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The importance of semi-arid natural mountain pastures for feed intake and recycling of nutrients by traditionally managed goats on the Arabian Peninsula

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ABSTRACT

Goat husbandry in Oman's Hajar Mountains supplies income and manure to farmers. An earlier analysis concluded that it uses purchased feeds inefficiently, but did not value the contribution of mountain pastures to goat nutrition and cropland fertilization. Therefore intake of pasture vegetation, cultivated forages and purchased feeds was determined in goats from three villages in spring and autumn 2005. Faecal excretion was quantified using TiO_2 and diet digestibility was calculated from faecal nitrogen (N).

Organic matter (OM) intake varied from 71 to 107 g $kg^{-0.75}$ d^{-1}. Pasture vegetation supplied 45–71% of OM intake, and at least 28%, 33% and 42% of phosphorus (P), metabolizable energy (ME) and N intake. While ME intake just covered maintenance and locomotion requirements, N and P intake exceeded the animals' requirements. Therefore faecal concentrations (g kg^{-1} OM) of 26–36 g N and 4–8 g P were high, making goat dung a key element of sustainability for the local cropping systems.

Since mountain pastures supply nutrients to goats and cropland, their long-term productivity is crucial. Feeding cultivated forages seemingly reduces intake on pasture, but a comprehensive evaluation of nutritional and economic implications of this strategy and possible alternatives is needed.

1. Introduction

On Al Jabal al Akhdar, the highest elevation in Oman's Hajar Mountains, the interaction of a strongly variable rainfall of 150–300 mm a^{-1} (Wilkinson, 1977) with a particular geology, topography and land use history resulted in a typical open shrubland vegetation (Brinkmann et al., 2009; Mandaville, 1977) giving the rugged range its name "The Green Mountain". Through skillful soil fertility management and irrigation of century-old terraces, farmers in scattered oases settlements maintain a productive system of cereal and vegetable cropping combined with fruit production (Gebauer et al., 2007). Goat husbandry is a major component of this small-scale mixed farming system (Zaibet et al., 2004), supplying food and income to the rural population (Dickhoefer, 2009) and dung to the crops in the irrigated gardens (Buerkert et al., 2005). The typically 1–55 goats per household (Dickhoefer, 2009) are kept in a barn overnight, where they are fed with dates, dried sardines and cultivated green forages. During the day goats graze the mountain pastures, which, due to their year-round use, show clear signs of overgrazing (Brinkmann et al., 2009; Ghazanfar, 2003; Schlecht et al., 2009). From their economic analysis of this system Zaibet et al. (2004) concluded that goat husbandry is substantially fueled by off-farm income and purchased feedstuffs are used inefficiently. Yet, these authors' conclusion that a shift from the traditional grazing system plus homestead feeding to a zero-grazing system would increase resource use efficiency fails to evaluate the contribution of the vegetation of the mountain pastures to goat nutrition and nutrient recycling to cropland. Such evaluation therefore was the aim of the present study.

2. Materials and methods

2.1. Site and farming system

The study was carried out in the oases settlements of Masayrat ar Ruwajah (Masayrat; 57 °40′13″E, 23 °02′37″N, 1030 m a.s.l.), Qasha' (57 °39′50″E, 23 °04′00″N, 1640 m) and Ash Sharayjah

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(Sharayjah 57 °39′30″E, 23 °04′10″N, 1900 m). The villages are situated within a distance of 10 km from Sayh Qatanah (57 °40′35″E, 23 °04′44″N, 1975 m), the major settlement and administrative center of Al Jabal al Akhdar. The region receives a precipitation of 100–340 mm a^{-1} that may occur throughout the year, but rainfall probability is highest in February–March and July–August (Luedeling and Buerkert, 2008). Just before the start of the present study (December 2004–March 2005) 150 mm of rain had fallen. Thereafter, no more rain was registered until November 2005. Annual average air temperature is 18.1 °C, with a monthly minimum of 3.6 °C in January and a maximum of 36.3 °C in June in Sharayjah.

Each of the three villages consists of a central settlement and surrounding terrace systems for crop cultivation. Water is supplied by springs fed by rainwater that percolates through highly fracturated calcareous rocks (Luedeling et al., 2005). An elaborated canal system conveys irrigation water to small plots cultivated with garlic (*Allium sativum* L.), onion (*Allium cepa* L.) and coriander (*Coriandrum sativum* L.). Perennials cultivated above 1500 m are roses (*Rosa damascena* Miller) for rosewater distillation, pomegranates (*Punica granatum* L.), peaches (*Prunus persica* L.), apricots (*Prunus armeniaca* L.), and walnuts (*Juglans regia* L.); at lower altitudes the dominant date palm (*Phoenix dactylifera* L.) is interplanted with some lime (*Citrus aurantiifolia* [Christm. et Panz.] Swingle) and banana (*Musa* spp.) plants. A major part of each village terrace area is sole- or intercropped with fodder crops such as alfalfa (*Medicago sativa* L.), barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.), sorghum (*Sorghum bicolor* L. Moench), and maize (*Zea mays* L.). In addition sown or spontaneously growing understorey grasses and weeds in fruit orchards, such as *Anagallis arvensis* L., *A. sativa* L., *Convolvulus arvensis* L., *Digitaria nodosa* Parl., *Eragrostis papposa* (Roem. & Schult.) Steud., *Euphorbia peplus* L., *Fumaria abyssinica* Hamm., *Lolium temulentum* L., *Stellaria media* (L.) Vill., and *Torilis stocksiana* (Boiss.) Drude (Patzelt, 2009), are regularly harvested and fed to livestock.

