Journal of Cleaner Production 108 (2015) 422–441

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Multi-objective optimization of the supply chain of biofuels from residues of the tequila industry in Mexico

Pascual Eduardo Murillo-Alvarado [a], Gonzalo Guillén-Gosálbez [b, c], José María Ponce-Ortega [a, *], Agustín Jaime Castro-Montoya [a], Medardo Serna-González [a], Laureano Jiménez [b]

[a] Chemical Engineering Department, Universidad Michoacana de San Nicolás de Hidalgo, Morelia 58060, Michoacán, Mexico
[b] Departament d'Enginyeria Química (EQ), Universitat Rovira i Virgili (URV), Campus Sescelades, Avinguda Països Catalans 26, Tarragona 43007, Spain
[c] Centre for Process Integration, School of Chemical Engineering and Analytical Science, The University of Manchester, Manchester M13 9PL, UK

ARTICLE INFO

Article history:
Received 7 August 2014
Received in revised form
12 August 2015
Accepted 13 August 2015
Available online 22 August 2015

Keywords:
Biofuels
Bioethanol
Supply chain
Multi-objective optimization
Environmental impact
Biogasoline

ABSTRACT

The tequila industry in Mexico generates large amounts of lignocellulosic residues from the cultivation fields as well as from the tequila processing industries. Nowadays, these residues are disposed, but they could be used as feedstock for a biorefinery. Before implementing a biorefinery system to treat the residues from the tequila industry in Mexico, it is necessary to assess the economic and environmental performance of the entire supply chain for biofuel production. Developing a proper optimization framework for supply chain management in the tequila industry in Mexico that will consider all the activities involved along with the conflicting objectives of its daily operation represents a scientific challenge. Therefore, this paper presents a multi-objective optimization approach for designing such a supply chain that accounts for the simultaneous maximization of the net present value and environmental performance of the network. The environmental objective function accounts for impacts in ecosystem quality, human health and damage to resources. These are quantified through the eco-indicator 99 method. Numerical results show that the implementation of a biorefinery system in Mexico based on the residues from the tequila industry can provide significant economic and environmental benefits. Particularly, results indicate that the best economic solution shows a profit of 7.9×10^8 USD/year. Furthermore, the distributed system involving several central and distributed processing plants allows obtaining significant economic improvements. Finally, the results reported through Pareto curves allow identifying several solutions that are appealing for decision makers.
© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Biofuels have been the subject of intensive research due to their great potential to replace fossil fuels and decrease greenhouse gas emissions (Maes et al., 2015). Nowadays, there are several techniques for biofuels production. One of the most promising alternatives is to use residues containing lignocellulosic materials as feedstock (Liew et al., 2014). Several works have analyzed the benefits of this technology (Patrizi et al., 2013). Kazi et al. (2010) presented a techno-economic analysis comparing several routes for bioethanol production. Cardona et al. (2010) studied the production of bioethanol from sugar cane bagasse considering several technologies and biological transformations. Albernas-Carvajal et al. (2014) proposed a model for the optimal design of the fermentation process for bioethanol production from molasses and hydrolyzed sugar cane bagasse. Alex-Marvin et al. (2012) presented an optimization study focusing on the net present value of five types of lignocellulosic biomass for ethanol production. Chouinard-Dussault et al. (2011) incorporated process integration into life cycle analysis for the production of biofuels and Patrizi et al. (2015) evaluated the emergy of bioethanol production.

Most of the works mentioned above focused on assessing the economic performance of the technologies that produce biofuels as unique criterion. In practice, however, economic, environmental and social aspects need to be considered for a proper optimization of the network. Unfortunately, quantifying social aspects is challenging, and for this reason, they are typically left out of the analysis.

* Corresponding author. Tel.: +52 443 3223500x1277; fax: +52 443 3273584.
E-mail address: jmponce@umich.mx (J.M. Ponce-Ortega).

http://dx.doi.org/10.1016/j.jclepro.2015.08.052
0959-6526/© 2015 Elsevier Ltd. All rights reserved.

