Energy for Sustainability 2013
Sustainable Cities: Designing for People and the Planet
Coimbra, 8 to 10 September 2013

A COMPARATIVE LIFE CYCLE ASSESSMENT OF BIODIESEL FROM SOYBEAN OIL AND BEEF TALLOW IN BRAZIL

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Keywords: Biodiesel, Life Cycle Assessment, Soybean Oil, Beef Tallow

Abstract *Soybean oil (SO) and beef tallow (BT) are the main feedstock for biodiesel production in Brazil. The main goal is to present a comparative Life Cycle Assessment (LCA) of biodiesel produced in Brazil using SO and BT, considering methylic and ethylic routes (MR and ER). A life cycle (LC) inventory and model were performed for the SO and BT biodiesel systems based on Brazilian data. The LC models include transesterification and transportation; land use change (LUC), soybean cultivation, oil extraction, for SO biodiesel and beef production and slaughtering, for BF biodiesel. The functional unit adopted was 1 MJ of biodiesel. Environmental Life Cycle Impact Assessment (LCIA) was performed based on the ReCiPe Midpoint method for the different categories. For allocation was considered the economic criteria. As a result it was observed a significant contribution for feedstock in all LCIA categories and BT biodiesel had the greater impact when compared with SO due to the high contribution of beef production. For soybean production the results show that CC impacts greatly depend on the LUC. It was not observed great differences in MR and ER.*

1. INTRODUCTION

In Brazil, the federal government created in 2004 the National Biodiesel Production and Use Program (PNPB), to promote the sustainable production and use of biodiesel and nowadays the blend of biodiesel with diesel oil is 5%, in volume basis (B5) [1]. The program started aiming to use vegetable oils produced in semi arid regions in Brazil, which correspond to the poorest regions in the country, with a significant social dimension. However, difficulties with capacity building of the local small farmers, as well economic barriers due to other end uses of castor (and other) oils have made these options fail. Current most of biodiesel production in Brazil is from soya and animal fat, since these are by-products of the production of animal feed and meat for export. To analyze these environmental impacts for these two main crops used for biodiesel, it is crucial to establish the characterization of the production chain. In this context the project BIOACV (Comparação da Avaliação do Ciclo de Vida de Biodiesel Produzido a partir de Óleo de Soja e Gordura Animal via Rotas Metílica e Etílica / Comparison of Life Cycle Assessment of Biodiesel Produced from Soybean Oil and Beef Tallow by Methylic and Ethylic Routes) was developed to evaluate the environmental impacts in the biodiesel production from soya and animal fat (beef tallow), comparing the results both for methylic and ethylic routes. The main results of this project are presented here.

2. BIODIESEL PRODUCTION IN BRAZIL

Biodiesel production in Brazil grew from 736 m3 in 2005 to around 2.7 million m3 in 2011 [2]. The regions with a higher nominal capacity (produced over 76% of the biodiesel in Brazil) are Center-West (states of MatoGrosso, MatoGrosso do Sul, Goiás and Distrito Federal) and the South Brazil (states of Rio Grande do Sul, Paraná and Santa Catarina).

Soybean oil is currently the main feedstock of biodiesel production in Brazil. In 2010 this raw material was responsible for 82% of biodiesel production [3]. The other main raw material is are beef tallow (17%). Since 2001/02, the soybean cultivated area grew about 53% [4][i]. As discussed in [5], most of soya expansion was due to animal feed exports.

Beef tallow is a by-product from the beef meat industry. In 2011, a production of more than 430 thousand (metric) tons of beef tallow was calculated, assuming that each slaughtered cattle provides an average of 15 kg of usable tallow [6], [7]. Beef tallow consumption in Brazil almost doubled in the last fourteen years (since 1997), but little information is available about the various uses of tallow. One of the reasons is that tallow has been considered a low-value co-product of the cattle beef industry and, historically, the main consumer of tallow is the soap industry.

The main driving force behind the use of soya and tallow as feedstock for biodiesel in Brazil is the low price of raw material, since soya oil and beef tallow are by products. There is also the fact that Brazil has the second largest cattle herd in the world [6]. Biodiesel from beef tallow presents advantages in some properties (cetane number and stability), compared with biodiesel produced from soybean oil [8] but some important limitations, namely viscosity,

[i] North and Northeast are the regions where the cultivated area is lower but the area increased about 395% and 90% in the last 10 years.

which does not allow 100% production from beef tallow, as concluded from field visits for this study.

3. BIODIESEL PRODUCTION USING METHANOL - ETHANOL

Regarding biodiesel production, it is important to identify opportunities for using bioethanol in the transesterification process. In 2010, more than 97% of the biodiesel produced in Brazil used methanol to produce biodiesel (a total consumption of about 302 thousand m^3), and only two companies used (anhydrous) bioethanol [3]. Chemically, the methyl and ethyl routes are very similar; however, in practice there are differences between these two routes, namely reaction time, catalyst amount and reaction temperature. According to [9], difficulties in the separation phase are a major barrier in ethyl ester production for any feedstock used. Beyond these technical aspects, the main limiting factors for the implementation of ethyl transesterification are the price of bioethanol. Brazil has the cheapest bioethanol price in the world but is strongly depend on the geographical location and on fluctuations over the time. On the other hand, methanol prices are relatively constant along time, but witnessed a sharp increase recently.

