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Age and season effects on quality of diets selected by Criollo crossbred goats on rangeland

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Abstract. The objectives of this study were to determine the effects of age of goats (4-week old, 6.2 ± 0.7 kg vs mature, 46.9 ± 5.6 kg) and season (rainy vs dry) on nutrient content of diets selected by Criollo crossbred female goats on an overgrazed Chihuahuan desert rangeland. Two groups of goats, 10 goat kids and 10 non-lactating pluriparous goats from a commercial goat herd were used. Diet quality and dry matter (DM) intake was assessed via repeated collections (3-h periods) of forage from the mouth of goats, which were momentarily restrained using a light short permanent rope tightened to their neck while grazing. Feed intake was assessed by 24-h fecal collection with canvas fecal-collection bags. Mature animals ate more ($P < 0.01$, 23 g DM/kg bodyweight ± 7 s.d.) than goat kids (19.5 g DM/kg bodyweight ± 6 s.d.) across grazing seasons, but DM digestibility of selected diet was greater ($P < 0.01$) in goat kids than in mature goats (58.5 ± 4.0% vs 55.3 ± 3.5%, respectively) across seasons. Ash (100 ± 16 vs 79 ± 13 g/kg DM), phosphorus (1.36 ± 0.41 vs 1.13 ± 0.36% DM) and crude protein (94.5 ± 4 vs 88.5 ± 5 g/kg DM) contents were greater ($P < 0.01$) in diets selected by goat kids compared with mature goats. Dietary protein was greater in rainy than in the dry season. Across grazing seasons, herbage selected by goat kids had a lower ($P < 0.01$) concentration of neutral detergent fibre and acid detergent fibre than did that selected by mature goats. There was an age by grazing season interaction ($P < 0.05$) for most chemical components of forages selected by goats. In conclusion, both age and season affected diet quality of goats on rangeland, as goat kids ingested a diet richer in nutrients than that of mature goats. This supports the theory that herbage selection is shaped by physiological effort and, consequently, nutrient consumption is driven by higher nutrient requirements for growth, although incomplete development of rumen function and small body mass limited feed intake in preweaning goat kids.

Additional keywords: body size, diet quality, feed intake, foraging, forage selection, herbivore.

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Introduction

Most goats in the arid and semiarid ecosystems of northern Mexico are kept in harsh and resource-poor environments. These goats play a key role in the utilisation of available forage resources in arid ecosystems and provide a practical mean of using vast areas of rangeland in regions where crop production is unfeasible, due to low and highly variable rainfall conditions and rugged and steep terrain.

A common practice in these pastoral systems is to keep the goat kids indoors during the first days of life, because they are unable to keep pace with mature goats while grazing (~5 km journey away from the pen). After ~3 weeks of age female goat kids (males remain indoors until ~40 days of age when they are slaughtered; they suckle their dams from dusk until dawn and receive extra milk from aborted goats and goats that lose their kids at parturition) are moved to the rangeland to graze/browse together with the mature animals, in order for the kids to complement their limited milk diet (goats are milked before taking them out for grazing). This practice prevents diseases that thrive in damp unroofed corrals, encourages physical activity and allow kids to ingest a greater amount of nutrients to enhance kid growth rates.

Because of their short stature, inexperience in selecting plant species, lower ability to metabolise toxins, lower gut capacity and reduced capacity of mobilisation while grazing, it is probable that young goat kids are not fully capable of effectively utilising the different forage species and vegetation types. This is so because in young ungulates the social influences of maternal and peer examples are important contributors to the shaping of an animal's dietary selection (Mirza and Provenza 1990;

Thorhallsdottir *et al*. 1990) and foraging skills improve with age (Flores *et al*. 1989). An animal is born with a set of behavioural patterns, which affect behavioural decisions (Launchbaugh and Howery 2005), but as goats mature, their experiences drive modifications to these behavioural patterns, from environmental factors and the influence of parents and conspecifics (Searle *et al*. 2010). Therefore, feeding behaviour is shaped from a complex and permanent interaction between the genotype and environmental conditions.

Early in life goat kids possibly can discern between a variety of forages because compounds and flavours of herbage ingested by their mothers are transferred to the fetus through the blood reaching the placenta (Hepper 1988; Wiedmeier *et al*. 2012) and through the milk (Babcock 1938). Given that ungulate herbivores select nutrients in amounts to meet their needs (Verheyden-Tixier *et al*. 2008; Villalba *et al*. 2008), and that this selection varies with the internal state (Kyriazakis *et al*. 1999), it was considered pertinent to assess the foraging capacity of very young goat kids ingesting a limited amount of milk, in a landscape with scarce and patchy forage resources.

On the other hand, in the arid zones of northern Mexico goat kids normally are born early in the growing season when vegetation is at its highest level of nutrients, thus it would be convenient to find out how young kids can cope with dry residual forage from the previous growing season.

