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# Crude Protein Content does not Determine the Preference Value of Plant Species for the Raini Goat (*Capra aegagrus hircus* L.) in Dry Rangelands

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**Abstract**

In order to estimate the relationship between forage quality and preference value of plant species for Raini goats (*Capra aegagrus hircus*), a field study was carried out on Raini goats' grazing behavior in some desert habitats. Crude protein (as the most important factor affecting forage quality) of all plant species was measured at two phenological stages (spring and summer, 2010) in the dry rangeland of Talkhabad, Iran. In addition, the preference value of plant species by free-ranging goats was estimated by visual estimation during the two seasons. One-way ANOVA and paired t-test revealed that forage quality and preference value by goats differed among plant species and between seasons. There was no significant relationship between forage quality and preference value (linear regression and Pearson correlation). Only a few plant species had both high quality and high preference (e.g., *Taverniera cuneifolia*). An interesting outcome was the importance of minor low-quality feeds such as *Ziziphus spina-christ* fruit in the goats' diet. Raini goats were also highly selective feeders, changing their diet from grazing to browsing and *vice versa*, which highlights the importance of diversified botanical structures and the preservation of shrubs and trees in their desert habitats.

***Keywords:*** Dry rangeland; Forage quality; Raini goat; Plant phenological stage; Preference value

Nomenclature: Rechinger (1964)
Abbreviations: CP (Crude Protein), PI (Preference Index)

## 1. Introduction

The estimation of plant species' characteristics which affect their forage quality is necessary to improve the management of grazing regimes in rangelands. The relationship between herbivores and (a)biotic environmental factors is mutual. It has been repeatedly reported that herbivores directly influence the productivity, structure, and diversity of plant communities (Bakker, 1998; Adler *et al*., 2001; Vallentine, 2001; Loucougaray *et al*., 2004; Lamoot *et al*., 2005), forage quality of plant species (Erfanzadeh, 2009; Milotic *et al*., 2010) and soil physico-chemical characteristics (Sadeghi *et al*., 2005) through defoliation, trampling, production of excrement, and rolling. In previous studies, we demonstrated that ruminants can affect plant quality and diversity as well as the rate of some edaphic factors in different habitats (e.g., deserts and salt marshes; see Sadeghi *et al*., 2005 and Milotic *et al*., 2010, respectively). Nevertheless, the effects of vegetation characteristics on the behavior, diet selection, and performance of ruminants have not been well documented

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(Silveira Pontes *et al*., 2010), especially in desert habitats.

Understanding the diet selection and behavior of grazing animals in natural habitats, especially in fragile ecosystems, is important for an environmentally friendly management strategy and profitable animal production (Sanon *et al*., 2007). Moreover, optimal intake of nutrients by ruminants can be more easily achieved if we know their dietary habits and preferences (Ngwa *et al*., 2000). However, understanding food preferences is relatively difficult, since choices made by grazing or browsing herbivores of what and how much plant species to take are dependent on several factors, viz. local conditions (Field, 1979; Odo *et al*., 2001), spatial abundance of the preferred plant species or food (Dumont *et al*., 2002; Papachristou *et al*., 2007), phenological stage of the plant (Sanon *et al*., 2007), forage quality (Ball *et al*., 2000; Marquardt *et al*., 2010), and supplemental protein and energy (Dziba *et al*., 2007). Previous authors have repeatedly shown that there is a significant correlation between diet selection of large herbivores and crude proteins, i.e. protein alone often drives food choice (for steers: Hardison *et al*., 1954; for kangaroos: Tiver and Andrew, 1997; for white-tailed deer: Berteaux *et al*., 1998; for ewes: Silveira Pontes *et al*., 2010).

