



## Environmental assessment of the entire pork value chain in Catalonia – A strategy to work towards Circular Economy



Isabel Noya <sup>a,\*</sup>, Xavier Aldea <sup>b</sup>, Sara González-García <sup>a</sup>, Carles M. Gasol <sup>c,d</sup>, María Teresa Moreira <sup>a</sup>, Maria José Amores <sup>b</sup>, Desirée Marín <sup>b</sup>, Jesús Boschmonart-Rives <sup>c,d</sup>

<sup>a</sup> *Departament of Chemical Engineering, School of Engineering, University of Santiago de Compostela, 15782 Santiago de Compostela, Spain*

<sup>b</sup> *Cetaqua, Centro Tecnológico del Agua, Cornellà de Llobregat, 08940 Barcelona, Spain*

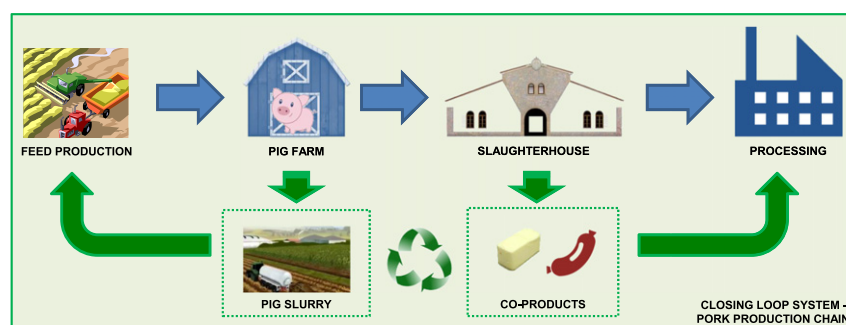
<sup>c</sup> *Inèdit Innovació SL, Research Park of the Autonomous University of Barcelona (PRUAB), Bellaterra (Cerdanyola del Vallès), 08193 Barcelona, Spain*

<sup>d</sup> *Sostenipra (ICTA-IRTA-Inèdit), Institute of Environmental Science and Technology (ICTA) & Department of Chemical Engineering, Autonomous University of Barcelona (UAB), Bellaterra (Cerdanyola del Vallès), 08193 Barcelona, Spain*

### HIGHLIGHTS

- Representative primary data from the Catalan pork sector was provided by collaborating stakeholders.
- Environmental impacts of traditional linear pork chain in Catalonia were evaluated through a LCA approach.
- Alternative schemes based on the Circular Economy philosophy were defined according to environmental hotspots.
- Potential environmental benefits were evidenced with the implementation of the Circular Economy perspective.

### GRAPHICAL ABSTRACT



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### ABSTRACT

Pork industry in Catalonia plays a foremost and representative role in the Spanish pork sector. Beyond the economic benefits, conventional practices in the pork industry also imply a number of environmental impacts that need to be dealt with. In this context, the environmental performance of traditional linear pork chain in Catalonia was evaluated through a LCA approach. The outcomes of the analysis showed that both fodder production and transport activities were identified as the critical stages of the system. Accordingly, alternative schemes based on circular economy principles were proposed and potential environmental credits were estimated. Within this framework, comparative results highlighted the advantages of moving towards a closing loop production system, where resource efficiency and waste valorisation were prioritised over final disposal options.

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### 1. Introduction

Circular Economy (CE) concept is receiving increasing attention worldwide as a means of overcoming the conventional production and consumption pattern focused both on continuous growth and

\* Corresponding author.

E-mail address: [isabel.noya@usc.es](mailto:isabel.noya@usc.es) (I. Noya).

increasing resource performance (Ellen MacArthur Foundation, 2013a, 2013b; Ghisellini et al., 2015). Opposing unsustainable traditional economy (linear economy), which is based on unlimited resources consumption and waste disposal, CE uses theory and principles from industrial ecology (Jurgilevich et al., 2016). Accordingly, CE promotes the adoption of the closing-the-loop production model to increase the efficiency of resource use and reduce pollution levels (Ghisellini et al., 2015; Jun and Xiang, 2011; Jurgilevich et al., 2016; Scheepens et al., 2015). Thus, it is characterised with low consumption of materials and resources in the production scheme as well as limited discharges into the environment, enabling resources to be put to full use to increase global efficiency (Jun and Xiang, 2011). In this way, CE achieves better balance and harmony between economy, environment and society (Ghisellini et al., 2015; Jun and Xiang, 2011).

With the aim of endorsing the paradigm of sustainable development, CE is emerging main development strategy in more and more regions and countries within the European community (European Commission, 2015). The transition to a more circular economy provides the opportunity for a sustainable, efficient and competitive economy for Europe (European Commission, 2015). However, despite the increasing interest about CE model, a limited number of studies focused on the European free market economy are available to date in literature (Ghisellini et al., 2015; Jurgilevich et al., 2016; Pagotto and Halog, 2015; Scheepens et al., 2015; Strazza et al., 2015). Although general guidelines have been published on the development of circular productive model (Ellen MacArthur Foundation, 2013a, 2013b), existing gaps in design and implementation have to be solved (Jurgilevich et al., 2016; Scheepens et al., 2015). Therefore, substantial changes regarding design, production, consumption, use, waste and reuse practices are required throughout the productive chain (Hobson, 2015).

