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Research article

Carbon and water footprint of pork supply chain in Catalonia: From feed to final products

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ABSTRACT

A systematic tool to assess the Carbon Footprint (CF) and Water Footprint (WF) of pork production companies was developed and applied to representative Catalan companies. To do so, a cradle-to-gate environmental assessment was carried out by means of the LCA methodology, taking into account all the stages involved in the pork chain, from feed production to the processing of final products, ready for distribution. In this approach, the environmental results are reported based on eight different functional units (FUs) according to the main pork products obtained. With the aim of ensuring the reliability of the results and facilitating the comparison with other available reports, the Product Category Rules (PCR) for Catalan pork sector were also defined as a basis for calculations. The characterization results show fodder production as the main contributor to the global environmental burdens, with contributions higher than 76% regardless the environmental indicator or the life cycle stage considered, which is in agreement with other published data. In contrast, the results in terms of CF and WF lay above the range of values reported elsewhere. However, major discrepancies are mainly due to the differences in the co-products allocation criteria. In this sense, economic/physical allocation and/or system expansion have been mostly considered in literature. In contrast, no allocation was considered appropriate in this study, according to the characteristics of the industries and products under assessment; thus, the major impacts fall on the main product, which derives on comparatively higher environmental burdens. Finally, due to the relevance of fodder production in the overall impact assessment results, strategies to reduce greenhouse gases (GHG) emissions as well as water use associated to this stage were proposed in the pork supply chain.

1. Introduction

In recent times, the world is facing increasing problems of food safety and environmental damage (Reckmann et al., 2013, 2012). In this context, both meat and dairy products account for the greatest environmental burdens, mainly due to the significant requirements of feed, energy and water, as well as the greenhouse gases (GHG) emitted to air and the pollution risks associated to inefficient practices of waste management (McAuliffe, 2016; Vries and de Boer, 2010; Roy et al., 2009; Steinfeld et al., 2006). Indeed, it is known that 18% of the total anthropogenic GHG emissions are associated with the animal husbandry sector (Steinfeld et al., 2006). Consequently, consumers are demanding a change towards more environmental friendly products. In this framework, sustainable productive systems within the meat sector must be recognized and implemented (Notarnicola et al., 2012; Nguyen et al., 2010).

As a primary dietary source of protein and micronutrients, meat

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can be considered as an important element of the human diet (González-García et al., 2015; Davis et al., 2010). In fact, its demand is consistently growing worldwide, and specifically in Europe meat consumption has increased by 63% in the last 40 years (Ciolos, 2012; FAO, 2004). Among the main European meat varieties (beef, pork, chicken, poultry and sheep), pork is the most widely meat consumed, with an annual average rate of 31.8 kg per capita in relation to the average consumption of all types of meat in Europe: 64.7 kg of meat per capita (Eurostat, 2013). However, in parallel with its socioeconomic relevance, pork production is also the second largest contributor of GHGs emissions, accounting for around 26% of total emissions from livestock sector in Europe, below dairy products (41%) and beef (28%) and above poultry meat (5%) (Weidema et al., 2008). This underlines the need to assess the environmental impacts influencing the pork supply chain with the aim of keeping European pork products competitive in the world market, not only from an economic perspective but also taking into account the environmental approach (Philippe and Nicks, 2014; Reckmann et al., 2013; Nguyen et al., 2010).

In this sense, the environmental impacts of different pork production systems have been assessed in the literature, not only all over the European region but also outside its boundaries. In most of these studies, the principles of Life Cycle Assessment (LCA) methodology have been followed as a basis for the environmental evaluation (McAuliffe, 2016). However, the lack of consensus in the methodological choices (system boundaries, functional units, allocation approaches) and assumptions considered impede comparative analysis among the different environmental studies (McAuliffe, 2016; De Vries and de Boer, 2010). Thus, whereas some authors focus their attention in specific stages of the production chain, such as feed production (Garcia-Launay et al., 2014; Ogino et al., 2013; Meul et al., 2012; Mosnier et al., 2011; Kool et al., 2010) or waste management (Rodriguez-Verde et al., 2014; Brockmann et al., 2014; Lijó et al., 2014; Bayo et al., 2012; Lopez-Ridaura et al., 2009), other studies extend the boundaries of their systems to include all the processes involved in pork production until farm facilities or slaughterhouse gate (González-García et al., 2015; Dourmad et al., 2014; Reckmann et al., 2013; Nguyen et al., 2011, 2010Pelletier et al., 2010; Wiedemann et al., 2010; Dalgaard et al., 2007; Basset-Mens and Van der Werf, 2005). This variability also affects the choice of functional unit as well as the allocation approach, since the final product and sub-products obtained in each case will be different (McAuliffe, 2016). Moreover, all these environmental studies aim at evaluating the environmental burdens related to GHG emissions, finding that one of the most important requirements for sustainable production is reducing the climate change related impacts (McAuliffe, 2016; Philippe and Nicks, 2014; Nguyen et al., 2010). However, other interesting impact categories, such as water use, are omitted by arguing data limitations (McAuliffe, 2016).

