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From farm to fork – A life cycle assessment of fresh Austrian pork

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ABSTRACT

With 7.5% total nutritional value, pork is a staple food for many members of the Austrian population. Among members of the general public, little is known about the environmental impacts "from farm to fork" in the production of pork. This paper identifies three main impact categories for the environmental profile of Austrian pork using the Life Cycle Assessment (LCA) method. In a transparent and comprehensive manner, this LCA studied environmental impacts occurring throughout the production chain of pork, also including the transport and consumption stages. The results are expressed in terms of the global warming potential (GWP), soil acidification and eutrophication, specifically in CO_2-equivalents, SO_2-equivalents and NO_3-equivalents normalized to one kg of fresh Austrian pork (carcass weight) as the functional unit. The main results of the study indicated that the environmental burden is primarily related to the farming stage: 92.3% of GWP, 98.4% of soil acidification and 95.4% of eutrophication. The processes taking place after the agriculture stage (i.e., during the slaughtering stage, retail market and consumption) play a minor role, except for the relative impact of eutrophication during the slaughtering stage. The transportation that took place between the different life cycle stages only marginally influenced the emissions analysed, with private transport from the retail market to the household contributing most of the emissions considered in this part of the life cycle. These results point to the farming stage as the main focus for future improvements. Due to its high contribution to the GWP, soil acidification and eutrophication potential, enhancing the efficiency and environmental protection measures implemented during the farming stage (or improving the choice of commodities used from feed production) could generate the highest reductions in impacts on soil acidification, eutrophication and potentially on the global climate.

1. Introduction

As one of the fastest growing subsectors of the agricultural economy, the production of livestock is a major contributor to global environmental problems (e.g., through its impact on the world's water, land and biodiversity resources). Moreover, livestock production contributes significantly to climate change and is responsible for about 18% of global anthropogenic greenhouse gas (GHG) emissions. When considering not only direct, but also indirect, effects such as grazing and the production of feed-crops, the livestock sector occupies approximately 30% of the ice-free terrestrial surface of the Earth (Steinfeld et al., 2006).

In global livestock production, meat production is an important element. In 2010, 37% of meat was produced from pigs and 24%, from chickens. The global annual production in 2010 of the three pig systems (backyard, intermediate and industrial) resulted in emissions of 668 million tonnes CO_2-equivalents (eq). The rising population and escalating demand for pig meat, which is projected to grow by 32% between 2005 and 2030, is predicted to result in further increases in the corresponding environmental problems (MacLeod et al., 2013).

Many scientific studies have dealt with the environmental effects of nutrition. One approach taken in these studies is from the context of "footprints", or the assessment of the environmental consequences of certain actions beyond the specific process in question. The "nutritional footprint" and "nutrient footprint" have been analysed in this way recently (Lukas et al., 2015; Grönman et al., 2015). Another approach is through life cycle assessment (LCA). LCA is a holistic approach that supports the detection of environmental "hotspots" and allows the analysis of the most environmentally-friendly methods of the various life cycle stages

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from the production phase of a certain commodity to the treatment of its remains after use. In this way, the LCA approach can be used to detect and, as a consequence, avoid problem-shifting between life cycle phases, different environmental effects or regions (Finnveden et al., 2009).

LCA has been previously applied to the agricultural sector, and several LCA studies and reviews have been undertaken with regard to the context of this paper, livestock production in general, or specifically pork production (cf. Daalgaard et al., 2007; De Vries and De Boer, 2010; González-García et al., 2015; Kool et al., 2009; Kral, 2011; MacLeod et al., 2013; Nemecek et al., 2005; Nguyen et al., 2010; 2011; 2012; Roy et al., 2012; Weidema et al., 2008).

As one common key result of these LCAs, the environmental burden of the agricultural stage has been identified because it generates the highest share of relevant emissions along the meat supply chain. However, the majority of pork LCAs only considered the agricultural, slaughtering and transport stages; an exception was Woitowitz (2007), who also took the trade stage into account. In our "farm-to-fork" approach, we extend this concept to include the consumer stage on a national level (including such aspects as packaging materials and electricity for cooling). Along with literature reviews, the environmental effects of meat production and consumption need to be assessed in a "bottom-up" manner and, thus, regional and sectoral quantification is necessary. A number of country-specific pork LCAs have been published. Most of them have dealt with specific European countries, namely Denmark (Daalgaard et al., 2007; Kool et al., 2009; Nguyen et al., 2011), Germany (De Vries and De Boer, 2010; Weidema et al., 2008), Portugal (González-García et al., 2015), Switzerland (Nemecek et al., 2005) and Austria (Kral, 2011). In this paper, the focus is on Austria and on fresh pork. In 2009, 63% of the meat consumed in Austria was pork, and represented a total consumption of 40 kg per capita (Statistik Austria, 2013). To analyse the environmental impacts of the production of Austrian pork, an LCA was performed that covered the life cycle stages from "farm to fork", including the consumer stage as mentioned above, as well as the impacts from soy bean importation from Latin America. This considerably extends the work of Kral (2011), which was thus far the only pork LCA undertaken for Austria.

