Influence of biofuels production on the climate change

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Abstract: This work technically analyzes the biodiesel production from palm, bioethanol production from sugar cane and biotechnological hydrogen productions as well as the GHG emissions associated with the feedstocks production and processing. For this purpose modeling and simulation was used in combination with ASPEN PLUS software and Ecoinvent database for GHG calculations derived from material and energy balances obtained by process simulation. Different critical stages were simulated and analyzed: fertilizers production and use, biofuel production and pesticide production. Results indicated the importance of considering different stages and how these inclusions or exclusions affect GHG balances. For instance, fossil fuel used for industrial stage in bioethanol production increase GHG emissions eighteen-fold. According to this work, bioethanol from sugar cane was the system with largest emissions while biodiesel from palm oil had lowest emissions.

Keywords: *Green House Gas emissions, Climate change, Biodiesel, Bioethanol, Biohydrogen.*

1. Introduction

Current energy situation has reached a critical point according to different points of view: economical, social and environmental aspects [1]. It is necessary to find substitutes for conventional fuels in order to avoid environmental and social adverse effects derived from its non-renewability [2-6]. Usually, the best alternative to conventional fuels should be a substance with high calorific value, availability, easy production, transport and use. However, last is also limited by several social and environmental policies which can frustrate the possibilities to find quick and satisfactory solutions [6-7].

In the last decades it has been found as possible solution the development of biofuels as replacement for fossil fuels [8,9]. The biofuels are produced from different types of biomass and they are subject of exhaust investigations [5,8]. Today, biofuels are considered to be bioethanol, biobutanol, biodiesel, biogas and biohydrogen [9].

Bioethanol and biodiesel have been thoroughly investigated worldwide and a proof of this is the industrial plants available in America, Asia and Europe [7]. Bioethanol is produced by fermentation of sugars, starch crops or lignocellulosic materials [10]. Biodiesel is produced by extraction and methyl or ethyl- transesterification of oils contained in oleagineous plants or waste oils [4,8]. Regardless development level reached for these fuels it is suggested, but not unequivocally proven, the connection to global warming because GHG emissions with their production and use, specifically in agricultural stage [1-3,5,8,11,12]. Scientists hold unprecedented debate relating to assessment of environmental aspects in biofuels production. Many studies have been made, but their results have not helped to provide strong response and quantitative information about relationship between biofuels production and use and climate change using global warming potential [2,5,8].

Hydrogen is an energy source of recent consideration although it is a very important industrial material and its heating value and clean combustion are already well known [13-15]. Extensive investigation for this fuel use is a relatively new issue [16,17]. Different researchers focus new goals in finding biological pathways for competitive hydrogen production [16,18]. Currently, there is no a known biohydrogen production technology competitive compared to other fuels[19-22]. The present work analyses for biohydrogen case the environmental assessment for dark fermentation technology.

2. Methodology

Biofuel assessment was carried out through quantification of GHG emissions associated with biofuel production. Input information is listed in table 1. Figure 1 shows generic process flowsheet for biofuels analysis. Analysis was separated in two parts:

- Agricultural stage: This phase contains all GHG emissions associated with biomass growth. It was assumed that the respiration process during the growth of biomass absorbs CO_2 emissions from biofuel combustion. Considered N-fertilizer was ammonium nitrate, P-fertilizer was triple superphosphate and K-fertilizer was potassium chloride. The used pesticide was carbofuran. During the mechanical harvest, the fuel used was diesel. 1.325% N-fertilizer was emitted as N_2O to the atmosphere [5].
- Industrial stage: Where biomass is converted to biofuel. GHG emissions were calculated from mass and energy balances of the biofuel production from biomass using Aspen Plus ® and Matlab® Softwares following rigorous models and synthesis procedures as described in [31,32]. Production rates were based mostly on Colombian biofuels production.

The functional unit was megajoule of energy per biofuel produced. Comparisons between studies are made using the work with lowest GHG emissions for each biofuel. Below are described the systems studied.

