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Browsing ratio, species intake, and milk fatty acid composition of goats foraging on alpine open grassland and grazable forestland

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ABSTRACT

Aims of this study were to investigate diet selection of dairy goats foraging on two alpine vegetation types and to assess the related effects on milk fatty acid (FA) composition. Two enclosures laid out on an open grassland (OG) and a grazable forestland (GF) were exploited by 14 Camosciata goats. A commercial concentrate was supplemented during milking. Forty-five plots were randomly selected inside each enclosure and used to assess the species relative abundance (SRA) and phenological stage of plants, as well as goats' preferences (browsing ratio, BR) and intake (SI) for each species. Representative samples of the diet in each enclosure were built up considering the most ingested plant species and plant parts. Feed samples were analyzed for proximate, FA, and phenolic compositions. Milk samples were collected in each enclosure and analyzed for their FA profile. The enclosures showed a similar level of vegetation diversity. If compared to the GF enclosure, the OG one had higher proportion of *Poaceae* (81.2 *vs* 44.8% of SRA) and lower proportion of non-legume dicotyledons (14.6 *vs* 50.7% of SRA). The goats mostly selected eutrophic species in OG and forbs and woody species leaves in GF. The ingested vegetation was almost completely represented by grasses in OG (89.6% of SI), and by similar proportions of grasses, herbs and woody species in GF (54.9 and 45.1% of SI, respectively). The ingested forages from the OG and GF showed a comparable proximate composition; if compared to OG, the GF vegetation type was however richer in α-linolenic acid (ALA) and phenolic compounds (PC). Fatty acid analysis showed that GF milk had higher concentrations of ALA, total omega-3 FA, total *trans*-octadecadienoic acids, total conjugated linoleic acids, total *trans*-octadecenoic acids, and a reduced omega-6/omega-3 FA ratio than OG milk. Branched-chain FA were not significantly affected by treatment, suggesting that the activity of ruminal bacteria in the goats was not inhibited by the higher concentration of PC in GF plants. The main reason for the observed improvement of the FA profile in GF milk seems to be attributable to the FA profile rather than the concentration and composition of PC of the ingested plants. The abundance of herbs and woody species in the ingested vegetation was positively associated with the presence of nutritionally desirable FA in goat milk fat.

1. Introduction

In North Italy, in the mountain belt, small semi-natural grasslands are interspersed within forests (Sitzia and Trentanovi, 2011; Garbarino et al., 2014). These areas had been traditionally grazed for millennia. However, during the last decades they have been broadly abandoned due to industrialization and urbanization processes, which brought to an intensification of agriculture and animal husbandry in the lowlands, determining important effects on the rural landscape (Probo et al., 2013). The resultant lack of control of shrub and tree species encroachment by animal trampling, grazing, seed transport, and nutrient redistribution has led to changes in land-cover (Celaya et al., 2010; Riedel et al., 2013; Tocco et al., 2013). Forest and pasture surface has notably increased and decreased, respectively (Falcucci et al., 2007), affecting both plant and animal diversity (Laiolo et al., 2004; Falcucci et al., 2007). At the mountain belt, where cattle rearing is not profitable anymore, small ruminant breeding plays a key role (Lombardi, 2005). In this contest, goat farms are usually very small (mainly less than 50 animals) and represent about 70% of all goat farms (ISTAT, 2010).

A lot of studies have been conducted to investigate the feeding preferences of goats in different management systems. Goat

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feeding preferences are very different from those of sheep and cattle, if compared under the same farming conditions. Such differences mainly regard the number of browsed species and their intake (both higher for goats than sheep and cattle) (Papachristou et al., 2005; Sanon et al., 2007; Osoro et al., 2013). Silanikove et al. (2010) reported that goats can utilize, more than other ruminants, feedstuffs rich in tannins or other plant secondary metabolites (PSM) thanks to their digestive efficiency. The majority of studies dealing with goat feeding preferences were performed indoors or compared indoor and grazing conditions (e.g., hay *vs* grazing, concentrate and hay *vs* grazing) (Morand-Fehr et al., 2007; Silanikove et al., 2010). Only in the last years some research has been conducted on goat feeding behaviour in shrublands of Mediterranean regions (Ataşoğlu et al., 2009; Delgado-Pertíñez et al., 2013; Mancilla-Leytón et al., 2013) and in rangelands of Africa (Sanon et al., 2007) or America (Foroughbakhch et al., 2013).

