SheepToShip LIFE: Looking for an eco-sustainable sheep supply chain. Preliminary results on GHG emission of dairy sheep farms

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SheepToShip LIFE: Looking for an eco-sustainable sheep supply chain. Preliminary results on GHG emission of dairy sheep farms

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Abstract. SheepToShip LIFE is an EU project launched in 2016 to develop an intervention model for the eco-innovation of the Sardinian sheep-dairy supply chain, able to reduce greenhouse gas (GHG) emissions by 20% over the next 10 years through improved efficiency of production systems. This work shows the preliminary results of the Life Cycle Assessment (LCA) conducted in four case study farms, characterized by different production and management systems. The environmental performances of each farm are expressed in terms of Carbon Footprint (CF) per unit of product (fat and protein corrected milk, FPCM) and unit of area (ha of utilized agricultural area, UAA), with the additional goal of identifying the main processes that contributed to the total CF (hotspots). Farms were surveyed to gather primary data for a "from cradle to farm gate" LCA study. The average CF (CO_2-eq kg $FPCM^{-1}$) of the four farms was equal to about 3.4 kg CO_2-eq, ranging from 2.6 to 4.2. Cropland-based farms with a higher Dairy Efficiency (DE – expressed as kg FPCM kg DMI^{-1}) showed lower values of CF, as compared with pastureland-based farms. Contrasting results were obtained when one ha of UAA was used as functional unit. Enteric CH_4 emission contributed on average about 57% of total CF, representing the main environmental hotspot.

Keywords. Carbon Footprint – Dairy efficiency – Sheep system – Environmental hotspot.

Sheep ToShip LIFE : À la recherche d'une chaîne d'approvisionnement ovine éco-durable. Résultats préliminaires sur les émissions de GES des exploitations ovines laitières

Résume. *SheepToShip LIFE est un projet européen lancé en 2016 pour développer un modèle d'intervention pour l'éco-innovation de la filière ovine-laiterie sarde, capable de réduire les émissions de gaz à effet de serre (GES) de 20% au cours des 10 prochaines années grâce à une meilleure efficience des systèmes de production. Ce travail présente les résultats préliminaires de l'analyse du cycle de vie (ACV) réalisée dans quatre fermes d'étude de cas, caractérisées par différents systèmes de production et de gestion. Les performances environnementales de chaque exploitation sont exprimées en termes d'empreinte carbone (EC) par unité de produit (lait corrigé en matières grasses et en protéines, LCMP) et par unité de surface (ha de surface agricole utilisée, SAU), avec pour objectif supplémentaire d'identifier les principaux processus qui contribuent à l'EC totale (points chauds). Les exploitations agricoles ont été interrogées afin de recueillir des données primaires pour une étude ACV "du berceau à la porte de la ferme". La EC moyenne (CO_2-eq kg $LCMP^{-1}$) des quatre exploitations était égale à environ 3,4 kg CO_2-eq, allant de 2,6 à 4,2. Les exploitations basées sur des cultures et présentant un rendement laitier (DE - exprimé en kg LCMP kg DMI^{-1}) plus élevé ont présenté des valeurs de EC inférieures à celles des exploitations basées sur des pâturages. Des résultats contrastés ont été obtenus lorsqu'un ha de SAU a été utilisé comme unité fonctionnelle. Les émissions de CH4 entériques ont contribué en moyenne à environ 57% de la EC totale, représentant le principal point chaud environnemental.*

Mots-clés. *Empreinte carbone – Efficacité laitière – Système ovin – Point chaud environnemental.*

I – Introduction

Agriculture largely contributes to global warming and ruminants are major responsible to greenhouse gas (GHG) emissions in this sector (Gerber *et al*., 2013). Small ruminants in the world are about 56% of global ruminant domestic population (FAO, 2016a). Sheep production systems contribute to global GHG emissions with around 254 Mt CO_2-eq (Opio *et al*., 2013), with 67.1 Mt CO_2-eq attributed to the sheep milk production (Hristov *et al*., 2013). However, most of Carbon Footprint (CF) studies were carried out on dairy cattle, whereas few studies were based on dairy sheep (Opio *et al*., 2013; Marino *et al*., 2016, Vagnoni and Franca, 2018).

