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# Diets supplemented with starch and corn oil, marine algae, or hydrogenated palm oil differentially modulate milk fat secretion and composition in cows and goats: A comparative study

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## ABSTRACT

A direct comparative study of dairy cows and goats was performed to characterize the animal performance and milk fatty acid (FA) responses to 2 types of diets that induce milk fat depression in cows as well as a diet that increases milk fat content in cows but for which the effects in goats are either absent or unknown. Twelve Holstein cows and 12 Alpine goats, all multiparous, nonpregnant, and at 86 ± 24.9 and 61 ± 1.8 DIM, respectively, were allocated to 1 of 4 groups and fed diets containing no additional lipid (CTL) or diets supplemented with corn oil [5% dry matter intake (DMI)] and wheat starch (COS), marine algae powder (MAP; 1.5% DMI), or hydrogenated palm oil (HPO; 3% DMI), according to a 4 × 4 Latin square design with 28-d experimental periods. Dietary treatments had no significant effects on milk yield and DMI in both species, except for COS in cows, which decreased DMI by 17%. In cows, milk fat content was lowered by COS (−45%) and MAP (−22%) and increased by HPO (13%) compared with CTL, and in goats only MAP had an effect compared with CTL by decreasing milk fat content by 15%. In both species, COS and MAP lowered the yields (mmol/d per kg of BW) of <C16 and C16 FA. With COS, this decrease was compensated by an increase of >C16 FA in goats, but not in cows, and the >C16 FA yield decreased with MAP in both species. HPO supplementation increased the milk yield of C16 FA in cows. Compared with CTL, COS induced an increase of *trans*-10,*cis*-12 conjugated linoleic acid by 18 fold in cows and 7 fold in goats and of *trans*-10 18:1 by 13 fold in cows and 3 fold in goats. Moreover, other conjugated linoleic acid isomers, such as *trans*-10,*trans*-12 and *trans*-7,*cis*-9, were increased to a greater extent in cows (8 and 4 fold, respectively) compared with goats (4 and 2 fold, respectively) on the COS treatment. In both species, the responses to MAP were characterized by a decrease in the milk concentration of 18:0 (3 fold, on average) and *cis*-9 18:1 (2 fold, on average) combined with a 3-fold increase in the total *trans* 18:1, with an increase in *trans*-10 18:1 only observed in cows. Compared with CTL, the response to HPO was distinguished by an increase in 16:0 (10%) in cows. This comparative study clearly demonstrated that each ruminant species responds differently to COS and HPO treatments, whereas MAP caused similar effects, and that goats are less sensitive than cows to diets that induce a shift from the *trans*-11 toward the *trans*-10 ruminal pathways.
**Key words:** ruminant species, lipid supplement, milk fatty acid, milk fat plasticity

## INTRODUCTION

The ability to better control milk fat content and composition is central to improving both the nutritional quality of dairy products, as some fatty acids (**FA**) have potential positive or negative effects on human health (Givens, 2015; Ferlay et al., 2017), and the production efficiency of dairy ruminants. In recent decades, the addition of lipid supplements to ruminant diets has been used to improve energy intake in high-producing dairy cows (Chilliard et al., 1993) and to influence milk FA composition (Doreau et al., 2012). However, certain dietary conditions in dairy cows; (1) diets rich in starch (e.g., high-grain/low-forage diets) and supplemented with PUFA from plants or (2) diets supplemented with PUFA of marine origin (mainly fish oils and algae) cause milk fat depression (**MFD**; Bauman and Griinari, 2001), whereas others, such as dietary addition of calcium salts from palm oil, increase milk fat content (Mosley et al., 2007).

Different theories have been proposed to explain the causes of MFD. For diets rich in starch and supplemented with vegetable oil (rich in PUFA), the biohydrogenation (**BH**) theory prevails and attributes MFD to the antilipogenic effect of specific *trans* FA that are

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formed in the rumen, particularly *trans*-10,*cis*-12 CLA (Bauman and Griinari, 2003; Shingfield and Griinari, 2007). For diets including marine supplements, an extension of the BH theory was proposed that includes the role of changes in the availability of long-chain FA in the mammary gland that essentially consist of an increase in the total *trans* 18:1 at the expense of 18:0, which would increase the milk fat melting point and contribute to lower milk fat synthesis (Shingfield and Griinari, 2007; Gama et al., 2008). However, the underlying mechanisms remain poorly documented.

