Trends in Food Science & Technology 54 (2016) 94–102

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: http://www.journals.elsevier.com/trends-in-food-science-and-technology

Environmental impacts of the meat chain – Current status and future perspectives

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A R T I C L E I N F O

Article history:
Received 29 January 2016
Received in revised form
27 May 2016
Accepted 3 June 2016
Available online 6 June 2016

Keywords:
Meat chain
Environmental impact
Life-cycle
Environmental practices

A B S T R A C T

Background: The meat chain sector is recognized as one of the leading polluters in the food industry. Research on environmental performance in the meat industry has been analyzed in terms of the meat product(s), the manufacturing processes and environmental practices in which the meat companies operate.

Scope and approach: A literature review was performed by analyzing published scientific papers in the domains of environmental impacts in the meat chain. The selection criteria were focused on different environmental approaches applied in the meat chain and on the perspectives of future research.

Key findings and conclusions: This review revealed that the focus of product based approach performed through life-cycle assessments were mainly farms. Scientific papers covered calculations of global warming, acidification and eutrophication potentials. On the contrary, process based approaches investigated on-site environmental impacts of meat production. They were focused on discharge of waste water and solid waste and consumption of water and energy. Finally, environmental systems in the meat chain were the least investigated stream and they analyzed level of practices in respect to the size of the meat companies, their role in the meat chain and certification status. Future research should focus on the development of new dimensions of environmental improvements in the meat chain to enable benchmarking and comparing various meat technologies. Also, analysis of environmental practices throughout the meat chain could be of added value in the exploration of environmental improvement techniques on-site.

1. Introduction

World's consumption of meat shows two significant increases – increase of the overall consumption as a result of growth of world's population and increase of the consumption of meat per capita (Henchion, McCarthy, Resconi, & Troy, 2014). Reasons for expected increase of meat consumption are economic such as trade liberalization and globalization of food systems (Delgado, 2003), demographic such as urbanization and population projections (Allievi, Vinnari, & Luukkanen, 2015) and nutritional in respect to 'nutritional transition' of dietary patterns and consumption of foods with higher content in animal protein (Hawkesworth et al., 2010; Mathijs, 2015). Last but not least important are consumer preferences towards meat products in terms of their sensory attributes and cultural habits worldwide (Font-i-Furnols & Guerrero, 2014). The meat production and consumption affect the three pillars of sustainability – economy, society and environment (Allievi et al., 2015).

Meat is considered as the food product with the greatest environmental impact throughout the food chain whereas the greatest impacts arise from livestock farms (Röös, Sundberg, Tidåker, Strid, & Hansson, 2013). The livestock sector's environmental impact is in the need for natural resources (land, water and energy) resulting in severe emissions on air, water and soil (de Vries & de Boer, 2010). Similar to the farms, manufacturing processes such as slaughtering and meat processing have environmental impacts either from emissions into the environment or from the consumption of resources (Lopez-Ridaura, Werf, Paillat, & Le Bris, 2009). Refrigeration of refrigerated or frozen foods/meats within the cold chain is a food safety issue responsible for ozone depletion and global warming (Coulomb, 2008). Finally, consumers participate in global warming since the cooking stage releases a great deal of greenhouse gases,

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http://dx.doi.org/10.1016/j.tifs.2016.06.001
0924-2244/

joint with energy consumption (Xu, Sun, Zhang, & Zhu, 2015). The meat chain consists of farm(er)s, slaughterhouses, meat processors, customers (horeca, supermarkets, butcheries, retailers) and consumers (Bickerstaffe, Gately, Jay, Ridgway, & Morton, 2009; Borrisser-Pairó et al., 2016). Many review papers were only focused on the environmental impacts of livestock production (Davis et al., 2015; McAuliffe, Chapman, & Sage, 2016; Reckmann, Traulsen, & Krieter, 2012; Thornton, 2010; de Vries & de Boer, 2010). On the contrary, research papers mainly investigated environmental impacts of other participants in the meat chain.

A literature review was performed by analyzing published scientific papers and the major sources of information were the scholarly databases such as Web of Science, EBSCO and ScienceDirect. This research identified relevant articles, both review and research papers, published in the domains of environmental impacts in the meat chain. There were no geographical restrictions applied. The selection criteria chosen to identify the relevant articles were related to the objectives of this paper: (1) focus on the specific environmental approach applied in the meat chain; (2) focus on the potential for future research.

The outcome of articles assessing the environmental impacts of meat chain depends not only on the systems studied, but also on the environmental methodologies and evaluation methods used (Reckmann et al., 2012). As mentioned, the majority of research highlighted the environmental impacts that arise at farms as a result of livestock production. However, the entire meat chain has not been in focus of such research, and so this was identified as a research gap by the authors of this paper. Three environmental research perspectives recognized in the meat chain are meat products, the manufacturing processes and the environmental systems in which the companies operate, Fig. 1 (Djekic, 2015). The objective of this review paper was to present three main research streams for analyzing meat chain's environmental performance and identify future research perspectives.

