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

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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_4**) emissions, which represent 80% of CH_4 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_4 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_4 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).

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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 cis9-C18:1 (+8.0 g/100 g of total FA) and PUFA (essentially, C18:3n-3 (+1.0) and cis9,trans11-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_4 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_4 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_4 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_4 emissions (Martin et al., 2016). Extruded linseed efficiently and linearly reduced CH_4 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_4 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_4 yield (g/kg of DMI) (the dietary ether extract content varies from 12 to 114 g/kg DM) or CH_4 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_2 availability for methanogens. Reduction in rumen pH with increasing dietary starch is known to inhibit H_2 producing microorganisms (cellulolytic bacteria, protozoa) and methanogens activities and in turn to decreases CH_4 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_4, 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_4 production (g/d); iso C16:0, *cis*-11 C18:1, *trans*-10 C18:1 and C18:2n-6 for CH_4 yield (g/kg of DMI); iso C16:0, *cis*-15 C18:1 and *trans*-10+*trans*-11 C18:1 for CH_4 intensity (g/kg of milk)] were able to predict CH_4 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).

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