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Effect of grass silage harvesting time and level of concentrate supplementation on goat milk quality

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ABSTRACT

Milk fat lipolysis giving high concentrations of free fatty acids (FFA) and off-flavor in the goat's milk is a challenge for the dairy industry in Norway. This has been considered to be caused by underfeeding of the goats and thereby energy mobilization in early and mid lactation. Energy intake can be improved by feeding silage of early harvesting time (HT) and supplementation with concentrate. In the present experiment, 18 goats in early lactation were fed grass silages prepared from the primary growth at a very early, early or normal stage of maturity (HT 1, HT 2 and HT 3, respectively), supplemented with a low (LC; 0.6 kg per goat daily) or normal (NC; 1.2 kg per goat daily) level of concentrate. The experiment was conducted as a cyclic change-over design with four periods of 28 days using three blocks of goats according to their initial body condition (poor, medium or high). Milk and blood samples were collected at the end of each period. Milk yield and yields of milk constituents decreased with delayed harvesting time and with LC. Sensory milk taste quality was not affected by dietary treatment, and milk FFA was highest when NC was fed. The proportion of short and medium chain fatty acids in milk fat decreased with postponed harvesting time and LC, while most of the long chain fatty acids (including C18:1c9) increased with postponed harvesting time and LC. The calculated energy balance decreased and the serum concentration of non-esterified fatty acids (NEFA) increased with decreasing energy content in the diet (postponed harvesting time and low level of concentrate). Goats with initial poor body condition had higher milk FFA concentrations than goats in higher initial body condition. High milk FFA concentration was correlated to poor milk taste quality, low serum NEFA concentration, low C18:1c9 proportion and high energy balance. Our findings suggest that increasing energy intake and energy balance during the first 4 months of lactation does not reduce FFA concentration in goats' milk.

1. Introduction

Milk quality is of specific concern in goat milk production. Rancid and tart flavor is a prominent problem in Norwegian goat milk, and is a challenge for the dairy industry (Eknæs and Skeie, 2006). Recent studies have shown that underfeeding appears

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Abbreviations: BMI, body mass index; BHBA, β-hydroxybutyric acid; BW, body weight; DM, dry matter; ECM, energy corrected milk; FA, fatty acids; FFA, free fatty acids; LPL, lipoprotein lipase; MFGM, milk fat globule membrane; MUFA, monounsaturated fatty acids; NDF, neutral detergent fiber; NEFA, non-esterified fatty acids; NEL, net energy lactation; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids.

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to be an extensive problem, especially in early and mid lactation. This results in energy mobilization and subsequently high concentrations of free fatty acids (FFA) and off-flavors in the milk (Eknæs et al., 2006). The concentration of FFA in milk is a measure of lipolysis, *i.e.* the hydrolysis of fat globule triglycerides into FFA (Chilliard et al., 2003), and the total concentration of FFA is found to be correlated to the frequency of off-flavor (Collins et al., 2003) and rancid and tart flavor specifically (Eknæs and Skeie, unpublished). The level of dry matter (DM) intake or ingested energy is the main factor influencing milk yield and composition of dairy goats (Morand-Fehr et al., 2007). The problem with underfeeding was expected to be solved by feeding silage of high quality supplemented with concentrate.

The fatty acid composition of milk may influence its nutritive and health value for consumers (Mensink et al., 2003). In addition, it may influence sensory quality (Chilliard and Ferlay, 2004). The fatty acid composition of the milk will partly be reflected by the physiological state of the goats. During periods of negative energy balance, animals mobilize lipids stored in adipose tissue (Chilliard et al., 2003), and the fatty acid composition will therefore differ from that of milk synthesized when animals are in energy balance. The composition of the diet will also influence fatty acid composition in milk. Harvesting at an early stage of plant development will increase the concentration of polyunsaturated fatty (PUFA) acids in silage (Boufaied et al., 2003). Increased content of not protected PUFA in the diet will mainly increase the concentration of milk C18:0 and C18:1 due to hydrogenation in the rumen, at the expense of the short and medium-chain fatty acids (Chilliard et al., 2003). Increasing the concentrate proportion in the diet will mainly decrease C18:3, and increase C18:2 in milk (Chilliard and Ferlay, 2004). The antioxidant α-tocopherol (vitamin E) is an important nutrient which contributes to stabilize the unsaturated fatty acids in milk (Focant et al., 1998).

