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Greenhouse-gas mitigation potential of agro-industrial by-products in the diet of dairy goats in Spain: a life-cycle perspective

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Abstract. Goat milk production is an important agricultural resource in the Mediterranean basin. Market demands and scarcity of pastures during drought periods has led to farms becoming more intensive and based on imported concentrate feeds. The use of alternative feedstuffs from agro-industry can help decrease dependence on external concentrates, while preventing the environmental issues associated with livestock production and by-product disposal. From a life-cycle assessment perspective, we investigated the change on greenhouse-gas (GHG) emissions of replacing a conventional dairy goat diet in southern Spain with two alternative dietary strategies, including tomato waste or olive by-products silages. The effect on enteric methane emissions and milk productivity was assessed through specific feeding trials. Experimental data were integrated within a modelling framework comprising different submodels to describe the farm system and associated production chain. A new model describing carbon and nitrogen losses from solid waste was applied to estimate the emissions associated with the baseline scenarios for food by-product management. The assessment revealed that the two dietary strategies achieve GHG reductions (~12–19% per kg milk). In both cases, nitrous oxide and carbon dioxide emissions from crop production were partially reduced through the displacement of typical concentrate ingredients. An additional mitigation effect was obtained when including tomato wastes in the diet because it reduced the methane emissions from enteric fermentation. Results suggested that use of agro-industrial residues for feeding is a feasible mitigation option in this case. However, as organic by-products could have alternative uses (bioenergy, soil amendment), with different implications for land use and soil carbon stocks, a more complete overview of both scenarios is recommended. Potential trade-offs from non-GHG categories may play an important role in a decision-making process.

Additional keywords: GHG, LCA, methane, olive cake, tomato.

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Introduction

The livestock sector significantly contributes to global greenhouse-gas (GHG) emissions. When considering direct and indirect land use, its contribution is estimated at ~18% of total global GHG emissions, with ruminant livestock being responsible for the largest share (Hristov *et al*. 2013). Globally, goat milk and meat production are responsible for ~174.5 million tonnes of carbon dioxide equivalents (CO_2-eq), which are mainly associated with methane (CH_4) and nitrous oxide (N_2O) emissions, respectively, from enteric fermentation and manure management (Zervas and Tsiplakou 2012; Opio *et al*. 2013).

In Europe, most of the small ruminant populations are concentrated in the Mediterranean countries, where they play a very important role both socioeconomically and ecologically. Not only do these farming systems occupy large areas in these countries, but they are also well adapted to consume low-quality forages from areas of poor agricultural productivity (e.g. mountains). However, during the past decades, market demands for increasing productivity and reducing seasonality have driven many farms to intensify production through a higher share of grain concentrates in their animal diets. A yet greater increased dependence of goat farms on external cereal-based concentrates is expected to occur as a result of climate change. Future climate change projections in the Mediterranean area basin indicate a decrease in rainfall and increased risk of drought periods (Giorgi and Lionello 2008), which will negatively affect pasture productivity and quality. As a potential adaptation measure to overcome pasture scarcity and grain prices, it will be essential to maximise the use of local and sometimes, underused available feed resources (e.g. wine, olive oil and horticultural produce).

The optimal use of these alternative resources as animal feed could be an effective measure to decrease production costs of dairy goat farms, thus enhancing their competitiveness, but also an opportunity to reduce the environmental issues associated to livestock products (e.g. cheese) and organic-waste accumulation.

Nevertheless, agro-industrial by-products might have other uses than animal feed (e.g. bioenergy), with different implications on climate regulation, both direct (GHG and soil carbon) and indirect (e.g. as ammonia), resource-use efficiency (e.g. land use and porous-media use) and soil quality (e.g. soil organic matter). Provided that farm income in the goat sector in the European Union (EU) is strongly influenced by specific EU Common Agricultural Policy (CAP) support measures (e.g. 'greening': beneficial practices for the climate), it is strategic that the most sustainable management of the agro-industrial by-products is compatible with overall climate change mitigation. The environmental analysis of such complex systems requires a holistic and systematic approach and life-cycle assessment (LCA) technique is often preferred for the comparison of scenarios.

