NITROGEN UTILISATION AND GREENHOUSE GAS EMISSIONS IN SMALL-SCALE DAIRY SYSTEMS IN THE HIGHLANDS OF CENTRAL MEXICO †

[UTILIZACIÓN DE NITRÓGENO Y EMISIONES DE GASES DE EFECTO INVERNADERO EN SISTEMAS DE PRODUCCIÓN DE LECHE EN PEQUEÑA ESCALA EN EL ALTIPLANO CENTRAL DE MÉXICO]

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SUMMARY

Background: Nitrogen (N) plays an important role within milk production systems (MPS), as an indicator of environmental and economic efficiency. **Objective.** The objective was to determine utilisation of N offered in the ration and estimate GHG from the enteric fermentation and manure management in 12 small-scale dairy farms under two feeding strategies. **Methodology.** Six farms had their herds in confinement under a cut-and-carry feeding system, and six farms implemented day grazing of mixed pastures, both systems used commercial concentrates as a supplement. Cows in milk production and their replacements were considered in the study. Pasture intake was calculated by difference in dry matter intake, using 3.2 % of live weight as intake factor. The N utilisation was determined by difference between N intake and excretion at each farm during a whole year operation. The GHG emissions were estimated following Tier 2 guidelines rom IPCC. Differences in feeding strategies were analysed with a completely random block design using farms as a blocking factor. **Results.** Mean farm size was 5.0 ha for cut-and-carry and 16.0 ha for grazing, and dry matter feed self-sufficiency was 62 and 83% respectively, considering 12% and 22% refusals for each strategy. There were no statistically significant differences (P>0.05) for any of the N utilisation components (N in diet, N in milk, N in manure, NH_3 and N_2O or GHG emissions. **Implications.** This is a novel report on assessing N fluxes and GHG emissions from small-scale dairy systems in Mexico and Latin America. **Conclusions.** In general, 87.6% of the N consumed is excreted in manure and urine. The feeding strategies did not diverge enough to have an impact on GHG emissions.
Keywords*:* Environmental management; Family dairy; Manure management; Mass balance.

RESUMEN

Antecedentes: El nitrógeno (N) juega un papel importante dentro de los sistemas de producción de leche (SPL), como indicador de la eficiencia ambiental y económica. **Objetivo.** El objetivo fue determinar la utilización del N ofrecido en la ración y estimar los GEI de la fermentación entérica y el manejo del estiércol en 12 granjas lecheras de pequeña escala bajo dos estrategias de alimentación. **Metodología.** Seis granjas tenían sus rebaños en confinamiento bajo un sistema de alimentación de corte y transporte, y seis granjas implementaron el pastoreo

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diurno de pastos mixtos, ambos sistemas emplearon concentrados comerciales como suplemento. En el estudio se consideraron las vacas en producción de leche y su remplazo. El consumo de pasto se calculó por diferencia de consumo de materia seca, empleando como factor de consumo el 3.2 % del peso vivo. La utilización de N se determinó mediante la diferencia entre la ingesta y la excreción de N en cada granja durante un año de operación. Las emisiones de GEI se estimaron siguiendo las pautas de Nivel 2 del IPCC. Las diferencias en las estrategias de alimentación se analizaron con un diseño de bloques completamente al azar, empleando como factor de bloqueo a las unidades de producción. **Resultados.** El tamaño medio de la finca fue de 5.0 ha para corte y acarreo y 16.0 ha para pastoreo, y la autosuficiencia de alimento de materia seca fue de 62 y 83% respectivamente, considerando 12% y 22% de rechazos para cada estrategia. No hubo diferencias estadísticamente significativas (P> 0.05) para ninguno de los componentes de utilización de N (N en la dieta, N en la leche, N en el estiércol, NH_3 y N_2O o emisiones de GEI. **Implicaciones.** Este es un informe novedoso sobre la evaluación de los flujos de N y emisiones de GEI de los sistemas lácteos de pequeña escala en México y América Latina. **Conclusiones.** En general, el 87.6% del N consumido se excreta en el estiércol y la orina. Las estrategias de alimentación no difirieron lo suficiente como para tener un impacto en las emisiones de GEI.

