



**HAL**  
open science

# The nutrition of dairy ruminants: a lever for increasing their milk quality and decreasing their methane emissions?

Anne Ferlay, Cécile Martin, Adeline Bougouin, Maguy Eugène

## ► To cite this version:

Anne Ferlay, Cécile Martin, Adeline Bougouin, Maguy Eugène. The nutrition of dairy ruminants: a lever for increasing their milk quality and decreasing their methane emissions?. 23th Congress of the European Society of Veterinary and Comparative Nutrition, University of Torino - Animal nutrition unit Dept of Veterinary Sciences, Sep 2019, Turin, Italy. hal-04220206

**HAL Id: hal-04220206**

**<https://hal.inrae.fr/hal-04220206>**

Submitted on 27 Sep 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## The nutrition of dairy ruminants: a lever for increasing their milk quality and decreasing their methane emissions?

Ferlay A, Martin C, Bougouin A, Eugène M  
 Université Clermont Auvergne, INRA, VetAgro Sup, UMR Herbivores, F-63122 Saint-Genès-  
 Champanelle, France  
 e-mail: [anne.ferlay@inra.fr](mailto:anne.ferlay@inra.fr)

Global demand for meat and milk is expected to increase considerably until 2050, due to rise in consumption in developing countries, such as India, and increased living standards. In contrast, at European level, the consumption of meat and dairy products decreases per se in different countries, partly due to new consumption patterns (FAO, 2017, Animal Task Force, 2019) but the demand for high-quality animal products increases. Ruminants play also a major role in food security contributing to 51% of all livestock proteins (FAO, 2019). Quality represents nutritional, health, sensorial and technological dimensions, but responds also to ethical and societal concerns (animal health and welfare, environmental footprint). These characteristics represent extrinsic value of dairy products, determining increasingly the choice of consumers. Nevertheless, ruminant livestock productions are more and more particularly criticized for their high contribution to greenhouse gas (GHG) emissions on the global scale. Ruminants are the major producers of enteric methane (CH<sub>4</sub>) emissions, which represent 80% of CH<sub>4</sub> emissions from the livestock supply chain, the remaining 20% coming from manure management (Gill et al., 2010). Dairy cows are responsible of 32% of total enteric CH<sub>4</sub> emissions in France (Vermorel et al., 2008). Methane released by ruminants also represents an energy loss for the animals, ranging from 2% to 12% of gross energy intake for feedlots or ruminants fed poor-quality forages, respectively (Johnson and Johnson, 1995). Ruminant diets represent a rapid, direct and reversible lever for the farmers to improve dairy performance, milk composition including fatty acid (FA) profiles, and to mitigate CH<sub>4</sub> emissions of their herds. Thus, appropriate feeding strategies could be applied in order to improve the milk lipid quality in line with recommendations for human health. Several FA have positive or negative effects on human health. For the last several decades, the consumption of saturated FA (SFA) in excess has been associated with increased risks of cardiovascular diseases, although this concept is still under debate. Indeed, SFA cannot be considered as a single group in terms of their physiological effects, but at individual level (Bernard et al., 2018). Concerning polyunsaturated FA (PUFA), linoleic (C18:2 n-6) and linolenic (C18:3 n-3) acids are essential FA that must be provided by the diet, because they cannot be synthesized by the organism. C18:2 n-6 and C18:3 n-3 are involved in numerous biological processes: they are incorporated into cell membranes, and are precursors for other unsaturated FA (eicosanoids) that are necessary for cell membrane function and metabolic regulations implicated in inflammation and reproduction (Palmquist, 2009). *Trans* FA have been implicated in increases in LDL and decreases in HDL in humans. These effects are due to the *trans* FA supplied by hydrogenated fats, predominately elaidic acid (*trans*-9 C18:1). The putative harmful effects of ruminant *trans* FA are still under debate (Ferlay et al., 2017). These observations led to the reconsideration of recommended dietary allowances, particularly for SFA. In France, dietary guidelines recommend that consumption of C12:0, C14:0 and C16:0 should be limited to 8% of energy intake (EI), C18:2n-6 between 3 and 5 % of EI, C18:3n-3 to 1 % of EI, with C18:2n-6: C18:3n-3 ratio inferior to 5 and *trans* FA to 2% of EI, without distinguishing the origin of the *trans* FA (Anses, 2011).

