J. Dairy Sci. 100:1–18
https://doi.org/10.3168/jds.2016-12383
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Feeding a concentrate rich in rapeseed oil improves fatty acid composition and flavor in Norwegian goat milk

R. A. Inglingstad,*[1] S. Skeie,* G. E. Vegarud,* T. G. Devold,* Y. Chilliard,† and M. Eknæs‡
*Faculty of Chemistry, Biotechnology and Food Science (KBM), Norwegian University of Life Sciences (NMBU), 1430 Ås, Nroway
†UMR1213 Herbivores, Institut National de la Recherche Agronomique (INRA)-Clermont-Theix-Lyon, F-63122 Saint-Genès-Champanelle, France
‡Faculty of Biosciences (BIOVIT), Norwegian University of Life Sciences (NMBU), 1430 Ås, Norway

ABSTRACT

Impaired quality due to a high content of free fatty acids (FFA) and off-flavors has caused challenges in the development of Norwegian goat milk products. The present study aimed to examine the effect of lipid-supplemented concentrates on milk fat content, fatty acid composition, FFA, lipoprotein lipase activity, sensory properties, and size of milk fat globules of goat milk. Thirty goats assigned to 3 experimental groups were fed different concentrates from 60 d in milk (DIM) until late lactation (230 DIM). The diets were (1) control concentrate (no added fat); (2) control concentrate with 8% (added on air-dry basis) hydrogenated palm oil enriched with palmitic acid (POFA); and (3) control concentrate with 8% (added on air-dry basis) rapeseed oil (RSO). The POFA group produced milk with the highest fat content, and fat content was positively correlated with the mean size of milk fat globules. Goats in the RSO group had a higher content of long-chain and unsaturated fatty acids, whereas milk from goats in the POFA group had a higher content of palmitic and palmitoleic acids (C16:0 and C16:1 *cis*). The control group produced milk with a higher content of short-, medium-, odd-, and branched-chain fatty acids compared with the 2 other groups. The content of FFA in milk was low in early and late lactation and peaked in mid lactation (90 DIM). A high content of FFA was correlated with poor sensory properties (tart/rancid flavor). The RSO group produced milk with lower content of FFA and off-flavors in mid lactation and a higher proportion of unsaturated fatty acids. Therefore, replacement of palm oil with rapeseed oil as a lipid source in dairy goat feed would be favorable.

Key words: rapeseed oil, palm oil, goat milk, fatty acid composition, free fatty acids

Received December 1, 2016.
Accepted May 15, 2017.
[1]Corresponding author: raaboe@nmbu.no

INTRODUCTION

Norwegian goat milk has been of variable quality in respect to both rennet coagulation properties and off-flavors, which may be a problem in the production of cheese. The problem is most prominent in mid lactation, which sometimes coincides with the time when the goats are let out on mountain or rangeland pasture (Eknæs et al., 2006). The off-flavors of goat milk are correlated with the content of free fatty acids (**FFA**; Dønnem et al., 2011), and goats deficient in α_{S1}-CN [goats homozygous for a deletion in exon 12 of the gene encoding α_{S1}-CN, which causes low or no synthesis of this protein in their milk (E12–00)] have higher frequencies of FFA and off-flavors compared with goats not deficient in α_{S1}-CN [goats with no or only one deletion in exon 12 of the gene encoding α_{S1}-CN; these goats express this protein in their milk (E12–11/E12–01); Dagnachew et al., 2011]. Free fatty acids result from the action of lipoprotein lipase (**LPL**), a highly potent enzyme that hydrolyses mainly triglycerides (**TG**) into glycerol and FFA. However, LPL does not reach its full lipolytic potential in milk because its substrate (TG) is localized in milk fat globules (**MFG**) surrounded by a protective membrane—the milk fat globule membrane (**MFGM**; Deeth, 2006). In cow milk, LPL is associated with the casein micelles. However, in goat milk it is probably associated with the MFGM (Chilliard et al., 2003). If the MFGM is damaged or broken, LPL will have immediate access to TG, resulting in excessive lipolysis. Previous studies (Eknæs et al., 2009) have shown that extra supplements of saturated fat (C16:0 and C18:0) in goat feed improves the milk flavor. Calcium salts of palm oil-derived fatty acids are largely used as dairy energy supplements (Onetti and Grummer, 2004; Rabiee et al., 2012). However, the use of palm oil is severely criticized, both from an environmental sustainability point of view (Wilcove et al., 2013) and from a consumer health perspective, because it increases milk palmitic acid, which is not recommended (Hayes et al., 1997; Shingfield et al., 2008). Hence, the search for a

good substitute to palm oil in animal feed becomes increasingly important.

