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Carbon footprint of milk produced at Italian buffalo farms

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ABSTRACT

The carbon footprint (CF) of milk produced in six Italian Mediterranean Buffalo farms was estimated through a simplified Life Cycle Assessment. Functional unit was 1 kg of fat and protein corrected milk (FPCM).The farms were characterized by high levels of inputs, as purchased feeds, chemical fertilizers and fossil fuels. Average cultivated area was 53.2 ha; the forage system was based mainly on maize silage, immediately followed by Italian ryegrass and/or whole cereal silage. Average herd size was 360 and the average FPCM per lactating buffalo was 3563 kg/year with an average milk fat and protein percentage of 8.24 and 4.57 respectively. The CF assessment was from cradle to farm gate. The greenhouse gases (GHG) that were taken into account were CH_4 from enteric fermentations, CH_4 from manure in the stable and in the tank; N_2O from nitrification and denitrification processes in the manure before application into the soil and N_2O produced after organic and synthetic fertilizer application; direct emissions of CO_2 from the fossil fuels combustion within the farms and indirect emissions of CO_2 deriving from production of electricity, off-farm feeds, synthetic fertilizers and other minor inputs. Carbon footprint of 1 kg of FPCM was 3.75 kg CO_2eq. Main sources of GHG are enteric CH_4 (45%) and indirect CO_2eq (25%). Besides enteric CH_4, the farm activity that gives the highest contribution to milk CF is on-farm feed production, with 34% on total greenhouse gas emissions (TGE). Carbon footprint with economic allocation (CFea) was estimated by considering the live-weight of males calves and culled cows: its value was 3.60 kg CO_2eq. If the economic value of the increase of the herd size is considered in the assessment, CFea decreases to 3.45 or 3.27 kg CO_2eq with an increase of 10% or 20% of the number of mature buffalos.

1. Introduction

Countries that signed the Kyoto Protocol (1997) established to reduce the atmospheric emissions of greenhouse gases (**GHG**) estimated in 1990. In the International Panel of Climate Changes (**IPCC**) framework, GHG attributed to the agricultural sector are CH_4 and N_2O. Methane is produced mainly with enteric fermentation and decomposition of manure organic matter; N_2O derives from the N content of manure and from N of organic and chemical fertilizers once they are applied to the soil. Technological progress and the adoption of best practices made possible to reduce GHG emissions from livestock production systems: 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). However, CO_2 has also a great interest for agriculture; in fact, this gas is emitted from the fossil fuel combustion of engines used for farming operations or from industrial activities supplying goods such as chemical fertilizers or equipment.

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Life Cycle Assessment (**LCA**) is a widely accepted methodology for estimating the environmental effects that a unit of product causes during the entire life cycle. Carbon footprint (**CF**) is an LCA referring exclusively to Global Warming Potential (**GWP**).

In Italy, there is an important population of dairy buffalos, whose milk is used for the production of "Mozzarella di bufala campana – DOP". The population of Italian Mediterranean Buffalos (**IMB**) has increased considerably in the last decades; between 1985 and 2010 the number of buffalo cows increased from 45,000 to 245,000 (AIA, 2010). However, in spite of the relevant economic importance of these animals in some southern regions of Italy and of the worldwide spread of buffalos, so far we do not know any specific study about CF of buffalo milk.

On the contrary, there are several studies concerning CF of cattle milk, as reviewed by Pirlo (2012). In order to harmonize the studies and make them comparable, the International Dairy Federation (FIL-IDF, 2010) proposed a standardization of the methodology for estimating the CF of 1 kg of fat and protein corrected milk (**FPCM**). FAO (2010) calculated that the average emission of GHG at the farm-gate is about 2.4 kg of carbon dioxide equivalent (CO_2eq) per kg of FPCM, with wide variations depending on the geographic area: from 1 kg of CO_2eq in North America to 7.5 kg of CO_2eq in South Africa. The production system has also a great influence on milk CF: Capper et al. (2009) demonstrated that technological progress, occurred between 1944 and 2007, determined a reduction from 3.66 to 1.35 kg CO_2eq per kg of milk. The main driver of this pattern is the output of milk per cow per year (Gerber et al., 2011), that makes it possible to produce the same amount of milk with a reduced number of cows.

In IMB population, the introduction of rational feeding technologies and improved management has also determined a strong increase of average milk production; from 1990 to 2012 the average milk production of buffalo cows of the IMB Herdbook increased from 1893 to 2218 kg per year, while milk fat and protein contents remained steady: about 8.2% and 4.5% respectively (ANASB, 2013). Rearing system is very similar to that of highly producing dairy cattle and the diet is commonly based on maize silage, concentrates, alfalfa hay and a minor portion of by-products (Borghese and Mazzi, 2005).

Milk production accounts for the greatest part of the environmental burden of milk end products, such as drinking milk, cream, butter, or cheese (Fantin et al., 2012; Flysjö, 2011; González-García et al., 2013); consequently, a reduction of the GHG emissions in the agricultural phase can have positive effects on the environmental impact of the whole production chain. However, similar considerations can be made for buffalo milk too.

Aims of this study were: (i) to estimate the CF of buffalo milk at farm gate and (ii) to point out the main drivers that influence it.

2. Material and methods

2.1. Simplification

A simplified LCA was used for evaluating the CF of one kilogram of milk produced in six buffalo farms. Main simplifications were: (i) dry matter intake was not measured, but was estimated from buffalos' nutrient requirements; (ii) resource consumptions and GHG emissions caused by on-farm production were not estimated for each crop, but as a whole; and (iii) electric consumptions were estimated as a whole, without considering every specific activity, such as milking, cooling, or lighting.

2.2. Data collection

The milk CF was estimated in 6 buffalo farms located in Campania region. The farms were chosen at random from the population of farms assisted by the technical service in that region. The data, referring to 2010, were collected through a questionnaire that was distributed among the farmers. The questionnaire concerned technical data about farm size, crops, herd size and herd composition, manure storage and processing, agricultural operations, forage system, amounts and kind of seeds, chemical fertilizers, pesticides, plastics, detergents, medicines, fuels, electricity, equipment, agricultural machines, amounts of off-farm feeds, production of on-farm crops and diet fed to the different animal categories. Farmers also filled in the questionnaire with milk composition and output of milk and meat. The questionnaire also required economic data concerning the yearly revenue for milk and for culled or replacement animals.

The farms adopted a very intensive forage system (Table 1), permitted by the great availability of irrigation water. Maize silage was the main crop, immediately followed, after the harvesting, by Italian ryegrass and/or whole cereal silages. Table 1 reports the levels of *N* and *P* fertilizers per hectare. A small portion of cultivated area was exploited for alfalfa hay production. Only in one farm buffalos had access to pasture for a short period of the year.

Herd size and herd composition are reported in Table 2. Manures were handled and stored for at least 3 months before spreading.

Table 1
Forage system.

		Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Mean
Total cultivated area	(ha)	38	24	45	157	20	35	53.2
Maize+Italian ryegrass or whole cereal silage	(ha)	36	21	39	3	18	34	25.2
Synthetic N fertilizers	(N kg/ha)	349	201	310	4	307	277	241
P fertilizers	(P_2O_5 kg/ha)	70.8	80.3	78.8	60.5	78.2	79.0	74.6

In farm 3 the animals have access to pasture.