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Greenhouse gas emissions from beef production systems in Denmark and Sweden

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ABSTRACT

The purpose of the study was to define and describe typical beef production systems in Denmark and Sweden and estimate greenhouse gas (GHG) emissions including contribution from soil carbon changes and land use change (LUC) in a life cycle perspective (LCA). Five typical Danish (DK) and four typical Swedish (SE) systems were identified; hereof three systems with beef from beef breed cattle and six systems with beef from bull calves derived from dairy production system (including steers). The beef breed systems include an extensive system (DK) and two intensive systems (SE, DK). In the systems with beef from dairy bull calves, the bull calves were slaughtered at different ages; 9.0 months (SE), 9.4 months (DK), 11.5 months (DK), 19.0 months (SE) and at 25.0 months in the two systems with steers (DK, SE). Feed use and carbon footprint (CF) per kg meat were positively correlated. Beef from dairy bull calves slaughtered between 9.0 and 19.0 months had the lowest CF (8.9–11.5 kg CO_2/kg carcass) and feed use (7.3–11.1 kg DM/kg carcass). The steer systems had a CF of 16.6–17.0 kg CO_2/kg carcass and feed use of 13.2–15.5 kg DM/kg carcass. The highest CF and feed use were seen for beef breed systems at 23.1–29.7 kg CO_2/kg carcass and 20.9–29.8 kg DM/kg carcass, respectively.

The GHG contribution from LUC was positively correlated to the use of arable land. Beef from dairy bull calves had the lowest LUC contribution (1.3–1.6 kg CO_2/kg carcass) from a land use of 9.4–11.5 m^2/kg carcass. The highest LUC contribution (2.5–3.5 kg CO_2/kg carcass) and land use of 17.3–24.7 m^2/kg carcass was seen for beef from beef breed systems, the Swedish dairy bull calf slaughtered at 19 month, and the Danish steer. Besides arable land, the beef breed systems also used permanent pastures that were assumed not to contribute to LUC. Carbon (C) sequestration from crop residues and use of manure had a mitigating effect on GHG emission in all beef systems. The lowest C sequestration was seen for systems with beef from dairy bull calves slaughtered between 9 and 19 months, making up 0.2–0.9 kg CO_2/kg carcass, and the highest C sequestration was for the steer production and the beef breed systems, contributing between 2.3 and 4.8 kg CO_2/kg carcass.

The present study supports the hypothesis that feed use per kg carcass weight is a main driver for variation in greenhouse gas emission, land use change and soil carbon changes for beef meat sourced from different beef production systems. For the carbon

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footprint per kg carcass there was a positive correlation with feed use and therefore also the lowest carbon footprint per kg carcass in systems with the lowest feed intake, such as bull calves from dairy production.

1. Introduction

Agricultural production is responsible for 10–12% of global greenhouse gas (GHG) emissions (IPCC, 2007). Hereof the livestock sector represents a significant contribution to climate change. These figures do not include the contribution from land use change (LUC), although an increased demand for land for animal feed or food production can result in deforestation (Herzog, 2009). Based on a life cycle assessment (LCA) approach, it was estimated that the livestock sector emits about 18% of total global anthropogenic GHG emissions when contribution from LUC was included (FAO, 2006). With the demand for livestock products expected to double by 2050, the impact from livestock production becomes even more important (Garnett, 2008). Beef products, in particular, are reckoned to be the food products that cause the largest environmental impact per kg food (Mogensen et al., 2009).

There are large variations in the farming structure and resource use of the different beef production systems and, consequently, also in the environmental load of the systems (Nguyen et al., 2010, Veysset et al., 2014). In general, there are two main categories of beef: beef from beef breed production and beef from dairy production, both including beef from bull calves, non-replacement heifers and culled cows. Furthermore, within each of these main categories of beef, the production systems differ in a variety of parameters such as breed, age and weight at slaughter, housing system, feeding level and composition of the feed ration. Nguyen et al. (2010) studied major European beef production systems and found a huge variation in resource use for the different systems, ranging from 8.4 kg DM feed/kg carcass weight in an intensive fattening system with dairy bull calves slaughtered at 12 months and up to 21.0 kg DM feed/kg carcass weight for beef from a beef breed system, and carbon footprint (CF) per kg carcass 16.0–27.3 kg CO_2 for beef from the two system.

Livestock production is the world's largest user of land since the production of animal feed takes up almost 80% of the agricultural area (FAO, 2010) with beef production being responsible for a significant part of this. Nguyen et al. (2010) showed a variation in land use from 16.5 m^2/kg carcass for an intensive indoor dairy bull system to 42.9 m^2/kg for an extensive beef breed farming system. However, it should be noted that some of the land used for feeding beef breed cattle will be pastureland with no alternative use to grazing.

Due to the extensive use of land for beef production, GHG emissions from LUC may contribute significantly to the CF of beef production. The question is how to account most accurately for this contribution. Basically, there are two quite contrasting approaches for including LUC: a product-based and a land-based approach (Cederberg et al., 2013). According to the product-based approach (BSI, 2011), LUC is considered to be directly associated with the feeds grown on deforested areas; so only beef systems that depend on, for example, soybeans from South America will include such a contribution from LUC to the CF. In contrast, in the land-based approach (e.g. Audsley et al., 2009), LUC is a factor calculated into the CF of all feeds based on the assumption that all use of land for crop production will increase the demands for land and thereby cause LUC somewhere in the world. It can be discussed whether the use of permanent pastures with no alternative value except grazing will cause LUC.

Growing an animal feed affects the soil carbon balance. Typically, grasslands will sequester carbon, whereas growing annual crops like cereals will release carbon (Vellinga et al., 2004). The GHG contribution from soil carbon changes might therefore be different in a beef system based on grazing and grass silage compared with a system based mainly on maize silage and cereals. So far, very few LCAs include a contribution from soil C changes in GHG estimations, mainly due to methodological limitations. Petersen et al. (2013) suggested how soil carbon changes could be included in LCA by calculating a partial carbon budget for individual crops and combining this with the degradation and emissions of CO_2 from the soil and the resulting change in CO_2 in the atmosphere. Mogensen et al. (2014) illustrated how this approach can be used to include the contribution from soil C changes in estimations of the CF of animal feed.

The hypothesis of the present study was that the resource use per kg carcass weight as well as impacts on greenhouse gas emission, land use change and soil carbon changes would differ for beef sourced from different beef production systems within and across countries.

The objective was to define and describe typical beef production systems in Denmark (DK) and Sweden (SE) and estimate GHG emissions including the contribution from soil carbon changes and land use change in a life cycle perspective (LCA).

2. Material and methods

Typical beef production systems in Denmark (DK) and Sweden (SE) were initially identified by analysing the statistics on cattle herd structures as well as on cattle slaughtered (Anonymous 2008, 2011b, 2012d, 2012e, 2013c). The aim was to include widely diverging systems as well as the most typical ones. Two main categories of beef were identified: beef from beef cattle breeds and beef from bull calves derived from dairy production. In Denmark, beef cattle breeds represent 15% of the 207,000 cows slaughtered in 2011 (Kviesgaard, 2012) and in Sweden, beef cattle breeds represent 28% of the 145,000 cows slaughtered (Anonymous, 2013c). In Denmark, beef breed farming systems are very diverse; therefore, both an extensive and an intensive system were defined, whereas the Swedish system is more homogeneous, resulting in only one Swedish beef breed system being included in this study.