Rapeseeds could be a more sustainable substitute for palm oil in the dairy feed. Oilseeds were introduced in Norway in the late 1950s; however, the land used for cultivation of oilseeds today is less than 1% of total cultivated farmland (Granlund et al., 2010). Several experiments feeding rapeseeds or rapeseed oil to dairy goats have shown positive effects on milk quality in terms of milk flavor and fatty acid composition. Activity of LPL and content of FFA were reduced (Ollier et al., 2009), which improve the sensory quality of the milk. Contents of SFA, especially C16:0, decreased, and contents of *trans*-C18:1 isomers, linoleic, linolenic, and conjugated linoleic acids increased (Gulati et al., 1997; Mir et al., 1999; Andrade and Schmidely, 2006; Ollier et al., 2009). The *trans* isomers C18:1 *trans*-6–9 are found in hydrogenated vegetable oils and believed to have a negative effect on human health, whereas C18:1 *trans*-11 and the CLA isomer C18:2 *cis*-9,*trans*-11 found in ruminant milk have neutral or health-promoting effects (Shingfield et al., 2008). We therefore hypothesize that rapeseed oil in the goats' diet will reduce the frequency of off-flavors and the content of FFA, and increase the proportion of UFA in the milk fat.

The aim of this study was thus to evaluate the effect of lipid-supplemented concentrate fed to Norwegian dairy goats on the following milk parameters: fat content, fatty acid composition, lipolysis, LPL activity, FFA, and MFG size. Two lipid sources were compared (saturated palm oil and unsaturated rapeseed oil) with a concentrate with no added fat (control feed). Milk samples from individual goats were collected throughout the lactation cycle. We also investigated and report separately milk protein composition and cheesemaking properties (Inglingstad et al., 2016) and goats' energy balance and milk production parameters (Eknæs et al., 2017) from the same experiment.

MATERIALS AND METHODS

Experimental Design

Thirty Norwegian dairy goats in second to fourth lactation, kidding in February 2011 (average kidding date: February 17 ± 8 d) and with average BW 2 d after kidding of 54.4 ± 6.7 kg were fed a control diet until 60 DIM (preparatory period). The control concentrate consisted of barley, rapeseed meal (Expro 00SF, AarhusKarlshamn Sweden AB, Karlshamn, Sweden), soybean meal, beet pulp, molasses, and mineral/vitamin premix. At 60 DIM, the goats were assigned to 3 experimental groups each of 10 goats receiving 3 types of feed. The diets were (1) control concentrate (**CON**), (2) control concentrate with 8% (air-dry basis) hydrogenated palm oil enriched with palmitic acid (Akofeed Gigant 60, AarhusKarlshamn Sweden AB; **POFA**), and (3) control concentrate with 8% (air-dry basis) rapeseed oil (AarhusKarlshamn Sweden AB; **RSO**). The treatment designations CON, POFA, and RSO are also used to describe the milk from the goats on the respective treatments. The experimental groups were balanced according to lactation number, kidding date, milk yield, and BW. Each group consisted of 7 goats heterozygous (E12–01) for the deletion in exon 12 at the α_{S1}-CN locus (*CSN1S1*), whereas 3 were homozygous (E12–00) for this deletion. From 0 to 130 DIM and from 200 to 230 DIM, the goats were stabled indoor in individual pens and received silage according to appetite (10% refusals). From 130 to 200 DIM, the goats were grazing free-range in a mountain pasture about 1,000 m above sea level. The mountain pasture consisted of boggy areas with sedges (mainly *Carex nigra* and *Carex rostrata*) and drier areas with grass, herbs, and shrubs (mainly *Deschampsia cespitosa*, *Salix* spp., and *Betula* spp.; Eknæs et al., 2006). The goats received 0.9 kg of the experimental concentrate per day until the start of the mountain grazing season, and 0.7 kg/d thereafter. The concentrate was fed individually with no refusals to the goats 3 times a day during the indoor period and twice a day during the mountain grazing period. Further details on animal feeding management and production performances are described in Eknæs et al. (2017).

Feed Production and Analysis

The experimental concentrate mixtures were produced by the Centre for Feed Technology at the Norwegian University of Life Sciences, and the fat contents and fatty acid composition of the concentrates and the silage are shown in Table 1.

Silage was harvested at the experimental farm at Ås, Norway, and consisted of grass of timothy (*Phleum pratense*), meadow fescue (*Festuca pratensis*), and red clover (*Trifolium pratense*). After cutting, the grass was wilted to achieve a DM content of 250 g/kg of DM. The grass was baled using an Orkel HiQ (Orkel AS, Fannrem, Norway) roundbaler, preserved with Ensil1 (Felleskjøpet Agri SA, Lillestrøm, Norway; 4 L/t), and wrapped in 6 layers of plastic film (Trio Wrap, Trioplast AB, Sweden).

Fatty acid composition in silage and concentrate was analyzed by Vitas (Oslo, Norway). Dried and milled samples were accurately weighed (200 mg) and transferred to soda lime tubes. Internal standard, methyl

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