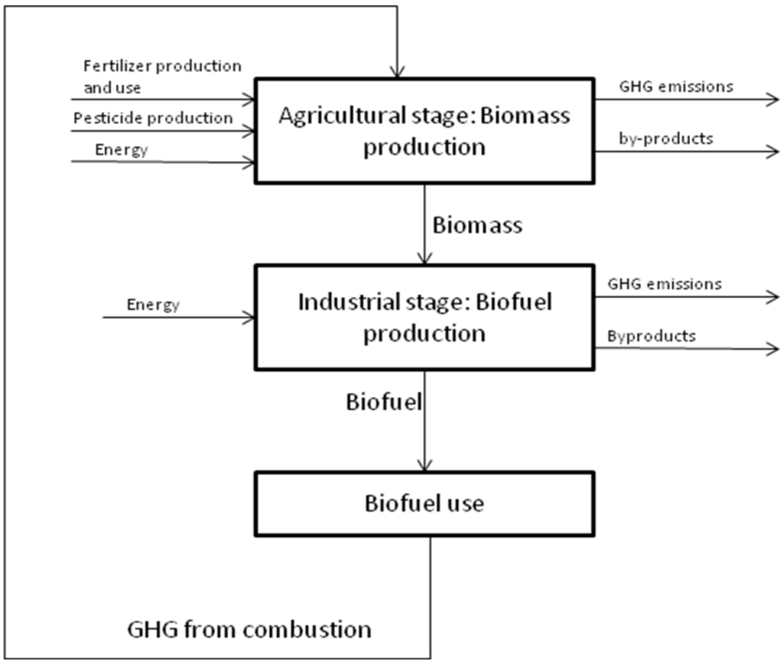

Fig 1. Process included in this work for all biofuels studied

2.1. Bioethanol from sugarcane

Information for agricultural stage was obtained from Ecoinvent database [33], which includes emissions from: fertilizer production, fertilizer use, pesticide uses, harvesting, 20% mechanical harvest. Industrial stage phase was simulated using Aspen Plus® software. Conversion technologies were fermentation, distillation and dehydration with molecular sieves.

Table 2. Values used in this study

Parameter	*Value*	*Reference*
Production rate (L/yr). Bioethanol from sugarcane	*52,800,000*	
Production rate (L/yr). Biodiesel from palm	*33,400,000*	
Production rate (L/yr). Biohydrogen from molasses	*9,504,000*	
N-P-K fertilizer. Palm. (kg/Ha)	*41.2-147.8-804*	*[23]*
Pesticide. Palm. (kg/Ha)	*1.2*	*[23]*
Factor emissions for N-fertilizer ($KgCO_2e/KgN$)	*8.66*	*[24]*
Factor emissions for P-fertilizer ($KgCO_2e/KgP_2O_5$)	*2.1*	*[24]*
Factor emissions for K-fertilizer ($KgCO_2e/KgK_2O$)	*0.90*	*[24]*
Factor emissions for pesticide ($KgCO_2e/Kg$)	*12.98*	*[24]*
Factor emissions for agricultural stage. Sugarcane. ($KgCO_2e$/Kgsugarcane)	*0.028*	*[24]*
Factor emissions for electricity ($KgCO_2e/Kwh$)	*0.306*	*[25]*
Isothermal compression efficiency (biohydrogen) (%)	*65*	*[20]*
Recuperation percentage of biofuel (%)	*99*	
Compression pressure (biohydrogen) (atm)	*200*	
Maximum hydrogen production rate (ml H_2/h)	*13.7*	*[26]*
Lag-time (h)	*4.04*	*[26]*

2.2. Biodiesel from palm

GHG emissions in agricultural stage were considered for: fertilizer production and use, pesticide production and manual harvest. Location of the production plant was considered close to the field. Industrial phase was simulated using Aspen Plus ® S oftware and the conversion technology included oil extraction followed by transesterification with methanol, neutralization and distillation.

2.3. Biohydrogen from molasses

Agricultural phase was considered to be the same as sugarcane case. Molasses were obtained as co-product from sugar industry. Information required was taken from Ecoinvent database. Biohydrogen was produced by dark-fermentation using mixed culture for their production. Data for industrial phase was calculated using Matlab® software and the emissions corresponded to fermentation, separation and compression steps.

3. Results and Discussion

Figure 2 summarizes GHG emissions associated to biofuel production for each feedstock. According to the Figure 2, biodiesel from palm was the system with the lowest GHG emissions for all stages, while bioethanol from sugar cane showed the biggest GHG emissions in its industrial phase. The total GHG emissions for bioethanol were eight-fold related to biodiesel and total GHG emissions for biohydrogen is twice bigger that biodiesel.

