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Effect of forage type and season on Norwegian dairy goat milk production and quality☆

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ABSTRACT

Goat milk quality produced by goats grazing on rangeland may have inferior quality with low content of solids and high content of free fatty acids (FFA). The main objective of this experiment was to test the effect of grazing woodland or cultivated pasture on dairy goat milk production and quality in early (EGS) and late (LGS) grazing seasons. Two different hay qualities (high and low quality) were used as control feeds. Eighty Norwegian dairy goats were grouped according to genotype and lactation number and randomly divided into two groups with approximately 8 weeks difference in kidding date. The EGS and LGS feeding experiments had 8 weeks departure in time, when the goats in the two kidding groups were in the same stage of lactation, on average 132 (SD 11.5) days in milk. The goats in each group were randomly allocated to four forage treatment groups: WR, woodland rangeland; PC, cultivated pasture; HH, high quality hay; HL, low quality hay. Goats on WR yielded less milk (1.58 *vs.* 2.15 kg/d, $P < 0.001$) but with higher milk fat (47.7 *vs.* 37.6 g/kg, $P < 0.01$) and total solids content (122 *vs.* 114 g/kg, $P < 0.05$) than goats on PC. Milk FFA content was not affected ($P > 0.1$) by pasture type. The effects of pasture type on milk yield and milk gross composition were similar in EGS and LGS, but milk yield (2.44 *vs.* 1.36 kg/d, $P < 0.001$) and milk content of FFA (0.35 *vs.* 0.23 mEq/L, $P < 0.05$) were higher in EGS than LGS. Grazing resulted in similar milk yield but higher milk fat (42.6 *vs.* 34.8 g/kg, $P < 0.001$), protein (32.3 *vs.* 29.6 g/kg, $P < 0.001$) and total solids (118 *vs.* 107 g/kg, $P < 0.001$) content and tended to yield lower content of FFA (0.23 *vs.* 0.34 mEq/L, $P = 0.068$) than hay diet. The milk from the goats on WR had lower ($P < 0.05$) proportion of medium-chain fatty acids (FA), C10:0–C14:0 and C18:2c9t11, but higher ($P < 0.05$) proportion of C18:0, C18:2c9,12 and C20:0 than on PC. Grazing compared to hay feeding resulted in milk with lower proportion of medium-chained FAs (C12:0–C14:0) and C16:0 and higher proportion of the long-chained FAs C18:0, C18:1t11, C18:2c9,t11, C18:3c9,12,15, C20:0 than hay feeding. The milk proportion of the short- and medium-chained FAs (C6:0–C14:0) and C16:0 was higher ($P < 0.0001$) in LGS than in EGS, whilst the proportion of long chained FAs (C18:0, C18:1c9, C18:1t11, C18:2c9,12, C18:2c9t11 and C18:3c9,12,15) were lower ($P < 0.001$). In conclusion, woodland rangeland yielded less milk than cultivated pasture but milk gross composition and content of FFA were not altered.

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1. Introduction

Dairy goat milk quality in Norway is variable, and it often does not meet the requirements of the industry for cheese making. Lipolysis and high content of free fatty acids (FFA) and tart and rancid off-flavour are among the main problems. Much of the inferior milk quality may be ascribed to genetic factors. The Norwegian dairy goat breed has a very high frequency (>0.70) of a defective allele with a single nucleotide deletion in exon 12 of the gene encoding α_{s1}-casein in milk (Hayes et al., 2006; Dagnachew et al., 2011). Milk from goats with deletion in exon 12 α_{s1}-casein gene has reduced protein and fat content (Dagnachew et al., 2011), low or no α_{s1}-casein and poor rennetability (Devold et al., 2010). Milk from goats that have "weak" variants of α_{s1}-casein is also more prone to lipolysis and high content of FFA (Chilliard et al., 2003; Dagnachew et al., 2011). As long as goat milk was used for the traditional whey product 'brown cheese', inferior clotting properties and high FFA content were not major problems. However, the interest for rennet- and acid coagulated cheeses by Norwegian industries and consumers is increasing, and production of these types of cheeses requires milk of a different quality.