Among ruminants, goats are well-known for feeding upon a wide spectrum of plants and for possessing some degree of nutritional wisdom enabling them to select foods that meet their nutritional needs and avoid those causing toxicosis (Provenza *et al*., 1994a, b). Haenlein *et al*. (1992) reported that goats exhibit a definite preference for a varied diet, often consuming no less than twenty-five different plant species. Goats utilise a wide variety of plant types (Peter *et al*., 1979; Odo *et al*., 2001) and select from them the materials with the highest nutrient concentrations (Narjisse, 1991). However, in some cases, plants that constitute only a small proportion of a habitat make up a large part of the grazing animal`s diet (Ngwa *et al*., 2000). In addition, due to a wide temporal and spatial variation in forage preference and nutrient composition of diets selected by different types of animals, research findings from a given area and kind or class of animal have limited inferences and should not be applied to a wide area. It is therefore important to ascertain the locally available food types and preferred diets for a specific species and/or breed of livestock dominated in a particular region. Moreover, information on the food habits of pastoral animals is generally scarce; studies on the relationship between forage quality and diet preferences of goats are particularly missing for drylands. This field study, carried out in an Iranian desert, aimed to 1) estimate the crude protein content of plant species in dry rangelands. Because it has been proven that crude protein (further abbreviated as CP) content is the most important vegetation parameter that influences forage quality (Biondini, 1986), we considered only crude protein in our estimation of forage quality; 2) determine the preference value of plant species in Raini goats as the most important plant feeder in the study area; and finally, 3) find out if the time goats (*Capra aegagrus*) spend on grazing or browsing plant species is correlated to the quality of those plants.

## 2. Materials and Methods

### *2.1. Study area and sampling design*

The study was carried out in the Talkhabad rangelands, a part of Kerman province, Iran (Fig. 1). The general climate of the study area (57º42´ to 57º46´ East; 28º02´ to 28º06´ North) is dry (domarton method), having 216.6 mm annual precipitation (Iranian Meteorological Organization: www.IRIMO.ir).

The vegetation is mostly xero-halophyte and largely dominated by annual species in spring and shrubs in summer (Table 1). Goat is the most important livestock that roam during the entire year, is corralled at night, and is let out by pastoralist and dog to feed during the day (Arzani, 2009). The studied goat (*Capra aegagrus hircus*), natively named Raini, is the most important cashmere variant in Iran, and it has great economic wealth. This breed is encountered in the southeast of Iran, in Kerman province (Sakha *et al*., 2009).

Diet selection and vegetation data were collected in 2010 during two seasons: in spring, from 15 to 30 March, when annual plant species dominate the vegetation, and in summer, from 23 July to 6 August, when perennial species are dominant. A preliminary survey was done at the beginning of both sampling periods in order to identify all plant species present in the study area. Despite the domination of shrubs in parts of the area during the last period, shrub individuals were mostly sparse. Forty 1*1 m random plots were used to estimate relative cover of all plant species during each period. Above-ground vegetation composition was determined during the two periods (vegetative growth stage and seed ripening stage) by estimating the cover of all plant species

(according to the method described in Londo, 1976).

### 2.2. Vegetation data

At each plot, the above-ground biomass of herbaceous and current-year growth of woody species (with the exception of *Ziziphus spina-christi*) was cut using garden shears, leaving a stubble height of approximately 1 cm for herbaceous species. As the twigs of *Ziziphus spina-christi* were not available for browsing, only the fruit fallen onto the ground were collected during the spring sampling. In summer, the fruit of that species was not observed. Herbage samples were hand-sorted in the laboratory into several subsamples at the species level, and the subsamples were subsequently dried at 65ºC for 48 h to a constant weight (Milotic *et al*., 2010). Next, the protein content of each plant species was measured using the Kjeldahl crude protein method (AOAC, 1984).


Fig. 1. Location of the study area in Talkhabad, Kerman province (Iran)

Table 1. List of plant species in the study area (A= annual, P= perennial)

| Species | Life form | Family |
|---|---|---|
| *Asphodelus tenuifolius* Wendelbo | Aherb | *Liliaceae* |
| *Astragalus triboloides* Delile | A forb | *Leguminoseae* |
| *Calligonum bungei* Rech. & Sch.-Cze | P-small tree | *Polygonaceae* |
| *Fagonia bruguieri* Hadidi | A forb | *Zygophyllaceae* |
| *Gaillonia aucheri* Guill | P-shrub | *Rubiaceae* |
| *Gymnocarpus decander* Forssk | P-cushion | *Caryophyllaceae* |
| *Hammada salicornicum* (Moq.) Bunge ex Boiss. | P-shrub | *Chenopodiacese* |
| *Lycium edgeworthii* Sch.-Tem. | P-small tree | *Solanaceae* |
| *Plantago stocksii* Rech. | A forb | *Plantaginaceae* |
| *Rhazya stricta* Dc. | P-shrub | *Polygonaceae* |
| *Stipa capensis* Thunb. | A herb | *Gramineae* |
| *Taverniera cuneifolia* (Roth) Arn. | P-shrub | *Fabaceae* |
| *Ziziphus spina-christi* Boiss. | P-tree | *Rhamnaceae* |
| *Zygophyllum eurypterum* Hadidi | P-shrub | *Zygophyllaceae* |

