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Environmental trade-offs of pig production systems under varied operational efficiencies

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ABSTRACT

Production of pork, the most consumed meat globally, is estimated to emit 668 m tonnes CO_2-eq of greenhouse gases each year. Amongst various production systems that comprise the pig industry, grain-based intensive production is widely regarded as the largest polluter of the environment, and thus it is imperative to develop alternative systems that can provide the right balance between sustainability and food security. Using an original dataset from the Republic of Ireland, this paper examines the life-cycle environmental impacts of representative pig farms operating under varying production efficiencies. For the baseline farm with an average production efficiency, global warming potential (GWP), acidification potential (AP) and eutrophication potential (EP) per kg carcass weight departing the slaughterhouse were estimated to be 3.5 kg CO_2-eq, 43.8 g SO_2-eq and 32.1 g PO_4-eq, respectively. For herds with a higher production efficiency, a 9% improvement in feed conversion ratio was met by 6%, 15% and 12% decreases in GWP, EP, AP, respectively. Scenario and sensitivity analyses also revealed that (a) a switch to high-protein diets results in lower GWP and higher AP and EP, and (b) reducing transportation distances by sourcing domestically produced wheat and barley does not lower environmental impacts in any notable manner. To improve cross-study comparability of these findings, results based on an auxiliary functional unit, kg liveweight departing the farm gate, are also reported.

1. Introduction

Agricultural production is one of the key anthropogenic activities where environmental burdens can potentially be reduced. The farming sector occupies 30% of the Earth's terrestrial surface (Steinfeld, 2006) and 75% of this land use is associated with livestock production (Cassidy et al., 2013). Food systems generate 19–29% of global greenhouse gas (GHG) emissions, of which various forms of primary production contribute 80–86% (Vermeulen et al., 2012). Changing diets and population growth have been associated with 65% of land use change between 1961 and 2011 (Alexander et al., 2015), and demand for livestock products will continue to exceed expected population growth (34%) at least until 2030 because of the ongoing dietary shifts in developing countries (Havlík et al., 2014).

While it is widely accepted that ruminants are the primary drivers of agriculture-related global warming through enteric fermentation, recent evidence suggests that production of monogastric animals also require significant attention, as they too compete for human edible-food for land resources. In particular, pork is the most consumed meat globally (OECD, 2017), and its production is estimated to emit 668 M tonnes CO_2-eq yr^{-1}, or 9% of total livestock emissions (Gerber et al., 2013). Given the continuing globalisation of food and feed markets and the upward pressures on farmland prices, it is imperative to develop pig production systems that provide the right balance between economic, environmental and societal sustainability and food security. To date. studies have demonstrated that improved sow efficiency, through higher numbers of piglets born alive and reduced dry periods, can

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decrease environmental burdens (Reckmann and Krieter, 2015). Furthermore, higher feed conversion efficiency (FCE) has also been shown to reduce the environmental impact per pig unit, as emissions and losses associated with the feed production stage become smaller (Nguyen et al., 2011). However, published research investigating these effects on the system-wide footprint is rather limited, and thus the environmental benefit of economically improved pig operations is not clearly understood.

Using the life cycle assessment (LCA) framework, which has been applied to a diverse range of pig production systems as reviewed by McAuliffe et al. (2016), the present study investigates the environmental performances of intensive pig production systems in the Republic of Ireland (RoI) under different production efficiencies. Pig production is the third most important agricultural sector in RoI based on gross agricultural output (Teagasc, 2016). Contrary to the country's beef and dairy sectors that have frequently been examined for their environmental impacts (Casey and Holden, 2005, 2006), and despite nationwide discussions on the merits of LCA in national GHG evaluations (Schulte et al., 2011), Irish pig production has not been the subject of a systems study to date. As of June 2015, there were 1.54 million pigs in RoI and, with an annual net production of just over 276,000 tonnes, the national self-sufficiency rate was 195%; nearly half of total production was exported. Although the Irish pig industry is relatively small compared to some of the EU 'powerhouses', it has the highest exporting percentage to non-EU countries within the union (Forde, 2016) and thus is strongly linked to the international market. For this reason, the majority of findings from the present study are likely to be also applicable to pork supply chains elsewhere.

Similarly to continental Europe, most pig production in RoI occurs on large-scale integrated units, where piglets are born, weaned and fattened on the same farm. On these farms, feed is typically purchased from specialised production mills, but with the recent volatility of international cereal prices, a small number of Irish pig farmers have constructed their own on-farm mills to minimise costs and maximise nutritional control over their feed formulations. In addition to the baseline analysis whereby feed is assumed to be mass-produced, the present study investigates the effect of this 'local feed' movement on the environment footprint. While a range of LCA studies have considered differences in feed composition (Garcia-Launay et al., 2014; Ogino et al., 2012; Stone et al., 2012), no identified studies have considered the location and the ownership of feed mills.