## The nutrition of dairy ruminants: a lever for increasing their milk quality and decreasing their methane emissions?

Ferlay A, Martin C, Bougouin A, Eugène M  
 Université Clermont Auvergne, INRA, VetAgro Sup, UMR Herbivores, F-63122 Saint-Genès-  
 Champanelle, France  
 e-mail: [anne.ferlay@inra.fr](mailto:anne.ferlay@inra.fr)

Global demand for meat and milk is expected to increase considerably until 2050, due to rise in consumption in developing countries, such as India, and increased living standards. In contrast, at European level, the consumption of meat and dairy products decreases per se in different countries, partly due to new consumption patterns (FAO, 2017, Animal Task Force, 2019) but the demand for high-quality animal products increases. Ruminants play also a major role in food security contributing to 51% of all livestock proteins (FAO, 2019). Quality represents nutritional, health, sensorial and technological dimensions, but responds also to ethical and societal concerns (animal health and welfare, environmental footprint). These characteristics represent extrinsic value of dairy products, determining increasingly the choice of consumers. Nevertheless, ruminant livestock productions are more and more particularly criticized for their high contribution to greenhouse gas (GHG) emissions on the global scale. Ruminants are the major producers of enteric methane (CH<sub>4</sub>) emissions, which represent 80% of CH<sub>4</sub> emissions from the livestock supply chain, the remaining 20% coming from manure management (Gill et al., 2010). Dairy cows are responsible of 32% of total enteric CH<sub>4</sub> emissions in France (Vermorel et al., 2008). Methane released by ruminants also represents an energy loss for the animals, ranging from 2% to 12% of gross energy intake for feedlots or ruminants fed poor-quality forages, respectively (Johnson and Johnson, 1995). Ruminant diets represent a rapid, direct and reversible lever for the farmers to improve dairy performance, milk composition including fatty acid (FA) profiles, and to mitigate CH<sub>4</sub> emissions of their herds. Thus, appropriate feeding strategies could be applied in order to improve the milk lipid quality in line with recommendations for human health. Several FA have positive or negative effects on human health. For the last several decades, the consumption of saturated FA (SFA) in excess has been associated with increased risks of cardiovascular diseases, although this concept is still under debate. Indeed, SFA cannot be considered as a single group in terms of their physiological effects, but at individual level (Bernard et al., 2018). Concerning polyunsaturated FA (PUFA), linoleic (C18:2 n-6) and linolenic (C18:3 n-3) acids are essential FA that must be provided by the diet, because they cannot be synthesized by the organism. C18:2 n-6 and C18:3 n-3 are involved in numerous biological processes: they are incorporated into cell membranes, and are precursors for other unsaturated FA (eicosanoids) that are necessary for cell membrane function and metabolic regulations implicated in inflammation and reproduction (Palmquist, 2009). *Trans* FA have been implicated in increases in LDL and decreases in HDL in humans. These effects are due to the *trans* FA supplied by hydrogenated fats, predominately elaidic acid (*trans*-9 C18:1). The putative harmful effects of ruminant *trans* FA are still under debate (Ferlay et al., 2017). These observations led to the reconsideration of recommended dietary allowances, particularly for SFA. In France, dietary guidelines recommend that consumption of C12:0, C14:0 and C16:0 should be limited to 8% of energy intake (EI), C18:2n-6 between 3 and 5 % of EI, C18:3n-3 to 1 % of EI, with C18:2n-6: C18:3n-3 ratio inferior to 5 and *trans* FA to 2% of EI, without distinguishing the origin of the *trans* FA (Anses, 2011).

Pasture feeding and oilseed supplementation of cow diets are the most nutritional factors able to modify milk fat content and composition in dairy cows. Fresh grass is rich in total FA (1-3%) with C18:3n-3 as the main FA (50-75% of total FA). In cows, grazed grass generally increases the milk concentration of *cis*-9-C18:1 (+8.0 g/100 g of total FA) and PUFA (essentially, C18:3n-3 (+1.0) and *cis*-9,*trans*-11-CLA), and it decreases the concentration of C12:0 to C16:0 when compared to conserved grass (hay or silage) (Ferlay et al., 2017). Linseed or rapeseed supplementation is used because of their high content in essential FA, having health interest (55% C18:3n-3 and 60% *cis*-9-C18:1 of total FA for linseed and rapeseed, respectively). Oilseed supplementation decreased milk short- and medium-chain FA concentrations and concomitantly increased the sum of FA with 18 carbons. Linseed increased the C18:3n-3 concentration (on average 1.0% of total FA), whereas rapeseed increased it slightly. Globally, oilseed supplementation increased the milk concentration of *trans* FA (Ferlay et al., 2017).

