BIOMASS AND BIOENERGY 67 (2014) 304–311

Available online at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

Life cycle assessment of corn- and cassava-based ethylene production

Jinglan Hong [a,*], *Yanlu Zhang* [a], *Xu Xu* [a,b], *Xiangzhi Li* [b,*]

[a] *Shandong Provincial Key Laboratory of Water Pollution Control and Resource Reuse, School of Environmental Science and Engineering, Shandong University, Jinan 250100, PR China*

[b] *School of Medicine, Shandong University, Jinan 250012, PR China*

ARTICLE INFO

Article history:
Received 8 June 2012
Received in revised form
13 May 2014
Accepted 16 May 2014
Available online

Keywords:
Life cycle assessment
Uncertainty analysis
Corn
Cassava
Ethylene

ABSTRACT

A life cycle assessment was performed to estimate the environmental impact of corn- and cassava-based ethylene production. An uncertainty analysis based on Taylor series expansion was conducted to confirm the results and add credibility to the study. Both corn- and cassava-based ethylene production significantly contributed to respiratory inorganics, land occupation, and global warming scores, as well as increased the adverse environmental impact of non-renewable energy. The uncertainty analysis results show that cassava-based production has more significant effects on dominant categories than corn-based production, except for land occupation. Increasing the energy and crop consumption efficiency, decreasing the road transport distance, and using natural crop drying are highly recommended to reduce the adverse effect of corn- and cassava-based ethylene production on the environment.

1. Introduction

Ethylene is an organic compound used in the production of synthetic resin, fiber, rubber, coatings, adhesives, and surfactants polymer. Ethylene production in China has grown significantly because of vast economic development and rapid urbanization. Approximately 10.3 and 16.2 Mt of ethylene were produced in China in 2008 and 2013, respectively, exhibiting a rapid annual increase of 9.5% within a span of only five years [1]. The growth in production increased the demand for energy, because ethylene production alone accounts for 30% of the energy consumption of the chemicals industry [2], which recently accounted for 13% of the total energy consumption in China [3]. The rate has an important implication on global carbon reduction and energy savings because China is one of the world's largest global warming gas emitters and energy consumers [4].

Biorefinery technology for fuel, power, and chemical production is being developed globally to reduce energy consumption and greenhouse gas emissions significantly [5–7]. However, biorefineries may have other environmental effects (e.g., eutrophication, acidification, land use, carcinogenics) because of the fertilizers and pesticides they require. Accordingly, reliable environmental assessments must be conducted to identify the environmental impact of biorefineries.

Life cycle assessment (LCA) is a quantified analytical tool extensively applied to biorefinery technologies [5,6,8,9]. However, few LCA studies have been performed on the environmental effects of biomass-based ethylene production in China, and very few have discussed the uncertain propagation of biomass-based ethylene globally, which is essential for the appropriate use of LCA in decision making. Most LCA studies in China on biomass-based ethanol production, a feedstock

* *Corresponding authors*. Tel.: +86 531 88362328; fax: +86 531 88382021.
E-mail addresses: hongjing@sdu.edu.cn (J. Hong), xiangzhi@sdu.edu.cn (X. Li).
http://dx.doi.org/10.1016/j.biombioe.2014.05.014
0961-9534/

for ethylene production, mainly focus on energy and global warming potential categories [9,10]. Ethylene production via the dehydration of ethanol, an old process practiced before the 1950s when petrochemical-derived ethylene became widespread, remains widely applied in China. The environmental impact of this process needs to be better characterized to avoid the pollutant transfer and secondary pollution caused by biorefinery technologies.

This study aims to introduce a Chinese biomass-based ethylene production database to address the aforementioned needs, as well as to identify methods to improve the energy efficiency, use of raw materials, and processes in the Chinese biomass-based ethylene industry. LCA was used to estimate the environmental impact of biomass-based ethylene production. Two alternative ethanol production scenarios, corn-based and cassava-based, were tested for ethylene production. Uncertainty analysis based on the Taylor series expansion was conducted to confirm the results and add credibility to the study.