While several LCA studies have been published on small-ruminant systems in Europe, most of them have focussed on meat (Williams *et al*. 2006; Edwards-Jones *et al*. 2009; Ripoll-Bosch *et al*. 2013; Jones *et al*. 2014) or milk production from sheep farms (Batalla *et al*. 2015; Vagnoni *et al*. 2015) and just a few have involved products from goat farming systems (Weiss and Leip 2012; Opio *et al*. 2013), and were mainly based on estimations from modelling approaches at a regional level. The main objective of the present study was to apply a LCA approach to explore the change in GHG emissions and other environmental impacts arising from the substitution of a typical dairy goat diet in southern Spain by the following two alternative diets including different by-products from local food industry: (1) leaves and olive cake from olive oil extraction process and (2) tomato waste from horticulture. With this aim in mind, particular attention is paid to providing comprehensive information on the environmental benefits and trade-offs considering the alternative use of the selected by-products. In addition, the present study also provides an estimation of the carbon footprint of milk from goat farming in southern Spain, which, to our knowledge, has not been estimated in such detail in the Mediterranean context.

Materials and methods

Goat milk production system in southern Spain

The Spanish goat milk sector is the second largest in the EU region, with more than 2.7 million goats and a milk production of 370 000 t/year, being ~27% of the EU total (FAOSTAT 2015). Regionally, goat milk production is of particular importance in Andalusia (southern Spain), which accounts for ~50% of the Spanish production (MAGRAMA 2015) and 36% of the goat flocks in the Spanish census. Similarly to other regions and livestock systems, a rapid intensification process of the sector has occurred during the past decade. Consequently, ~50% of the extensive systems which predominated during the 1990s have been displaced by intensive or semi-intensive farms (Castel *et al*. 2011).

In the present study, data from six dairy goat farms in southern Spain were collected. Data collection was based on surveys that provided a detailed inventory for the on-farm activities (Yáñez-Ruiz and Rufino 2014). Key characteristics of the studied farms are provided in Table 1. On the basis of the collected data, a farm model describing the typical herd structure, technical parameters and management was designed.

Table 1. Technical indicators relative to the dairy goat system (mean and s.d.)

Variable	Value
Herd structure	
Female goats	259 (±81)
Male goats	11 (±4)
Young goats	435 (±156)
Technical parameters	
Replacement rate (%)	21 (±8)
Fertility (%)	90 (±4)
Kids at birth	1.8 (±0.5)
Bodyweights	
Culled goats (kg)	35 (±8)
Kid goats sold (kg)	8 (±0.5)

Diets considered

Every year, large volumes of agro-industrial by-products are produced in the Mediterranean basin, which are not always adequately valorised, thus contributing to the environmental pollution. Low nutritive value and the difficulty for long-term conservation as fresh material are the main constraints for their wider use as animal feed (Ben Salem and Nefzaoui 2003). In the present study, the following two types of locally available by-products were used: (1) olive leaves and olive cake from olive oil extraction process and (2) tomato waste from horticulture production. Ensiling is applied as a feasible preservation technique. The inclusion of the selected by-products as components of goat diets may have different implications in terms of GHG emissions (i.e. enteric fermentation) and milk productivity. So as to account for this effect, detailed data were gathered from specific trials under controlled conditions (Arco-Pérez *et al*. 2014).

Three diets were formulated to supply the dietary requirements of lactating goats of Murciano-Granadina breed involved in the trial (Table 2). The control diet (CO), representing a typical dairy goat diet in southern Spain, was composed of alfalfa hay (30%), oat hay (20%), oat grain (20%), soybean meal (10%), maize grain (10%) and beet pulp (10%). Two alternative diets were formulated by replacing the oat hay (20%) with olive oil by-product silage (OS) or tomato-waste silage (TS). In both cases, a silage process was applied as a simple and efficient method for the preservation of high-moisture materials. TS contained 70% tomato fruit wastes, 20% wheat straw and 10% barley flour. OS contained 50% olive leaves, 25% olive cake (from olive oil extraction process) and 25% barley flour, as fresh matter. During the trial period, a range of parameters were monitored, including feed intake, milk yield, enteric CH_4 emissions, and nitrogen (N) in urine and faeces. A summary of the results from the trial is shown in Table 3.

LCA methodology

Functional unit and LCA approach

Life-cycle assessment is an internationally accepted method to assess quantitatively the environmental impacts related to all the stages of a production cycle, from raw material extraction to the end products. The present study followed the principles described in the international standards ISO 14040–14044 (ISO 2006a, 2006b), which have established the overall methodological framework to carry out LCAs. The assessment was conducted using 1 kg of fat- and protein-corrected milk (FPCM) as a functional unit, as recommended by the most common LCA guidelines for dairy sector (IDF 2015). Milk yield was corrected at 6.5% fat and 5.8% protein on the basis of Pulina *et al.* (2005).

