Greenhouse gas emission intensity of milk production in three Slovenian sheep breeds

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Abstract

The aim of the study was to determine the intensity of greenhouse gas (GHG) emissions from the milk production of three sheep breeds in Slovenia, to identify the trends and to determine the main impacts on greenhouse gas emissions. Based on information on milk yield, protein, fat and lactose content, average body mass of each breed, litter size, and lambing interval, we estimated methane and nitrous oxide emissions for the period 2010-2022. Emissions were estimated for 21,655 lactations. GHG emissions were expressed in carbon dioxide equivalents. Emission intensity was expressed as emissions per kg of milk produced. Enteric methane contributed to almost 92% of the total GHG emissions. Methane from manure stores contributed about 2% to total GHG while the total contribution of nitrous oxide was about 6%.

The differences in the intensity of GHG emissions among sheep were fivefold, ranging from about 0.7 to more than 3.6 kg of CO_2 equivalent per kg of milk. On average, the emission intensity expressed in kg CO2 equivalent per kg milk was 1.555 for Bovec sheep, 1.379 for Improved Bovec sheep, and 2.026 for Istrian Pramenka. The intensity of GHG emissions decreased between the first parity (1.682 kg CO_2 equivalent per kg milk) and the fourth parity (1.534 kg CO_2 equivalent per kg milk) and then gradually increased until the tenth parity (1.714 kg CO_2 equivalent per kg milk). The emission intensity decreased with increasing litter size. The average emission intensity, expressed in kg CO_2 equivalent per kg milk, was 1.639 for sheep delivering single lambs, 1.442 for sheep delivering twins, and 1.241 for sheep delivering triplets.

The emission intensity increased with increasing lambing interval from 1.430 kg CO_2 equivalent per kg milk for sheep with a lambing interval between 280 to 314 days to 1.769 kg CO_2 equivalent per kg milk for sheep with lambing interval between 416 to 450 days. This means that the total milk yield of sheep with a longer lambing interval, was not high enough to compensate for the higher maintenance requirements of these sheep. The intensity of GHG emissions from milk production in flocks with controlled sheep varied over the years (ranging from 1.522 kg CO_2 equivalent per kg of milk in year 2021 to 1.657 kg of CO_2 equivalent per kg of milk in years 2013 and 2014). Overall, the intensity of GHG emissions decreased by around 6% during the study period. To summarise, some fertility traits are correlated with milk production and consequently also with the intensity of GHG emissions. In particular, a relatively short lambing interval could reduce the intensity of GHG emissions by increasing daily milk production.

Keywords: milk yield, litter size, parity, lambing interval, trends.
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Introduction

Livestock production contributes to anthropogenic (human) greenhouse gas (GHG) emissions. Globally, small ruminant production contributes 6.5% of all emissions in livestock production (Opio *et al*., 2013). Major greenhouse gases produced by small ruminants are methane (CH_4) and nitrous oxide (N_2O). While methane is produced both by fermentation in the digestive tract (enteric methane) and by manure management, the main source of emissions of nitrous oxide in small ruminant production is the manure management (Opio *et al*., 2013). In 2023, a study about GHG emissions from milk production of three Slovenian goat breeds was made. Still, no study about GHG emissions in sheep production has been prepared in Slovenia. The present study was conducted to determine the intensity of GHG emissions from milk production of three sheep breeds in Slovenia (Bovec sheep, Improved Bovec sheep and Istrian Pramenka), to identify the trends, and to determine the main impacts on the GHG emissions.

