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Environmental impact of heavy pig production in a sample of Italian farms. A cradle to farm-gate analysis

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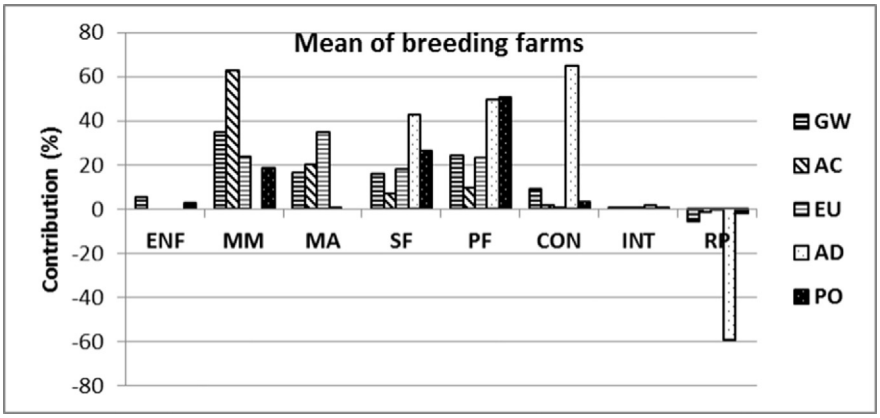
HIGHLIGHTS

- Pig production has relevant effects on water and air quality, global warming and natural resource depletion.
- An LCA was performed on the production of heavy pig (>160 kg of body weight) production.
- There is a wide variability of environmental performances among farms.
- It is shown that there is wide margin of reduction of environmental impact of heavy pig production.

GRAPHICAL ABSTRACT



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ABSTRACT

Four breeding piggeries and eight growing-fattening piggeries were analyzed to estimate potential environmental impacts of heavy pig production (>160 kg of live height at slaughtering). Life Cycle Assessment methodology was adopted in the study, considering a system from breeding phase to growing fattening phase. Environmental impacts of breeding phase and growing-fattening phase were accounted separately and then combined to obtain the impacts of heavy pig production. The functional unit was 1 kg of live weight gain. Impact categories investigated were global warming (GW), acidification (AC), eutrophication (EU), abiotic depletion (AD), and photochemical ozone formation (PO).

The total environmental impact of 1 kg of live weight gain was 3.3 kg CO_2eq, 4.9 E−2 kg SO_2eq, 3.1 E−2 kg PO_4^{3-}eq, 3.7 E−3 kg Sbeq, 1.7 E−3 kg C_2H_4eq for GW, AC, EU, AD, and PO respectively.

Feed production was the main hotspot in all impact categories. Greenhouse gases responsible for GW were mainly CH_4, N_2O, and CO_2. Ammonia was the most important source of AC, sharing about 90%. Nitrate and NH_3 were the main emissions responsible for EU, whereas P and NOx showed minor contributions. Crude oil and natural gas consumption was the main source of AD. A large spectrum of pollutants had a significant impact on PO:

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they comprised CH_4 from manure fermentation, CO_2 caused by fossil fuel combustion in agricultural operations and industrial processes, ethane and propene emitted during oil extraction and refining, and hexane used in soybean oil extraction. The farm characteristics that best explained the results were fundamentally connected with performance indicators Farms showed a wide variability of results, meaning that there was wide margin for improving the environmental performance of either breeding or growing-fattening farms. The effectiveness of some mitigation measures was evaluated and the results that could be obtained by their introduction have been presented.

1. Introduction

According to IPQ-INEQ (2014) approximately 13 million pigs were slaughtered in Italy in 2013 and about 61% of them were used for the production of the Protected Designation Origin (**PDO**) hams, which are obtained according to the Regulations of Prosciutto di Parma or Prosciutto di San Daniele, ruling on every production step. In the last decades, pig production has been increasing considerably in the northern regions of Italy, and four regions (Piemonte, Lombardia, Veneto and Emilia-Romagna) currently account for approximately 83% of total pig population (ERSAF, 2014). Intensification of the production system and concentration of pigs in large farms on restricted areas have increased the environment load and have caused several acceptability problems, due to emissions contributing to climate change and affecting human and environment health. The underlying feed production requires also the consumption of non-renewable resources and the combustion of fossil fuels for agricultural operations as well as the synthesis and extraction of inorganic fertilizers. The environmental burden of the pork sector in Europe-27 accounts for approximately 25% of total animal greenhouse gases (**GHG**) emissions, on a life cycle assessment (**LCA**) basis (Weiss and Leip, 2012). Several European directives regulate intensive pig production. For example, Directive 2010/75/EU of the European Parliament (Directive IED on industrial emissions) specifically addresses the installation of intensive rearing poultry and pig plants, with the aim to reduce emissions to air, soil and water and to improve resource efficiency, by adopting the best available techniques. Nitrate Council Directive (91/676/EEC) is another fundamental tool for preventing the excess of nutrients from agriculture (namely N) which pollute surface and groundwater. Intensive pig production is also subject to the National Emission Ceilings Directive (2001/81/EC), aiming to control the airborne emissions of SO_2, NO_X, VOCs and NH_3. Finally, similarly to any economic activity causing GHG emissions, pig production should contribute to achieve the goals of the Paris Agreement.

