Science of the Total Environment 576 (2017) 129–137

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Carbon footprint of conventional and organic beef production systems: An Italian case study

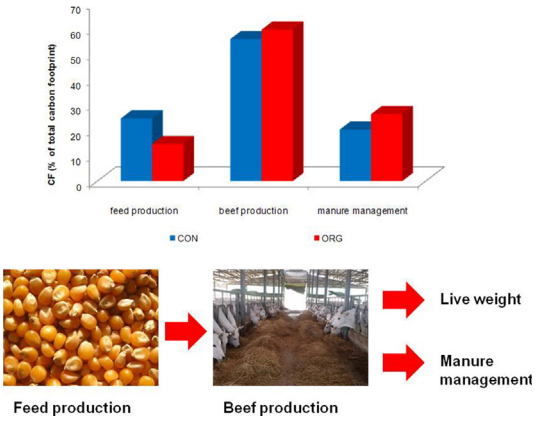
C. Buratti [a,*], F. Fantozzi [a], M. Barbanera [a], E. Lascaro [a], M. Chiorri [b], L. Cecchini [b]

[a] CRB, Biomass Research Centre, Via G. Duranti, 63, 06125 Perugia, Italy
[b] Department of Agricultural, Food and Environmental Sciences, University of Perugia, Borgo XX Giugno, 74, 06121 Perugia, Italy

HIGHLIGHTS

- Organic and conventional beef production are compared by carbon footprint.
- Conventional system has lower GHG emissions.
- The most impacting phase is represented by enteric fermentation in both scenarios.
- Sensitivity analysis evaluates the contribution from changes in soil C.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 19 May 2016
Received in revised form 27 September 2016
Accepted 10 October 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Livestock
Meat production
GHG emissions
Carbon footprint
Life Cycle Assessment

ABSTRACT

Beef cattle production is a widespread activity in Italy in the agricultural field and determines an important impact on environment and resources consumption. Carbon footprint evaluation is thus necessary to evaluate the contributions of the different stages and the possible improvements of the production chain.
In this study, two typical Italian beef production systems, a conventional and an organic one are investigated in order to evaluate the greenhouse gas emissions from "cradle to gate farm" by a Life Cycle Assessment (LCA) approach; the carbon footprint (CF) per 1 kg of live weight meat is calculated.
The contributions from feed production, enteric fermentation, and manure management are taken into account, in order to compare the life cycle of the two productions; also the carbon balance in soil is evaluated, in order to verify the impact in a life cycle perspective.
The results of CF calculation of the two farms show that organic system (24.62 kg CO_{2eq}/kg live weight) produce more GHG emissions than the conventional one (18.21 kg CO_{2eq}/kg live weight) and that the enteric fermentation is the more heavy contribution, with a range of 50–54% of the global CF value. Improvements of the production chain could be realized by accurate feeding strategies, in order to obtain reduction of methane emissions from enteric digestion of cattles.

* Corresponding author.
E-mail address: cinzia.buratti@unipg.it (C. Buratti).

http://dx.doi.org/10.1016/j.scitotenv.2016.10.075
0048-9697/

1. Introduction

Worldwide the agriculture sector, including crop and livestock production, forestry and associated land use changes, was estimated to contribute up to 30% of the greenhouse gas (GHG) emissions. According to Tubiello et al. (2013), at the global level, the largest source of GHG emissions within agriculture is enteric fermentation, which accounted in 2012 for 38.6% of the sector's total GHG outputs.

The livestock sector is responsible for about 7.1 Gt CO_{2eq}/yr (14.5% of all anthropogenic emissions) and, in particular, the cattle sector emits about 4.3 million tons of CO_{2eq} (65% of the livestock sector) of which about 2.8 million tons are associated with beef production (Opio et al., 2013).

In Italy the agricultural sector represents the second largest source of GHG emissions (6.9% of total anthropogenic emissions in 2011). In 2012, the livestock farming, mainly ruminants, was the principal contributor, above all due to the enteric fermentation (37.5% of GHG emissions from the agriculture sector) and manure management (20%).

The beef production industry is particularly relevant for the Italian agribusiness. Italy is the fourth European producer of beef (Eurostat, 2013), with three main production systems: dairy breed bull calves fattened for meat production (805,000 heads slaughtered in 2012, corresponding to 12% of the Italian cattle meat production), dairy culled cows (507,000 heads slaughtered in 2012, representing 15% of the Italian cattle meat production), and beef cattle breeds (2,039,000 heads slaughtered in 2012, representing 69% of the Italian cattle meat production) (Rama, 2014).