Material and methods

Records were provided by the Slovenian breeding programs for dairy sheep collected from the year 2010 to 2022. Data about animal breed, flock, lambing date, litter size, parity, date of the end of lactation and records of milk recording were acquired from the Central Database for Small Ruminants in Slovenia. GHG emissions were estimated on an annual basis. Methane emissions from enteric fermentation were calculated based on the net energy requirements (IPCC, 2019). The sum of net energy for maintenance, activity, lactation, pregnancy and wool growth was considered for the estimation of gross energy intake. Methane emissions from manure management were estimated based on the amount of daily volatile solid excreted (VS), maximum methane producing capacity for manure produced (B_o) and methane conversion factors for each manure management system (MCF). The estimation of direct and indirect nitrous oxide emissions based on the assumption that each sheep excretes 15.5 kg of nitrogen per year (EMEP, 2019) and was used only to estimate full GHG emissions in dairy sheep. Greenhouse effect of methane and nitrous oxide emissions were expressed in carbon dioxide equivalents (CO_2 eq). To calculate GHG emissions expressed in CO_2 eq, methane emissions were multiplied by GWP_{100} factor 28 while nitrous oxide emissions were multiplied by GWP_{100} factor 265. GHG emission intensity was calculated as the ratio of the quantity of GHG emissions and total milk yield.

Results and discussion

The intensity of GHG emissions by sources is presented in table 1. Enteric methane contributed almost 92% to the total GHG emissions. Total contribution of nitrous oxide was around 6%, while the methane from manure stores contributed around 2% to total GHG. These findings are confirmed by Gerber *et al*. (2013) who reported that emissions from manure were very low because excretes of small ruminants are mainly deposited

Table 1. Intensity of greenhouse gas (GHG) emissions by sources

		Mean	S.D.	Minimum	Maximum
GHG emission intensity (kg CO_2 eq/kg milk)	Enteric methane	1.457	0.383	0.655	3.302
	Methane from manure stores	0.027	0.007	0.012	0.062
	Nitrous oxide from manure stores	0.090	0.032	0.025	0.253
	Indirect nitrous oxide	0.013	0.004	0.003	0.036
	Total	1.587	0.426	0.695	3.636

on the pasture. The differences in the intensity of GHG emissions among sheep were fivefold, ranging from about 0.7 to more than 3.6 kg of CO_2 equivalent per kg of milk.

The intensity of GHG emissions by sheep breed is presented in table 2. The intensity of GHG emissions was the highest in the Istrian Pramenka (2.026 kg CO_2 eq/kg milk) and the lowest in Improved Bovec sheep (1.379 kg CO_2 eq/kg milk) while the intensity of GHG emissions was slightly higher in Bovec sheep (1.555 kg CO_2 eq/kg milk). The relatively high intensity of GHG emissions in Istrian Pramenka is due to low total milk yield as well as high dry matter content of the milk compared to the other two breeds.

Table 3 shows the intensity of GHG emissions by litter size. The emission intensity was the lowest in sheep delivering triplets (1.241 kg CO_2 eq/kg milk) and the highest in sheep delivering single lambs (1.639 kg CO_2 eq/kg milk) which is a consequence of increasing total milk yield with increased litter size.

The intensity of GHG emissions by parity is shown in figure 1. The emission intensity decreased between the first parity (1.682 kg CO_2 eq/kg milk) and the fourth parity

Table 2. Intensity of greenhouse gas (GHG) emissions by the sheep breed.

	Breed		
	Bovec sheep	**Improved Bovec sheep**	**Istrian Pramenka**
GHG emission intensity (kg CO_2 eq/kg milk)	1.555	1.379	2.026

Table 3. Intensity of greenhouse gas (GHG) emissions by the litter size.