4. THE BIOACV PROJECT

In the BioACV Project it was analyzed (through LCA methodology) the environmental impacts from soya and beef tallow biodiesel, comparing the two routes (methylic and ethylic). One of the main challenges was to develop models that could represent processes in use in Brazil (or those quite similar to those being used), not only in the field assessment (primary data) but also when using secondary data. The models adopted considered 100% of soy bean oil and 100% of beef tallow for both routes. It was considered the production of 1 MJ of biodiesel in all scenarios. Only a few LCA studies were performed for soybean and tallow biodiesel produced in Brazil, focusing on energy and GHG balances [10], [11], [12], and more recently on impacts resulting from water (consumption and pollution), land use and LUC [13], [14], [15], [16].

5. RESULTS FROM THE BIOACV PROJECT – ENVIRONMENTAL IMPACTS FROM BIODIESEL PRODUCTION IN BRAZIL

For each type of biodiesel the environmental impacts were evaluated according to the LCA methodology, using the SIMAPRO software adapted to the Brazilian energy matrix (regarding the indirect effects). In the Figure 1 below the comparison of the four types analyzed in the project is presented considering MC – climate change, Tox – toxicity, AC – acidification, EU – eutrophisation, Oc – land use, DCF – depletion of fossil fuels.

From the Figure 1, it can be seen the biodiesel from beef tallow presented the highest impacts compared to soya-based biodiesel. The highest environmental impacts are due to the systems of cattle raise in the country, and to the low efficiency, based in an extensive production system (less than 1.0 head per hectare). In the case of toxicity it was found a smaller difference when compared the two raw-materials. The soya bean agricultural production showed high figures due to the high use of pesticides.

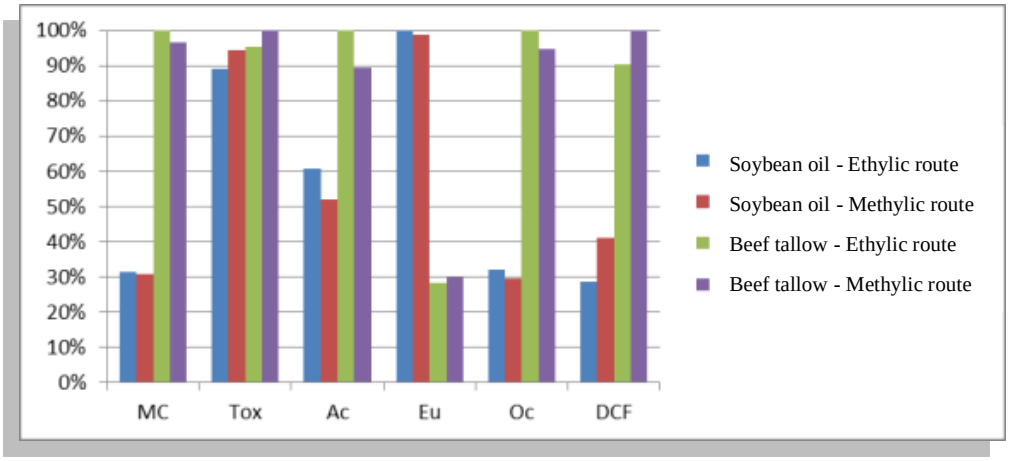

Figure 1. Comparison of the indicators for the different categories of impact for each type of biodiesel [17]

If carbon emissions from land use change in soya agricultural production are not considered, GHG emissions were reduced by 70%. Also when it is excluded the environmental impacts of the cattle raise and slaughtering sub-systems, all impacts were reduced significantly, showing the high impact of such processes.

In [16] the environmental impacts related to GHG emissions from soya-based biodiesel were discussed, considering the different emissions depending on how the by-products are allocated (in mass, energy or economic basis). But in all cases the main impact on GHG emissions are from land use and from the use of fertilizers and fuels. The higher contribution for GHG emissions from land use is from Mato Grosso state (64-74% from total GHG emissions).

As shown in these instructions, the first page has one header and the header of the remaining pages consists of the authors' names. The authors are kindly asked to include them, formatted according to these instructions. Note that the headers are outside the print area (see Figure 1).

Acknowledgements

The authors are grateful to CNPq (BIOACV Project– 558733/2010-7) for the financial support and are also grateful to FCT/CAPES for the recently approved project in 2013 (350/2013). The research presented in this article was also supported by the Portuguese Science and Technology Foundation (FCT) projects: MIT/SET/0014/2009 and PTDC/SEN-TRA/117251/2010. Érica Castanheira gratefully acknowledges financial support from FCT, through grant SFRH/BD/60328/2009.

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