The functional unit is the most useful output of the system, and all inputs and outputs are quantified according to this reference unit, enabling comparison among scenarios. Furthermore, multifunctional systems, such as agricultural systems, often involve additional co-products (e.g. meat) and other externalities. Depending on the type of LCA (attributional or consequential), they are addressed through appropriate methodological choices for partitioning of environmental impacts on the basis of system expansion or allocation rules. In the present study, an attributional LCA was conducted but system expansion was applied to account for the change in the use of feed products as in other similar approaches (Tufvesson *et al.* 2013).

Table 2. Feed ingredients and nutritive value of the three proposed diets for lactating goats

Feed type	Unit	Conventional diet (CO)	Olive oil by-products (OS)	Tomato by-products (TS)
		Ingredients		
Alfalfa hay	%	30	30	30
Oat hay	%	20	–	–
Oat grain	%	20	20	20
Soybean meal	%	10	10	10
Maize grain	%	10	10	10
Beet pulp	%	10	10	10
		Silage		
Olive leaves	%	–	10	–
Olive cake	%	–	5	–
Tomato waste	%	–	–	14
Barley flour	%	–	5	2
Wheat straw	%	–	–	4
		Nutritive value[A]		
Crude protein	g/kg DM	196	169	177
Neutral detergent fibre	g/kg DM	330	292	353
Metabolisable energy	MJ/kg DM	13.2	13.0	13.9

[A]Nutritive value expressed on dry matter (DM) basis.

System boundaries

A ‘cradle to gate’ perspective was considered for defining the system boundaries of the goat milk production (see Fig. 1). It involves all the inputs and outputs related to animal housing, crop cultivation, feed processing and transport, and also the emissions from ruminant digestion and manure management that might be strongly affected by diet composition.

We coupled a modelling framework comprising experimental data for enteric CH_4 emissions, animal productivity and excretion gathered from trials under the selected diets, with different submodels describing the farm system and the associated production chain. Among these, a model to calculate carbon (C) and N losses from different options of organic-waste management (Pardo *et al.* 2013) was applied, so as to account for the emissions related to goat manure temporarily stored in the farm as well as those associated with the application of food by-products for alternative purposes other than feed, such as bioenergy (e.g. anaerobic digestion) or compost production. Environmental burdens related to the food by-products entering the system boundaries were assumed negligible, as they were considered a residual output from other production systems.

Inventory analysis

Farm activities were modelled according to data gathered from six dairy goat farms in Andalusia (see Table 1). The data collected included the main inputs, such as energy consumption and

Table 3. Results of selected parameters from experiment of lactating goats under the three studied diets
DMI, dry matter intake; FPCM, fat- and protein-corrected milk

Parameter	Conventional diet (CO)	Olive oil by-products (OS)	Tomato by-products (TS)
	Production		
Dry matter intake (kg DMI/day)	0.90	1.45	1.30
Milk production (kg FPCM/day)	0.80	1.07	1.01
Milk yield (kg FPCM/kg DMI)	0.89	0.74	0.77
	Enteric fermentation		
Methane production (g CH_4/kg DMI)	21.4	19.6	19.2
	Faeces		
Excreted (kg/day)[A]	0.28	0.43	0.34
Excreted N (g N/day)	6.6	11.1	8.4
Excreted N (%N_{Intake})	23.3	28.3	22.6
	Urine		
Excreted (kg/day)[A]	1.14	1.43	1.34
Excreted N (g N/day)	15.5	19.3	19.9
Excreted N (%N_{Intake})	55.1	49.2	53.7

[A]Expressed as fresh weight.