Regarding CH<sub>4</sub> emissions, mitigation strategies aim at modifying rumen parameters via feeding practices (modification of diet composition, supplementation with lipids or additives) or by using biotechnologies (use of probiotics, inhibitors or vaccines). We focused on feeding practices that both improve milk yield and fat composition and decrease CH<sub>4</sub> emissions. Methane emissions (g/d, g/kg of dry matter intake (DMI)) were decreased by increasing levels of concentrate in the diet or replacing dietary structural carbohydrates from forages (cellulose, hemicellulose) with non-structural carbohydrates (starch and sugars) from energy-rich concentrates (Martin et al., 2010). Moreover, CH<sub>4</sub> emissions decreased linearly with an increase in the proportion of concentrate (Aguerre et al., 2011; McGeough et al., 2010). Concerning lipid supplementation, we studied the effect of nature of forage (hay vs corn silage) with increasing amounts of extruded linseed in the diet on CH<sub>4</sub> emissions (Martin et al., 2016). Extruded linseed efficiently and linearly reduced CH<sub>4</sub> emission in both experiments without altering intake, digestibility, or milk production with the hay-based diets. With the corn silage-based diets, intake and fiber digestibility decreased numerically with the highest linseed FA amount. The decrease in rumen protozoa number and the shift of fermentation toward C3 production appear to be related to the CH<sub>4</sub> mitigating effect of linseed with the hay- and corn silage-based diets. Moreover, several meta-analyses (Moate et al., 2011; Grainger and Beauchemin, 2011) demonstrated that lipid supplementation usually efficiently decreases CH<sub>4</sub> yield (g/kg of DMI) (the dietary ether extract content varies from 12 to 114 g/kg DM) or CH<sub>4</sub> emissions (g/kg of DMI) by 9% in dairy cows (Eugène et al., 2008), due to a reduction in DMI (-6%) by lipids added. The effects of dietary starch and lipid supplementation in dairy cows result from changes in total VFA composition with decrease in C2 towards increase in C3 resulting in reduction in H<sub>2</sub> availability for methanogens. Reduction in rumen pH with increasing dietary starch is known to inhibit H<sub>2</sub> producing microorganisms (cellulolytic bacteria, protozoa) and methanogens activities and in turn to decrease CH<sub>4</sub> emissions.

These changes in rumen fermentation parameters via modifications of microorganisms could have consequence on methanogenesis and lipid metabolism in the rumen. Relationships are then expected among CH<sub>4</sub>, rumen biohydrogenation of PUFA and precursors of *de novo* synthesized FA, and thus milk FA concentrations. Indeed, milk FA [C10:0, iso C17:0 + *trans*-9 C16:1, *cis*-11 C18:1, and *trans*-11,*cis*-15 C18:2 for CH<sub>4</sub> production (g/d); iso C16:0, *cis*-11 C18:1, *trans*-10 C18:1 and C18:2n-6 for CH<sub>4</sub> yield (g/kg of DMI); iso C16:0, *cis*-15 C18:1 and *trans*-10+*trans*-11 C18:1 for CH<sub>4</sub> intensity (g/kg of milk)] were able to predict CH<sub>4</sub> emissions in dairy cows with different level of prediction errors (65.1 g/d, 2.8 g/kg DMI and 2.9 g/kg milk, respectively) (Bougouin et al., 2019). Complex equations that

additionally used DMI, dietary NDF, ether extract, days in milk, and body weight had lower prediction errors (root mean square error of 46.6 g/d, 2.6 g/kg DMI and 2.7 g/kg milk, respectively). External evaluation, with individual or mean data not used for equations development, led to variable results. The performance of evaluation of the predictive equations was dependent on the domain of validity of the evaluation datasets used (individual or mean data).