Palabras clave: Gestión ambiental; Lechería familiar; Manejo de estiércol; Balance de masa.

INTRODUCTION

There is worldwide concern on the environmental impacts of animal production since the production systems have a significant effect on the environment of the agroecological regions where they are found (Figueroa-Viramontes *et al*., 2015). Therefore, there is a recognized need to develop sustainable animal production systems that minimize negative environmental impacts. (Fabienne-Barataud *et al*., 2015; O'Brien *et al*., 2015). Dairy cattle have a low efficiency in nutrient utilisation, between 15 and 35% of feed nitrogen (N) (Figueroa-Viramontes *et al*., 2015), and between 65 and 85% of N intake is excreted in dung and urine (Gilker and Weil. 2018). Only 19% of the N consumed is recovered in milk production and close to 72% is excreted in urine and manure regardless of whether the feeding system is through animal housing or pasture grazing (Pozo-Leyva *et al*., 2021b).

Different dairy production systems have a marked effect on N and other nutrient utilisation, as well as on greenhouse gases (GHG) emissions; both due to feeding strategies as well as from manure management. There is a recognized need to develop sustainable animal production systems minimizing environmental impacts (Fabienne-Barataud *et al*., 2015; O'Brien *et al*., 2015). The Intergovernmental Panel on Climate Change (IPPC) guidelines for GHG inventories, note that emissions from manure management must be included, since emissions of nitrous oxide (N_2O) from management, storing and final disposition of manure are an important contributor to the environmental impact of livestock operations (IPCC. 2006). It is then important to identify areas for improvement in nutrient utilisation to reduce the environmental footprint of dairy production, and of the role those small-scale dairy systems have worldwide (FAO, 2012). Although in Mexico these systems are represented by more than 78% of dairy farmers, the existing information regarding the use of N and its environmental implication is limited (Pozo-Leyva *et al*., 2021b). The objective was to determine the utilisation of N offered in rations and estimate GHG emissions from enteric fermentation and manure management in 12 small-scale dairy farms in the highlands of central Mexico under two feeding strategies: cut and carry of irrigated temperate pastures, or day grazing of pastures.

MATERIALS AND METHODS

Study area

The study was from May 2016 to April 2017 in the municipality of Aculco in the State of Mexico, (between 20° 00′and 20° 17′ N, and between 99° 40′ and 100° 00′ W). Mean temperatures during the research were between 7.8 and 21.2°C, with an overall mean of 14.5°C. The mean rainfall during the year was 765.4 mm, from four meteorological stations in the study area. Soils are Phaeozem 49.94%, Vertisol 29.13%, Lluvisol 8.96%, Planosol 6.57% and Leptosol 1.73% (Fadul-Pacheco *et al*., 2013).

Description of small-scale dairy farms

Twelve small-scale dairy farms participated in this study, with a total of 139 cows plus their replacements (approximately 30 animals per year, mostly Holstein (a few crosses of Brown Swiss or Jersey x Holstein), with six farms each on different feeding, housing and resource management strategies. Table 1 presents the characterisation of participating farms.

Six farms followed the conventional strategy based on total confinement of cattle, where cattle spend the day on earthen or concrete floor pens. Three farmers left their cows loose in pens all time except during milking, but three farmers tied cows to feeding troughs on concrete floor pens overnight. The basis of the feeding strategy in confinement farms is cut-and-carry of sown irrigated temperate pastures.

Table 1. Characterization of small-scale dairy farms by feeding strategy.