Although diet characteristics (Mellado *et al*. 2011, 2012) and seasonal change of voluntary food intake (Ramírez *et al*. 1991; Juárez-Reyes *et al*. 2004, 2008) have been well documented for mature goats, few studies have elaborated on the feed habits of young goat kids in arid ecosystems. Consequently, there is generally scanty information on the ability of preweaning goat kids to utilise the forage resources of rangelands.

Therefore, this study was conducted to test the hypothesis that preweaning goat kids display an efficient foraging behaviour in a rangeland with scarce and patchy resources with vegetation in different phonological phases, but constraints due to body mass (i.e. metabolism and digestive constraints, size of the feeding apparatus) lead to variations in grazing patterns.

Materials and methods

Study site

The study was conducted in a rural community of north-east Mexico (35 km south of Saltillo, Coahuila; 25°23′N, 101°59′W). Elevation of the study area is 1525 m above sea level. Average long-term annual rainfall is 322 mm. It is erratically distributed throughout the year, although summer and autumn rainfall is higher and more reliable. Most of the precipitation in the area falls during high-intensity thunderstorms during the growing season (June–October). Average maximum daily temperatures range from 28°C in January to 37°C in July. Average minimum daily temperatures range from −7°C in January to 12°C in July. The topography of the grazing area is relatively flat. The most commonly encountered shrub species are *Acacia farnesiana* (L.) Willd, *Acacia greggii* Gray, and *Dalea bicolor* Humb. & Bonpl. ex Willd. The principal perennial grasses are *Bouteloua curtipendula* (Mich.) Torr. and *Aristida arizonica* Vasey. The most abundant forb species are *Sphaeralcea angustifolia* (Cav.) D. Don., *Tiquilia canescens* (DC.) A. Rich. and *Solanum elaeagnifolium* Cav. Mean aboveground standing crop at the beginning of the study was ~2000 kg DM/ha. The rangeland presented a deteriorated condition due to decades of overgrazing by cattle, equines and small ruminants.

Animals and management

This research adheres to the Guidelines of the Autonomous Agrarian University Antonio Narro for the use of animals in research. A commercial flock of ~200 mature goats typical of the farming systems of the arid zones of northern Mexico was used. Goats were Criollo crossbred goats (mixture of dairy and native goats) with an average body condition score of 2.5 (determined by tactile appraisal of fat in the sternum and lumbar vertebrae; scale 0–5; Santucci and Maestrini 1985) during the rainy season.

Goats were penned in an unroofed corral adjacent to the household at night without access to water. Goats drank water once a day from a pond in the grazing site. No salt or food supplements were provided to the goats throughout the year. Goats were not subjected to an anthelmintic drenching program or vaccinated against endemic infectious diseases. Goats were bred either in March or October, in order to have kids during the rainy (September) or dry (March) season. Dams and goat kids did not remain together during grazing, so goat kids did not have the chance of suckling on rangeland; only after the flock returned to the pen, reunion was immediately followed by suckling. Kids were later separated from their mothers for the rest of the night. Milk yield of goats in this production system is ~400 mL/day at the beginning of lactation in the rainy season (Mellado *et al*. 2006), and goats are hand-milked once daily early in the morning. It is estimated that goat kids ingested 200 mL of milk daily during the rainy season. On the other hand, drought profoundly reduces milk production of goats in this landscape; therefore, goat kids ingested a meagre amount of milk during the dry period.

To evaluate the effect of animal age, 10 pluriparous non-pregnant non-lactating goats (mean ± s.d., 46.9 ± 5.6 kg) and 10 4-week-old female goat kids (6.2 ± 0.7 kg) were selected for the study. During the dry period both mature goats and kids were not the same as those used during the rainy season. Goats grazed on open range, driven by a herdsman, 7 h per day (1100 hours to 1800 hours).

Feed and feces sample collection

Goats included in the study were fitted with a short plastic rope (1.5 m in length and 0.5 cm in diameter) tightened around their neck with a non-slip knot. The loop was adjusted so that it was comfortable around the base of the goat's neck. This light and short rope allowed the goats to walk in all kinds of terrain without hindering their motion or feeding activity, and was used to momentarily restrain them to get the herbage collected from their oral cavity. Plants selected by goats were obtained by separating the mandibles of goats by hand, immediately after feeding. This operation was repeated approximately every 5 min during a 3-h grazing period per day, using one person per goat. Personnel followed the goats at close range without disturbing them while grazing/browsing and grasped the goat's rope by its end only during the forage collection episodes. Forage collections were made for 5 consecutive days during the morning grazing when goats were grazing most intensely due to the overnight fasting.