Italy is one of the first world sheep milk producers and sheep cheese exporters. In particular, about 25% of total EU-27 sheep milk is produced in Sardinia (Italy) (Rural Development Programme of Sardinia, 2014-2020). In this region, characterized by typical Mediterranean climate, the variable farming systems determine different forage systems (Porqueddu *et al*., 2017), depending on the pedo-climatic context. Usually, farms with extensive management have forage systems based on natural pastures, while annual forage crops characterize the farms with more intensive management (Vagnoni *et al*., 2015).

SheepToShip LIFE is an EU project launched in 2016 to develop an intervention model for the eco-innovation of the Sardinian sheep-dairy supply chain, able to reduce GHG emissions by 20% over the next 10 years through improved efficiency of production systems. Twenty farms located in contrasting pedo-climatic zones were selected to conduct a Life Cycle Assessment (LCA) study. This work shows the preliminary results of the LCA performed in four case study farms, characterized by different production and management systems. The environmental performances of each farm are expressed in terms of CF per unit of product (CO_2-eq per kg of fat and protein corrected milk, FPCM) and per unit of area (ha of utilized agricultural area, UAA) with the additional goal of identifying the main processes that contributed to the total GHG emissions (hotspots).

II – Materials and methods

The study was carried out from October 2016 to September 2017 on four dairy sheep farms located in different area of Sardinia. Farms were surveyed to gather primary data for a "from cradle to farm gate" LCA study. Main information on the geographical location, crop system, milk production, herd size and sheep diet of each farms are reported in Table 1. Using a model based on IPCC (2006) Tier 2 with updated values for CH_4 and N_2O characterization factors, farm data were analyzed to estimate CF values. One kg of fat and protein correct milk (FPCM) and one ha of utilized agricultural area (UAA) were adopted as function units (FUs). The main processes that contributed to the total CF were also analyzed.

Table 1. Main characteristics of the four different dairy sheep farms

	Unit	Farm 1	Farm 2	Farm 3	Farm 4
Altitude	m a.s.l.	540	464	50	121
Geographical areas	Latitude, pedologic substrate	Centre, granitic	North, alluvial	North, alluvial	South, alluvial
Utilized Agricultural Area (UAA)	ha	79.3	51.8	71.7	182.3
Natural pasture area	% UAA	66.7	49.8	23.7	0.0
Annual forage crops	% UAA	33.3	50.2	76.3	100.0
Heads (number of mature ewes)	N	240	248	375	1312
Stocking rate	head ha^{-1}	3.0	4.8	5.2	7.2
Milk total annual production	kg FPCM	29,692	38,017	72,649	277,577
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	123.7	153.3	193.7	211.6
Concentrate Intake	% on total dry matter intake (DMI)	25	21	29	34
Dairy Efficiency (DE)	kg FPCM kg DMI^{-1}	0.27	0.28	0.36	0.46

III – Results

CF (CO_2-eq kg $FPCM^{-1}$) was equal to 4.2, 3.7, 3.1 and 2.6 in Farm 1, Farm 2, Farm 3 and Farm 4, respectively (Fig. 1a). The total GHG emissions of 1 ha of UAA were 1,581, 2,710, 3,090 and 3,983 kg of CO_2-eq in the same farms, respectively (Fig. 1b). The contribution analysis underlined that enteric CH_4 emissions determined on average about 57.5% ± 1.1 (± standard error) of total CF. Emissions relative to on-farm and off-farm feed production, on-farm manure production and energy use (diesel and electric energy) contributed for about 19.7% ± 0.9, 13.8% ± 0.4 and 9.0% ± 1.4, respectively.