## References

- Aguerre, M.J., Wattiaux M.A., Powell J.M., Broderick G.A., Arndt C. 2011. Effect of forage-to-concentrate ratio in dairy cow diets on emission of methane, carbon dioxide, and ammonia, lactation performance, and manure excretion. *J Dairy Sci.* 2011 94:3081-93. doi: 10.3168/jds.2010-4011
- Animal Task Force, 2019. Vision Paper, towards European Research and Innovation for a sustainable and competitive livestock production sector in Europe. A framework for suggested priorities for R&I within Horizon Europe, February 2019. 36 pages.
- Anses, 2011. Actualisation des apports nutritionnels conseillés pour les acides gras. Rapport d'expertise collective. 323 pages.
- Bernard, L., Bonnet, M., Delavaud, C., Delosière, M., Ferlay, A., Fougère H., Graulet, B. 2018. Milk Fat Globule in Ruminant: Major and Minor Compounds, Nutritional Regulation and Differences Among Species. *Eur. J. Lipid Sci. Technol.* DOI: 10.1002/ejlt.201700039.
- Bougouin, A., Ranga Niroshan Appuhamy, J. A. D., Ferlay, A., Kebreab, E., Martin, C., Moate, P. J., Benchaar, C., Lund, P., Eugène, M. 2019. Individual milk fatty acids are potential predictors of enteric CH<sub>4</sub> emissions from dairy cows fed a wide range of diets: approach by meta-analysis. *J Dairy Sci.* In press.
- Eugène, M., Massé, D., Chiquette, J., Benchaar, C. 2008. Meta-analysis on the effects of lipid supplementation on methane production in lactating dairy cows. *Can. J. Anim. Sci.* 88:331-337. doi:10.4141/CJAS07112.
- FAO, 2017. Trade policy briefs. 11th WTO Ministerial Conference in Buenos Aires 2017.
- FAO, 2019. Climate change and the global dairy cattle sector. The role of the dairy sector in a low-carbone future. Global agenda for sustainable livestock. Rome, 36 pages.
- Ferlay, A., Bernard, L., Meynadier, A., Malpuech-Brugère, C. 2017. Production of trans and conjugated fatty acids in dairy ruminants and their putative effects on human health. *Biochimie*, 141, 107-120. DOI: 10.1016/j.biochi.2017.08.006
- Giger-Reverdin, S; Morand-Fehr, P; Tran, G. 2003. Literature survey of the influence of dietary fat composition on methane production in dairy cattle. *Livestock Prod. Sci.* 82:73-79.
- Gill, M., Smith, P., Wilkinson, J.M. 2010. Mitigating climate change: the role of domestic livestock. *Animal*. 43:323-33.
- Grainger, C., Beauchemin. K. A. 2011. Can enteric methane emissions from ruminants be lowered without lowering their production? *Anim. Feed Sci. Technol.* 166-167: 308-320.
- Johnson, K. A., Johnson, D. E. 1995. Methane emissions from cattle. *J. Anim. Sci.* 73: 2483-2492.
- Martin, C., Ferlay A., Mosoni P., Rochette Y., Chilliard Y., Doreau M. 2016. Increasing linseed supply in dairy cow diets based on hay or corn silage: Effect on enteric methane emission, rumen microbial fermentation, and digestion. *J Dairy Sci.* 99:3445-3456. doi: 10.3168/jds.2015-10110.
- Martin, C., D. P. Morgavi, Doreau, M. 2010. Methane mitigation in ruminants: from microbe to the farm scale. *Animal* 4: 351-365.

additionally used DMI, dietary NDF, ether extract, days in milk, and body weight had lower prediction errors (root mean square error of 46.6 g/d, 2.6 g/kg DMI and 2.7 g/kg milk, respectively). External evaluation, with individual or mean data not used for equations development, led to variable results. The performance of evaluation of the predictive equations was dependent on the domain of validity of the evaluation datasets used (individual or mean data).