Item	Cut-and-Carry	Grazing	Mean	SEM	*P value*
Farm characteristics					
Farm size (ha)	5.5	15.8	10.7	1.56	0.01
Milking cows (Head)	11.8	11.3	11.6	1.28	0.72
Live weight (kg/cow)	512.8	490.1	502	9.49	0.83
Annual calving rate (%)	69.2	67.0	68.1	2.95	0.17
Annual replacement rate (%)	20.5	22.0	21.3	1.83	0.34
Feed Independence Index (%)	61.7	82.7	72.2	1.03	0.001
Milk production					
Milk yield (kg/cow/day)	12.8	13.8	13.1	0.22	0.01
FPCM (kg/cow/day)	11.5	12.7	12.1	0.19	0.02
FPCM after deducting calf rearing (kg/cow/day)	10.2	11.1	10.7	0.20	0.01
FPCM after deducting calf rearing (kg/year)	26697.3	26191.4	26444.4	4454.2	0.34
Milk composition					
CP (g/kg)	33.2	33.4	33.3	0.02	0.25
Milkfat (g/kg)	33.3	33.7	33.5	0.01	0.19
Sold cattle					
Sold cattle (kg/cow/year)	311.7	252.2	281.9	19.08	0.23
Sold cattle (kg/year) at 18.5% CP	3065.8	2320.3	2693.1	391	0.51

SEM= Standard Error of the Mean; CP= Crude Protein; FPCM= Fat and Protein Corrected Milk (Milk yield (kg/day) × [0.1226 × milkfat (%) + 0.0776 × milk crude protein (%) + 0.2534]).

The other six farms have implemented day grazing (from 6 to 11 h/day), and at night the cows were confined in similar pens as the cut-and-carry farms. Cows and replacement stock spend between 50 and 75% of time in pens.
Cows were hand-milked twice a day at 6:00 and 17:00 h. Three of the six grazing farms also grazed native grassland mainly by growing cattle. One grazing farm cuts-and-carry native grassland during the rainy season to complement the herd.

Sown pastures were of annual ryegrass (*Lolium multiflorum*) and white clover (*Trifolium repens*) for cut-and-carry, perennial ryegrass (*L. perenne*) and white clover with other grasses as tall fescue (*Festuca arundinacea*), festulolium (*L. multiflorum* × *F. arundinacea*), and kikuyu grass (*Pennisetum clandestinum*) for grazing farms (Plata-Reyes *et al*., 2018). Main species of native grasslands identified in the area were *Hilaria cenchroides*, *Enneapogon desvauxii*, *Bouteloua gracilis*, *Bouteloua hirsuta*, and *Paspalum prostratum* (Sainz-Sánchez *et al*., 2017). Grazing represented between 65 to 75% of the total diet. All 12 farms complemented their feeding with commercial concentrates at 18% or 20% CP, as well as maize silage in the dry season and purchased inputs. Both strategies used purchased maize straw and ground maize grain (Pozo-Leyva *et al*., 2019) representing between 25 and 35% of the total diet. Cut-and-carry farms also purchased alfalfa hay and yellow maize bran (a by-product of high-fructose syrup production) Table 2.

Table 2. Overall mean chemical composition of feeds according to feeding system.

Ingredients	DM g/kg	N g/kg DM
Sown pastures (Cut-and-carry)	176.0	20.0
Alfalfa hay (Cut-and-carry)	870.0	31.0
Maize bran (Cut-and-carry)	880.0	24.0
Native grasses (Grazing)	350.0	27.0
Sown pastures (Grazing)	200.0	31.0
Oat silage (Grazing)	175.0	13.0
Barley silage (Grazing)	244.0	10.0
Maize silage (Both feeding strategies)	320.0	12.0
Maize straw (Both feeding strategies)	960.0	7.0
Ground maize grain (Both feeding strategies)	890.0	17.0
Concentrate 18% CP (Both feeding strategies)	920.0	28.0
Concentrate 20% CP (Both feeding strategies)	920.0	31.0

