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Feasibility study of microalgal and jatropha biodiesel production plants: Exergy analysis approach

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ABSTRACT

The exergy analyses performed in this study are based on three thermodynamic performance parameters namely exergy destruction, exergy efficiency and thermodynamic improvement potentials. After mathematical analysis with Aspen Plus software, the results showed that 64% and 44% of the total exergy content of the input resources into microalgal methyl ester (MME) and jatropha methyl ester (JME) production plants were destroyed respectively for 1 ton of biodiesel produced. This implies that only 36% and 56% (for MME and JME production plants respectively) useful energy in the products is available to do work. The highest and lowest exergy destructions were recorded in the oil extraction units (38% and 39% of the total exergy destroyed for MME and JME plants respectively) and transesterification units (5% and 2% of total exergy destroyed for MME and JME plants respectively) respectively for 1 ton biodiesel produced. Since sustainable biodiesel production depends on cultivation of feedstock, oil extraction and transesterification processes, exergy analysis which is carried out on only the transesterification unit cannot justify the thermodynamic feasibility of the whole biodiesel production plant unless a complete thermodynamic assessment has been done for the whole plant. Thus, according to this study which considers all the biodiesel production processes, MME and JME production plants are not thermodynamically feasible.

1. Introduction

Though liquid fuel such as gasoline, petro-diesel etc., is reported to be consumed more than any other fuel in the world, the 2010 global production or supply of crude oil (of about 72 million barrels/day) was less than the global demand (about 86 million barrels/day) [1]. Again, the peak of extraction of crude oil is predicted to occur in 2047 [2] implying that world's energy security based on liquid fossil fuel cannot be completely assured in the next 50 or less years.

Biodiesel, a non-exhaustible liquid biofuel therefore presents a better option to replace fossil based liquid fuel in the near future. Microalgae have significantly higher areal productivity (between 58,700–136,900 L/ha/year) [3] and their growth in saline media or in photobioreactors on large scale do not compete with agriculture for the very limited land and fresh water resources. By the year 2009, the number of companies involved in the development and implementation of algae biofuels technologies had increased to over 60 worldwide [4]. Biodiesel from *Jatropha curcas* oil presently forms about 50% of the total share of world's biodiesel production with over 300 companies involved [4]. These data illustrates the potential of microalgal and jatropha biodiesel as reliable sources of liquid biofuels to replace fossil based liquid fuel in the near future. Thus, the production processes of the methyl esters from these feedstocks must well be analysed with respect to resource consumption in order to ascertain the sustainability of the production plants and suggest improvements for their performances.

Nowadays, sustainable energy development has been the issue of discussion concerning the production of biofuels since fossil fuel is consumed in large quantities during biofuels production. Energy resource consumption has been found to be the principal cost of many energy-intensive chemical processes such as biodiesel production [5] from jatropha and microalgae. Due to this, the vision of energy-intensive process designs has been to reduce energy consumption so as to decrease its capital and operational costs. The

Abbreviations: JME, jatropha methyl ester; MME, microalgae methyl ester; UCOME, used cooking oil methyl ester; LABEN, labour energy (MJ/ha); LABOUR, number of working labourers; TIME, operating time (h); AREA, operating area (ha); LABENF, labour energy factor (MJ/h); ED, specific direct energy use (fuel) for field operation (MJ/ha); AFU, average fuel use per working hour (l/h); PEU, specific energy value per litre of fuel (MJ/l); RU, runs (number of application in the considered field operation).

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