Effects of feeding and physiological factors on goat milk fatty acid secretion and milk fat lipolysis

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This review is focused on the specificities of goats compared to cows, with specific emphasis on the responses of milk fatty acid (FA) secretion and milk fat lipolysis to physiological and nutritional factors, and possible underlying mechanisms.

The effect of lactation stage on milk fat yield and FA composition is similar between goats and cows, whereas the responses of milk fat yield and composition to dietary factors, in particular the types of lipid supplements, differ largely between the two species. With almost all studied lipid supplements, milk fat content increases in goats but not in cows. Marked interactions occur in both species between the composition of basal diet (forages, starchy concentrates) and lipid supplementation on milk FA responses, including trans-10 and trans-11 18:1 and isomers of conjugated linoleic acid (CLA). The goat is much less sensitive than the cow to alterations in ruminal biohydrogenation pathways causing the shift from trans-11 to trans-10 18:1 as a major intermediate which occurs on diets rich in starch and polyunsaturated FA (PUFA). Interestingly, changes in milk fat melting points to diet were small and of similar magnitude in goats and cows, despite of differences in milk fat secretion and FA profile responses between the two species. Goat milk cis-9,trans-11-CLA content increases greatly after either fresh grass feeding or vegetable oil supplementation, but does not change markedly when animals receive whole untreated oilseeds.

In goats, milk fat content and yield are not altered by dietary fish oil supplementation at doses which induce milk fat depression (MFD) in cows. However, significant reductions do occur in goats fed high-starch high-fish oil diets, but the relative decreases are lower compared with cows. Even during high starch and fish oil induced MFD in goats, milk trans-10-18:1 concentration did not increase (contrary to cows) whereas cis-9,trans-11CLA was substantially increased (more than in cows).

With regard to the regulation of mammary lipid metabolism, species differences have also been identified. Changes in the transcription of major lipogenic genes (mRNA abundances of genes involved in FA uptake (LPL), de novo synthesis (ACACA and FASN) and delta-9 desaturation (SCD)) in mammary tissue to nutritional factors do not always correspond with observed milk FA secretion responses. In goats as for cows, data suggest i) that the availability of substrates is more limiting than the lipoprotein lipase (LPL) activity in the uptake of long-chain FA, except with extreme diets fed to cows, in which mammary LPL expression decreased, and ii) that other proteins involved in the FA uptake and intracellular transport (e.g., fatty acid translocase, CD36; fatty acid-binding protein, FABP) may be implicated. In cows and goats ACACA and FASN mRNA abundances were linked to short- and medium-chain FA synthesis, even though the abundance of these transcripts are not always decreased by the addition of PUFA in the diet, in goats at least. In this species, ACACA and FASN mRNA are regulated by dietary factors at a transcriptional level, and SCD is regulated at a transcriptional and/or post-transcriptional level, depending on the lipid supplements. However, in cows, the abundance of SCD mRNA varies little with diet composition, except for a decrease when "rumen-protected" fish oil or docosahexaenoic acid (DHA)-rich algae were fed.

As previously stated for diet-induced MFD, feeding diets of similar composition to cows and goats does not substantially alter mammary lipogenic gene expression in the caprine. Altogether, these data suggest that variations between ruminants in mammary FA secretion and lipogenic responses to changes in diet composition reflect inherent inter-species differences not only in ruminal lipid metabolism, but also in mammary specific regulation of cellular processes involved in the synthesis of milk fat.

Post-ruminal infusions in cows have demonstrated that trans-10,cis-12-CLA or trans-10 18:1 have anti-lipogenic effects. Moreover, in cows, the responses of mRNA abundances of the lipogenic genes involved in de novo FA synthesis, FA uptake, transport and esterification to either trans-10,cis-12-CLA infusion or diets that induce MFD, showed a large decrease that occurred prior to any decrease in SCD1 mRNA. Conversely, in goats, administration of trans-10,cis-12-CLA at the duodenum or when fed as calcium salts lowered milk FA product/substrate ratios for SCD in the absence of, or only a small decrease in milk fat secretion. This suggests that the expression of mammary lipogenic genes is less sensitive to the anti-lipogenic effect of trans-10,cis-12-CLA in goats than cows, which was confirmed in vitro using bovine and caprine mammary slices. However, for SCD the converse is true with a higher sensitivity being reported in goats. This is in agreement with data on milk FA, since comparisons between studies in goats and cows with similar dietary changes showed that, in general, milk FA product/substrate ratios for SCD decreased in goats whereas these ratios increased in cows.

Furthermore, post-ruminal infusion studies in cows have shown that in addition to trans-10,cis-12-CLA, trans-10,trans-12-CLA and trans-9,trans-11-CLA reduced milk FA product/substrate ratios for SCD. This suggests that these two biohydrogenation intermediates could be specific inhibitors of SCD activity, since they were not associated with MFD. In particular, the large increase in milk trans-9,trans-11-CLA in goats receiving diets supplemented with sunflower oil could be involved in the typical decrease of milk FA product/substrate ratios for SCD in this species. In contrast, increases in milk trans-9,cis-11-CLA concentrations that may lower milk fat synthesis in cows, did not occur in goats receiving high starch-high PUFA diets.

The development of either goat flavour (linked to free, branched and medium-chain FA release) or rancidity (due to excessive release of free butyric acid) is related to the peculiarities of the goat milk FA composition and lipolytic system. The milk LPL activity is lower in goat than in cow. This enzyme has a higher affinity for fat globules with an activity more closely correlated with post-milking spontaneous lipolysis of milk fat in goats compared with cows. Goat milk lipolysis and LPL activity are low during early and late lactation, and decrease when animals are underfed or receive a diet supplemented with plant oils, varying considerably across goat breeds or genotypes. This could explain, at least in part, the observed decreases in the goat flavour of dairy products when animals receive lipid-rich diets.

In goats the alpha-s1-casein (CSN1S1) gene polymorphism affects milk composition, with a decrease in milk fat content, and 8:0-12:0 concentrations, and an increase in milk FA product/substrate ratios for SCD (without changing milk fat melting point), and in milk fat spontaneous lipolysis in the low CSN1S1 genotype. Moreover, with diets supplemented or not with extruded linseeds, several genotype x feeding interactions were observed, with lower responses in milk fat content and FA concentrations, and much higher response in milk fat spontaneous lipolysis in goats of the low than of the high CSN1S1 genotype. In the same way, genotype x feeding interaction could be responsible

for the lower amplitude of the response to food-deprivation observed on production and composition of milk as well as on mammary gene expression in goats carrying low compared to high genotype.

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