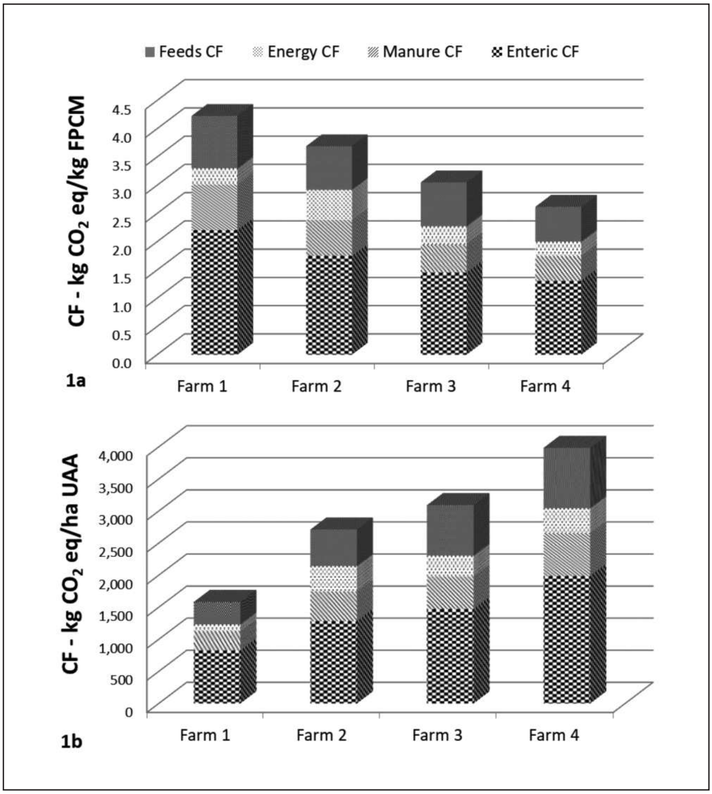

Fig. 1. Carbon Footprint (CF) of the milk produced in the four case study farms, using 1 kg of Fat Protein Corrected Milk (FPCM) (1a) and 1 ha of Utilized Agricultural Area (UAA) (1b) as functional units.

III – Discussion

Different environmental conditions influenced and characterized both structure and management system in the four case study farms. The increase of natural pastures as forage resource was proportionally associated to a reduction of Dairy Efficiency (DE), which, in turn, was the main cause of the CF increase per kg FPCM. CF values appeared strictly linked to animal requirements and production levels. Similar results were observed by other recent studies carried out under Mediterranean conditions, where CF per kg FPCM was lower in intensive farms than extensive ones (Batalla *et al.*, 2015; Vagnoni *et al.*, 2018).

However, when GHG emissions were estimated per ha of UAA, farms showed an opposite trend. This result may be explained by a lower milk production per ha of UAA for farms with lower DE. This outcome confirmed that is advisable to adopt both mass and area-based FUs for CF estimation of livestock products (Salou *et al*., 2017). On the other hand, for a comprehensive assessment of the environmental implications of dairy sheep farming systems, it is strongly recommended to use other impact categories than CF, such as eutrophication, acidification, land use, etc. (PEFCR, 2018). Moreover, an effective estimate of the environmental implications of dairy sheep productions might consider the ecosystem services provided by the sheep farm, soil carbon sequestration from pasture and crops, *in primis* (Batalla *et al*., 2015; FAO, 2016b).

Estimated enteric CH_4 emission based on IPCC 2006 was by far the main environmental hotspot, as observed in other studies carried out on dairy sector (FAOa, 2016; González-García *et al*., 2013; Marino *et al*., 2016; Vagnoni *et al*., 2015). Mitigation strategies based on diet modification seem to be an effective way to improve environmental performances (Rossi *et al*., 2017). However, diet modification in dairy sheep could be different from other ruminants (van Gastelen *et al*., 2019) and specific studies are needed.

IV – Conclusions

Preliminary results indicated that, as expected, CF in the four dairy sheep farms studied was affected by the management and structure of farming system. Cropland-based farms with a higher DE showed lower values of estimated CF per kg FPCM than pastureland-based farm. When GHG emissions were estimated per ha of UAA, CF values showed an opposite trend that can be explained by the lower milk production per ha of UAA observed in farms with lower DE. Enteric CH_4 emissions resulted the main environmental hotspot in all farms, contributing for about 57% to total GHG emissions.

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