Traditionally, goat milk production in Norway is seasonal with kidding in winter and early spring and with peak milk production during the summer grazing season. During the grazing season, goats to a large extent graze natural unimproved grasslands or graze free range in woodlands and mountains. The forage quality of rangeland herbage is variable and declines during the grazing season due to the phenological development of the grazed plants (Lunnan and Todnem, 2011). Reduced allowance and decreased quality of herbage, together with underfeeding and consequently negative energy balance, are also assumed to contribute substantially to the problems of high FFA content and off-flavour (Eknæs and Skeie, 2006). Supporting this, the milk content of FFA (recorded by the Norwegian Goat Milk Recording System, Blichfeldt personal communications) is highest during the summer months. Increased FFA in milk during the grazing season has also been observed in experimental trials (Eknæs et al., 2006; Eknæs and Skeie, 2006). Off-flavour occurs in periods when dry matter (DM) content in milk is low, and a number of studies have revealed a negative correlation between off-flavour and milk DM content (Rønningen, 1965; Bakke et al., 1977; Skjevdal, 1979). It is therefore recommended to supplement goats on pasture with concentrate, preserved forages, vegetable oils and fat-enriched concentrates. Particularly oil and fat supplementation has shown to be efficient in decreasing the frequency of off-taste, lipolysis and the concentration of milk FFA (Skjevdal, 1979; Astrup et al., 1985; Chilliard et al., 2003; Eknæs et al., 2009). Chilliard et al. (2003) found that the lipoprotein lipase (LPL) activity decreased with increasing milk C16:0 proportion ($r = -0.70$). Diets that increase the milk fat proportion of C16:0 and reduce the proportion of C6:0–C10:0 reduce the frequency of rancid and tart flavours (Eknæs et al., 2009) and the level of FFA (Astrup et al., 1985). However, it has also been found that high C16:0 and low C18:1c9 proportion in milk and a high energy balance may be related to high FFA content and off-flavours (Dønnem et al., 2011b). It is well known that grazing has strong impact on milk fatty acid (FA) composition by decreasing saturated FA and increasing FA considered beneficial, like C18:1c9, C18:3c9,12,15 and C18:2c9t11, in goats when compared to diets based on preserved forages and concentrates (Tsiplakou et al., 2006; Chilliard et al., 2007; Renna et al., 2012b). However, less is known on how rangeland, as used in Norway, influence milk FA profile and milk content of FFA. Eknæs and Skeie (2006) found that goat milk sensory quality improved (less rancid taste) and milk content of FFA decreased when hay, fed *ad libitum*, replaced rangeland for a short period (2 d). They also found that when the goats later grazed a cultivated pasture after rangeland, the milk quality improved with reduced FFA content. It is known that the lipoprotein lipase activity and lipolysis are more pronounced during mid-lactation (3–6 months) than at early (<2 months) and late lactation (Chilliard et al., 2003). Mid-lactation coincides with the time goats traditionally are on pastures in Norway. Therefore, the effect of forage type (rangeland) or grazing season on milk quality is confounded with the effect of lactation stage.

The aim of this study was to unravel some of these discrepancies, by testing the effects of forage type and quality, *i.e.* rangeland *vs.* cultivated pasture or grazing *vs.* hay, on goat milk production and milk quality. Additionally, we tested whether there was a seasonal effect (early and late season) of forage quality on the same production traits with goats in the same stage of lactation. We used two hay types, with known quality (high and low), as controls as pasture quality changes during the grazing season.

2. Materials and methods

2.1. Animals, experimental design and management

Eighty Norwegian dairy goats at Senja videregående skole, Norway (N 69°21.397′, E 17°56.319′) were blocked according to genotype (with and without double deletion in exon 12 of the gene encoding α_{s1}-casein (CSN1S1)) and lactation number (5 groups; 1–4 according to lactation number, group 5 = more than 4 lactations) before mating and randomly divided into two groups: early grazing season (EGS) and late grazing season (LGS) with approximately 8 weeks difference in mating time. The genotyping was performed according to Hayes et al. (2006). Average kidding date was February 2 (SD 9 d) and April 1 (SD 12 d), 2010. At the start of the grazing season, June 28th, the goats within each of the two groups, EGS and LGS, blocked for genotype (with and without deletion in exon 12 of the CSN1S1 casein gene) and lactation number (1–5), were randomly allocated to four forage treatment groups: PC = cultivated pasture, WR = woodland rangeland, HH = High quality hay, HL = low quality hay. Thus, the design applied was a 2 × 4 factorial with season (EGS and LGS) as one factor and forage type (PC, WR, HH and HL) as the other factor, with 10 goats in each treatment. The 10 goats in each forage treatment were randomly divided into two sub-groups (pens) with 5 goats, accounting for genotype and lactation number. In the two hay treatments the five goats in each group within treatment were kept indoors in separate pens (*i.e.* two replicates per treatment), while the sub-groups of goats within each pasture treatment grazed together.

The EGS goats went directly from the indoor silage based ration to their respective forage treatment groups on the 28th of June 2010. The 40 goats in the LGS group grazed together with the WR group of the EGS goats until the 16th of August 2010 before they were allocated to their respective forage treatment groups. The forage treatment periods lasted for 3 weeks.

All goats were machine milked twice a day at 06:30 and 16:00 h. Concentrate was distributed in equal amounts two times per day at each milking. The goats were weighed for three consecutive days in the week before they entered the feeding treatments (June 21–23 and August 9–11