In order to avoid mineral contamination of ingested samples, following forage collection, a portion of the sample was thoroughly rinsed, first with tap water and then with distilled water, in order to remove saliva and these samples were used for mineral analyses.

Total fecal collection (24 h) was conducted in both mature and kid goats with canvas fecal-collection bags fastened to the animal with a harness and allowed 3 days to adapt to them followed by total collection of feces for 4 consecutive days. Fecal-collection bags were emptied twice daily. The daily fecal output of each goat was weighed and recorded. About 5% of fresh feces for each animal were taken to be dried at 55°C; this was followed by a 48-h air equilibration to determine air-dried fecal output. Daily fecal samples were pooled relative to 24-h air-dried fecal output (the same percentage from each day's output) to provide a representative sample of the 4-day fecal output.

Analytical procedures and other measurements

Both mature and kid goats were weighed before forage and feces collection.

Forages collected during the 4-day period were pooled and these samples were oven-dried and then ground to pass through a 1-mm-mesh sieve. Dry matter was determined by drying at constant weight at 60°C for 48 h in a forced-air oven; ash by incineration at 600°C for 2 h with a TGA-500 furnace (Leco Corporation, St Joseph, MI, USA; AOAC no. 942.05). Ether extract was analysed with a Soxhlet extractor (Extraktionssystem B-811, Büchi, Flawil, Switzerland; AOAC no. 963.15). Crude protein (CP) was determined by the micro-Kjeldahl procedure (N × 6.25; AOAC 1996).

Fibre fractions – neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin and cellulose – were determined by the procedures described by Van Soest *et al.* (1991) and Van Soest and Wine (1968) using procedures modified for an Ankom 200 fibre analyser. Hemicellulose was calculated as NDF – ADF.

Concentrations of calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) were determined by atomic absorption spectrophotometry. Phosphorus (P) was measured by colourimetry (AOAC 1996). All analyses were performed in triplicate.

The disappearance of DM from nylon bags (7 × 15 cm; 40-µm pore size, three bags per sample) was determined as described by Orskov *et al.* (1980). Three-gram samples were ground to pass through 2.5-mm mesh screen using a hammer mill. Forage samples were incubated for 48 h in the rumen of a cannulated Holstein steer fed oat hay. The disappearance of DM (dry weight difference between bags before and after incubation) was considered as rumen-degradable DM. Digestible DM was estimated from degradable DM using the equation of Fonseca *et al.* (1998) for 48-h rumen degradability. DM intake (DMI) was calculated as follows: DMI = DM fecal production/(1 – diet DM digestibility) (Handl and Rittenhouse 1975). We acknowledge potential limitations and inaccuracies of DMI estimations by this procedure due to possible differences in forage degradability between the steer, mature goats and goat kids. The under-developed rumen of kids compared with the fully-developed rumen of mature goats, as well as the effects of the milk ingested by kids, which undoubtedly altered fecal output in these animals, and consequently DMI in young kids may be somehow biased.

Statistical analyses

Given that different goat kids and mature goats were used during the two grazing seasons, age could not be used as a repeated-measures variable. The effects of age, season of sampling and the age by season interaction on nutrient content of diets, DM digestibility (DMD) and feed intake were analysed by ANOVA using the MIXED procedure of SAS (SAS Institute, Cary, NC, USA). Goat was considered the experimental unit.

The statistical model used was $Y_{ijk} = \mu + A_i + S_j + (A \times S)_{ij} + e_{ijk}$, where Y_{ijk} = dependent variable for Goat k on Age group i at Season j, μ = population mean, A_i = age effect (I = 1,2), S_j = season effect (j = 1,2), $(A \times S)_{ij}$ = age by grazing season interaction term and e_{ijk} = the residual error term. Significant differences detected by ANOVA were further investigated using a Tukey's honest significant differences *post hoc* test comparing age categories within grazing season. Data on feed intake are presented as g/day, percentage of bodyweight (BW) or as metabolic BW (g/kg $BW^{0.75}$.day) for comparison with other studies. Significance was declared at $P < 0.05$.

Results

The chemical composition of herbage selected by goats is presented in Table 1. Across seasons forage selected by goat kids had greater (P < 0.01) concentrations of ash than pluriparous goats. There was an age by grazing season interaction (P < 0.01). The mean ash content of forages selected by goat kids was higher in the dry season than in the rainy season; the opposite occurred with mature goats. Crude protein content of forages selected by young goat kids was greater (P < 0.01) than mature goats. This nutrient was higher in forages harvested by goats in the rainy season compared with the dry season (P < 0.01). There was a significant interaction detected between grazing season and age of goats for CP content in forages selected by goats. The reduction in CP content from the rainy to the dry season was greater in mature (15%) than in young goats (7%).