2. Materials and methods

2.1. *Functional unit*

In this study, corn-based and cassava-based ethylene production scenarios were assessed using life cycle assessment method. The functional unit is 1 tonne of ethylene production. All inputs and outputs (e.g., raw materials and energy consumption, transport, waste disposal, emissions levels) are based on this functional unit.

2.2. *System boundaries*

Fig. 1 presents system boundary which are set using a cradle-to-gate approach. Corn-based and cassava-based ethylene production scenarios were studied. Co-product allocation based on product mass was performed. Processes included in present study are summarized as follows:

1) Corn and cassava production at farm
2) Ethanol and ethylene production
3) Machinery drying
4) Road transport
5) Waste treatment
6) Material and coal based energy production
7) Energy recovery on site

The infrastructure for ethylene production was excluded because of the lack of detailed information in the present ethylene production site.

2.3. *Methodology*

LCA evaluation is calculated using the IMPACT2002+ method [11], which consistently treats fate exposure in multimedia modeling. This method is a combination of results of the IMPACT2002 model for human health [12], Eco-indicator 99

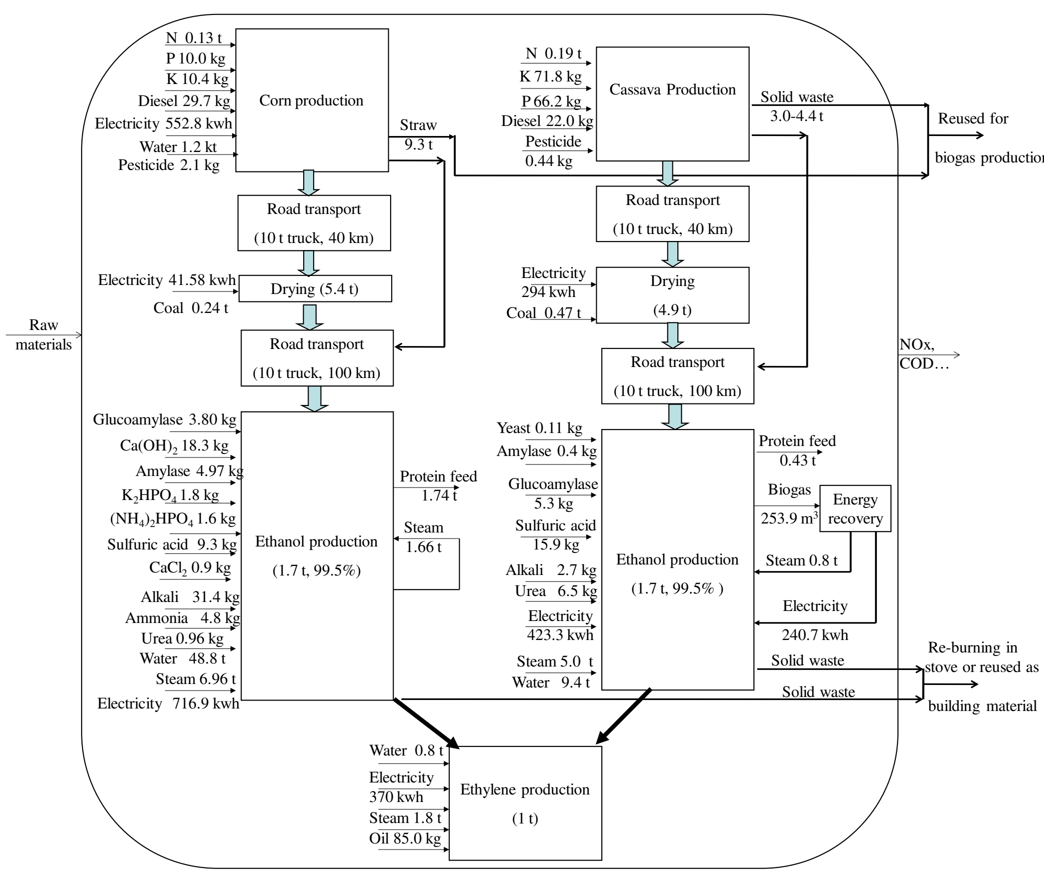

Fig. 1 – System boundary and material flow.