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Life cycle assessment of biodiesel in Spain: Comparing the environmental sustainability of Spanish production versus Argentinean imports

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ABSTRACT

The spread of biofuels has generated controversy at international, national and regional levels due to the environmental, economic and social impacts that its production and consumption can cause. Recently, the Spanish government has been promoting the production of biodiesel in industrial plants located in Spain and other EU countries. These developments are expected to stimulate the cultivation of rapeseed in the EU to the detriment of extra-EU imports of biodiesel mainly based on soybean oil from Argentina, which has been one of the main suppliers of biodiesel in Spain for years. As a result, the environmental impacts produced throughout the life cycle of biodiesel consumed in Spain could be radically affected. In this context, the environmental impacts of biodiesel produced in Spain and Argentina with rapeseed cultivated in Spain and soybean cultivated in Argentina were compared under certain growing conditions using life cycle assessment (LCA). Consequential and attributional approaches were compared under the ReCiPe method to test potential biases. The results showed that the biodiesel produced with Argentinean soybean oil had fewer environmental impacts than biodiesel produced with Spanish rapeseed oil. Seed production (and fertilization) was the process (and sub-process) that generated the greatest environmental burdens, and it is an area in which improvement is necessary in order to increase sustainability, particularly with regard to Spanish rapeseed-based biodiesel.

Introduction

Environmental issues have been a key driver for the establishment of policies to promote biofuels in the EU. The European Energy Directive 2009/28/EC (EU-RED) on the promotion of the use of energy from renewable sources (European Commission, 2009), which established a 10% target for energy from renewable sources in transport by 2020, restricts public support only to those biofuels and bio-liquids, produced within or outside the EU, which meet a series of sustainability criteria. In its environmental dimension, it includes requirements for GHG emissions, biodiversity, land use changes and good farming practises. These same criteria were adopted into Spanish law by Royal Decree 1597/2011 (MITYC, 2011). The sustainability criteria set by these regulations mainly affect the agricultural phase in the production of raw materials for use in biofuels. This means that farmers play a crucial role in biofuel sustainability. However, sustainability requirements were not needed in order to comply with biofuel targets in Spain until the 1st January 2016, because of the moratorium on biofuel sustainability established by Royal Decree-Law 4/2013 (Jefatura del Estado, 2013).

In 2011, 45.3% of biodiesel consumed in Spain was produced in Argentina (CNE, 2013), mainly with soybean crops (*Glycine max*), which were cultivated in extensive areas using monoculture techniques but adhering to the 'Round Table on Responsible Soy EU RED' (RTRS) scheme for demonstrating compliance with the sustainability criteria under the EU-RED Directive. By contrast, less than 2% of the total biodiesel consumed in Spain (produced both inside and outside Spain) was produced with rapeseed (*Brassica napus*) (CNE, 2013). In 2012, the Spanish government enacted Order IET/822/2012 (MINETUR, 2012a), and IET/2736/2012 (MINETUR, 2012b) which promotes biodiesel production in European plants. In 2014, the Spanish Ministry of Industry, Energy and Tourism approved an annual production of 4.8 million tonnes of biodiesel for 2014 and 2015 in 37 industrial plants located in the EU, 23 of which are in Spain (MINETUR, 2014). This has undoubtedly affected the biodiesel market, and consequently, the sustainability of biodiesel consumed in Spain. It has resulted in a decrease in imports

Abbreviations: 1,4-DCB, 1,4-dichlorobenzene; ALO, agricultural land occupation; ASME, Argentinean soy methyl ester; CC, climate change; EU-RED, European Energy Directive 2009/28/EC; FD, fossil depletion; FE, freshwater eutrophication; FU, functional unit; GHG, greenhouse gas; HDPE, high-density polyethylene; HT, human toxicity; LCA, life cycle assessment; LCI, life cycle inventory; LDPE, low-density polyethylene; ME, marine eutrophication; OD, ozone depletion; POF, photochemical oxidation formation; RME, rape methyl ester; RTRS, Round Table on Responsible Soy; SME, soy methyl ester; SRME, Spanish rape methyl ester; SSME, Spanish soy methyl ester; TA, terrestrial acidification.

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and an increase in domestic production (Fig. 1). In fact, biodiesel domestic production has already led to a significant expansion of rapeseed (*B. napus*) oil production in Europe in recent years (Malins, 2013). As a consequence, in 2013, the consumption of soy-based biodiesel in Spain decreased by 18.6%, whereas the consumption of rape-based biodiesel increased by 9.7% (CNMC, 2015a).

As a result of new biofuel policies, in future years, a notable increase in first generation biodiesel is expected in Spain (CNMC, 2015b), as well as an increase in rapeseed production (MAGRAMA, 2015a). Therefore, it seems that great uncertainty surrounds the future of sustainable biofuels used in Spain.

As Milazzo et al. (2013) suggest, only demonstrably sustainable feedstock, which complies with sustainability criteria, should be used and promoted by governments in biodiesel production. Therefore, we believe that an in-depth analysis is essential to eliminate uncertainty regarding biodiesel sustainability in Spain so that governments can promote the most sustainable feedstock. Life cycle assessment (LCA) is a widely used technique to analyse the environmental impacts of goods or services. In the scientific community, there is a broad consensus on this being one of the most appropriate methods for assessing environmental impacts associated with the production of biofuels (Requena et al., 2011). LCA allows for the objective comparison of environmental impacts that could potentially be caused by two or more products used for the same purpose. It can be conducted throughout the whole life cycle of a product or service, from production through to consumption, or just for a certain part of the life cycle.

