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Review article

Comparing environmental impacts of beef production systems: A review of life cycle assessments

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ABSTRACT

Livestock production, and especially beef production, has a major impact on the environment. Environmental impacts, however, vary largely among beef systems. Understanding these differences is crucial to mitigate impacts of future global beef production. The objective of this research, therefore, was to compare cradle-to-farm-gate environmental impacts of beef produced in contrasting systems. We reviewed 14 studies that compared contrasting systems using life cycle assessment (LCA). Systems studied were classified by three main characteristics of beef production: origin of calves (bred by a dairy cow or a suckler cow), type of production (organic or non-organic) and type of diet fed to fattening calves ($<50\%$ (roughage-based) or $\geq 50\%$ (concentrate-based) concentrates). This review yielded lower global warming potential (GWP; on average 41% lower), acidification potential (41% lower), eutrophication potential (49% lower), energy use (23% lower) and land use (49% lower) per unit of beef for dairy-based compared with suckler-based systems. In suckler-based systems, maintaining the mother cow is the dominant contributor to all impacts, which is attributable to the low reproductive rate of cattle and the fact that all emissions are allocated to the production of beef. GWP was slightly lower (on average 7%) for organic compared with non-organic systems, whereas organic systems showed higher eutrophication potential, acidification potential and land use (36%, 56%, and 22% higher), and lower energy use (30% lower) per unit of beef produced. Except for GWP, however, these results should be interpreted with care because impacts were compared in few studies. Lower GWP (on average 28% lower), energy use (13% lower) and land use (41% lower) per unit of beef were found for concentrate-based compared with roughage-based systems, whereas no clear pattern was found for acidification and eutrophication potential. An LCA comparison of beef systems that differ in type of diet, however, is limited because current LCA methodology does not account for the competition for land between humans and animals. To enhance future food supply, grassland less suitable for crop production, therefore, might be preferred over high productive cropland for direct production of animal feed. Furthermore, studies included in our review did not include all relevant impact categories, such as loss of biodiversity or water use. We concluded that beef production from dual-purpose cows or dairy cows inseminated with beef breeds show largest potential to mitigate environmental impacts of beef. Marginal grasslands unsuitable for dairy farming may be used for production of suckler-based beef to contribute to availability and access to animal-source food.

Contents

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1. Introduction

Beef has become an important protein source in human diets, especially in industrialized countries. Around 58% of the protein content of an average diet in OECD (Organization for Economic Cooperation and Development) countries consists of livestock products, of which about 12% is beef (FAOSTAT, 2013). The global demand for beef is expected to further increase due to population growth, rising incomes and urbanization, especially in developing countries (Alexandratos and Bruinsma, 2012).

Beef production, however, has a major impact on the environment. It is responsible for about 41% of the global emission of greenhouse gases from livestock (Opio et al., 2013), and one of the drivers of land degradation and deforestation (Cederberg et al., 2011). The environmental impact of beef as published in scientific literature, however, shows a large variation (De Vries and De Boer, 2010). Expressed per kg of edible beef, for example, De Vries and De Boer (2010) found that land use varied from 27 to 49 m^2, whereas emissions of greenhouse gases varied from 14 to 32 kg CO_2 equivalents.

This variation in environmental impact between studies partly results from differences in methodological choices, but might also partly reflect fundamental differences among beef production systems (De Vries and De Boer, 2010). Beef production systems differ, for example, in the origin of the calves, i.e. beef calves can be bred by dairy cows or suckler cows, and the type of feed used during fattening of beef calves, i.e. roughage-based or concentrate-based.

Quantifying these differences in impact among beef production systems is crucial to mitigate impacts of future global beef production systems. To this end, a systematic overview of impacts between contrasting systems is needed. Such an assessment requires a quantification of the resource use and emissions to air, water and soil during the entire life cycle of that product. Life cycle assessment (LCA) is a generally accepted method to evaluate the environmental impact during the life cycle of a product (Guinée et al., 2002). Many studies have used LCA to assess the environmental impact of beef production. To our knowledge, however, no scientific overview has been published that compared environmental impacts of contrasting beef production systems. The objective of this research, therefore, was to compare environmental impacts for beef produced in contrasting systems. We reviewed all scientific reports and peer-reviewed publications that used LCA to assess the environmental impact of beef production.

2. Material and methods

2.1. Beef production systems

Beef can be produced in systems that fundamentally differ in their interaction with milk production systems. In many systems, production of milk and meat is interrelated: (dairy) cows produce milk and meat, and surplus calves are fattened for meat production. Specialized beef production systems, however, produce only meat from beef cows and their calves. Another large difference in beef production systems concerns the feeding of the mother cow and her calves. In Brazil, for example, most beef cows and their calves are raised on pastures or rangelands (Dick et al., 2015), whereas in the USA, beef calves are commonly finished on feedlots, and this fattening phase is based mainly on concentrates (Pelletier et al., 2010). These fundamental differences in beef production might influence the environmental impact of beef.

2.2. Life cycle assessment

The environmental impact of food products is increasingly quantified using LCA. In an LCA of beef, resource use and emissions from all production stages (Fig. 1) are quantified, assigned to environmental impact categories and related to the main output of the system, e.g. 1 kg of live weight, slaughter weight or edible beef. Environmental impacts generally considered in LCAs of animal-source food are use of fossil energy, land, water, global warming potential (GWP), acidification potential and eutrophication

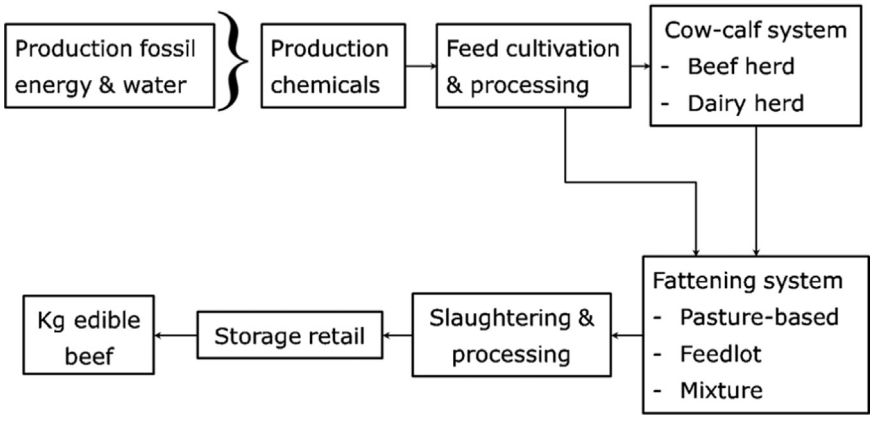

Fig. 1. Stages in the beef production chain.