While most of the LCAs mentioned focussed on the climatic impacts of meat production, other impact categories are also important. Because they were included in some other studies, soil acidification and eutrophication were also considered during the current study. One chemical element, nitrogen, seems to be an important contributor to all of these impact categories, and measures on nitrogen abatement could be generally beneficial (Sutton et al., 2011). The formation of particulate matter from livestock NH_3 emissions is another, additional nitrogen-related aspect. Indeed, the abatement of agricultural NH_3 emissions has recently been described as an important and cost-efficient way to reduce pollution with regard to particulate matter in Europe (Amann et al., 2014). Nitrogen (N) *per se* is not considered an impact category in an LCA, however, because N is an important factor in food production, it was also of interest to investigate this parameter in detail (see also Pierer et al., 2014, 2016).

This paper describes and discusses the first comprehensive LCA of Austrian fresh pork by covering the three key impact categories, global warming potential (GWP), soil acidification and eutrophication, which have also been considered by comparable LCAs conducted outside Austria. In order to identify, analyse and describe the main environmental problems over the entire life cycle of the pork (production, consumption and distribution), the goal and scope of the LCA are presented first (section 2), followed by a depiction of the life cycle inventory analysis (LCI) in section 3. Afterwards, the life cycle impact assessment (LCIA) is described in section 4 and, subsequently, the results are described (section 5) and discussed using a comparative delineation (section 6). Finally, conclusions are drawn in section 7.

2. Definition of goal and scope

2.1. Goal of the study

The goal of this study was to identify the environmental profile "from farm to fork" of fresh Austrian pork. Pork represents 7.5% of the total amount of food consumed in an average Austrian household (Friedl et al., 2007). The analysis of the process chain was performed using LCA methodology according to the ISO standards 14040 and 14044 (ISO, 2009; ISO, 2006), with the aim to generate results that can help identify system parts with high levels of environmental impact. Therefore, the product life cycle was separated into five modules, namely (i) agriculture, including the feed production, (ii) slaughterhouse, (iii) trade, (iv) consumption and (v) transport.

2.2. System boundaries

The system boundaries determined which processes were included in the life cycle assessment (ISO, 2009). An overview of the production chain of Austrian pork and the included process is presented in Fig. 1.

The study included environmental impacts caused by the provision of energy, raw materials and operating resources as well as transport emissions and waste and wastewater directly generated as a result of these processes. Not included were the emissions related to waste/wastewater treatment beyond the consumer stage or emissions caused by setting up infrastructure. Furthermore, the provision, maintenance and disposal of capital goods were not considered.

The study focused on Austrian pork. Therefore, the geographic border reflects the Austrian border, and imports and exports of livestock or pig meat were excluded from the life cycle assessment. This assumption seemed reasonable at a national level of self-sufficiency of 106% (Statistik Austria, 2013). Data derived refer to an Austrian production system, characterized by a "model pig farm" (see section 3).

The reference period for the process data covered the time period from 2007 to 2010, as data from different sources were not always available for identical years.

2.3. Functional unit

A life cycle assessment for the analysis of the environmental impact of a product involved an evaluation of all resource flows and emissions within a system that were related to the production and delivery of an entity of a given magnitude, the "functional unit" (ISO, 2006).

The functional unit chosen to best represent the pork production system was "1 kg fresh Austrian pork (carcass weight)", which is a common tare weight used in the retail trade. Only fresh pork, directly cut up at the slaughterhouse, was taken into account. Therefore, a carcass weight of 78% of the live weight of the pigs (ca. 120 kg), which equals an average 94 kg per animal (average value, cp. González-García et al., 2015; Jungbluth, 2000; Walter et al., 2008), was used in this study. About 80% of the carcass weight is sold as packaged meat (Oklahoma State University, n.d., USDA, 2015).