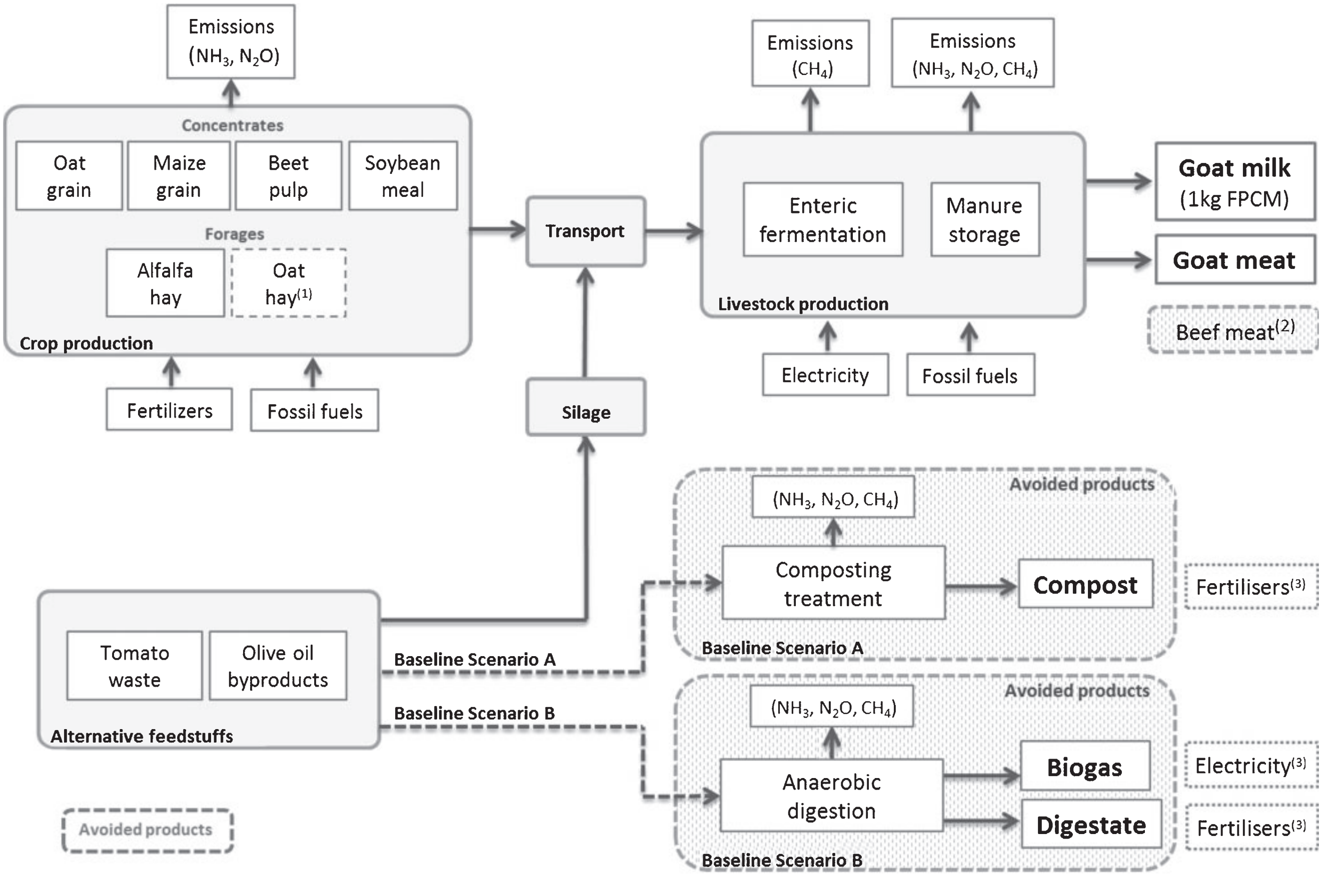

Fig. 1. System boundaries for milk goat production system and alternative uses of the by-products. [1]Oat hay is substituted by silage when food by-products are applied as animal feed. [2]Beef meat production is avoided by goat meat production. [3]Fertilisers and electricity have to be produced as a consequence of a change in the use of food by-products from composting or anaerobic digestion to animal feed.

bedding material, as well as technical parameters describing the flock structure, such as fertility and prolificacy levels, goat mortality and replacement rate, among others.

As detailed above (section *Diets considered*), data collected during specific trials were used to describe feed intake, milk yield, CH_4 emissions and manure production for lactating goats under the three considered diets.

Data used to describe crop cultivation, processing and transport activities of the feed components were collected from available literature and databases (Ecoinvent® 3.01 Database 2013). Secondary data such as electricity production from Spanish national grid, fossil fuels and mineral fertiliser production, were also collected.

Finally, the main inputs and outputs associated with the manure and food by-product management were estimated through a specific model (Pardo *et al*. 2013). This model simulates the C and N flows from an organic-waste management process according to the selected treatment (e.g. composting, anaerobic digestion) and the specific substrate composition.