DM= Dry matter, N= Nitrogen

Management in each farm over a year was documented via a structured interview applied to farmers on monthly visits (Pozo-Leyva *et al*., 2019). Information collected at each visit was on N management (acquisition and consumption of feed, milk production, manure management and sale of agricultural products), productive and reproductive information of the herds, as well as information on land management. All feeds were quantified and sampled, whether home produced or purchased, and milk yield and composition, as well as live weight of individual cows recorded on the visits every three months. The Feed Independence Index was estimated by the ratio between home-grown feed and total feed consumed; and refusals calculated by difference between offered and consumed feeds for both feeding systems.

Utilisation of nitrogen offered in ration

Determination of feed N was from weighing offered feeds, and intake at grazing calculated by difference from an estimated intake of DM at 3.2% (Barros *et al*., 20017) of live weight minus DM in offered feeds. Live weight of each animal and days in lactation were considered following the procedure described in previous investigations by Pozo-Leyva *et al*. (2021a, b) for dairy cows as is the case of this research. Sampling of feeds was every three months, as carried out in previous investigations (Pozo-Leyva *et al*., 2021b); since changes in the feeding systems are not drastic within the same season of the year and in this way the changes in the chemical composition of the pastures associated with the agroecological conditions of the study site can be accounted for. Dry matter (DM) was determined by drying in a draught oven and N content by the Kjeldahl method following standard procedures described by López-González *et al*. (2020).

Another source of N input was the replacement heifers that stayed on-farm which was 21.3% per year, which was used to adjust the crude protein output of both products (milk and beef), previous to taking a standard value of 3.5% CP for milk and 18.5% for live cattle.

Milk yield of individual cows was weighed with a spring balance and samples taken for milk composition every three months during one year of operation. Milk was analysed for protein content with an ultrasound milk analyser (Pincay-Figueroa *et al*., 2016), divided by the factor 6.38 for N content (NRC, 2001).

The N content in manure, was calculated from total N inputs as offered feed plus N in replacement stock that remained in farms minus N outputs as milk and sold cattle. The difference was considered as manure N (urine, dung and refused feeds) (O´Brien *et al*. 2015). The N from animals sold was calculated from the expected content of live weight considering their live weight and physiological state for each animal (NRC, 2003).

Greenhouse gas emissions and global warming potential (GWP)

Analyses of data from each farm and feeding strategy followed Tier 2 guidelines from IPCC (2006), by means of a model built in spreadsheets for each farm. The model enabled estimation of GHG emissions from methane, ammonia, nitrates, and nitrogen oxides; as well as GWP equivalents. The model also enabled to characterize N balances from N outputs as co-products (milk and beef) or as GHG emissions.

The model incorporated consecutive lineal equations and quadratic regressions to consider local effects on expected emissions in manure management, harmonized following IPCC (2006). The model allowed the adjustment of GWP for each emission, and to express GWP in kg of CO_2 equivalent (kg CO_2-eq) per product unit (kg) in each farm. Used CO_2 equivalents were 298 for NO_x and 23 for CH_4 (IPCC, 2006). Since milk and live cattle are produced in each farm, the model assigns total GWP to milk, to animals sold, or to a summary measure of production (milk + sold animals), in relation with the proportion that each product has in total protein output.

Functional unit

The N utilisation and GHG emissions were expressed per kg of fat and protein corrected milk (FPCM) (Battini *et al*., 2015). Protein content per kg of sold cattle was estimated at 18.5%. Calculation of GHG emissions was both for milk production as for animals sold. N data from milk and sold cattle were converted to FPCM for whole farms, so that the GWP was expressed in kg CO_2 – eq / kg FPCM.

$$FPCM = \text{Milk yield (kg/day)} \times [0.1226 \times \text{milk fat (\%)} + 0.0776 \times \text{milk crude protein (\%)} + 0.2534]$$