LCA has recently become a key methodology in bioenergy governance, seeking to incorporate externalities that have major implications for long-term sustainability (McManus et al., 2015). It has been used to guide public decision-making toward sustainable production and consumption of biofuels in countries such as Italy (Blengini et al., 2011; Fazio and Monti, 2011) or Malaysia (Yee et al., 2009). The impact of EU biofuel policies on agricultural production, imports and changes in land use has also been examined both at international level (Banse et al., 2011) and in Spain (Lechon et al., 2011). However, most previous LCA studies for rapeseed-based biodiesel do not delve into the specific conditions of production, such as the cultivation techniques or geographical variability (farming locations), which could change the results significantly (Kim and Dale, 2009). This is an additional advantage of the present study, since edaphological and climatic data from the specific locations have been incorporated in the LCI (life cycle inventory) to assess the potential environmental impacts. The same is true for studies of soybean-based biodiesel LCA that have been carried out to date (e.g., Hou et al. (2011) and Panichelli et al. (2009) used mean data in the LCIs for countries such as China and Argentina, respectively). Moreover, most previous studies were limited to energy and greenhouse gas (GHG) emissions, thus excluding other environmental impacts that are relevant throughout the life cycle of the products.

With all this in mind, the objective of this study is to compare the environmental impacts [climate change (CC), ozone depletion (OD), human toxicity (HT), photochemical oxidation formation (POF), fossil depletion (FD), terrestrial acidification (TA), freshwater and marine eutrophication (FE and ME), agricultural land occupation (ALO) and natural land occupation (NLO)] of Argentinean soybean-based biodiesel with biodiesel produced in Spain, both with Argentinean soybean oil and with Spanish rapeseed oil. In the assessment we take into account the specific cultivation techniques, transport of biodiesel or feedstock and geographical variability (Spain or Argentina) of biodiesel production. Only after analysing the environmental burdens of the different systems will it be possible to select the most efficient solutions for improving the sustainability of the biodiesel consumed in Spain. The ultimate aim of this study is to determine whether policies that have been recently enacted to promote biodiesel production in Spain are improving environmental protection, which is the main objective of the promotion of biofuels in the EU, or whether they are in fact having the opposite effect.

Material and methods

Goal and scope

The main objective of the study was to analyse the environmental burdens of biodiesel production systems in Spain in order to contribute to a more efficient design of policies which promote environmentally friendly biodiesel production systems.

The environmental effects of rapeseed-based and soybean-based biodiesel production for the Spanish market were calculated and evaluated using the LCA methodology for three alternative pathways:

A) Argentinean soy methyl ester (ASME): soybean-based biodiesel produced entirely in Argentina and exported to Spain.
B) Spanish soy methyl ester (SSME): soybean-based biodiesel produced in Spain (transesterification) using soybean oil imported from Argentina.
C) Spanish rape methyl ester (SRME): rapeseed-based biodiesel produced entirely in Spain.

The system boundaries included from the raw material extraction up to the factory gate. This study analyses the impacts generated in the cultivation of the raw materials (Argentinean soybean and Spanish rapeseed), grain screening and drying, oil extraction and refining, transportation (of soybean oil or biodiesel from Argentina to Spain) and biodiesel production (methyl transesterification). Therefore, in this study, all the input and output flows of materials and energy up to the factory gate were taken into consideration.

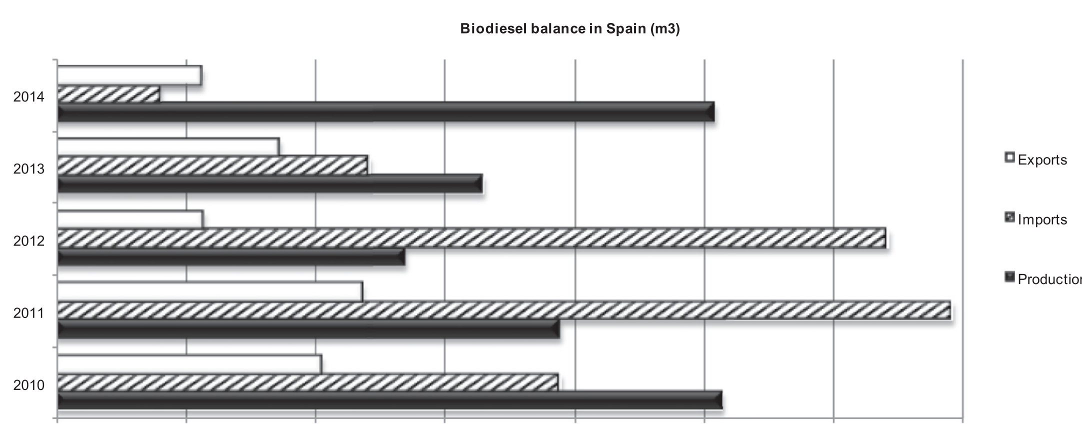

Fig. 1. Biodiesel balance in Spain: exports, imports and domestic production (m^3) Source: CNMC, 2015a.