Definition of scenarios and substituting products

Organic by-products might have other uses than animal feed (e.g. bioenergy) and these may involve different environmental burdens. So as to account for the implications of this change, a system-expansion method is usually applied when conducting LCAs. This procedure involves an expansion of the boundaries of the system, so that the alternative production of exported or imported function is included. To do so, a product with a similar function is identified to represent indirect effects of the exported or imported functions (Thomassen *et al*. 2008).

In our study, the goat milk system was expanded to include the co-product goat meat because it is produced as a consequence of the farming system. Beef from calves and beef from culled cows was identified as the avoided product substituted by meat from goat kids and culled goats, respectively. Data on beef production were based on Ecoinvent® 3.01 Database (2013).

A system expansion was also applied to cover the change in the application of the selected by-products. In accordance with European policies that promote the use of organic waste for land fertilisation, and penalise waste dumping (European Landfill Directive 99/31/EC 2015), composting was assumed as the baseline management option for the food industry by-products considered in the study (Baseline scenario A). This option has become quite popular in southern Spain because of the demand for high-quality organic fertilisers from the ecological agriculture production. Emissions and energy linked to composting process are avoided in this scenario, but the mineral fertiliser production needed to replace compost is considered through system expansion. Potential C sequestration from compost application was also accounted for using the compost composition results from the model.

In addition, a second scenario was proposed, where food by-products are processed through anaerobic digestion (Baseline scenario B). In this case, they were considered fossil fuels to substitute for reduced biogas production, and mineral fertilisers to replace digestate. Potential C sequestration attributed to digestate agricultural application was also considered in this second scenario.

An overview of the proposed scenarios is shown in Table 4 and illustrated in Fig. 1.

Impact assessment

The CML-IA baseline v3.01 method was chosen for impact assessment. Four impact categories were selected among the so-called 'baseline impact categories', including abiotic depletion, abiotic depletion (fossil fuels), acidification potential, eutrophication potential and global warming potential. SimaPro 7.3.3 (PRé-Consultants 2014) LCA software was used for the calculations.

Results and discussion

Carbon footprint (CF) of milk

For the CO diet, representing a dairy goat diet in a typical semi-intensive farm in southern Spain, the CF was estimated as 2.6 kg CO_2-eq per kg of FPCM. Figure 2 displays the share of the main GHG sources and processes contributing to the goat milk CF. According to the results, feed purchased is the most important source, accounting for 45% of the total GHG emissions estimated. Almost half of them (23% of the total CF) are attributed to N_2O emissions from soil produced during the crop-cultivation stage, while the remaining are mainly associated with different agricultural activities that involve fossil fuel consumption and direct CO_2 emissions. Biogenic CH_4 from enteric fermentation in ruminant animals has been identified as the second-largest GHG source, accounting for 33% of the total GHG emissions. Finally, other activities contributed to the goat milk CF to a lesser extent, such as manure management (7%), energy consumption (7%) and mineral fertiliser manufacturing (6%).

To our knowledge, only a few LCA research studies have been conducted on goat milk, and the comparisons among them must be performed with caution, taking into account the different

Table 4. Definition of selected scenarios
n.a., not applicable

Scenario	Diet	Alternative by-product application
FPCM–CO	Control (CO)	n.a.
FPCM–OS–A	Olive oil by-product silage (OS)	Composting (Scenario A)
FPCM–OS–B	Olive oil by-product silage (OS)	Anaerobic digestion (Scenario B)
FPCM–TS–A	Tomato by-product silage (TS)	Composting (Scenario A)
FPCM–TS–B	Tomato by-product silage (TS)	Anaerobic digestion (Scenario B)