Statistical analyses

A completely randomised block design was used with the feeding strategy as treatments and farms, considering the heterogeneity of the feeding that the farms show, were considered as blocking factor. Data analyses was ANOVA using Minitab® V-10 software, according to the following model:

$$Y_{ij} = \mu + B_i + t_j + E_{ij}$$

Where:
Yij= response variable
μ= general mean
B_i= effect due to farm (1,2,3,4,5,6…12)

t_j= effect of treatment (feeding system) (1,2)
E_{ij}= residual error term

RESULTS

Characteristics of feeding strategies

Farms were similar in their productive characteristics, the difference being on available land, which relates to the capacity to produce homegrown feed, and therefore in determining feed dependency (Table 1). Table 2 shows the overall means for chemical composition of feeds used in each feeding strategy. There were statistical differences (P<0.05) with higher milk yields for grazing systems, determined by the higher nutritive value of grazed herbage.

Nitrogen utilization by feed system

No significant statistical differences (P>0.05) were observed for any of the variables in the utilisation of nitrogen according to feeding system, which includes feeding of replacement stock, milk production and manure excretion (Table 3). Out of the 1901.2 kg N/year offered as feed to the herds, 170.0 kg N/year was utilised in milk production, 90.1 kg N/year in cattle growth of which 25.1 kg N/year were kept as replacement heifers and 65.0 kg N/year left the systems as cattle sold. In terms of excreted N, 87.6% of N in offered feeds was excreted in manure representing 1666.2 kg N/year.

Greenhouse gas emissions from N utilisation

There were no significant differences (P>0.05) in GHG emissions between feeding strategies for any variable (Table 4). As mentioned before, manure is managed differently in the two feeding strategies. In the cut-and-carry farms, with total confinement of herds, 100% of manure is deposited in the concrete and earth floors, collected every day and stored outdoors in an open heap, and applied every six months to agricultural land (mostly to pastures, but some also to the maize crop).

In the grazing farms, from 60 to 75% of manure is collected overnight (some farmers do not have pasture to graze their replacements) in the pens and managed similarly to cut-and-carry farms except in two farms that apply the collected manure to pastures once a week. Grazing cattle deposited 25 to 40% of manure directly on the pasture. Every six months, farmers spread manure, by hand, onto their fields, which has an impact on the GHG emissions.

Figure 1 shows estimated CH_4 and N_2O emissions calculated from the two management systems expressed as kg CO_2-eq/ kg FPCM. Most CH_4 emissions are from ruminal fermentation and from manure storage as a secondary source, as has been described by Kebreab *et al*. (2006).

DISCUSSION

Characteristics of feeding strategies

The chemical composition of feeds was similar to reports by Velarde-Guillén *et al*. (2017). The grass sown in the cut and carry systems contains les dry matter and protein. In this feeding strategy farmers cut the grass at a height of approximately 30 cm (Pincay-Figueroa *et al*., 2016), a more mature grass with a higher proportion of stem. Herbage from the grazing feeding strategy contain marginally more dry matter and a higher content of crude protein. The animals in these systems tend to consume young tender grass which is rich in water and nitrogen (Pincay-Figueroa *et al*., 2016), so farmers invest less in feed supplements relative to cut and carry systems.

Farms under cut-and-carry need to purchase 38% of feeds, while grazing farms only need 17%. Therefore, cut-and-carry farms are more vulnerable to price changes and availability of feed inputs which corresponds to what was proposed by Gilker and Weil (2018) and Schiavon *et al*. (2021).

Pincay-Figueroa *et al*. (2016) did a study on small-scale milk production systems in the same research area, and reported that these systems are dependent on the purchase of commercial concentrates, that reach 60.7% of feeding costs for cut and carry systems, and 45.4% for grazing systems, with a reported lower profitability in cut and carry farms given higher costs and labour requirements, which corresponds to what is stated by Schiavon *et al*. (2021).

Table 3. Nitrogen utilisation according to feeding system (kg N/year).