Meat consumption is consistently growing worldwide (63% in the last 40 years) as a result of the high demand as the primary dietary source of protein and micronutrients in emerging countries (Ciolos, 2012; Davis et al., 2010). Pork is the main meat variety produced in Europe as well as the most widely consumed in the world, with 115.5 million tons in 2014 (FAO, 2014). Moreover, an increase by almost 40% in its production is expected by 2050 (FAO, 2011). Spain ranks second (after Germany) within the European pork sector, with 13% of the total production (FAOSTAT, 2013). Catalan pork production is one of the largest industries in terms of economic revenue of the Spanish pork sector. Specifically, it holds about 40% of the national pork industry and 50% of pork processing activities (Observatori del Porcí, 2013). Moreover, Spain exported 1,402,407 tons of pork products in 2012, being Catalonia responsible for 61% of the total exported volume (Observatori del Porcí, 2013). However, in parallel with its relevance in the Spanish economy, the pork industry also demands large requirements of natural resources (water and energy) and generates remarkable waste flows (PRTR, 2014). Thus, conventional practices in the pork production chain are responsible for significant stress on the Catalan ecosystems carrying capacity, so that stakeholders and consumers are demanding a change towards more environmental friendly pork products (Notarnicola et al., 2012; PRTR, 2014).

In this context, the main aim of this study was to shed light on the concept of CE within the Catalan pork industry. Thus, a cradle-to-gate environmental assessment was carried out, taking into account all the life cycle stages involved in the pork production chain, from feed production to pork cutting stage (LCA perspective). The most critical processes (*hotspots*) were identified and alternative strategies were defined based on the CE model (cradle-to-cradle approach) in order to demonstrate the potential benefits on the environmental profile of the pork sector in Catalonia. In this way, major findings are expected to support Catalan pork industries to increase their sustainability and enhance their competitiveness in the international market.

## 2. Materials and methods

LCA tool was implemented in accordance with the principles and guidelines established by ISO standards (ISO, 2006a, 2006b). Overall, the CE goal is to keep valuable materials in circulation through a series of feedback loops between life-cycle stages, powered through resource-efficient industrial processes (Hobson, 2015). In this sense, Life Cycle Assessment (LCA) is a suitable approach to analyse the environmental aspects of complex food systems (McAuliffe, 2016), including recycling and circular schemes (Scheepens et al., 2015). LCA evaluates the environmental performance of a product or service by identifying critical stages in a supply chain where emissions should be reduced (McAuliffe, 2016). Thus, through LCA the feasible tradeoffs among diverse impact categories can be documented when analysing different solutions for more environmentally friendly systems (Aubin et al., 2009).

### 2.1. Goal and scope

#### 2.1.1. Purpose

In this study, the environmental profile related to pork production chain in Catalonia region was evaluated through a LCA approach (Fig. 1). Accordingly, the main *hotspots* were identified as basis for the proposal of alternative strategies susceptible of reducing the environmental impacts of Catalan pork sector as well as improving its eco-efficiency performance from a CE perspective.

#### 2.1.2. Description of pork production system and system boundaries

High quality data should be used when an environmental study is to be exposed for dissemination to the public (ISO, 2006b). For this reason, close collaborative work between the research team and different stakeholders, either companies or industries of the pork sector, was the key factor in the development of the present study. Thus, several representative companies collaborated in the project, including feed factories, pig farms, slaughterhouses and cutting facilities. The integration of individual data of each company for the different stages of the production chain allowed to develop a global inventory, which were representative of the average results for the Catalan pork sector. These outcomes set the benchmark value of production, so that companies can compare and evaluate their environmental profile in relation to the reference one.

A cradle-to-gate environmental assessment was conducted. Accordingly, all the processes involved in the pork production chain up to the cutting room stage were considered while the final stages of pork processing fell out of the system boundaries (Fig. 2). Thus, all activities related to feed production, breeding and fattening pigs at farm, slaughterhouse and cutting stage (where fresh/frozen pork is obtained as output) were encompassed in this study. This perspective goes beyond those defined in most of previous LCA studies involving pork production, where the prevailing scope comprises from feed production to pig farm gate (McAuliffe,

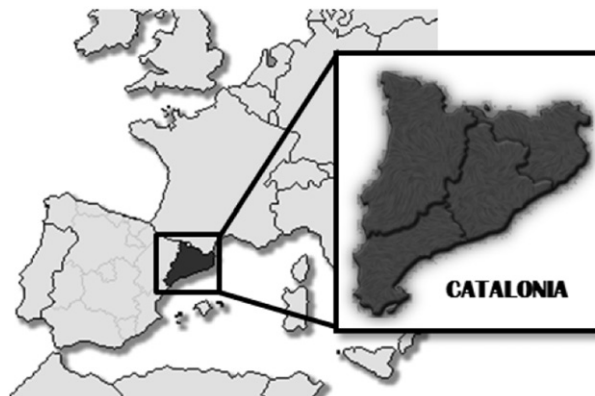


Fig. 1. Pork production system location (Catalonia, Spain).

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