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Selective behavior of Creole goats in response to the functional heterogeneity of native forage species in the central Monte desert, Argentina☆

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ABSTRACT

The changes in forage availability and the physicochemical variability of plants influence the diet selection by herbivores. In this study, the foraging behavior of Creole goats was studied in terms of botanical composition of the diet, food availability and physicochemical properties of vegetation. The study was performed in a desert rangeland in the northeast (NE) Mendoza region in Argentina. Experiments with grazing goats were made in dry (winter) and wet (summer) seasons and cafeteria experiments (feeding trial) were performed during the summer. Food availability was estimated from forage species cover. Botanical composition of the goat's diet was determined by microhistological analysis of fecal samples. Morphological parts of forage species consumed by goats were sampled and analyzed to determine chemical traits (plant nutrients and secondary metabolites) in both seasons. Also, during summer, the two morphological traits of browse species stem specific density (SSD) and specific leaf area (SLA) were evaluated. In the experiments with grazing goats, diet selection was evaluated based on Ivlev's electivity index ($\hat{I}$) and, in cafeteria experiments, preference was estimated based on the number of bites. Diet selection varied between the two seasons. Grazing goats showed differences in the patterns of diet selection related to changes in forage availability. The botanical composition of the diet had a greater ($p < 0.001$) participation of woody species in relation to grass species in both seasons, but the herbaceous stratum was more utilized by goats during the summer according to their higher availability. Correlations between diet and availability were positive in both seasons, but not significant in summer. The models including crude protein (CP), neutral detergent fiber (NDF) and total phenols (TP) had substantial support for predicting variation in diet selection in summer and winter. In both seasons the preference increased as the concentrations of CP, NDF and TP increased, but the effect of CP was significant only in winter. Thus, goats selected supplementary food mixtures (mixed diet) and tannins were not considered dissuasive but, rather, were maintained below a certain threshold. In summer, SSD was negatively and significantly related to diet selection by grazing goats. This morphological trait allowed explaining a greater percentage of the variation in $\hat{I}$ (36%) with regard to the variation explained by the chemical variables (16%). In cafeteria experiments,

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in summer, the optimization of nutrient intake rate through consumption of species with low SSD values represented a best explanation for the preferences observed, whereas the hypotheses of minimization of secondary metabolites and maximization of nutrients were not able to fully explain the preferences observed in cafeteria experiments. To conclude, dietary decisions by goats in desert rangelands could be interpreted in terms of intake rate optimization and complementation of nutrients and secondary compounds, rather than by explanations involving the isolated effects of nutrient intake maximization or tannin intake minimization.

1. Introduction

Domestic goats (*Capra hircus*) possess diverse adaptations to harsh environments, where they face a complex food source dominated by woody plant species with marked variability in their morphological and chemical characteristics and heterogeneity in both spatial and temporal dimensions (Silanikove, 2000; Provenza, 2008; Waghorn, 2008). These adaptations involve integrated physiological and behavioral mechanisms that allow grazing goats to perceive the complexity of the food resource through chemosensory stimuli, in some cases detoxify and/or tolerate certain types of substances and finally, generate preference or aversion to certain foods (Hofmann, 1989; Villalba et al., 2002; Provenza, 2003; Glendinning, 2007).

Traditionally, chemical compounds that affect foraging decisions of mammalian herbivores have been classified into three major groups: nutrients, fiber and secondary metabolites (Cooper et al., 1988). In relation to secondary compounds (PSMs), numerous studies highlight the wide distribution and variability in the content and biological activity of polyphenolic compounds in woody plants, with special emphasis on tannins (Waterman and Mole, 1994; Hagerman, 2002; Makkar, 2010). For herbivores, this represents positive or negative effects depending on various factors such as the chemical nature and concentration of tannins in the plant, interaction with other metabolites, plant phenological stage or animal species (Baraza et al., 2009; Muir, 2011). The dissuasive power of these compounds would be mediated by their deleterious effects on palatability, intake and digestibility of forage species (Cheeke, 1988; Goel et al., 2005). However, tannins are not completely avoided by goats, but rather are tolerated under certain threshold (Jansen et al., 2007). This may be related to benefits provided by intake of small amounts of tannins, including supplying bypass protein (Makkar, 2010), reducing methane production (Muir, 2011) and anthelmintic and antitumor activities (De Bruyne et al., 1999; Min et al., 2003).

Some plant morphological traits such as specific leaf area (SLA), specific stem density (SSD), tensile strength and spines affect and/or restrict the food ingestion–digestion process (Cooper and Owen-Smith, 1986; Cornelissen et al., 2003; Sebata and Ndlovu, 2010). The dietary decisions performed by goats, based on the physical characteristics of forage, would have important implications for nutrient intake rate and the performance of these animals (Illius et al., 1999; Shipley et al., 1999).

The objective of this study was to investigate the foraging behavior of grazing goats in a desert ecosystem of Argentina in terms of botanical composition of the diet, availability and physicochemical properties of vegetation and forage selection in relation to seasonal variations. The hypotheses were tested in this study and their predictions are listed below:

(1) The dominant functional groups of plants in the diet and some morphophysiological adaptations of grazing herbivores are some of the criteria that allowed defining goats as opportunistic mixed feeders (Hofmann, 1989; Shipley, 1999; Dziba et al., 2003; Rogosic et al., 2008). Based on this hypothesis, we expect that grazing goats will show differences in the diet selection patterns related to changes in forage availability.
(2) Considering the learning model based on postingestive consequences diet selection behavior can be conceptualized as a functional behavioral response of grazing herbivores facing the dilemma of what and how much to eat (Provenza, 1995, 2003; Howery et al., 1998). The structural and chemical traits of forage plants address these behavioral responses because they can modify the internal state of the animal (Villalba and Provenza, 2009). According to this hypothesis, we expect that the dietary decisions of goats rather than maximize nutrients and minimize tannins, will enable them to eat complementary food mixtures (mix diets).
(3) The structural characteristics of plants primarily affect the rate at which herbivores can harvest food (Wright and Vincent, 1996). Considering that herbivores spend almost half of their daily time harvesting food (Owen-Smith, 1988), plants characteristics that increase the time to harvest enough food reduce the time available for other life requirements (Laca et al., 2001). Therefore, the effect of structural anti-quality traits on food selection may exceed the effect of chemical anti-quality properties (Spalinger et al., 1986; Shipley et al., 1999). We expect that the morphological traits of forage plants will provide a better explanation than their chemical traits for the selective behavior of goats.

2. Materials and methods

2.1. Study site

This study was conducted in the household "La Majada" (32°19′39′S, 67°54′36′W) situated in the northeast (NE) of Lavalle, Mendoza province (Argentina). This region is located on the plains at the Eastern foothills of