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Environmental impact of dairy buffalo heifers kept on pasture or in confinement

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ABSTRACT

In western countries buffaloes are emerging as an alternative species for dairy product differentiation. In the near future dairy enterprises will have to meet increasing environmental regulations. Life Cycle Assessment has been widely used to assess the environmental impact of different milk production systems. We aimed to examine the environmental consequences of two dairy buffalo heifer farming systems using the Life Cycle Assessment approach. The primary data were collected from 32 subjects aged 7–8 months at the start of the experiment until they reached the age of puberty in about 12 months (i.e. at the age of 19–20 months). Sixteen animals were group-housed and confined in an indoor slatted floor pen (4 m^2/animal) with an outdoor paddock (4 m^2/animal); 16 others free-ranged on a Mediterranean natural pasture. The environmental charges for global warming potential expressed in terms of total emissions of carbon dioxide equivalent (CO_2-eq) was 35.7% less in the free-ranging system as compared with the confined system. The main source of pollution for the confined system was biogenic methane (total amount produced = 2012 kg CO_2-eq) followed by CO_2 from fossil fuels (total amount produced = 1006 kg CO_2-eq). The environmental charges for acidification potential, eutrophication potential and non-renewable energy use were 86.3%. 60.0% and 81.4% lower in the free-ranging system compared with the confined system, respectively. In the confined system the largest pollutant in terms of acidification potential was ammonia, whereas nitrate leaching in water (total amount produced = 3311 g SO_2-eq) and the use of crude oil (total amount consumed = 5684 MJ-eq) were the most relevant for eutrophication potential and non-renewable energy use, respectively.

Our results represent the first example of study comparing the environmental impact of an intensive dairy farming system with an alternative natural pasture based system in the Mediterranean region and suggest that the conduction of the unproductive part of the cycle on natural pasture can promote the reduction of several sources of pollution both in atmosphere and in water. Conversely, land occupation was higher in the free-ranging system as compared with the confined system (20,349 vs 1381 m^2 year, respectively). However, the software and the database used for this calculation only considered duration of land use and yield per area unit, whereas no relevance was given to the quality of land use in terms of animal welfare promotion, contribution to biodiversity conservation, and maintenance of economically active social communities. Therefore, we suggest that the estimation of the impact categories related to land occupation would include aspects concerning the nature of the land.

1. Introduction

The carbon footprint has been defined as the total amount of greenhouse gas (GHG) directly and indirectly produced by a particular individual, in a particular event or during a particular productive process, and it is expressed in terms of CO_2-eq (ICTSD, 2008). Countries adhering to the Kyoto Protocol (1997) agreed to reduce the emissions of GHG as estimated in 1990. The main GHG emissions attributed by the International Panel of Climate Changes (IPCC) to the agricultural sector are methane (CH_4) and nitrous oxide (N_2O). Animal enterprises are responsible for the production of GHG under the form of CH_4 from enteric fermentations (EF), N_2O deriving from the use of nitrogenous

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fertilizers, and CH_4 and N_2O emitted from manure, either managed under intensive farming conditions, or directly deposited on pastures in more extensive systems (O'Mara, 2011). Animal productions are responsible for 8–11% of GHG emissions as assessed by IPCC. In Europe, within the animal production sector, dairy milk production shows the highest GHG emissions (28–30%), along with beef (28–29%) and pork production (25–29%) (Weiss and Leip, 2012).

The adoption of improved agricultural practices can promote the reduction of GHG emissions from livestock production enterprises. For instance, in Italy, from 1990 to 2009, emissions of enteric CH_4, manure CH_4, manure N_2O, and soil N_2O emissions decreased by 11.5%. 16.6%. 4.03%. and 20.6%, respectively (Cóndor, 2011). Recent studies indicate that the inclusion of more digestible forages in ruminant diets may reduce CO_2 emissions also in intensive systems (Sabia et al., 2015a).

Although in 1991 the Council of the European Communities issued the directive 91/676/EEC in order to reduce nitrate leaching and the consequent water pollution caused by agricultural practices, including those concerning animal production, by setting thresholds of spreadable organic N per hectare per year, no specific rules concerning the environmental impact of dairy enterprises is currently available. Nevertheless, in the near future dairy enterprises will have to meet an increasing number of environmental rules including limits on GHG and other noxious gas emissions (e.g. NH_3) and restrictions on nitrate (NO_3^-) leaching and phosphate (PO_4^{-3}) run-off (European Council, 1991; Lovett et al., 2008). Life Cycle Assessment (LCA) has been widely used to assess the impact of various milk production systems on the environment. In particular, LCA allowed the comparison between organic and conventional systems (e.g. Cederberg and Mattsson, 2000; Thomassen et al., 2008) as well as the evaluation of the environmental performance of different dairy (e.g. O'Brien et al., 2012) and beef enterprises (e.g. Bragaglio et al., 2017).

