. leafs, have not drawn sufficient attention for its valorization. This dry organic biomass is not consumed by animals and has traditionally been used in shading, house construction, crates, ropes, baskets, and other handicrafts (Chao and Krueger, 2007). Apart from that, the lignocellulosic biomass is burned without appropriate application. Regarding the discarded dates, these are used for limited applications such as animal feed and a component for compost preparation. Thus most of the wastes are problematic to environment

Please cite this article in press as: Bastidas-Oyanedel, J.-R., et al. Waste biorefinery in arid/semi-arid regions. Bioresour. Technol. (2016), http://dx.doi.org/10.1016/j.biortech.2016.04.010