### 2.3. Diet selection data

The method used to observe forage preference involved close observation of one randomly selected focal adult-female goat grazing with the others in the flock (Odo *et al*., 2001). Each focal goat was closely monitored by one observer who recorded the time spent on each plant species when the goat grazed or browsed. Observations were made during three hours (8am to 11am) on five different days for each period. Preference indices were then estimated for all plant species with the assumption that the time spent on a plant reflects the proportion of that plant in the diet (Becker and Lohrmann, 1992). From these records (five randomly-selected goats during five days; each day one goat was observed by the same observer), the following parameters were calculated: relative cover of the plant species in the habitat and proportion of individual plant species in the diet for each record (each day comprised three hours) and the preference index (further abbreviated as PI), measured as (Ngwa *et al*., 2000):

$$\text{Preference Index (PI)} = \frac{\text{Proportion of plant consumed}}{\text{Proportion available in the range}}$$

$$= \frac{\text{Time spent feeding on the plant species expressed as percentage of total feeding time}}{\text{Relative cover of plant species in the habitat}}$$

Preference indices were calculated for all species, for each record (5 days), and for both sampling periods.

*2.4. Data analysis*

As the data met normal distribution requirements, parametric analyses were performed using SPSS version 17. First, ANOVA and post-hoc (Duncan) tests were used to compare forage quality and PI among species for both periods separately. Then, the results obtained from forage quality (and PI) collected during spring and summer were treated likewise using paired t-test. Finally, linear inter-regression and Pearson correlation methods were used to estimate the relationship between forage quality and PI.

## 3. Results

Fourteen plant species were identified during the two sampling seasons (Table 1). Crude protein content was significantly different among species and between two phenological stages. Preferences of plant species for grazing by goats were also significantly different among plant species and between the two sampling periods.

During spring (vegetative growth stage), the highest crude protein content was recorded in *Astragalus triboloide*s with 19.6%, while *Ziziphus spina-christi* had the lowest CP content with 4.22% (Table 2). The highest preference index was found in *Plantago stocksii* with an average index of 3.24, while the lowest index was in *Asphodelus tenuifolius*, *Rhazya stricta* and *Hammada salicornicum* with an average value of 0.00. The latter plant species occurred in the study area, but were never grazed by goats (Fig. 2). During summer (seed ripening stage), the crude protein content was highest in *Rhazya stricta* with 14.85% and lowest in *Stipa capensi*s with 5.23%. The highest preference index was recorded in S*tipa capensis* with an average index of 7.37, while the preference value of *Rhazya stricta*, *Lycium edgeworthii*, and *Calligonum bungei* was 0.00 (Fig. 3). There was no significant correlation between CP (%) and PI for both sampling seasons (Table 3). The crude protein of species significantly decreased between spring and summer (from vegetative growth to seed ripening stage), whereas the preference index was higher in summer compared to spring (Table 4).