Beef cattle production is largely based on the fattening of Italian young cattle (62%), while the other fraction (38%) derives from finishing of imported young bulls and heifers (mainly from France, Ireland, and eastern European countries). With reference to the breeds of beef farms, Italy is characterized by a great number of autochthon breeds (Piemontese, Podolica, Chianina, Marchigiana, Maremmana, etc.), spreading over specific regions. In Umbria region cattle livestock farms for meat production are 2730, with 35,265 heads in 2014. The most typical cattle breed for beef breed farming systems is Chianina (18,772 heads corresponding to about 80% of the beef heads) (Umbria Region, 2014), while the diffusion of other valuable beef breeds is much more limited: Limousine (3391 heads), Charolais (1209), Marchigiana (1129). Umbria region is also the second largest Italian area for diffusion of Chianina breed after Tuscany.

From the production system point of view, in Europe the organic cattle livestock for meat production is still not widespread, because the share of the organic sector in relation with the whole bovine sector represents only around 3% in the EU-15 (EC, 2013). However, the number of certified organic cattle heads registered a significant growth from 2005 (1,490,201 heads) to 2012 (3,250,557 heads) in the EU-27. In Italy the organic beef cattle represents about 4% of the bovine sector and Central Italy is the area characterized by the wider diffusion of the organic cattle livestock production for beef cattle (INEA, 2014). The main barriers to the spreading of organic cattle breeding are the constraints imposed by European (EC, 2007; European Union, 2008) and National (Decree of the Ministry of Agricultural, Food and Forestry Policies No. 18,354/09) regulations, requiring that:

- cattle have to be fed with milk until at least 3 months of age;
- cattle housing systems should be mostly based on the use of grazing, when available;
- a minimum of 60% of the dry matter intake of the beef cattle should be made by forage;
- the use of chemical fertilizers, pesticides, antibiotics, feed additives, growth hormones, and genetically engineered breeding inputs has to be avoided.

In order to evaluate the environmental profile intensity of beef production, it is important to adopt a whole system modeling approach. Life Cycle Assessment (LCA) methodology (ISO, 2006a, 2006b) allows to identify and analyze the environmental impacts and hotspots of products and service systems (Rinaldi et al., 2014; Buratti et al., 2015) and should be the basis of any decision making strategy for environmental improvements in a life cycle perspective (Gonzalez-García et al., 2009). However, the comprehensiveness of the LCA methodology, due to the inclusion of a wide spectrum of environmental indicators, presents weaknesses when results are communicated to stakeholders and the general public (Weidema et al., 2008). Thus, the application of a single issue indicator, such as carbon footprint (CF), has become increasingly popular (Rugani et al., 2013). In particular, CF allows to evaluate the impact of a product in terms of global warming, providing an assessment of GHG emissions during part or all of its life (BSI, 2011).

The use of CF for assessing the environmental impact of beef production systems could have several limitations, mainly due to the trade-offs with other relevant environmental variables (Picasso et al., 2014). However, CF is strongly linked to energy consumption and therefore it represents other underlying environmental impacts (Weidema et al., 2008).

In order to overcome the differences in methodological approaches between different studies, causing an unfair comparison of calculated CFs (Flysjö et al., 2011), ISO 14067 was introduced with the aim of providing principles, requirements, and guidelines for the quantification and communication of the carbon footprint of a product (ISO/TS 14067, 2014).

LCA method has been widely used to evaluate the environmental performance of beef production, comparing different origin of calves (dairy or suckler calves), production systems (organic or conventional), and different types of diet (concentrate- or roughage-based systems) (de Vries et al., 2015). Furthermore, the existing studies are referred to specific countries such as France, Ireland, Japan, United States, Thailand, Brazil mostly based on farm model data (Ogino et al., 2016). In particular, only three studies concern the comparison of the organic and conventional production systems, and all of these are referred to middle and northern European countries (de Vries et al., 2015); the results show that the best scenario is not uniquely defined because the relative difference between organic and conventional production, in terms of GHG emissions per unit of product, ranges from −15% to 15%.

Therefore, further research is needed in order to understand if the organic system can be linked with lower environmental impact, also in relation to other geographical areas. The aim of this study was to evaluate and to compare the GHG emissions of organic and conventional beef production systems in Italy, using actual data from two typical farms located in the Umbria region.

2. Materials and methods

The first step of LCA is the definition of the goal and scope of the study; in this case, the goal was the evaluation and the comparison of the environmental impact, in terms of carbon footprint, of two Chianina beef production systems: a conventional system (CON) and an organic system (ORG). For each system cow-calf farms, characterized by self-produced cattle, were considered, because cow-calf system is the most typical one in Central and South Italy (Rama, 2014).

Two case study farms were selected in order to obtain primary data on the basis of the following criteria: (1) representativeness of Chianina beef farms operating in Umbria, in terms of herd size, farm size, and housing system; and (2) implementation of an accounting and management system organized to provide comprehensive and good-quality data for the LCA analysis.

In particular, typical farming system in Umbria was identified on the basis of data reported by BDN (2016) and ANABIC (2014), showing that the animals are mainly reared in an extensive production way based on a loose housing system on deep straw bedding with an outdoor paddock.

The two investigated farms that represent CON and ORG systems are located in Perugia Province. The annual mean temperature and annual