In RoI, 7.4% of the total agricultural land is used for arable crop production and the country is close to self-sufficiency (encompassing human, animal and industrial uses) for major cereals (DAFM, 2009). However, many feed mills source a significant portion of cereal ingredients from overseas, especially when the international market is in a favourable condition (in regard to cereal prices and exchange rate). Replacing these cereals with domestically grown barley (*Hordeum vulgare*) and wheat (*Triticum* spp.) could potentially contribute to lower total transport distances, more efficient use of manure (nutrient balancing) and, perhaps to a lesser extent, long-term food security. The present study tests this hypothesis by investigating whether the reduced transportation, when coupled with domestic conditions for crop production (and the associated emissions), would alter the overall LCA results. Finally, four sets of sensitivity analyses are conducted to evaluate the consequences of different allocation methods as well as alternative assumptions regarding land use change (LUC), utilisation of pig manure by crop farmers, and on-farm energy

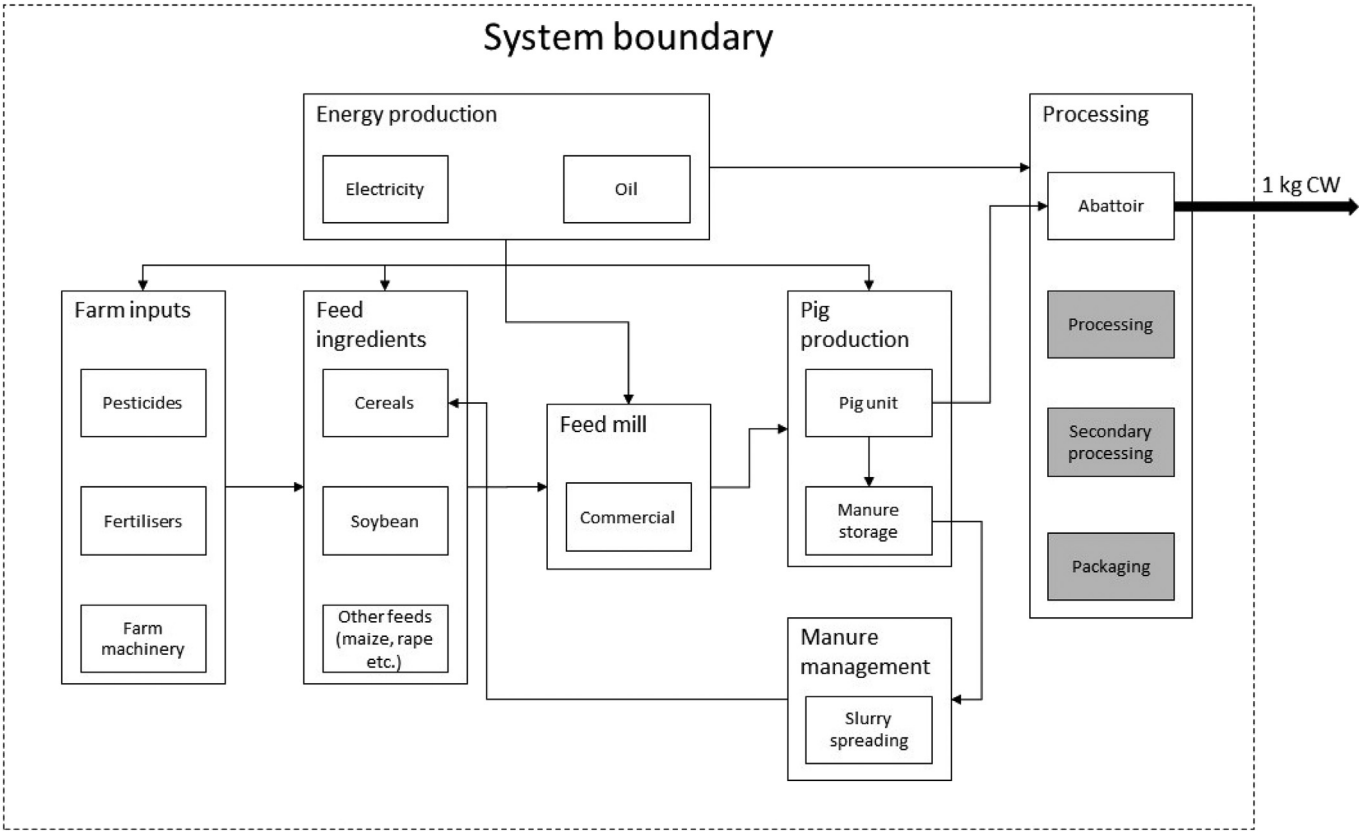

Fig. 1. Stylised schematic of the baseline study boundary. Grey processes are excluded from analysis.