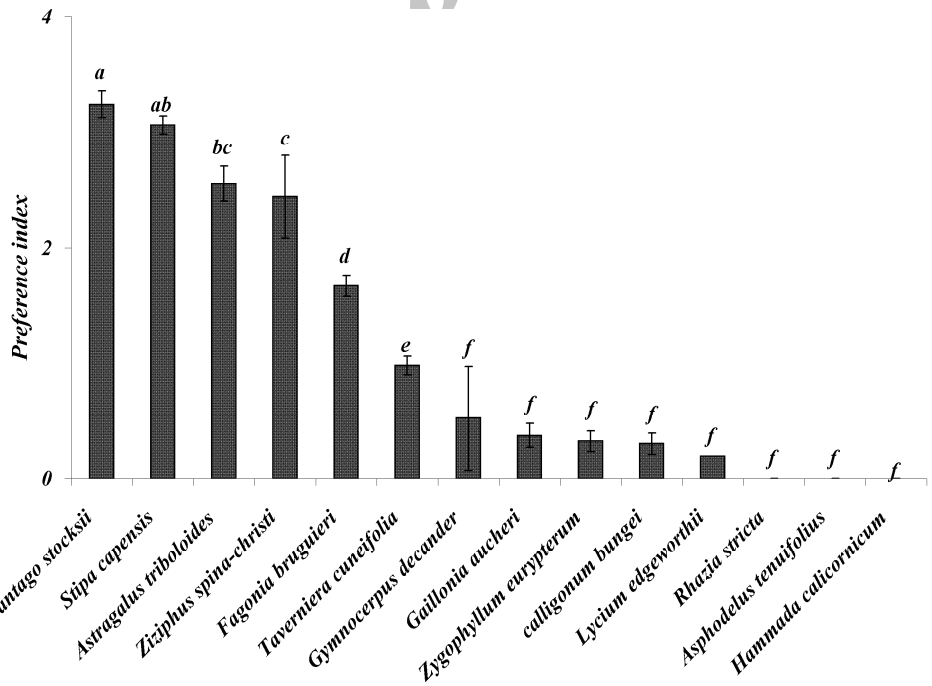


Fig. 2. Preference indices of plant species (Mean ± SE) during the first sampling session (spring 2010) and significance by ANOVA followed by post-hoc (Duncan) tests (different successive letters indicate significant differences at $P < 0.05$)

Table 2. Average (±SD) of crude protein content (CP, %, and cover percentages of the different plant species during the two sampling periods (n= 40 samples per plant and season)

| Species | CP in spring | CP in summer |
|---|---|---|
| *Asphodelus tenuifolius* | 15.97±1.02 | 5.59±1.13 |
| *Astragalus triboloides* | 19.60±0.82 | 8.52±0.41 |
| *Calligonum bungei* | 7.79±0.67 | 5.84±0.00 |
| *Fagonia bruguieri* | 16.48±0.70 | 10.45±1.58 |
| *Gaillonia aucheri* | 7.54±0.65 | 9.87±0.79 |
| *Gymnocarpus decander* | 9.42±1.49 | 6.01±1.08 |
| *Hammada salicornicum* | 10.99±0.42 | 13.41±3.13 |
| *Lycium edgeworthii* | 7.90±0.62 | 6.74±0.82 |
| *Plantago stocksii* | 11.85±1.02 | 5.90±2.01 |
| *Rhazya stricta* | 14.58±0.82 | 14.85±0.63 |
| *Stipa capensis* | 10.95±0.76 | 5.23±0.12 |
| *Taverniera cuneifolia* | 12.28±1.45 | 11.29±2.77 |
| *Ziziphus spina-christi* | 4.22±0.40 | - |
| *Zygophyllum eurypterum* | 13.33±0.81 | 9.00±0.00 |

Table 3. Relationship between crude protein content and preference indices using inter-regression and Pearson`s correlation methods (ns: not significant)

| Sampling session | | Spring | Summer |
|---|---|---|---|
| Inter-regression | t | 0.94 | 0.51 |
| | Sig. (p-value) | 0.333 (ns) | 0.622 (ns) |
| | *B* | 0.53 | 0.147 |
| Pearson`s correlation | R | 0.141 | -0.158 |
| | Sig. (p-value) | 0.935 (ns) | 0.625 (ns) |

Table 4. Comparison of crude protein content and preference index between spring and summer and significance by paired t-tests (*P < 0.05)

| | Preference index | Crude protein (%) |
|---|---|---|
| Mean in spring ± SD | 1.22 ± 1.40 | 11.64 ± 4.11 |
| Mean in summer ± SD | 2.75 ± 2.99 | 9.53 ± 3.31 |
| t | 2.21 | 2.63 |
| Sig. (p-value) | 0.044 (*) | 0.022 (*) |
| df | 11 | 12 |

