Journal of Cleaner Production 137 (2016) 105–115

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Environmental assessment of a pork-production system in North-East of Spain focusing on life-cycle swine nutrition

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ARTICLE INFO

Article history:
Received 9 March 2016
Received in revised form
8 July 2016
Accepted 9 July 2016
Available online 11 July 2016

Keywords:
Life Cycle Assessment (LCA)
Pig-meat production
Animal feed
Cumulative energy demand (CED)
Global warming potential (GWP)
ReCiPe (midpoint and endpoint approach)

ABSTRACT

Given the importance of pig-meat production in Spain, the present work (based on cumulative energy demand, global warming potential, ReCiPe method and different functional units) presents a life cycle assessment of an intensive pork-production system (growing-finishing pigs from 25 to 105 kg body weight) in North-East of Spain. Emphasis is given on animal feeding (which is separated into 3 phases) while the impact of drinking-water consumption, straw usage and transportation (for feed and straw) are also taken into account for certain scenarios. The results demonstrate that there is a cumulative energy demand of 5.6 MJ_{prim} per kg of animal feed and 14.5–35.6 MJ_{prim} per kg of meat (live or carcass weight). Moreover, global warming potential (based on a time horizon of 100 years: 100a) is 3.2–5.5 kg $CO_{2.eq}$ per kg of meat (live or carcass weight) and 336–460 kg $CO_{2.eq}$ per market pig. On the other hand, ReCiPe impact per market pig ranges from 60 to 76 Pts, depending on the scenario. Based on all the studied cases, animal feed is responsible for the greatest part of the total impact feed/drinking-water/straw/transportation and transportation is responsible for the second highest impact. A comparison with results from the literature is also provided and critical issues (about feed composition, cleaner-production solutions, etc.) are presented.

1. Introduction

Livestock at commercial level is related with considerable impacts on the environment. This is because animal production (e.g. of pork) is a complex system, involving multiple aspects: production of animal feed, transportation, animal care, breeding, rearing, fattening, waste management, etc. A useful tool for the assessment of the environmental performance of such complex systems is Life Cycle Assessment (LCA). LCA has been applied to pig-production systems and a review reveals that these studies refer to e.g. feed production, entire-system livestock rearing and waste management (McAuliffe et al., 2016). In the following paragraphs, several literature studies about the environmental profile of pig-production systems are presented, revealing crucial factors.

Nguyen et al. (2010) investigated fossil energy and GHG (greenhouse gas) saving potentials of pig farming in Europe. It was noted that in Europe, the highly developed livestock industry is associated with a high burden on resource use and environmental quality. Pig-meat production in North-West Europe (as a base case) was examined (based on different scenarios) in order to examine how improvements (in terms of energy and GHG savings) can be feasibly achieved. The analysis showed that pig farming in Europe presents a high potential to reduce fossil energy use and GHG emissions by improving the following aspects: feed use, manure management/manure utilization.

For the case of France, van der Werf et al. (2005) conducted an LCA study in order to investigate the environmental impact associated with the production and on-farm delivery of concentrated feed for pigs. Feed composition was based on average data for

Abbreviations: CED, cumulative energy demand; CML01, CML01 method; CML-IA, CML-IA method; $CO_{2.eq}$, CO_2 equivalent; CW, carcass weight; DALY, disability adjusted life years; Eco-indicator 99, Eco-indicator 99 method; EDIP97, EDIP97 method; F, W, S, T, feed, water, straw, transportation; F, feed; GHG, greenhouse gas; GWP 100a, global warming potential with a time horizon of 100 years; GWP 20a, global warming potential with a time horizon of 20 years; GWP 500a, global warming potential with a time horizon of 500 years; GWP, global warming potential; IPCC, Intergovernmental Panel on Climate Change; LCA, Life Cycle Assessment; LCI, life cycle inventory; LCIA, life cycle impact assessment; LW, live weight; MJ_{prim}, MJ primary; Pts, points; ReCiPe, ReCiPe method; S, straw; T, transportation; W, water.

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http://dx.doi.org/10.1016/j.jclepro.2016.07.051
0959-6526/

Bretagne (France, year 1998) and on published data for wheat-based, maize-based and co-product based feeds. It was mentioned that the environmental burdens related to production/delivery of pig feed can be decreased by: 1) optimising the fertilisation of the crop-based ingredients, 2) utilising more locally-produced feed ingredients, 3) reducing concentrations of Cu and Zn in the feed and 4) adopting wheat-based rather than maize-based feeds.

Moreover, in the literature there is a review study specifically about European LCA studies on pork production (Reckmann et al., 2012). It was mentioned that these assessments show an average GWP (global warming potential) of 3.6 kg $CO_{2.eq}$ per kg of pork.

