The Reduction of Environmental Impacts of Dairy Sheep Farming Through the Introduction of Innovative Feeding Strategies: An on-Farm Study in Tuscany

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Introduction

Dairy sheep rearing in Tuscany, mainly located in the Maremma Rural District (South Tuscany), is experiencing a particularly unfavourable condition. Farmers complain poor profitability of milk due to the difficulty to reach the requirements set by dairy industries in terms of seasonal distribution of milk production and quality. Farmers need to improve profitability by increasing production efficiency of the flocks and, at the same time, maintain high quality of milk. At this aim, several management strategies and processes can be implemented, such as: rational grazing, improving of pasture nutritive value and improving feeding strategies based on concentrate feeds. At the same time, an optimized use of inputs and management strategies may lead to a reduction of environmental impacts associated with the agricultural activity. Two innovation transfer projects funded by the Rural Development Plan (RDP), were developed in the Grosseto Province aiming at increasing knowledge in sheep dairy farms and testing innovative solutions at farm level: FORMANOVA – Measure 124 RDP 2007-2013 (Innovative forage and feed for the production of Tuscan pecorino with nutraceutical properties – 2011-2014) and STILNOVO - Measure 16.2 RDP 2014-2020 (Sustainability and innovative technologies for sheep milk chain - 2016-2018). The general objective of this study was to assess the effect of innovative feeding strategies to improve sheep productivity and milk quality in dairy sheep farms on the environmental impact of ewes' milk production. Thus, a traditional dairy sheep farming system (TF) was compared with an innovative dairy sheep farming system (IF) both applied at farm scale, through a Life Cycle Assessment (LCA) approach.

Materials and Methods

In Maremma, sheep rearing is carried out by small-medium farms characterized by a flock size lower than 300 ewes in 76% of the farms (BDN, 2018). In the 65% of the farms, the Utilized Agricultural Area (UAA) ranges between 10 and 50 ha, cultivated to produce forages, mainly annual species, and cereals (ISTAT, 2010). Traditional dairy sheep farming system is quite homogeneous and can be classified as semi-intensive. Innovative dairy sheep farming system was introduced in some farms since 2010 to improve milk production and quality. This farming system includes improvement both on the cultivation of pasture and the production of fodder with the introduction of perennial crops instead of annual crops, and on animal feeding introducing flaxseed, soybean oil and a precision feeding approach based on Cornell Net Protein and Carbohydrates System for diet formulation at farm level (Cannas et al., 2004). The LCA method was applied to evaluate the environmental impacts in TF and IF farms. In this study 3 traditional farms (TF) were compared with 3 innovative farms (IF). The LCA analysis was carried out through a cradle-to-farm-gate LCA using 1 kg of Fat Protein Corrected Milk (FPCM) as functional unit, calculated following the equation reported by Pulina and Nudda (2002). Data were collected through specific and detailed questionnaires to farmers to characterize farm management. Invoices for all inputs purchased, such as energy, water, seed, fertilizers and animal feeds were collected and used to compile and to elaborate the life cycle inventory. Data on monthly milk production, milk quality and farmer income were obtained from the invoices of the cheese factory. The study was carried out at annual scale from September 2015 to August 2016. The sheep flock was divided by animal category in lambs,

lactating ewes, non-lactating ewes, rams, for input data collection and estimation of emission to environment of animal feeding, manure management and for the calculation of methane emissions from enteric fermentation. The output results of the NDS Professional software for small ruminants were used to calculate the annual methane emissions in kg CH_4 ewe^{-1} $year^{-1}$ with a Tier 2 approach (IPCC, 2006). Economic allocation was used to distribute all inputs and outputs among product (milk) and co-products (lamb meat, sheep meat and wool). OpenLCA software was used to process data, ecoinvent 3.2 and Agribalyze databases were used for secondary data, while impact assessment was evaluated through the ILCD 2011 midpoint (August 2016) method (ILCD, 2011). One-way ANOVA was used to determine whether there was a statistically significant difference in each impact category between TF and IF.

Results

Main results highlighted that IF significantly reduced environmental impacts in 7 indicators out of 15 (CC, FE, IRe, ME, OD, PM, POF), while no differences were recorded in the other 8 indicators. Innovative feeding reduced by 43% climate change impact (Table 1).

Table 1: ANOVA table of the overall environmental impact in TF and IF for each indicator. (A: Acidification; CC: Climate Change; FE: Freshwater Eutrophication; FEx: Freshwater Toxicity; HTc: Human Toxicity cancer.; HTnoc: Human Toxicity non-cancer.; IRe Ionizing Rad. ecosystem; IRh: Ionizing Rad. human; ME: Marine Eutrophication; OD: Ozone Depletion; PM: Particulate Matter; POF: Photo Ozone Formation; RDm: Resource Depletion mineral; RDw: Resource Depletion water; TE: Terrestrial Eutrophication).

Impact category	Unit	Significance	Farm type					
			TF			IF		
			Value		se	Value		se
A	Mole H^+ eq	*ns*	0.07	±	0.01	0.05	±	0.01
CC	kg CO_2 eq	***	5.50	±	0.15	3.12	±	0.05
FEx	CTUe	*ns*	18.33	±	3.68	8.38	±	0.54
FE	kg P eq	**	8.73E-04	±	6.89E-05	4.73E-04	±	3.76E-05
HTc	CTUh	*ns*	1.31E-07	±	2.08E-08	8.52E-08	±	1.19E-08
HTnoc	CTUh	*ns*	1.30E-06	±	3.11E-07	1.83E-06	±	1.27E-06
IRe	CTUe	*	8.55E-07	±	1.13E-07	4.43E-07	±	2.72E-08
IRh	kg U235 eq	*ns*	0.22	±	0.05	0.12	±	0.01
ME	kg N eq	*	1.82E-02	±	1.64E-03	9.47E-03	±	1.52E-03
OD	kg CFC-11 eq	**	2.53E-07	±	2.11E-08	1.32E-07	±	3.76E-09
PM	kg PM2.5 eq	**	3.21E-03	±	1.82E-04	1.92E-03	±	2.08E-04
POF	kg C_2H_4 eq	**	1.53E-02	±	1.04E-03	7.82E-03	±	4.37E-04
RDm	kg Sb eq	*ns*	2.10E-04	±	3.00E-05	1.27E-04	±	1.76E-05
RDw	m^3	*ns*	1.90E-02	±	3.58E-03	1.34E-02	±	1.84E-03
TE	Mole N eq	*ns*	0.30	±	0.04	0.22		0.04

Conclusions

The introduction of innovative forage productions and feeding strategies showed positive results from an environmental point of view, with positive performance obtained in the reduction of climate change impact, one of the most important environmental indicators for the livestock sector.

References

BDN, 2018. Banca Dati Nazionale dell'Anagrafe Zootecnica.

IPCC 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the NGGIP (eds Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K). IGES, Hayama.

ISTAT 2010. Censimento Nazionale Agricoltura.

Cannas A., et al 2004. A mechanistic model for predicting the nutrient requirements and feed biological values for sheep. J Anim Sci 82:149-169.

Pulina G and Nudda A. 2002. Milk production. In: Pulina G, editor. Dairy sheep feeding and nutrition; p. 11–3. Ed. Avenue media, Bologna.