The main objective of this work was to investigate whether increased energy balance of goats during early lactation provided by improved grass silage quality could improve milk quality. The main measures of milk quality were considered to be milk FFA concentration and sensory milk taste, but other quality parameters were included as well.

2. Materials and methods

2.1. Experimental design, animals and diets

The study involved 18 goats of the Norwegian Dairy Goat breed in 2nd to 8th lactation (mean 4th) which kidded between 8th and 21st of January 2008. Their average body weight (BW) 2 days after kidding was 63.0 ± 10.5 kg. The experiment started about 2 weeks after kidding. The goats were assigned to three blocks according to their body condition 1 week before the beginning of the experiment, where block 1 = poor body condition; block 2 = medium body condition and block 3 = high body condition. As goats deposit most of their body fat as visceral fat (Colomber-Rocher et al., 1992; Marinova et al., 2001) scoring of body condition of goats may be difficult. Body mass index (BMI) (BW/neck height^2) the same as used for humans was used as a measure of body condition. A goat body mass index has previously been applied by Tanaka et al. (2002). The experiment was conducted according to a cyclic change-over design (Davis and Hall, 1969) with 6 goats in each block and four 28-days experimental periods. Dietary treatment was changed from period to period. Dietary treatment in a 3 × 2 factorial arrangement consisted of three silage qualities and two concentrate levels. Animals were offered silage from harvesting time (HT) 1, 2 or 3 and either low (LC; 0.6 kg per goat daily) or normal (NC; 1.2 kg per goat daily) level of concentrate. The crop was harvested from the primary growth at three stages of maturity: (1) Very early (HT 1), (2) Early (HT 2), (3) Normal (HT 3). More detailed information about the preparation of the silages and the concentrate has been given by Dønnem et al. (2010).

2.2. Animal management

The goats were housed in individual stalls and were milked twice a day at 06:30 and 16:00 h. Grass silage was given *ad libitum* twice daily at 06:00 and 15:00 h such that silage residues averaged 10%. Concentrate was distributed four times per day, at each milking and 2 h after each milking. The goats were weighed 2 days after kidding and thereafter at 12:30 h for three consecutive days in the beginning of week 2 and end of week 4 in each period.

2.3. Feed sampling and analysis

Feed intake was recorded four days per week. Representative samples of silage and silage residues from all harvesting times were collected once and twice a week, respectively, and stored for −20 °C until analysis. Concentrate was sampled from the whole batch in period 1, 2 and 3. Chemical analyses of silage and concentrate were done as reported previously by Dønnem et al. (2010). One representative sample of each silage, and a concentrate sample, were analyzed in duplicate for determination of fatty acid composition. The samples were freeze dried and milled through a 0.5 mm screen (Retsch hammer mill, Haan, Germany). The milled feed samples were directly methylated according to O'Fallon et al. (2007) and analyzed with a Thermo Finnigan Focus GC with a split/splitless Focus GC+ injector, and flame ionization detection (ThermoFinnigan, Milan, Italy). Separation was performed with a Restek RT-2560 (100 m × 0.25 mm internal diameter × 0.2 μm film thickness) column (Restek U.S., 110 Benner Circle, Bellefonte, PA). Temperature program, initial: 70 °C with 2 min hold, increased at 20 °C/min to 160 °C with 40 min hold, and further increased at 2 °C/min to 230 °C with 10 min hold. Carrier gas was He with a pressure of 270 kPa. Fatty acid analysis was performed by auto injection of 2 μl of each sample at a split ratio of 20:75,