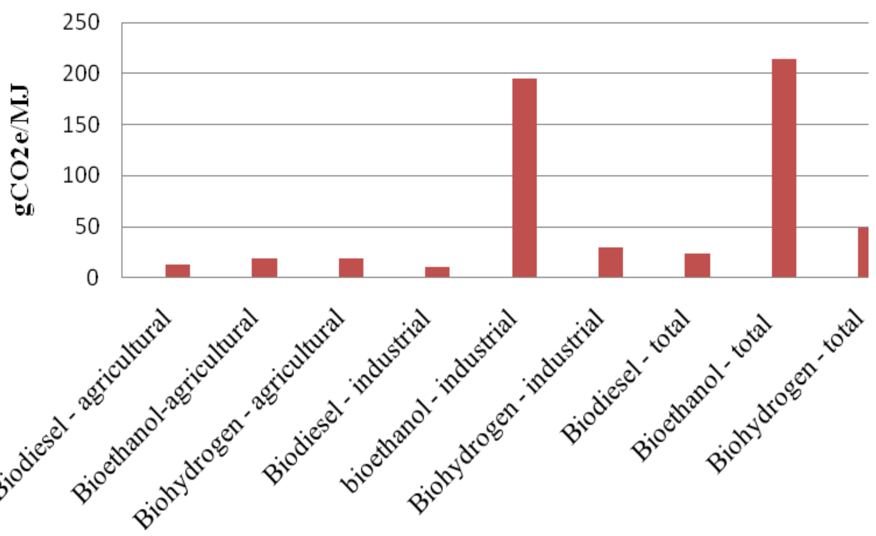

Fig. 2. GHG emissions for each system studied

Figure 3 shows emissions from different works. Macedo et al [27] and Smeets et al. [28] calculated emissions for bioethanol from sugarcane in Brazil; Yee et al [29] calculated emissions for biodiesel from palm in Malaysia and de Souza et al [23] studied biodiesel from palm oil in Brazil; Manish and Banerjee [30] estimated emissions for biohydrogen from sugarcane juice in India. In figure 3 differences between all studies are observed, even in works considering the same biofuel production. Taking as basis work for the bioethanol comparisons the one of Smeets et al. [28], GHG emissions obtained by Macedo et al [27] were almost twice bigger while for this work were eighteen-fold bigger. Based on de Souza et al [23] work for the Biodiesel comparisons, GHG emissions obtained by Yee et al [29] were more than twice bigger while for this work was one-third bigger. GHG emissions for biohydrogen in this work were eleven-fold bigger than that obtained by Manish and Banerjee [30]. Below, the obtained results are discussed in detail for each biofuel.