	Litter size		
	Single lambs	**Twins**	**Triplets**
GHG emission intensity (kg CO_2 eq/kg milk)	1.639	1.442	1.241

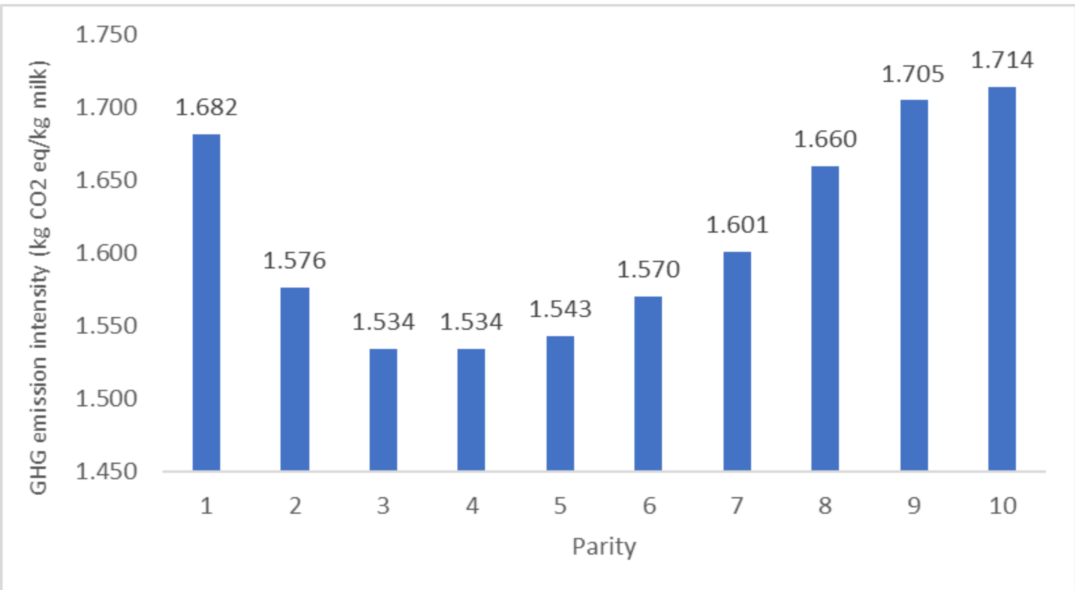

Figure 1. Intensity of greenhouse gas emissions by parity.

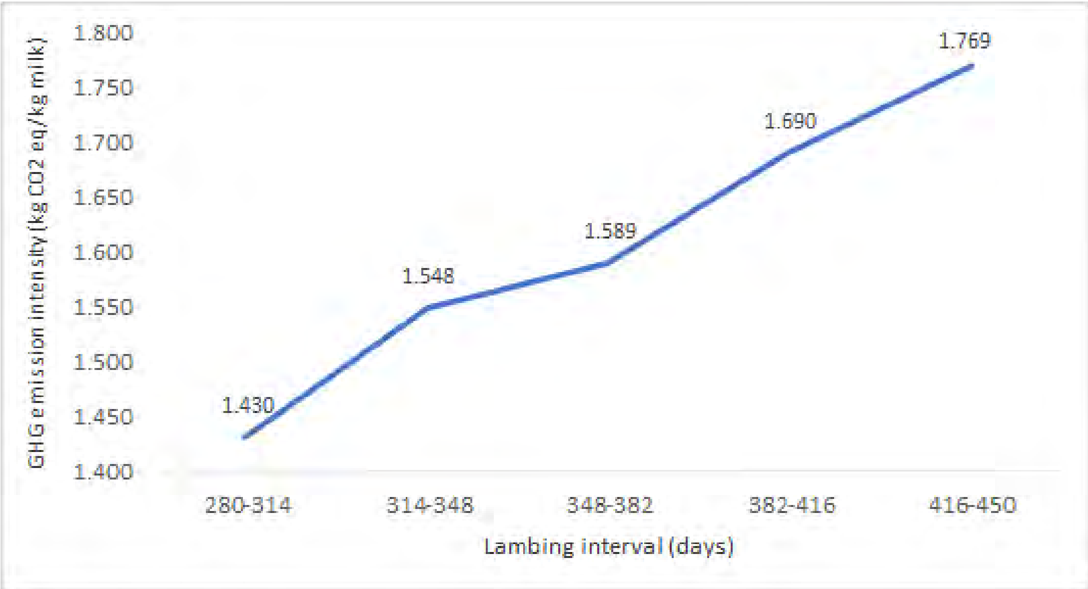

Figure 2. Intensity of greenhouse gas emissions related to lambing interval.