Conversely, regardless of dietary conditions, MFD is not commonly observed in small ruminant species, particularly in goats under dietary conditions similar to those that induce MFD in cows (Shingfield et al., 2010). Differences have been suggested in ruminal PUFA biohydrogenation pathways and mammary lipogenesis by indirect comparisons of the milk fat content and composition in cows (Roy et al., 2006; Shingfield et al., 2003) and goats (Ollier et al., 2009; Toral et al., 2014) fed similar diets, which induce MFD in cows but not in goats. This assumption was evaluated by a direct comparison experiment (Toral et al., 2015) in dairy cows and goats fed similar diets supplemented with sunflower oil and enriched with starch or only supplemented with fish oil. Their study showed interspecies differences in milk fat secretion and FA composition, with both diets inducing MFD in cow; however, surprisingly, MFD was observed in goats under fish oil supplementation at 2% dry DMI, although the degree was lower.

To confirm and complete these findings, the present comparative experiment was designed with the aim to describe the responses of dairy cows and goats to diets supplemented with corn oil and starch (**COS**) or marine algae powder (**MAP**) or hydrogenated palm oil (**HPO**). These dietary treatments have been chosen to either induce MFD for the 2 former or increase fat content in cows for the latter and for which the responses are putative (for COS and HPO) or unknown (for MAP) in goats. Another objective was to identify milk FA biomarkers of the different responses to the MFD diets, which could give insights into the mechanisms involved.

Our hypotheses were that (1) MFD induced by starch and plant oils or marine supplements was due to changes in ruminal (studied by inference with milk *trans* FA) as well as postabsorptive (transport and mammary uptake of FA and lipogenesis) tissue metabolism with different mechanisms involved; (2) diets inducing increased fat content is caused by postabsorptive tissue metabolism; and (3) that these mechanisms and responses differ between ruminant species, with the goat being less sensitive to rumen fermentation changes induced by diet than the cow. To achieve these goals, the effects of various lipid supplements on dairy performances, milk FA composition, with particular emphasis on *trans*-FA reflecting ruminal PUFA biohydrogenation pathway and plasma metabolites precursors of mammary de novo lipogenesis, were determined on dairy goats and cows.

## MATERIALS AND METHODS

### *Animals, Experimental Design, Diets, and Management*

All experimental procedures were approved by the Auvergne Rhône-Alpes Ethics Committee for Experiments on Animals (France; DGRI agreement APAFIS#3277–2015121411432527 v5), and were compliant with the guidelines established by the European Union Directive 2010/63/EU. Twelve Holstein cows and 12 Alpine goats, all multiparous, nonpregnant, and at the lactation stage of 86 ± 24.9 and 61 ± 1.8 DIM (±SD), respectively, were used for the experiment. Cows were housed in a common freestall and goats in individual stalls in separate dedicated facilities at the same research site. Animals were then allocated to 1 of 4 groups (3 cows and 3 goats per group), which were balanced according to DIM, milk production, and milk fat and milk protein content, in a replicated, 4 × 4 Latin square design to test the effects of 4 treatments that were randomly assigned to each group over four 28-d experimental periods (Kaps and Lamberson, 2009) from February to July 2016.

All animals were offered grass hay ad libitum (first cycle, harvested at the heading stage, and from natural permanent half mountain grassland) supplemented with concentrates containing no additional lipid (control; **CTL**), corn oil (Olvea, Saint Léonard, France) and wheat starch (**COS**), marine algae powder [DHA Gold (*Schizochytrium* sp.), DSM, Basel, Switzerland; **MAP**], or hydrogenated palm oil (Provimi, Cargill, Saint-Germain-En-Laye, France; **HPO**). The formulation, chemical composition, and FA profile of experimental concentrates, with or without lipid supplementation, and grassland hay are reported in Table 1. Concentrates (Neovia, Saint Nolff, France) were composed of cracked corn grain, soybean meal, and pelleted dehydrated alfalfa, except for COS, in which pelleted dehydrated alfalfa was replaced by flattened wheat grain to increase the starch content of that treatment (40% more starch in COS concentrate compared with the CTL concentrate). Lipid supplements were manually mixed with the concentrate immediately before feeding and allocated to the cows and goats as 920 and 111 g/d of corn oil, 310 and 40 g/d of marine algae powder, and 630 and 80 g/d of hydrogenated palm oil, respectively.