It is well known that fresh grass feeding positively affects the lipid fraction of goat milk by enhancing the presence of health-promoting fatty acids (FA) (e.g., rumenic and vaccenic acids, and omega-3 FA) and contemporarily lowering the omega-6/omega-3 FA ratio and the levels of specific FA considered detrimental for human health (e.g., hypercholesterolaemic medium-chain saturated FA) (Renna et al., 2012a,b; Mancilla-Leytón et al., 2013). Besides that, in the last decade it has also been repeatedly demonstrated that the FA composition of milk and cheese from grazing ruminants may be significantly influenced by the botanical composition of the ingested plants (among others, Collomb et al., 2002; Di Trana et al., 2005; Renna et al., 2014a). Such influence has partly to be ascribed to the variability in unsaturated FA levels of the grazed/browsed forages (Di Trana et al., 2005; Mancilla-Leytón et al., 2013). Additionally, plant-derived bioactive molecules such as phenolic compounds (PC), other PSM (e.g., essential oils and saponins), and enzymes (e.g., polyphenol oxidase), being potentially able to significantly affect the lipolysis of dietary unsaturated fatty acids (UFA) and the pattern of their biohydrogenation (BH) occurring within the rumen, have the potential to alter the FA composition of ruminant-derived food products (Doreau et al., 2011; Buccioni et al., 2012).

In alpine regions, diet selection of goats and the effects that different vegetation composition may exert on animal performance under grazing systems are still poorly investigated. This study aims therefore to assess (i) the feeding preferences of Camosciata goats grazing two alpine enclosures dominated, respectively, by an open grassland (OG) and a grazable forestland (GF), and (ii) the related effects on milk composition, with particular reference to the FA profile of milk fat.

2. Materials and methods

2.1. Study area and experimental design

The study was carried out during summer 2012 at Oasi Zegna, southwestern Alps, Italy (latitude 45°40′N, longitude 8°09′E). This area is characterized by an oceanic climate, with annual average air temperature of 7.2 °C and annual average precipitation of 1951 mm (Biancotti et al., 1998).

A dairy farm breeding a flock of 14 lactating Camosciata goats was selected in the area as during the summer season it managed a grazing land composed by both grasslands and forests. Two different enclosures, one dominated by an open grassland and the other by a grazable forestland, were arranged at an altitude ranging between 1250 and 1350 m a.s.l., at similar topographic conditions (mean slope: 26°; mean exposition: 315°N).

Each enclosure was exploited at the same stocking rate (on average 0.26 goat ha^{-1} $year^{-1}$). A low-density grazing management was applied with the objective of maintaining high forage-to-animal ratio and encouraging selective grazing by the goats (Allen et al., 2011). The OG (0.7 ha) and GF (0.9 ha) enclosures were exploited by the goats for a grazing period of five (26–30 June) and six (23–28 July) days, respectively. The same group of goats foraged on both vegetation types to exclude confounding effects related to differences in selection behaviour among individuals (Provenza et al., 2003). To minimize the effect of the physiological stage of the animals on their intake behaviour, the time period between OG and GF exploitation was reduced at the minimum (22 days) required to adapt to such different vegetation types, especially for stabilization of FA in goat milk fat (Renna et al., 2012b). For the latter purpose, before entering the enclosures the goats grazed for three weeks two grazing lands dominated by grasses and shrubs similar to OG and GF, respectively.

The goats were manually milked indoors twice a day (at 7.00 and 18.00 h). They were allowed to graze during the milking interval whereas they were maintained indoors during the night. At each milking, the goats were supplemented with 200 g $head^{-1}$ of a commercial concentrate containing flaked corn, flaked barley, flaked bean, and flaked soybean. The enclosures and the stable were equipped to provide fresh water *ad libitum*.