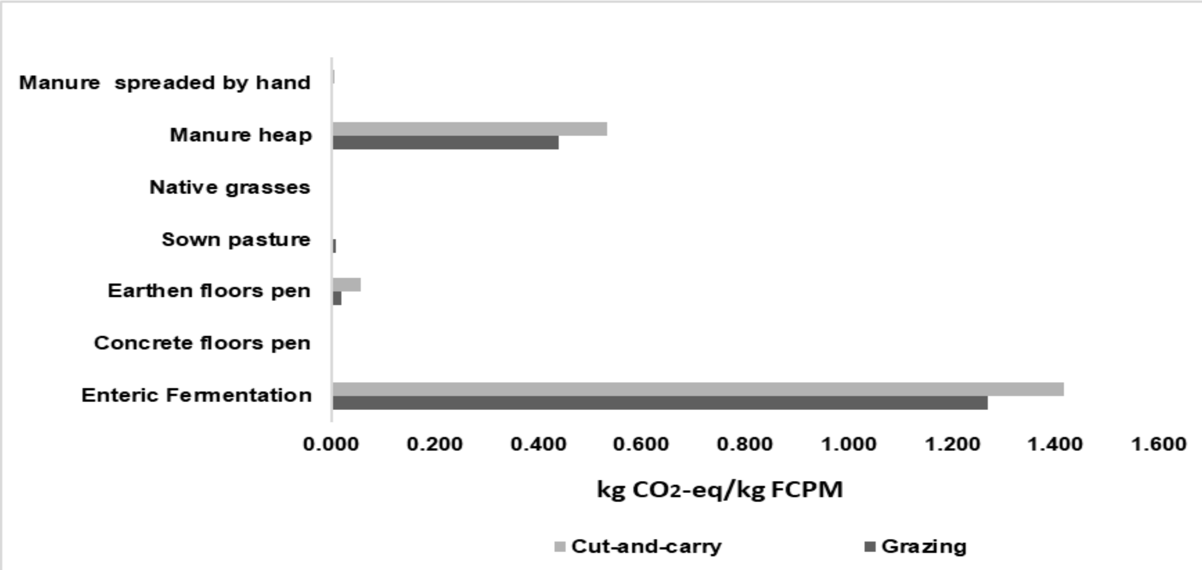
Item	Cut-and-Carry	Grazing	Mean	SEM	*P value*
Feed	1901.5	1900.9	1901.2	252.06	0.56
Replacements	25.5	24.7	25.1	3.76	0.74
Total	1927.0	1925.6	1926.3	255.75	0.28
Milk	171.2	168.9	170.0	13.06	0.16
Sold cattle	102.2	77.9	90.1	27.60	0.54
Manure	1653.6	1678.8	1666.2	216.74	0.18

SEM= Standard Error of the Mean.