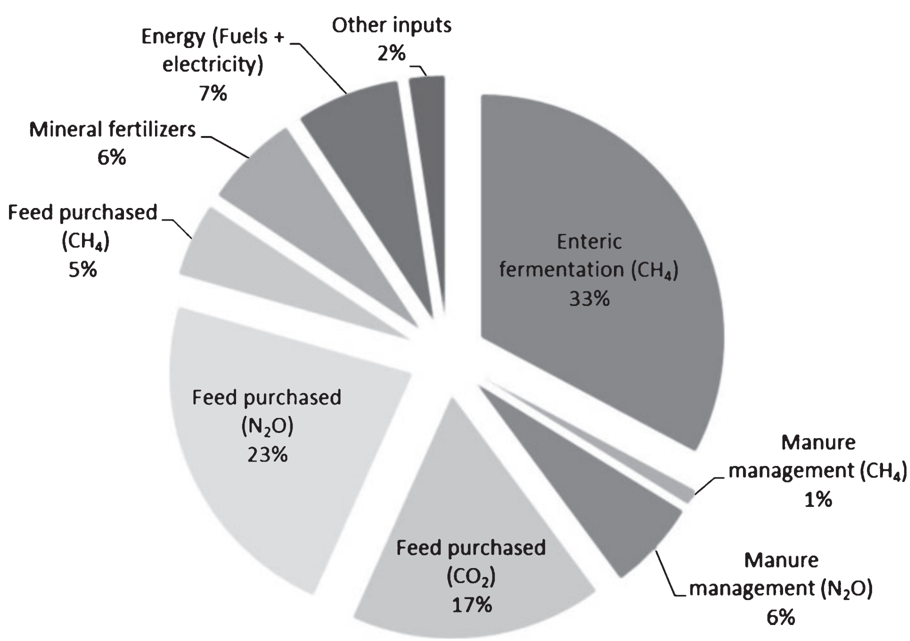

Fig. 2. Main greenhouse-gas sources of the goat milk production.

system boundaries and methodological approaches. Weiss and Leip (2012) applied the CAPRI model in an analysis at a regional level for the EU countries (EU-27). For sheep and goat milk, they obtained an EU-27 average value of 2.4 kg CO_2-eq/kg milk (7% fat) when not considering implications of land-use change, which is in the same range as the estimated value in the present study. Opio *et al*. (2013) also applied a modelling approach (GLEAM model) to calculate the GHG emissions from ruminant systems in different regions across the world. For arid zones within western Europe, Opio *et al*. (2013) estimated a range from 2.8 to 6.4 kg CO_2-eq per kg of FPCM. Methodological choices and assumptions (allocation vs system expansion) may explain in part the discrepancy with our estimation. Opio *et al*. (2013) applied a regional-scale analysis through generalised assumptions, making it difficult to capture the detailed characteristics of a specific system. For example, in western Europe, the enteric CH_4 emission factor used, i.e. ~50 g CH_4/kg milk, was higher than that observed in our study (38 g CH_4/kg milk), and this discrepancy may be due to the different level of intensification of systems studied.

Nevertheless, our results seem to be in accordance with recent LCA studies conducted on sheep milk in the Mediterranean region. Vagnoni *et al*. (2015) examined the environmental performance of milk sheep production in Sardinia (Italy). The observed trend for GHG emissions revealed a little range of variation among farm systems at different input levels (from 2.0 to 2.8 kg CO_2-eq per kg of FPCM). Similarly, Batalla *et al*. (2015) analysed the CF of sheep milk from 12 farms in northern Spain. Before soil carbon sequestration was included in the estimation, results varied from 2.0 to 3.2 kg CO_2-eq per kg of FPCM for intensive farms. The reported values are in the same range as the GHG emissions obtained in the present study for goat milk. In contrast, the CF estimated by Michael (2011) on an intensive Australian dairy sheep farm (3.57 kg CO_2-eq per kg of FPCM) is significantly higher than those reported by similar studies in the Mediterranean region. The methodological approach to define the enteric CH_4 emission factor has been identified as the main explanation for this discrepancy (Vagnoni *et al*. 2015).

In all the mentioned studies, CH_4 emissions from enteric fermentation were identified as the largest GHG source in the milk production chain from small ruminants. The importance of this seems to be more crucial in low-input extensive systems, while the contribution of embodied emissions (N_2O, CO_2) from purchased feed increases according to the level of intensification. Extensive systems usually involve the use of fibrous components in the animal diet through forages and grazing, which may enhance the formation of enteric CH_4 during ruminant digestion, due to its low digestibility and longer residence time in the rumen (Beauchemin *et al*. 2008). This effect may be reduced in intensive systems, where a higher proportion of grain concentrates is included in the ruminant feed, but the contribution of other GHG sources (N_2O, CO_2) related with external agricultural activities is expected to increase.