2.2. Characteristics of the goat husbandry system

During daytime, the Jebel Akhdar breed goats (Maghoub et al., 2005) of different families are grouped into several herds to graze the mountain pastures surrounding the settlements. Among these, one herd per village was selected for the present study. In all villages, goats started grazing between 6:30 and 7:30 a.m. The herd in Masayrat was conducted to pasture and left there to graze on its own (herd-release mode), while the herd in Sharayjah was accompanied by a herder who determined the grazing itinerary. In Qasha' two families alternately took care of the goats: one family herded them to pastures northeast of the village, while the other family turned to an area southwest of the village and released the goats there. Herded goats returned to the homestead around 5.30 p.m., whereas herd-release animals already returned around 3 p.m. At the homesteads, goats were subsequently fed with cultivated green forages and weeds, dried dates, dried sardines and cereal-based supplements. In some households, groups of pregnant and lactating goats or fattening males were fed separately, but mostly all animals were fed together. The type and amount of feed given was determined by each farmer individually and could vary from day to day, according to the availability of particular feedstuffs.

2.3. Determination of feed intake at the homestead

In spring (March/April) and in autumn (October/November) 2005, the feed intake of 5–8 male goats per village (Table 1) was determined during a 7 day experimental period. Since we studied the habitual goat feeding practices of farmers and did not introduce new feedstuffs, the adaptation of goats to experimental conditions was limited to 5 days. Selected goats were loosely tied to poles in the farmyard and fed from individual troughs. Feeding in Qasha' and Sharayjah took place at 6 a.m. and 6 p.m., while in Masayrat goats were only fed at 6 p.m. Shoots of barley, maize, and oats from the gardens were offered in the milk or dough stage of the grain. On some days, collected garden weeds or leaves from wild olive (*Olea europaea* ssp. *cuspitata* [Wall. ex G. Don] Ciferri) and Ziziphus trees (*Ziziphus spina-christi* L. Desf.) were also fed. In addition purchased supplement feeds such as dried fish, dry dates, wheat meal, bread, barley grain, and meal leftovers, such as boiled rice, were used. The type and amount of feed offered depended on the farmers' decision and could slightly vary from one day to the next. Before being offered, all feeds were weighed individually on a portable scale (range 0–5 kg, accuracy 2 g). Per type of cultivated green forage, one sample was kept daily; the different concentrate feeds were sampled every second day. At the end of each meal, leftovers were weighed and a sample of each type of leftover feed was kept. Leftovers of supplement mixtures were separated into individual components (such as dates and fish) and these were weighed separately. Samples of forages and supplement feeds were air-dried in cotton bags; for rice, the dry grain was sampled and was analysed after boiling in the laboratory.

2.4. Observation of fodder selection on pasture

In parallel to the two intake studies, the forage selection behavior of goats on pasture was observed during four consecutive days per village. Every 3 min an observer recorded the total number of goats in sight and the number of animals feeding on the shrub and tree strata or on the herbaceous vegetation, respectively. If identifiable, the grazed plant species were noted individually, whereby the vascular plant nomenclature followed Ghazanfar (1992, 2003) and Jongbloed et al. (2003). The observed number of goats per species or strata, respectively, was multiplied with the length of the observation interval. The daily sum of all animal-intervals per species or strata was divided by the total number of goats observed times the total daily observation time, to obtain the proportion of feeding time

Table 1
Number of goat keeping households, participating households and live weight of experimental (exp.) goats in three study villages on Al Jabal al Akhdar, Northern Oman, in spring (S) and autumn (A) 2005.

Parameter	Village	Masayrat	Qasha'	Sharayjah
Altitude (m a.s.l.)		1060	1640	1930
Households, total (n)		13	10	20
Goat keeping households (n)		11	7	15
Goats per village (n)		245	112	152
Participating households (n)	S/A	4/3	2/2	3/3
Total experimental goats (n)	S/A	8/8	7/8	8/5
Live weight of exp. goats (kg ± S.D.)	S/A	34.9 ± 11.01/25.9 ± 2.38	31.7 ± 6.57/33.8 ± 14.58	27.2 ± 5.55/36.4 ± 12.23
Goat management at pasture		herd-release	herded and herd-release	herded