Another study (Röös et al., 2013) with emphasis on carbon footprint as an indicator of the environmental impact of meat production (including pork) revealed that: 1) carbon footprint generally acts as an indicator of acidification and eutrophication potential (given the fact that more efficient use of nitrogen leads to less eutrophying and acidifying substances being released to the environment and lower GHG emissions in nitrous oxide form); 2) GHG mitigation strategies based on more efficient use of feed can lead to decreased acidification and eutrophication potential; 3) decreased GHG emissions (because of increased productivity) result in less land requirements for feed production (Röös et al., 2013).

Furthermore, Baumgartner et al. (2008) analysed the environmental impact of grain legume use in animal feed and evaluated the impact of several animal-production systems, including feed production, by means of multiple feeding strategies and different origins of feed. For the analysis, midpoint impact categories were selected (mainly from EDIP97 and CML01 methods). Different European regions/case studies were investigated, including pig-meat production in Catalonia, Spain.

Additional studies are those of: 1) Basset-Mens and van der Werf (2005) about LCA of pig production in France; 2) Eriksson et al. (2005) regarding pig production with emphasis on feed choice (Sweden); 3) Rigolot et al. (2009) about LCA of five virtual pig-production units with different manure-management systems; 4) Sasu-Boakye et al. (2014) regarding livestock protein feed production and the impact on land use and GHG emissions (the study included issues about pig production and emphasis was given on Sweden); 5) González-García et al. (2015) concerning LCA of pig-meat production in Portugal (based on ReCiPe midpoint); 6) Dalgaard et al. (2007) regarding an environmental assessment of Danish pork production; 7) Dourmad et al. (2014) regarding the environmental impact of 15 European pig farming systems in the European Union Q-PorkChains project (conventional and non-conventional systems were evaluated from: Denmark, The Netherlands, Spain, France and Germany); 8) de Miguel et al. (2015) concerning water footprint of the Spanish pork industry; 9) Bava et al. (2015) concerning the environmental impact of the typical heavy pig production in Italy; 10) Noya et al. (2016) regarding carbon and water footprint of pork supply chain in Catalonia, Spain; 11) Espagnol and Demartini (2014) about the environmental impact of extensive outdoor pig-production systems in Corsica, France.

By taking into account:

- The importance of pig-meat production in Spain (Spain is the second country in Europe in swine production), especially in North-East region which is the main pig-production area of Spain (Plà-Aragonés, 2015).
- The fact that most of the literature studies examine CO_2 emissions and there are few studies based on ReCiPe method, the present investigation presents the environmental profile of a pig-production system in North-East of Spain, by means of multiple approaches and LCIA (life cycle impact assessment) methods.

More specifically, the present study includes:

- Evaluation of the eco-profile of pig production based on data of a real pig-farming system, with emphasis on animal feed.
- Presentation of an LCA model based on the newly-developed LCIA method ReCiPe (midpoint and endpoint approach) along with CED (cumulative energy demand) and GWP (PRé, 2014), according to several scenarios (animal feed and drinking-water demand, etc.).
- Estimation of the impact by adopting different functional units.
- Analysis of the impact in terms of each component of animal feed and identification of the ingredients with the maximum impact for each phase of feeding.

The goal of the present work is to:

- Identify critical points related to the proposed pig-farming system (based on multiple approaches, environmental indicators and methods).
- Present results for important environmental issues related with human health, ecosystems and resources.
- Propose solutions for cleaner production.

2. Materials and methods

The implementation of the LCA has been conducted according to ISO 14040 (2006) and ISO 14044 (2006), for the phases of: 1) goal and scope definition, 2) life-cycle inventory, 3) life-cycle impact assessment and 4) interpretation.

2.1. Boundaries and functional units

The whole system includes raising pigs for meat production. More specifically:

- The raising of the animals refers to growing-finishing from an initial body weight of 25 kg to a final body weight of 105 kg.
- The production system has three cycles per year.
- Each cycle includes 120 days and 1872 pigs; thus, there is a production of 5616 pigs per year.
- Taking into account that the weight of one market pig is 105 kg, there is a meat production of 589.68 tonnes live weight (LW) and 465.85 tonnes carcass weight (CW).
- Animal feed is divided into three phases.
- Water consumption (drinking water for the animals), straw usage and transportation (for feed and straw) are included for certain scenarios.

The functional units refer to the production of: 1) 1 market pig, 2) 1 kg of meat LW and 3) 1 kg of meat CW. According to the literature (McAuliffe et al., 2016; Reckmann et al., 2012) the above mentioned functional units can be adopted in the frame of an LCA applied to pig production. In addition, for some cases, the impact is also calculated per kg of animal feed.

2.2. Definition of the studied system

2.2.1. Characteristics

The inputs of the pig-production system are based on data from a real swine farm (intensive pig farming) located in the North-East of Spain. Animal feeding has been separated into three phases: A, B and C (details are presented in Section 2.3). The phases A, B and C refer to pigs with a body weight of [25–40), [40–60) and [60–105] kg, respectively.