### References

- Aguerre, M.J., Wattiaux M.A., Powell J.M., Broderick G.A., Arndt C. 2011. Effect of forage-to-concentrate ratio in dairy cow diets on emission of methane, carbon dioxide, and ammonia, lactation performance, and manure excretion. *J Dairy Sci.* 2011 94:3081-93. doi: 10.3168/jds.2010-4011
- Animal Task Force, 2019. Vision Paper, towards European Research and Innovation for a sustainable and competitive livestock production sector in Europe. A framework for suggested priorities for R&I within Horizon Europe, February 2019. 36 pages.
- Anses, 2011. Actualisation des apports nutritionnels conseillés pour les acides gras. Rapport d'expertise collective. 323 pages.
- Bernard, L., Bonnet, M., Delavaud, C., Delosière, M., Ferlay, A., Fougère H., Graulet, B. 2018. Milk Fat Globule in Ruminant: Major and Minor Compounds, Nutritional Regulation and Differences Among Species. *Eur. J. Lipid Sci. Technol.* DOI: 10.1002/ejlt.201700039.
- Bougouin, A., Ranga Niroshan Appuhamy, J. A. D., Ferlay, A., Kebreab, E., Martin, C., Moate, P. J., Benchaar, C., Lund, P., Eugène, M. 2019. Individual milk fatty acids are potential predictors of enteric CH<sub>4</sub> emissions from dairy cows fed a wide range of diets: approach by meta-analysis. *J Dairy Sci.* In press.
- Eugène, M., Massé, D., Chiquette, J., Benchaar, C. 2008. Meta-analysis on the effects of lipid supplementation on methane production in lactating dairy cows. *Can. J. Anim. Sci.* 88:331-337. doi:10.4141/CJAS07112.
- FAO, 2017. Trade policy briefs. 11th WTO Ministerial Conference in Buenos Aires 2017.
- FAO, 2019. Climate change and the global dairy cattle sector. The role of the dairy sector in a low-carbone future. Global agenda for sustainable livestock. Rome, 36 pages.
- Ferlay, A., Bernard, L., Meynadier, A., Malpuech-Brugère, C. 2017. Production of trans and conjugated fatty acids in dairy ruminants and their putative effects on human health. *Biochimie*, 141, 107-120. DOI: 10.1016/j.biochi.2017.08.006
- Giger-Reverdin, S; Morand-Fehr, P; Tran, G. 2003. Literature survey of the influence of dietary fat composition on methane production in dairy cattle. *Livestock Prod. Sci.* 82:73-79.
- Gill, M., Smith, P., Wilkinson, J.M. 2010. Mitigating climate change: the role of domestic livestock. *Animal*. 43:323-33.
- Grainger, C., Beauchemin, K. A. 2011. Can enteric methane emissions from ruminants be lowered without lowering their production? *Anim. Feed Sci. Technol.* 166-167: 308-320.
- Johnson, K. A., Johnson, D. E. 1995. Methane emissions from cattle. *J. Anim. Sci.* 73: 2483-2492.
- Martin, C., Ferlay A., Mosoni P., Rochette Y., Chilliard Y., Doreau M. 2016. Increasing linseed supply in dairy cow diets based on hay or corn silage: Effect on enteric methane emission, rumen microbial fermentation, and digestion. *J Dairy Sci.* 99:3445-3456. doi: 10.3168/jds.2015-10110.
- Martin, C., D. P. Morgavi, Doreau, M. 2010. Methane mitigation in ruminants: from microbe to the farm scale. *Animal* 4: 351-365.

- McGeough, E.J., O'Kiely, P., Foley, P.A., Hart, K.J., Boland, T.M., Kenny, D.A. 2010. Methane emissions, feed intake, and performance of finishing beef cattle offered maize silages harvested at 4 different stages of maturity. *J. Anim. Sci.* 88:1479-1491. doi:10.2527/jas.2009-2380.
- Moate, P.J., Williams, S.R.O., Grainger, C., Hannah, M.C., Ponnampalam, E.N., Eckard, R.J. 2011. Influence of cold-pressed canola, brewers grains and hominy meal as dietary supplements suitable for reducing enteric methane emissions from lactating dairy cows. *Anim. Feed Sci. and Technol.* 166-167:254-264.
- Mohammed, R., McGinn, S., Beauchemin, K. 2011. Prediction of enteric methane output from milk fatty acid concentrations and rumen fermentation parameters in dairy cows fed sunflower, flax, or canola seeds. *J. Dairy Sci.* 94, 6057-6068.
- Palmquist, D.L. 2009. Omega-3 fatty acids in metabolism, health, and nutrition and for modified animal product foods. *The Professional Animal Scientist* 25:207-249.
- Vermorel, M., J.P. Jouany, M. Eugène, D. Sauvant, J. Noblet, Dourmad J.Y. 2008. Evaluation quantitative des émissions de méthane entérique par les animaux d'élevage en 2007 en France. *INRA Prod. Anim.* 21:403-418.