The environmental impact of pig production has been evaluated in several literature LCA studies (Table 1). Most of them are restricted to the agricultural phase and do not consider slaughter and processing phases. The survey shows that in all these studies, with the exception of Cederberg and Flysjö (2004), the final live weights are much lower than 160 kg, and therefore they are not fully representative of typical Italian heavy pigs. In fact, the abovementioned Regulations of PDO hams set the genotypes suitable for this production and the minimum age (9 months) and live weight (160 kg) at slaughtering. Consequently, these pigs must grow slower than the lighter pigs, which represent the most of worldwide production. Moreover, the use of a variety of feedstuffs (namely fats and oils) and byproducts is severely restricted in the first growing period (up to 80 kg of live weight) and are forbidden in the finishing period. Therefore, it is clear that both nutrient requirements (in particular energy to protein ratio) and feed formulations of heavy pig are quite different from those of younger and lighter pigs produced all over the world and that this specificity can influence environmental load, because feed efficiency and body weight are inversely correlated (Della Casa et al., 2009). The first study on this characteristic production system has been published very recently (Bava et al., in press).

Table 1
Literature LCA studies of pig production.

Authors	Country	Final weight (kg)
Basset-Means and van der Werf (2005)	FR	113–150
Bava et al. (in press)	IT	169
Bonesmo et al. (2012)	NO	92
Cederberg and Flysjö (2004)	S	105–160
Cherubini et al. (2015)	BR	125
Dalgaard et al. (2007)	DK	109–140
Dourmad et al. (2014)		
Garcia-Launay et al. (2014).	FR	115
Gonzàlez et al. (2012)	E	150
González-García et al. (2015)	PO	105
Halberg et al. (2010)	FR	100
Lammers et al. (2010)	USA	136
Pelletier et al. (2010)	USA	110–126
Reckmann et al. (2013)	D	129
Sagastume Gutièrez et al. (2015)	CU	120
Stone et al. (2012)	USA	118

Because of both the scarcity of quantitative data about the environmental impact of heavy pig production (>160 kg of live weight and 9 months of age) and the need to environmentally assess the mitigating strategies that can be adopted, the Italian Ministry of Agriculture, Food and Forestry funded a specific LCA study with the aim to address global warming (**GW**), acidification (**AC**) and eutrophication (**EU**), the most representative environmental impact categories of this production. This paper presents the results of the LCA study and includes also the assessment of the depletion of abiotic resources (**AD**), because an efficient use of resources is a key point for sustainability, and of the photochemical ozone formation (**PO**), as an indicator of air quality and responsible for significant effects on human health.

2. Material and methods

Life cycle assessment is a standardized methodology (ISO 14040, 2006; ISO 14044, 2006) for analyzing environmental potential impacts of a product or a service throughout life cycle. It applies a “cradle to grave” approach which includes extraction and processing of raw materials, manufacturing, product distribution, use, maintenance, recycling and final disposal. According to the ISO 14040 (2006) and ISO 14044 (2006), an LCA study consists of four main steps: 1) goal and scope definition, 2) life cycle inventory analysis, 3) life cycle impact assessment and 4) interpretation of results. In step 1, the purpose of the study, system boundaries, functional unit and assumptions are defined. Step 2 consists of a detailed compilation of all inputs (material and energy consumption) and outputs (products, airborne and waterborne emissions as well as waste generated) from the processes at each stage of the product's life cycle. Step 3 aims to assess potential environmental impacts based on the life cycle inventory results. Finally, the results are analyzed and interpreted in step 4.

2.1. Goal of the study and decision context

The goal of the study was to assess the environmental impacts of the production of heavy pig up to the farm gate and to identify the hotspots in the production chain. Two separated analyses were performed in this study: the first one concerning the breeding phase for the piglet production and the second one the growing-fattening phase; successively, the