2. Meat product-based perspective – current status

The meat product-based perspective considers calculation of various environmental indicators in relation to the product. Life Cycle Assessment (LCA) is the most applied environmental tool used to assess the potential environmental impacts and consumption of resources throughout a meat's life cycle (Lopez-Ridaura et al., 2009). As a scientific method it includes the following steps: mapping the process, setting scope and boundaries, collecting data, calculating and evaluating the results (ISO, 2006).

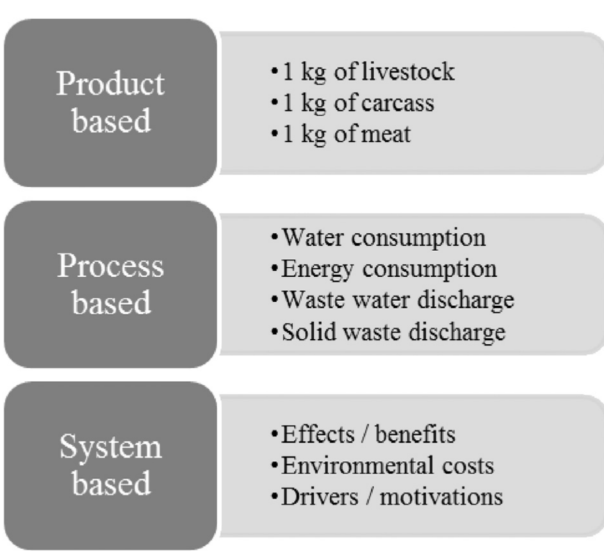

Fig. 1. Environmental research perspectives in the meat chain.

Mapping the process and setting the scope and boundaries are important in order to clarify parts of the meat chain analyzed from the “farm to the fork” perspective (Djekic, 2015). The system boundaries cover five subsystems. Subsystem 1 – ‘Farm’ includes all livestock activities which take place in a farm. It may include contribution of feed production and waste/manure management. When such subsystems are covered within LCA they enable comparing different methods of livestock production such as organic vs. conventional or indoor vs. outdoor animal husbandry (McAuliffe et al., 2016). Subsystem 2 – ‘Slaughterhouse’ includes activities such as reception of live animals, livestock handling, animal welfare, slaughtering and chilling (Djekic, Radović, Lukić, Stanišić, & Lilić, 2015). Subsystem 3 – ‘Meat processing plant’ contains all activities from reception of carcasses preparation, thermal processing, waste handling up to the storage of final meat products (Djekic et al., 2015). Subsystem 4 – ‘Retail’ comprises of activities that take place where meat is sold. These sales spots may be either in supermarkets and grocery shops or may be in specialized shops selling meat (butcher's shops/meat stores). Subsystem 5 – ‘Household use’ comprises of refrigeration of food (Coulomb, 2008), food preparation and cooking (Xu et al., 2015). A generic model of the meat product's life cycle system boundaries is presented in Fig. 2.

Depending on the role of the company in the meat chain, the most commonly used functional units are one kg of livestock (Basset-Mens & van der Werf, 2005; Dalgaard, Halberg, & Hermansen, 2007); one kg of carcass (Nguyen, Hermansen, & Mogensen, 2011; Williams, Audsley, & Sandars, 2006) and one kg of meat (Cederberg & Flysjö, 2004).

Raw data obtained from all actors in the meat chain are the main constituents of the foreground life cycle inventory for the five subsystems (Djekic et al., 2015). Collecting this information is very important, since the uncertainty of these data may cause imprecise calculation of various environmental indicators (Djekic, 2015). Analysis of inventory requires calculation of environmental impact categories set out in the goal and scope in order to determine potential environmental pressures (McAuliffe et al., 2016). For the purpose of conversion from the ‘whole of subsystem basis’ to a ‘functional unit basis’, allocation of inputs and outputs should be applied. There are three main allocation methods: economic allocation, physical allocation and system expansions (de Vries & de Boer, 2010). Interpretation of the results is in direct correlation with the boundaries and the quality of the data. A LCA study in the meat chain enables identifying mitigation strategies that can focus on the primary sources of environmental impact, interpreted in relation to the functional unit and subsystem(s) (Djekic, 2015).

In line with the defined system boundaries of the meat product's life cycle, Table 1 gives an overview of the meat chain LCA studies (emphasizing environmental impacts in each of the system boundaries). Analysis of 20 LCA studies showed that the range of GWP per kg of bone-free meat (subsystems 1 and 2) is from 3.6 to 8.9 kg CO_2 eq. (Cherubini, Zanghelini, Alvarenga, Franco, & Soares, 2015; Röös et al., 2013). These studies covered developed countries and different production systems (organic, conventional, high and low profit). In the EU average GWP of pork production is from 2.6 to 6.3 kg CO_2 eq per kg of pork (Reckmann et al., 2012). Due to large differences in model assumptions, system boundaries, functional units, data collection methods and software calculations, numeric results may vary. These methods consider different impact categories, emission factors, normalization methods and weighting factors which make comparisons difficult (Carvalho, Mimoso,