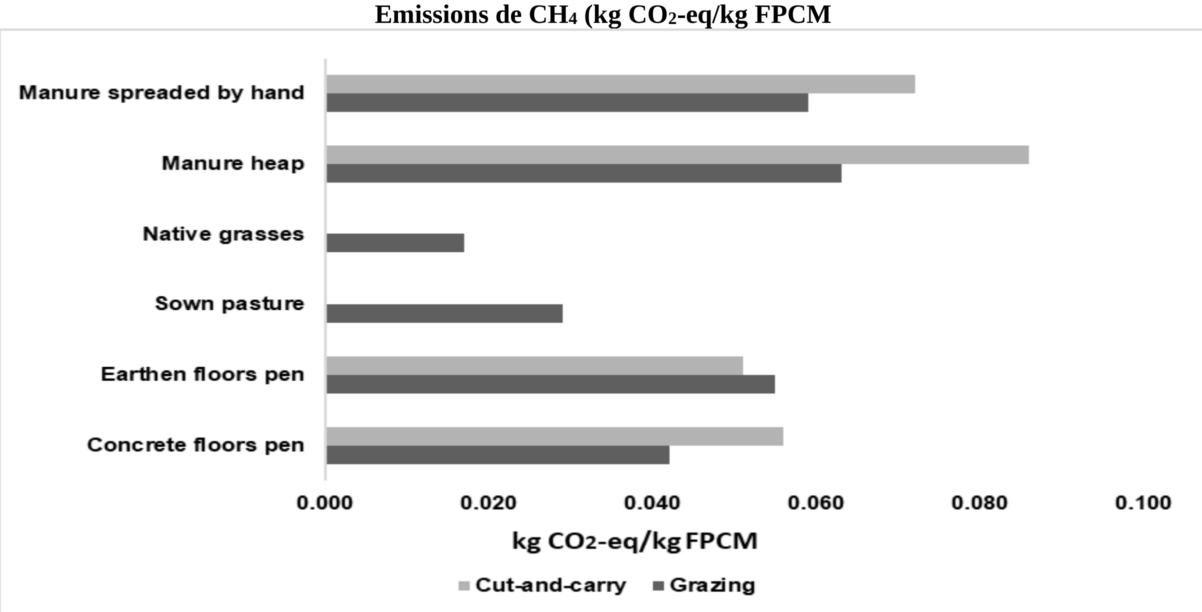
Table 4. Greenhouse gas emissions from N utilisation and manure management according to feeding system.

Indicator	Cut-and-carry	Grazing	Mean	SEM	*P value*
GHG (kg CO_2-eq/ kg FPCM)	2.2	2.0	2.1	0.18	0.37
GHG cattle sold (kg CO_2-eq / kg live weight)	20.4	22.5	21.4	1.81	0.61
GHG milk + cattle sold (kg CO_2-eq /kg)	1.4	1.3	1.3	0.10	0.42
GHG per cow (kg CO_2-eq /year)	4929.5	4340.9	4635.2	172.45	0.02
N_2O (kg/ kg FPCM)	0.265	0.264	0.264	0.01	0.28
CH_4 (kg/ kg FPCM)	1.952	1.718	1.835	0.25	0.36

SEM= Standard Error of the Mean; GHG = Greenhouse gases; FPCM= Fat and Protein Corrected Milk.



Emissions de CH_4 (kg CO_2-eq/kg FPCM



Emissions de N_2O (kg CO_2-eq/kg FPCM

Figure 1. CH_4 and N_2O emissions by feeding system (kg CO_2-eq/ kg FPCM).

Nitrogen utilization by feeding system

The N utilisation into co-products milk and cattle sold was only 9% for milk and 5% for sold animals. Powell *et al*. (2010) reported that between 65 and 85% of N inputs are not converted into animal products and excreted in manure and urine. Feeding comprise the main source of N inputs into farms, as stated by Gilker and Weil (2018) and Pozo-Leyva *et al*. (2019).

The N excretion in manure is related directly to N intake, so that minimising N intake is the main alternative to reduce N excretion, the reduction in GHG emissions, and the increase in profit from dairy production as protein is usually the most expensive nutrient. The nutritional component that most affects N utilisation is the crude protein content in rations. An increase in CP intake directly affects N utilization and the profitability of each farm. A reduction in the CP content of ration is possible without affecting milk yields and would have a lower environmental impact besides the economic improvement (Fadul-Pacheco *et al*., 2017).

Greenhouse gas emissions from N utilisation

Cut-and-carry farms have higher emissions from manure storage than grazing farms given the higher amounts of manure stored. Therefore, N_2O emissions are higher in the cut-and-carry strategy, during manure spreading, since N_2O is formed in farms by nitrification and denitrification processes (Soussana *et al*., 2010). Nitrification is the oxidation of ammonia to nitrates and nitrites giving rise to N_2O as a by-product, and denitrification is the microbial reduction of nitrates to nitrites, and from these, the formation of N_2O. Denitrification is slower when manure is fresh, since N_2O is favoured by an increase in available mineral N, which in turn increases the rate of nitrification and denitrification (IPCC. 2006; Kebreab *et al*., 2006). This process is influenced by meteorological conditions since low temperatures decrease N_2O formation.