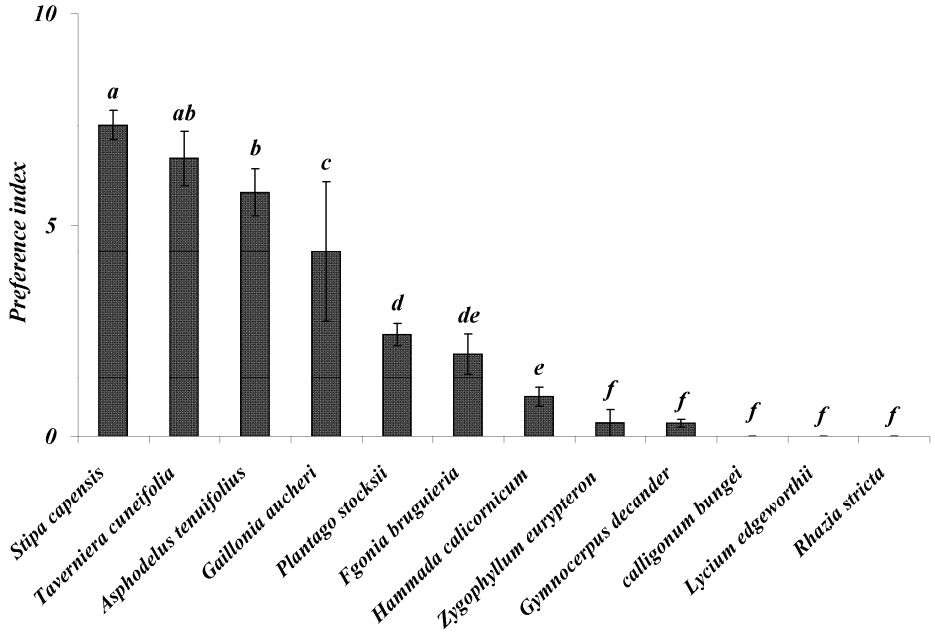


Fig. 3. Preference indices of plant species (Mean ± SE) during the first sampling session (summer 2010) and significance by ANOVA followed by post-hoc (Duncan) tests (different successive letters indicate significant differences at P < 0.05). During summer, the fruit of *Ziziphus spina-christi* was not observed, and the preference index of *Astragalus triboloides* was not measurable because it occurred veryrarely

## 4. Discussion

Recognizing the factors that influence diet selection was a hard task in this study. Predicting a grazing animal`s diet is actually difficult because of variations among animal species, and due to the location, weather, and maturity and availability of plants (Malechek, 1983; Cosyns *et al*., 2001; Lamoot *et al*., 2005). Hence, a more general characteristic is needed to represent diet selection. A good candidate might yet be crude protein of plant which was investigated in this research. However, in this study, plant species, besides having different qualities, were not selected according to their forage qualities. Crude protein in annual species varied within two phenological stages and declined from spring to summer. A higher CP was observed during spring when annual species were mostly in a vegetative growth. Decreased forage quality is expected as plants mature and leaves senesce (Angell *et al*., 1990; Ganguli *et al*. 2010). For most perennial species, this decrease in CP was less pronounced between the two phenological stages, and crude protein remained constant or increased slightly between the two sampling seasons. The nutritive value of browse species is known to be high, with low variation over time compared to grasses (Fadel Elseed *et al*., 2002). Moreover, crude protein significantly differed among plant species. Different factors affect forage quality, and the kind of species is indeed one of the most important factors influencing the rate of forage quality (Lyons *et al*., 1994; Chen *et al*., 2001).