2.2. Vegetation surveys, browsing ratio, and species intake assessment

In order to assess the botanical composition of vegetation and the browsing ratio (BR) percentage of each botanical species, a dataset of 4500 points was randomly-generated by a Python plugin of Quantum Geographic Information System (QGIS-Quantum Geographic Information System (version 2.1.0), 2013) within both enclosures, and forty-five plots were randomly selected within each dataset. Their positions were corrected (±1 m) considering that they had to represent a homogenous area and that the minimum distance among them allowed to avoid overlapping among neighbouring plots.

The botanical composition was surveyed using the vertical point-quadrat method along 5 m linear transects. At each transect, at every 10 cm interval, plant species touching a steel needle were identified and recorded (i.e., 50 points per transect) and species frequency of occurrence (SF = number of occurrences), which is an estimate of species canopy cover (Gallet and Roze, 2001), was recorded for each species. Species relative abundance (SRA) percentage was calculated for each species and plot in order to represent the proportion of different species, according to Daget and Poissonet (1971) and Probo et al. (2013). An average SRA was also calculated for each plant species in both enclosures.

A lot of methods have been used until now to evaluate ruminant diet selection under grazing systems [e.g., faecal analysis, esophageal fistulation (Papachristou and Nastis, 1993; Henley et al., 2006; Mellado et al., 2012), direct observation of grazing animals (Dumont and Boissy, 2000; Foroughbakhch et al., 2013; Mancilla-Leytón et al., 2013) and direct estimation of grazing damage of each species (Hejcman et al., 2008; Nagaike, 2012)]. However, in the current study the BR percentage of the whole flock on the half-long term was evaluated fitting the method proposed by Nagaike (2012) to the vertical point-quadrat method.

Ten consecutive 1 m^2-squares were laid out on each linear transect (five for each side) used for botanical surveys (450 squares per enclosure), and all species below 1.80 m were recorded. A value of 1 (grazed) or 0 (ungrazed) was appointed to each species present within every 1 m^2-square depending on its status after exploitations. The species were considered grazed when clear signs of browsing were observed on one or more plant parts (i.e., flowers, leaves, stems, buds, sprouts, or fruits). The phenological stage of all species was also recorded. Moreover, species were classified into the following functional groups: grasses (GR), legumes (LE), non-grass monocotyledons (NG), and non-legume dicotyledons (NL). The BR percentages were calculated for each species and plot as the ratio between the number of browsed quadrats (number of 1 m^2-squares with value 1 for the species i) and the number of quadrats where the presence of the same species was recorded. An average percentage BR was also calculated for each species in both enclosures.

Considering SRA and BR percentages as the most accurate indices to represent the species phytomass and the species preference, respectively, the percentage species intake (SI) of each species in each enclosure was calculated using the following Eq. (1):

$$SI_i = \frac{\frac{1}{n}\sum_{j=1}^{n}\left(BR_{ij} \times SRA_{ij}\right)}{\sum_{i=1}^{m}\left[\frac{1}{n}\sum_{j=1}^{n}\left(BR_{ij} \times SRA_{ij}\right)\right]} \quad (1)$$

where SI_i is the average percentage intake of the species i in the n plots (n = 45 in each enclosure), SRA_{ij} is the species relative abundance of the species i in the plot j, and BR_{ij} is the browsing ratio of the species i in the plot j. Then the numerator represents the average intake of the species i and the denominator represents the sum of the average intake of all the species, within each enclosure.

Average SRA, average BR, and cumulated SI were calculated for each functional group within both enclosures. Cumulated SI were calculated to better highlight the differences of diet composition between the two enclosures.

At each vegetation plot, the vegetation diversity was estimated and expressed as the Shannon-Weaver diversity index (H′; Magurran, 1988) and the evenness index (J′; Magurran, 2004), which were calculated according to the following Eqs. (2)–(4):

$$H' = -\sum_{i=1}^{m} SRA_i \times \log_2(SRA_i) \quad (2)$$

$$H_{MAX} = \log_2(m) \quad (3)$$

$$J' = \frac{H'}{H_{MAX}} \quad (4)$$