From animal wastes towards green fuels: a sustainability assessment

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Accounting the necessity to increase the share of renewable energy in the transportation sector the research efforts are focused on the exploration of residual bio-based feedstocks for biofuels production. Towards this direction the exploitation of animal wastes as feedstocks aims to support the development of sustainable transportation biofuels production processes. Nevertheless, due to the high greenhouse gas (GHG) emissions saving potential the use of animal wastes for biofuel production, is anticipated to have significant environmental advantages compared to food grade biomass, avoiding the emissions from cultivation and the conflicts arisen due to the indirect land-use change. Furthermore, considering that the biomass feedstocks depend strongly on their availability and supply prices, as well the future studies will be oriented towards feedstocks derived from wastes or residues (Dufour *et al* 2012, Souza *et al* 2017).

Moreover, the environmental profile assessment of biofuel's production process is systematically examined in order to discern the optimal biofuel processes and identify the most sustainable fuels. Life Cycle Assessment (LCA) is an internationally standardized methodology that quantifies the environmental potential impacts associated with a product by collecting the inputs and outputs of the examined production process and evaluating the associated impacts with them by interpreting the results obtained in the inventory analysis based on the impact assessment categories (Dufour *et al* 2012).

Based on the above, animal wastes (tallow beef and lard-pig) are being currently systematically investigated as potential feedstocks for the production of 2nd generation biofuels via thermocatalytic process (Dimitriadis *et al* 2019). Additionally, the environmental profile of this process is being examined in an attempt to identify sustainable bio-based fuels.

The present study aims to attain the environmental characterization of green fuels production via animal wastes (tallow beef and lard-pig) catalytic hydroprocessing in terms of GHG emissions.

The goal of this LCA study is to perform a "cradle to gate" analysis evaluating the environmental profile of green transportation fuels via animal waste's catalytic hydrotreating. Particularly, the tallow beef and lard-pig were submitted to mild hydrotreatment rendering to the production of primarily diesel- and jet- range hydrocarbons after mild hydrotreating of both types of animal fats, as presented by Dimitriadis *et al* 2019. The LCA methodology was based on the four basic steps following the ISO 14040 including the goal, scope and boundary definition, the life cycle inventory analysis, the life cycle impact assessment and the results interpretation. Apart from the real experimental data collected for the study, literature data were also employed (IFEU 2014, JRC 2014).

The investigated production process examined in the study is shown in Figure 1 depicting the system boundaries encompassed, covering the animal wastes collection and transportation to the processing unit, the pretreatment and their conversion to fuels through catalytic hydrotreatment.

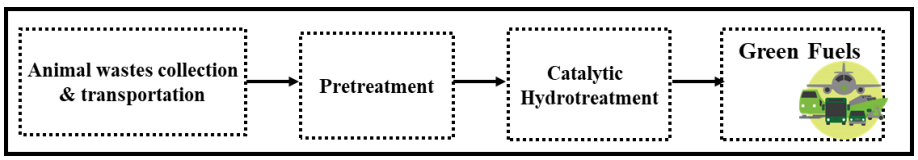

Figure 1. System boundaries of the examined production process

The functional unit was 1 MJ of the green fuels, whereas the inventory data sources employed for each of the investigated fuels were reproduced based on this functional unit. The impact category assessed in this study is the global warming potential (GWP) expressed in CO_2 equivalents (CO_2 eq-), since GHG emissions and energy use are of high interest in bio-based fuels LCA studies. The CO_2 eq- outlines the total effect of GHG emissions including related emissions of CO_2, CH_4 and N_2O.

The results are given in Table **1** and as it can be observed the estimated GHG emissions of the examined production process varied from 25-30 g CO_2 eq/MJ. The estimated GHG emissions are lower compared to the values reported in the literature for biodiesel production schemes incorporating variant biomass types (31-63 CO_2

eq/MJ for biodiesel produced via palm oil and soya beans, respectively, JRC, 2014). In general terms, the hydrotreatment process and its energy demands arose as the main source of GHG emissions impact.

Table 1. GWP emissions of the investigated production process

Process stage	g CO_2 eq/MJ
Animal wastes collection & transportation	~1-2
Pretreatment	~6-8
Hydrotreatment	~18-20
Total	~25-30

Moreover, the results showed that the proposed production process has lower environmental impacts with respect to biofuels originating from vegetable oils. These findings highlight that the green fuels produced via mild hydrotreating of animal wastes presents optimal environmental performance with respect to other production systems examined, validating their sustainability superiority.
With this in view animal wastes arise as a potential residual bio-based feedstock that support the research towards the sustainable transportation fuel production systems.

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