Contrary to our expectations, plant species were not selected according to their nutritive qualities (CP). During spring, *Asphodelus tenuifolius* with 15.97% CP, *Rhazya stricta* with 14.58% CP, and *Hammada salicornicum* with 11% CP all had relatively high quality. Nevertheless, they were not grazed (or browsed) by goats. In addition, *Rhazya stricta* with the highest CP from the summer values were not grazed by goats. Therefore, it can be concluded that some other plant traits determine whether a plant species will be eaten or not. Indices of forage quality (CP) were not significantly correlated with selectivity, conforming previous findings from Ganskopp *et al*., (1996) and Alonso-Diaz *et al*., (2008). Anatomical features such as thorns, awns, and dense pubescence can affect a plant`s preference value (Malechek and Provenza, 1983). Garin (1997) demonstrated that browsing on some woody species was very light. In our study area, those woody legumes had hard prickles between their protein-rich leaves, and browsing on those species was constrained mainly by the morphological features (spiny cushion form) rather than by their nutritive value. In addition, secondary metabolites lead ruminants to limit their intake of even the most nutritive food (Tanner *et al*., 1990), which in turn leads them to ingest a diverse array of plants to minimize toxicosis (Ngwa *et al*., 2000). Particularly, the preference of goats for woody and herbaceous plant species, in spite of lower intake rate of biomass and nitrogen, may be governed by the need of goats to avoid high levels of phenolics and tannins more than to maximize intake of nutrients and energy (Woodward and Coppock, 1995). Cooper and Owen-Smith (1985) found preferences of goats for woody plants to be little related to nutrient concentration, but to be low when concentration of phenolics exceeded 5%. The results of this study are contrary to the results of few authors (Aregheore *et al*., 2006; Johansson *et al*., 2010). The latter studies reported that there was a significantly positive (or negative) correlation between CP and selectivity of plant species by goat. In addition, Ngwa *et al*. (2000) demonstrated that goats are more selective feeders than sheep and cattle, tending to select the better quality (higher protein) plant species.

Surprisingly, *Stipa capensis* was a good candidate to be eaten by the goats. *Stipa capensis* Thunb. (Poaceae) is common as an annual grass in dry habitats around the Mediterranean and the Middle East up to the Persian Gulf. It is distributed in large areas of the Irano-Turanian phytogeographic regions (Boeken *et al*., 2004). This species has seeds with erect appendages which cause serious problems for large herbivores, and it is always reduced through management measures (Arzani, 2009). However, this species was a major part of the goats' diet in both sampling sessions, while it had a relatively low CP. During the spring sampling, *Stipa capensis* was in its vegetative stage and had soft and succulent tissues. In summer, the seeds of that species have already been dispersed, and the plant has dry but soft tissues. Therefore, the soft tissues of *Stipa capensis* might attract goats, inducing a relatively high preference index. *Ziziphus spina-christ* showed a high preference value during spring. We observed that goats ignored other neighboring species when they were confronted with that species. The goats browsed only on the fruit that had fallen to the ground. Previous studies also have reported that goats were more interested in the blossoms and pods of certain browse species, e.g., *Guirra senegalensis* and

*Combretum micrantum* (Ngwa *et al*., 2000). We also observed that the goats were not able to browse the twigs and leaves of *Ziziphus spina-christ* due to the high height of this plant species, emphasizing again the importance of plant availability in grazing or browsing (Odo *et al*., 2001; Goetsch *et al*., 2010; Marquardt *et al*., 2010).

*Lycium edgeworthii* was browsed in spring, yet it was not considered in the summer. The massive number of its hard prickles in the summer might prevent goats from browsing on this species. Spiny plant species may be less selected by ruminants due to morphological problems (Garin, 1997). In contrast, some species were selected more in summer than in spring (e.g., *Hammada salicornicum*). The production of secondary compounds during spring might influence these selections (Ball *et al*., 2000). Some species (e.g., *Taverniera cuneifolia*) showed both a relatively high quality and a high preference value. Although plant defences are abundant in wooded rangelands, they are not a complete barrier to small ruminants who often use woody plants as part of their diets (Papachristou *et al*., 2005), which indicates the importance of woody plants in rangelands as part of the diet of small ruminants.

Crude protein of dry rangeland plants is an unreliable index for predicting diet selection by goats. Further studies should investigate the role of other parameters, such as fibers and toxin or mineral concentration, in the preference value of plant species for Raini goats in dry rangelands. An interesting outcome is the importance of minor feeds such as fruits in a goat's diet. Range management measures, therefore, have to consider this opportunistic feeding, especially by maintaining some highly sparse plant species. Goats are highly selective feeders, changing their diet from grazing to browsing and *vice versa*, which highlights the importance of a diversified botanical structure and the preservation of shrubs and trees in desert habitats. Forage quality of plant species and their preferences for grazing are drastically affected by age; thus, further attention should be paid to plant species that have high both quality and preference for a longer time span (e.g., *Taverniera cuneifolia*). Rangeland management programs need to favor such valuable species, especially during the summer when these species are more prominent and the annual species have already dried.

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