For animal based production enterprises the identification of best practices from an environmental point of view is not simple as different systems often imply trade-offs between different forms of impact: some systems may favour biodiversity conservation and carbon sequestration, in others food production may be more efficient (Galka, 2004). For instance, systems based on free-ranging may show higher environmental performances due to the low inputs needed in the production process, albeit requiring more land. However, land can be used for several different purposes and if land use options are included in the assessment, results on environmental performances may change (Thomassen et al., 2008).

In Italy buffalo farming represents one of the most important dairy enterprises (AIA, 2013). It has been conducted for centuries in extensive conditions based on marshland environments. In the last forty years the increasing demand of mozzarella cheese induced a concomitant increase in the number of buffaloes, which in Italy increased from about 103.000 in 1980 to approximately 378.000 in 2015. These animals are distributed in about 2.455 farms mainly located in central-southern Italy (Italian Ministry of Health, 2015). This geographical area comprising Campania, Lazio, Apulia and Molise regions has been identified for the production of the cheese "Mozzarella di Bufala Campana" registered in the European Union's list of Protected Designation Origin products. The average production in 2013 was 2222 kg of milk per 270-day lactation (AIA, 2013). As a consequence, buffalo farming has moved to more intensive farming conditions with a feeding system based on three different rations corresponding to the three main buffalo productive stages (lactating cows, dry cows, growing heifers). Maize silage and ryegrass hay represent the main forages of their diet, whereas concentrates are only given to lactating buffalo cows (Sabia et al., 2015b). In these farming conditions animals have no access to pasture and water for wallowing, Such management changes concerned all animal categories, including juvenile, non-lactating animals such as heifers, which neither necessitate, unlike buffalo cows, milking facilities and feeding supplementation to fulfil the increased requirements induced by milk production, nor they need, unlike buffalo calves, particular protection from climate extremes and predator attacks.

Despite the economic relevance of buffalo farming in Italy and the increasing interest in this species worldwide, only few studies on its environmental impact as assessed by LCA have been conducted so far (Pirlo et al., 2014a,b). In addition, recent research was devoted to extensive grazing systems, where dairy farms can play a role in maintaining biodiversity and promoting landscape ecology (Penati et al., 2011). Extensive rearing systems may be conveniently used for species well adapted to the environment, such as buffaloes, and non-productive animal categories, such as heifers (Sabia et al., 2014). Extensive farming practices may also reduce production costs and environmental impact (Nilsson et al., 2004), while promoting animal welfare (De Rosa et al., 2007) and product differentiation through quality assurance (Napolitano et al., 2013). However, little is known about the sustainability of extensive buffalo heifer farming as only one paper by Sabia et al. (2014) dealing with the productive efficiency and the competition with the human nutrition of this system has been published so far. Therefore, the present study aims to evaluate the effects on the environment of two different rearing systems, both suitable for buffalo heifers (i.e. free-ranging and confinement), as assessed by LCA.

2. Materials and methods

LCA is the assessment of inputs, outputs and environmental impacts of any production systems through production, usage, and disposal (Guinee et al., 2002). The ISO standards (ISO, 2006a,b) describes four distinct phases of LCA: 1) identification of the aim, functional unit, and limits of the system; 2) analysis of the inventory (including input and output data collection for all processes); 3) assessment of the environmental impact; 4) result interpretation.

2.1. System boundary definition

The analysis included the life span comprised between 7 and 8 months of age and puberty of buffalo heifers (*Bubalus bubalis*) kept on pasture (System FR) or in confinement (System C); the boundaries of the two systems are depicted in Fig. 1a and b, respectively. For system FR the data were collected between the ages (mean ± SE) of 235 ± 18 days and 675 ± 11 (age of puberty), whereas for system C the experiment was comprised between the ages of 236 ± 17 days and 667 ± 11 days (age of puberty), corresponding to the period September 2010–October 2011. The reference data were retrieved from Sabia et al. (2014). We took into account any on-farm activities (such as feed production, electricity, fuel and energy use, manure and animal management) and the corresponding emissions. We also considered the consumption of energy and the emissions from activities conducted off-farm (i.e. production of bedding materials, fodders, pesticides and fertilizers were retrieved from Ecoinvent database), whereas fuel, electricity and concentrate consumptions were primary data. The transport of off-farm feeds and bedding material along with the transport associated with the transfer of buffalo heifers from the farm to the pasture were also included in the estimate.

2.2. Functional unit definition

Life cycle assessment is based on a mass and energy balance; therefore, 1 kg of weight gain in the period needed to reach the age of puberty was used as functional unit. However, buffalo heifers are part of dairy enterprises where the aim is to minimise the time needed to reach the age of puberty (as the animals are unproductive) with an appropriate weight in order to move on to the subsequent productive phases (pregnancy and lactation): the objective is the attainment of a physiological stage rather than a high weight. Therefore, although this temporal functional unit has never been used before, we deemed appropriate the use of 1 day of the period needed to reach the age of puberty, as a means to estimate the impact of the pre-pubertal phase.