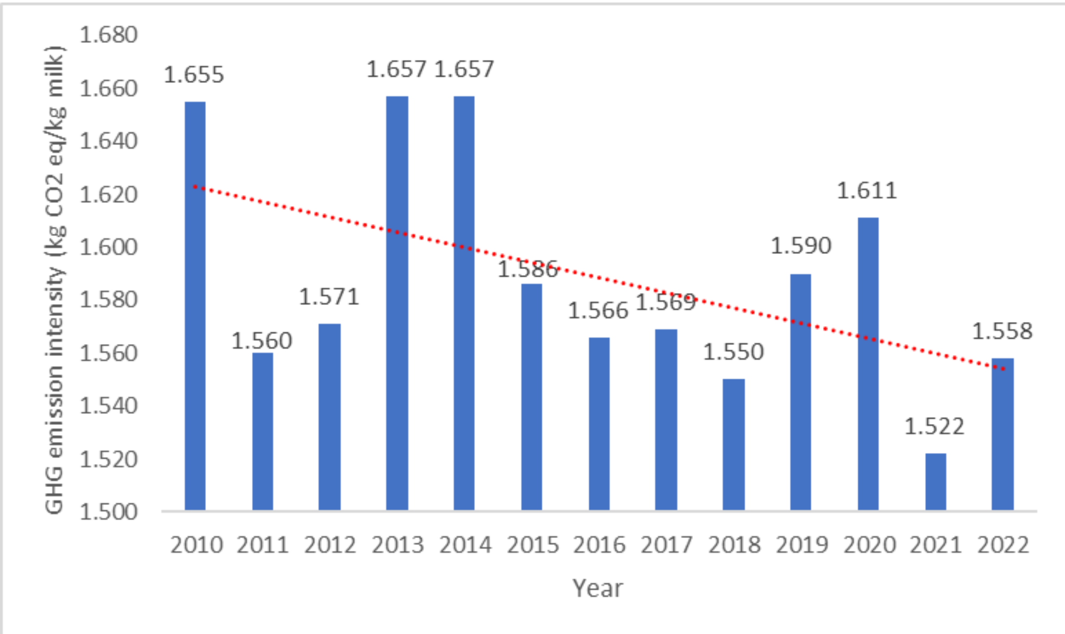

Figure 3. Intensity of greenhouse gas emissions by the year.

(1.534 kg CO_2 eq/kg milk) and then gradually increased until the tenth parity (1.714 kg CO_2 eq/kg milk).

Figure 2 shows the intensity of GHG emissions related to lambing interval of sheep. It could be noticed that the intensity of GHG emissions increased with increasing lambing interval, from 1,430 CO_2 eq/kg milk in ewes with lambing interval of 280-314 days to 1,769 CO_2 eq/kg milk in ewes with lambing interval of 416-450 days. These results indicate that total milk yield of sheep with extended lambing interval was not high enough to compensate the higher maintenance requirements of these sheep.

GHG emission intensity trends in the period 2010-2022 are presented in figure 3. The intensity of GHG emissions from milk production in flocks with sheep in breeding programs varied over the years (ranging from 1.657 CO_2 eq per kg of milk in years 2013 and 2014 to 1.522 kg CO_2 eq per kg of milk in the year 2021), but decreased overall by 5.9 % during the study period.

Conclusions

We conclude that the selection for high milk production of dairy sheep could be a useful tool to reduce the intensity of GHG emissions. Furthermore, some fertility traits such as lambing interval, parity, and litter size are correlated with milk production and consequently with the intensity of GHG emissions as well. In particular, relatively short lambing interval could significantly reduce the intensity of GHG emissions.

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