The GHG emissions from milk production were not different (P>0.05) between feeding strategies with a mean 2.1 kg CO_2-eq/kg FPCM. These values are higher than reports by Doltra *et al*. (2018) who found values between 1.5 and 1.2 kg CO_2-eq/ kg milk for zero grazing and grazing systems respectively when comparing feeding systems in northern Spain.

Observed values were also higher to levels of GHG reported by Battini *et al*. (2015) from work in Italy who reported from 1.02 to 1.26 kg CO_2-eq/kg FPCM when excluding emissions from land use change and soil carbon sequestration (as in the work herein reported). Observed values were also higher than reports by Christie *et al*. (2012) between 0.76 and 1.68 kg CO_2-eq/kg FPCM in a study of dairy farms in Australia; and closer to the values ranging from 1.7 to 2.6 kg CO_2-eq/kg FPCM reported from a comprehensive work in the United States (Asselin-Balençon *et al*., 2013). The foregoing could be given by the disposal of the slurry, handling, storage time, number of animals and land surface.

On the other hand, under tropical conditions there are not many reports from small-scale dairy systems, but work in India by Garg *et al*. (2016) reported values between 1.9 and 2.3 kg CO_2-eq/kg FPCM for cows, similar to the values reported herein. In terms of yearly GHG per cow, even though the cut-and-carry farms had 13.6% more emission than grazing farms, the analysis did not detect significant differences (P>0.05). The mean emission of 4635.2 kg CO_2–eq/cow/year was lower than the 5946 kg CO_2–eq/cow/year for zero-grazing and 5659 kg CO_2–eq/cow/year for grazing reported by Doltra *et al*. (2018) in Northern Spain, with milk yields of 18.1 kg/cow/day for zero-grazing and 19.1 kg/cow/day for grazing.

Mean N_2O were 0.264 kg CO_2-eq /kg FPCM, lower than the range between 0.502 to 1.11 kg CO_2-eq /kg FPCM reported by Christie *et al*. (2012) from work with Australian dairy farms. Differences found in contrast to international literature on GHG emissions in dairy farms per kg of FPCM were due to the moderate mean yields of 13.5 kg/cow/day in the studied farms from both feeding strategies. In example, Doltra *et al*. (2018) with lower emissions reported yields between 18 and 20 kg milk/cow/day, while Garg *et al*. (2016) from work with smallholder farms in India reported emissions per kg of FPCM from cows similar to values herein reported.

CONCLUSIONS

Grazing systems studied showed greater milk yields, influenced by the higher nutritional value of grazing with respect to cut and carry systems. For their part, cutting and transport farms are more vulnerable to price changes and the availability of external inputs. In general, 87.6% of the N consumed is excreted in manure and urine. The feeding strategies did not diverge enough to have an impact on GHG emissions.

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Conflict of interest. The authors declare they have no conflicts of interest with regard to the work presented in this report.

Compliance with ethical standards. The research presents original data that are not submitted to other journals at the same time. Moreover, the research was conducted according to the established procedures of the Autonomous University of the State of Mexico.

Data availability. Data are available with Felipe López González, flopezg@uaemex.mx upon reasonable request.

Author contribution statement (CRediT). D. Pozo-Leyva, writing original, draft and methodology, writing-review and editing. **F. López-González**, conceptualization, writing-review and editing, methodology, validation and data curation. **R. Olea-Pérez**, draft and methodology. **P. Balderas-Hernández**, draft and methodology, **F. Casanova-Lugo**, draft and methodology. **C.M. Arriaga-Jordán**, conceptualization, writing-review and editing, funding acquisition, supervision and validation.

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