In this study, special attention has been paid to Catalonia, a region in Northeast Spain which holds about 40% of the national pork industry and 50% of pork processing activities (Observatori del Porcí, 2013). Thus, Spain exported 1,402,407 tons of pork products in 2012, with Catalonia responsible for around 61% of the total exported volume (Observatori del Porcí, 2013). Given the importance of the pork sector in this Spanish region, improvements that can provide competitive advantages and create added value to the production chain will be important.

In this context, a cradle-to-gate environmental assessment was carried out in this study through a LCA perspective taking into account all the stages involved in the whole pork chain, from feed production to final products processing, ready for distribution. To ensure the reliability of the results and facilitate comparison, the Product Category Rules (PCR) for Catalan pork sector were first defined as basis for calculations. Different Catalan pork products, identified as the most commercialized and representative ones of the pork chain, were then environmentally evaluated within the framework of the study, while carbon and water footprints was selected as indicators of primary interest for companies in the sector (McAuliffe, 2016; Reckmann et al., 2012). Finally, the *SustainPork®* tool was developed as a self-assessment tool where Catalan companies related to pork industry can identify and act on their *hotspots* to obtain more competitive final products.

2. Materials and methods

A cradle-to-gate LCA study was carried out based on the ISO 14040 regulations (ISO, 2006a) that describe the four basic steps of the assessment procedure: (1) goal and scope definition, (2) Life cycle inventory (LCI), (3) Life cycle impact assessment (LCIA) and (4) Life cycle interpretation.

2.1. Goal and scope

2.1.1. Purpose

The main goal of this study was to develop the so-called *SustainPork®* tool capable to calculate and manage the Carbon Footprint (CF) and Water Footprint (WF) of whole pork products chain with the aim of helping Catalan industrial companies in the meat sector to reduce their impacts in terms of climate change and improve the efficient use of their resources (energy and water). In this way, they can increase their sustainability and enhance their competitiveness. Moreover, the analysis can provide added value to meat products with potential to be commercialized on an international market such as France or Germany, where availability of these indicators is becoming a legal requirement (EIA Directive, 2011; SEA Directive, 2001). To do it, a detailed evaluation of the Catalan pork sector was previously developed within the study framework, taking into account not only bibliographic references but also primary information provided by companies of proven reputation in the pork industry in Catalonia region.

Finally, once the environmental evaluation was performed and the most critical stages (commonly named *hotspots*) in the production chain were identified, strategies for reducing the greenhouse gas (GHG) emissions as well as the use of water throughout the life cycle of pork products were also proposed.

2.1.2. System boundaries

The study was performed through a cradle-to-gate perspective, taking into account the entire supply chain from feed production, going through breeding and fattening pigs, to processed products ready for distribution, obtaining as a result the CF and WF of eight different products corresponding to different steps of the pork chain (Fig. 1). The processes included are: feed production (fodder), farm, slaughtering, cutting & slicing, and processing stages for ham, dry-cured ham, spicy sausage and fuet. For final products, later slicing and packaging stages were also accounted. This perspective goes beyond those defined in most of previous LCA studies involving pork production, where the most prevalent scope comprises from feed production to pig farm gate (McAuliffe, 2016). Further stages of distribution and sales were excluded from the system boundaries, since they largely depend on market demand rather than on production conditions of the sector.

With the aim of facilitating the assessment, the whole system has been divided into five main subsystems of the life cycle, according to different secondary modules (Fig. 1): fodder production (S1), animal husbandry at farm (S2), slaughterhouse (S3), pork cutting (S4) and processing of final products (S5). All the environmental burdens related to the consumption of energy, fossil fuels,