Effects of including food by-products as dairy goat feed components

Figure 3 summarises the results for the different impact categories of the production of 1 kg of goat FPCM with the three respective diets compared in the study. The results vary depending on the impact category and the scenario considered, but, in all the cases, potential reductions were observed through the introduction of the respective food industry by-products when compared with the control CO scenario. Impact reductions were mainly related to a decrease of emissions from agricultural production, obtained through a displacement of some feed ingredients included in the conventional diet. Hence, impact categories that are strongly related with N and P losses during crop fertilisation, such as eutrophication potential and acidification potential, showed a significant drop-off when applying olive (OS_A: –29%, –34%; OS_B: –28%, –34%) and tomato (TS_A: –35%, –41%; TS_B: –26%, –31%) diets.

As shown in Fig. 4, biogenic CH_4 has the most important contribution to the category of global warming potential (35–40%), with enteric fermentation process being the main source of this GHG. Other important sources include N_2O emissions from soils, primarily associated with fertilising during crop cultivation stage (25–30%) and CO_2 emitted from combustion of fossil fuels resulting from different operations at farm and crop production stages (32–34%).

The reduction on GHG emissions by the introduction of alternative feedstuffs is mainly attributed to a decrease in N_2O emissions (and to a lesser extent on CO_2) during cultivation stage, obtained through the substitution of oat hay originally included in the conventional diet. Overall, the reductions estimated from the use of TS are higher (TS_A: –19%; TS_B: –13%) than those obtained for OS (OS_A: –15%; OS_B: –14%) (see Fig. 3). Olive leaves and olive cake have a low digestibility and nutritional value, which may constrain the productivity of goat milk (see Table 3). In contrast, when TS is included in the diet, the effect on milk yield is lower while a decrease in the production of enteric CH_4 is observed. The specific mechanisms behind this effect are not well known, but the decrease in enteric CH_4 emissions per kilogram of FPCM has a key relevance in the scenarios with TS and deserves further research.

From an environmental viewpoint, the results indicated that the application as dairy goat feed is the best management option for the selected by-products, i.e. for the strategies analysed in the study (animal feed, composting, anaerobic digestion). Otherwise, an increase in the environmental impact would have been obtained, as a consequence of the change in the use of the food by-product. Small differences can be noticed depending on the reference scenario considered. As a general trend, when shifting the use of food by-products from composting to goat feed (Baseline scenario A), the reductions in the environmental impacts estimated were higher than those observed when changing from anaerobic digestion to goat feed (Baseline scenario B). This indicates that the production of biogas from the selected substrates is preferred over composting, especially in the case of TS. The lower digestibility of olive leaves and olive cake influences these changes, because of the lower biogas potential obtained from these substrates through anaerobic digestion. Hence, only a slight difference was observed between Scenarios A and B involving OS.

Mitigation potential and limitations of the study

Results of LCA suggested that use of agro-industrial by-products as feed in small-ruminant systems is a feasible option for GHG

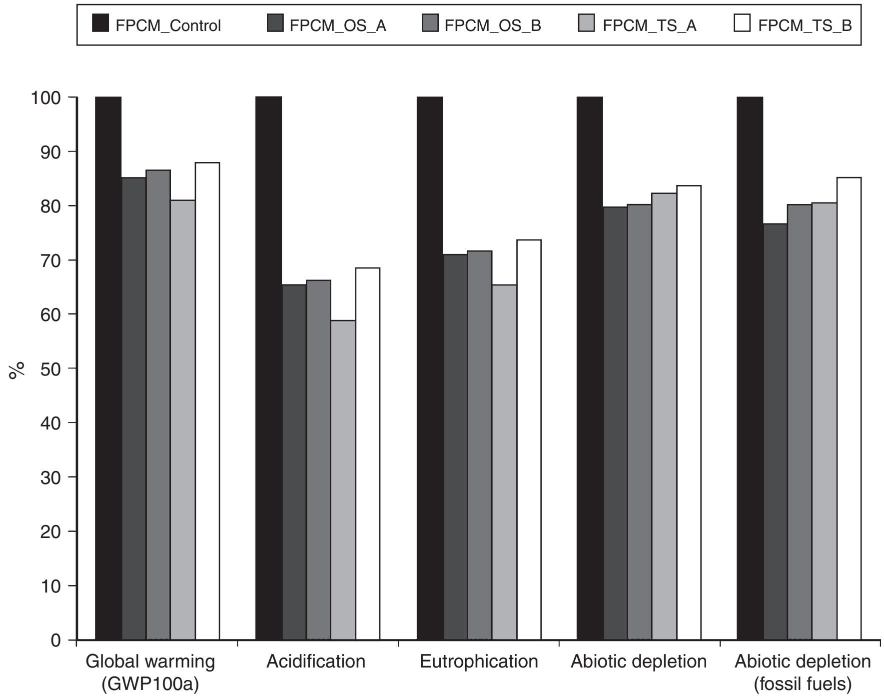

Fig. 3. Main results of life-cycle assessment (LCA) for the three dairy goat diets analysed (TS, tomato-waste silage; OS, olive oil by-product silage). Functional unit: 1 kg of goat fat- and protein-corrected milk (FPCM).