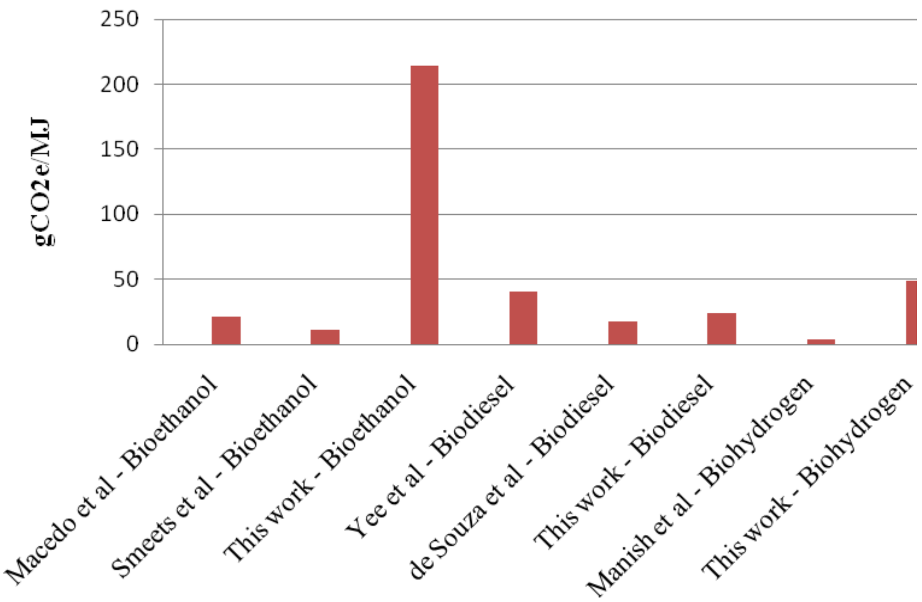

Fig. 3. GHG emissions for different studies

3.1. Bioethanol

Smeets et al. [28] study, Macedo et al. [27] study and this work differ in GHG emissions values. Smeets et al. [28] study reported lowest GHG emissions but in this paper were obtained the highest emissions. Macedo et al. [27] is considered a rigorous analysis for agricultural stage and took into account sugarcane burning. However, these authors assumed a self-sustainable plant, which implied zero GHG emissions for industrial stage. This assumption led to obtain low values in this stage.

In the case of Smeets et al. [28] study, it was similar to the Macedo et al [27] study. They assumed a global approach for bioethanol impact and their results were similar to that of Macedo et al [27]. In this work, emissions of industrial phase are bigger because alcoholic fermentation generates large amount of CO_2. Comparison of these works is significant because were made in Brazil and Colombia, countries with similar conditions. Macedo et al. [27] study reported twice GHG emissions and this work report eighteen fold GHG emissions compared to Smeets et al. study. Industrial stage proves to be very significant because of CO_2 emissions from fermentation. The CO_2 release is a problem to be stated seriously specially when land use change applied (and biomass per hectare is reduced).

3.2. Biodiesel

Yee et al. [29] study is very complete. They considered for agricultural stage: planning, nursery establishment, site preparation, field establishing, field maintenance, harvesting, and collection and replanting; milling stage: Fresh Fruit Bunches extraction, stripping and oil extraction. For industrial phase: oil conversion with methanol.

De Souza et al. [23] considered for agricultural stage: Fertilizer, pesticides, transport and manual harvest. For industrial phase: electricity and diesel use, methanol and catalyst; co-products are used for energy cogeneration.

De Souza et al. [23] study showed the lowest emissions while Yee et al. [29] reported the biggest. In this work were obtained intermediate values for emissions. Yee et al. [29] study, considered the largest secondary processes and, therefore, highest GHG emissions were obtained. Nevertheless, Yee et al [29] study was made for Malaysia while de Souza et al. [23] study was performed for Brazil. Using Colombian conditions then is more significant to compare de Souza work with the developed in this work. Taking as reference de Souza et al [23] study, Yee et al. [29] obtained 132% larger GHG emissions and this work reports 35% larger GHG emissions. Differences between De Souza et al. [23] study and these works are due to cogeneration and waste uses. Last, because these aspects change energy balance, and therefore, emissions values and rates.

3.3. Biohydrogen

GHG emissions for this work were around tenfold bigger than that obtained by Manish and Banarjee [30] because they considered exclusively industrial aspects and the input was sugarcane without any reflection of agricultural phase.

3.4. Final analysis

Agricultural stage generates significant GHG emissions because nitrous oxide and methane are emitted into the atmosphere and these gases have a Global Warming Potential (GWP) of 300 and 15 times more than carbon dioxide, respectively. Methane and nitrous oxide come from fertilizers and pesticides application, explaining the importance of their application rate in biofuels environmental assessment. Moreover, fertilizer production methods are essential for environmental evaluation. This fact explains high emissions factors (table 1) for fertilizer production using conventional technologies.

GHG emissions for biodiesel production were greater for agricultural stage while industrial stage emissions were greater for hydrogen and bioethanol production. This is due to fermentation emissions that strongly influenced the obtained values. Carbon substrate is inadequate, almost from environmental point of view, and traditional biochemical pathways promote high emission levels.

4. Conclusions

Results indicate that the most efficient system, in terms of GHG emission balances, was biodiesel production from palm oil while the system with highest emissions was the bioethanol production. Alcoholic and acetic fermentation proved to be of great influence on emissions balances and demonstrating a number of restrictions if compared to other studies. According to results presented in this paper, bioethanol from sugarcane contribute more to climate change that biohydrogen from sugarcane and biodiesel from palm oil.

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