The design of the supply chain associated to a biorefinery system aims to determine the optimal lignocellulosic material to be used as feedstock, the location and capacity of the biorefineries, the technologies used, the distribution of products as well as all the transportation tasks involved. As already mentioned, several objectives must be considered for a proper design of the network. Some research in the field of supply chains are the works proposed by Mele et al. (2009) that addressed the optimal planning of supply chains for bioethanol and sugar cane production considering economic and environmental concerns. In addition, Mele et al. (2011) reported a systematic optimization approach for designing and planning supply chains for the sugar cane industry accounting for economic and environmental aspects. Akgul et al. (2011) presented mixed-integer linear programming (MILP) models for designing bioethanol supply chains. Moreover, Karlsson et al. (2014) incorporated environmental issues in the assessment of bioethanol production. Previous analyses have considered only one product, this way Santibañez-Aguilar et al. (2011) proposed a multi-objective optimization formulation for a supply chain associated to a biorefinery involving economic and environmental aspects, including multiple products. Previous approaches considered deterministic information, but other authors like Guillén-Gosálbez and Grossmann (2010) proposed an approach for the optimal design of supply chains considering the environmental damage in the presence of uncertainty in the life cycle inventory of emissions, and Vujanovic et al. (2015) and Kostin et al. (2012) incorporated uncertainty in the analysis of biorefineries. It should be noted that targeting is an important issue that allows specifying the desired values of the objectives before the design is completed. In this way, Tay and Ng (2012) reported a targeting approach for designing integrated biorefineries. Integrated biorefineries incorporate the production of biofuels and energy, like it was done in the work by Lim et al. (2014), who designed integrated biorefineries based on rice. Identifying the proper objectives in designing biorefineries has become an important task. In this context, El-Halwagi et al. (2013) incorporated safety issues in the design of supply chains for biorefineries, and Martinez-Hernandez et al. (2014) reported an economic and environmental analysis for biorefineries. Process systems engineering is a research area that allows reducing the mass and energy consumption in an industrial process. In this field, Kelloway and Daoutidis (2014) presented a process systems approach for designing biorefineries, and Ng et al. (2015) presented an optimal planning for a bioenergy park. Furthermore, Santibañez-Aguilar et al. (2014) reported a study for the supply chains associated to biorefineries in Mexico, where the main bioresources required to yield biofuels were identified. Gong and You (2014) developed a global optimization approach for designing biorefineries. Their work provides alternative effective formulations to manipulate the nonconvex terms in the optimization approach. To improve the acceptability of biofuel, recently Yue and You (2014) included transfer price and revenue sharing in the production planning of biorefineries. Agostinho and Ortega (2013) presented an energetic and environmental assessment of bioethanol production in Brazil, and Moncada et al. (2014) reported the evolution from biofuels to integrated biorefineries in Colombia. Mota et al. (2015) analyzed supply chains in Portugal accounting for economic, environmental and social issues. Identifying the proper products from a biorefinery is an important issue. Kajaste (2014) reviewed the production of chemicals from biomass. It should be noted that the above-mentioned investigations have identified that there is a clear need to consider multiple objectives (such as economic, environmental and social aspects) in the optimal planning of supply chains associated to biofuels. Furthermore, previous works have highlighted the importance to consider the specific available bioresources for each place to determine the optimal planning of supply chains associated to biofuels. Therefore, in the present study, and for the case of Mexico, the biomass obtained as waste from the tequila industry is considered as bioresource in the optimal design of a supply chain of biofuels in Mexico that is carried out considering several objectives simultaneously.

The tequila industry, which is quite important in Mexico, generates many lignocellulosic materials that can be used as feedstock for biofuels production. Particularly, several tonnes of leaves (made of lignocellulosic material) are left in the fields, while many tonnes of plant heads (also lignocellulosic material) are discharged from the tequila factories. This lignocellulosic residue is called agave bagasse. For the specific case of Mexico, several approaches were reported for designing biorefinery systems. Saucedo-Luna et al. (2011) studied the optimal conditions of the saccharification of the agave bagasse for bioethanol production. Núñez et al. (2011) studied the economic viability of biofuels production from agave bagasse in Mexico. Murillo-Alvarado et al. (2014) reported an optimization approach for designing a biorefinery system based on residues from the tequila industry in Mexico. This study considered only the economic performance as main target. It should be noted that the above-mentioned approach did not assess the environmental impact of the associated supply chain. However, considering the environmental performance in the optimal design of a biorefinery system is of paramount importance for taking full advantage of the potential environmental benefits of biofuels production.

This paper addresses the design of a biorefinery supply chain based on residues from the tequila industry in Mexico. The proposed approach considers simultaneously economic and environmental aspects. The later ones are quantified following the Econ-indicator 99, which covers the damage to resources, human health and ecosystem quality. The motivation for selecting this approach is that it considers several impacts in the aforementioned categories. Note, however, that the proposed optimization method is general enough to incorporate any other environmental assessment method. The design task is formulated as a multi-objective MILP model that includes different sets of equations reflecting capacity limitations, mass and energy balances and economic and environmental performance calculations. Numerical results show that it is possible to identify appealing designs achieving good economic and environmental performance.

2. Problem statement

The problem under study is summarized in Fig. 1. A three-echelon supply chain is considered (production, storage, transportation to final consumers). Several sources of agave (i.e., the plant used to make tequila) are available, including the stalks from the harvested places and the residues generated by the tequila industry during the production of tequila. Potential places to install the central and distributed bioethanol processing facilities are available. The optimization model must determine the optimal location and size of such facilities. The problem then consists of determining the distribution for the agave residues, the required number, location and capacity of the biorefineries (along with the technology used in each of them), and the distribution of products and feedstocks.

Fig. 2 depicts the superstructure of alternatives associated with the problem described above. This superstructure is a mathematical representation that includes all the potential places for feedstocks, biorefineries and markets. Different transportation options are also considered (i.e., truck, train and pipe, depicted in Fig. 2 by colors red, black and blue, respectively, in the web version). The

Download English Version:

https://daneshyari.com/en/article/10688175

Download Persian Version:

https://daneshyari.com/article/10688175

Daneshyari.com