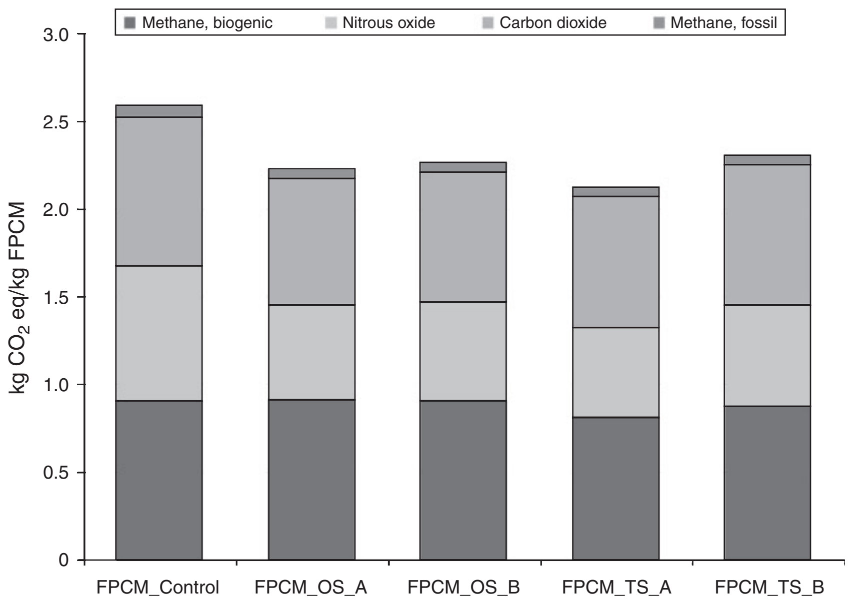

Fig. 4. Carbon footprint and greenhouse-gas sources for the three dairy goat diets analysed (TS, tomato-wastes silage; OS, olive oil by-product silage). Functional unit: 1 kg of goat fat- and protein-corrected milk (FPCM).

mitigation. Preservation through ensiling gives the possibility of including a broader range of agro-industrial by-products, overcoming the limitations of seasonal production. In addition, previous studies have shown that this strategy is a cost-effective method to enhance the profitability and sustainability of small-ruminant farms in less favoured areas (Chedly and Lee 2000; Ben Salem and Smith 2008). However, the wider adoption of these strategies may require adequate policies and institutional support, so as to overcome certain constraints (e.g. lack of experience, resource availability).

Furthermore, organic by-products could have alternative uses (bioenergy, soil amendment) with different implications for particular agroecosystems, which should be considered in a decision-making process. Mediterranean regions have soils with low organic C content (SOC) and high risk of land degradation (Jones *et al*. 2005). In addition to this, climate change projections predict that future harsh conditions may enhance desertification, resulting in a scarcity of pasture resources in semiarid areas (Ben Salem and Smith 2008). In these areas, the increase in SOC from the application of organic fertilisers (i.e. compost, digestate) may be crucial for maintaining SOC levels above the critical threshold needed for soil fertility (Aguilera *et al*. 2013). In this way, these management strategies not only strengthen the resilience of Mediterranean agroecosystems for climate change adaptation, but also help maintain the positive externalities and provision of ecosystems services associated with this landscape (Ripoll-Bosch *et al*. 2013).

Conclusions

Results obtained from this whole-farm modelling assessment suggested that the new dietary strategies tested offer promising overall reductions on the environmental burdens associated with goat milk production. The reduction on GHG emissions is mainly related to N_2O emissions from feed production stages. Additional decrease in enteric CH_4 was also obtained through the use of tomato wastes.

These findings must be used with caution because agro-industrial by-products can have alternative and competing uses, other than feed, such as energy production and soil organic amendment. Despite the GHG mitigation potential identified, a holistic approach for the analysis of scenarios is highly recommended, because several potential trade-offs from agroecosystem externalities may not be fully addressed through LCA technique, while playing an important role in the decision making process.

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