Across grazing seasons both NDF and ADF were lower (P < 0.01) in diets selected by young goat kids than mature goats. There was an age by grazing season interaction (P < 0.01) for both NDF and ADF in forages selected by goats. Both groups of goats selected forages with higher amounts of NDF during the rainy season compared with the dry season, however, NDF levels of forages selected by goat kids declined more sharply than for mature goats. Acid detergent lignin and cellulose in the dry season were lower in goat kids than in mature goats, while the contrary occurs in the rainy season for cellulose.

Goat kids showed a greater ability (P < 0.01) to select forages with higher DMD than mature goats (58.5% vs 55.3%;

Table 2). Digestibility of forage selected by goats was lower ($P < 0.01$) in the dry season (54.7%) compared with the rainy season (59.1%). DMI (g/kg BW) was greater in mature ($P < 0.01$) than young goats across grazing seasons. Regarding determination of DMI of goat kids, milk contribution to DMI was not considered. However, obtaining precise quantitative information on this issue in preweaning goat kids under grazing condition is not possible, because milk supply for kids cannot be suspended at this early age.

Across grazing seasons young goat kids selected forages richer (1.36% DM; $P < 0.01$) in P than mature goats (1.13% DM; Table 3). Levels of this mineral did not differ in herbage consumed by goats in both grazing seasons. The K content of herbage selected by goats was affected by age (greater in goat kids than in matures) and by grazing season. Levels of Ca and K in forages selected by goats (irrespective of age) were greater ($P < 0.05$) in the rainy season than the dry season. Across grazing seasons Cu and Zn concentrations in forage selected

Table 1. Chemical composition (g/kg DM) of diets selected by goat kids or mature goats during the rainy or dry season in a Chihuahuan desert rangeland

Values are means of 10 animals. Rainy season data are for September. Dry season data are for March. Kids, goat kids of 4 weeks of age (6.2 ± 0.7 kg). Matures, pluriparous goats (46.9 ± 5.6 kg). *$P < 0.05$, **$P < 0.01$

Item	Rainy season		Dry season		s.e.m.	Age effect	Season effect	Interaction
	Kids	Matures	Kids	Matures				
Ash	94	86	105	71	6.67	**	–	**
Crude protein	98	96	91	81	6.75	**	**	*
Ether extract	26	22	23	23	3.68	–	–	–
Neutral detergent fibre	522	540	448	521	27.37	**	**	**
Acid detergent fibre	403	365	317	410	30.12	**	*	**
Acid detergent lignin	65	71	45	68	2.18	**	**	*
Cellulose	338	294	272	342	23.33	–	*	**
Hemicellulose	119	175	131	116	22.75	**	**	**

Table 2. Dry matter digestibility (DMD) and dry matter intake (DMI) by goat kids or mature goats during the rainy or dry season in a Chihuahuan desert rangeland

Values are means of 10 animals. Rainy season data are for September. Dry season data are for March. Kids, goat kids of 4 weeks of age (6.2 ± 0.7 kg). Matures, pluriparous goats (46.9 ± 5.6 kg). *$P < 0.05$, $P < 0.01$

Item	Rainy season		Dry season		s.e.m.	Age effect	Season effect	Interaction
	Kids	Matures	Kids	Matures				
DMD (%)	60.0	58.1	57.0	52.4	5.04	**	**	–
DMI (g/day)	112	1121	130	1041	140	**	–	–
DMI (g/kg BW.day)	18.1	23.9	20.9	22.3	2.78	**	–	–
DMI (%BW/day)	1.86	2.39	2.09	2.22	0.33	*	–	–
DMI (g/kg $BW^{0.75}$.day)	28.6	62.6	33.2	58.1.3	6.31	**	–	*

Table 3. Mineral content of dietary samples of goat kids and mature goats grazing a Chihuahuan desert rangeland during the rainy or dry period

Values are means of 10 animals. Rainy season data are for September. Dry season data are for March. Kids, goat kids of 4 weeks of age (6.2 ± 0.7 kg). Matures, pluriparous goats (46.9 ± 5.6 kg). *$P < 0.05$, **$P < 0.01$

Item	Rainy season		Dry season		s.e.m.	Age effect	Season effect	Interaction
	Kids	Matures	Kids	Matures				
			Macrominerals (*%DM*)					
Calcium	0.42	0.41	0.39	0.39	0.04	–	*	–
Phosphorus	1.40	1.06	1.31	1.19	0.29	**	–	–
Potassium	1.28	1.05	1.01	0.85	0.24	**	**	–
Sodium	0.15	0.14	0.13	0.13	0.02	–	–	–
			Microminerals (*mg/kg DM*)					
Copper	10.4	11.2	12.0	9.6	0.81	**	–	**
Zinc	73.7	72.3	76.4	65.6	4.39	**	–	**
Manganese	42.7	40.4	34.6	48.5	2.94	**	–	**
Iron	434	452	420	466	25.9	**	–	–

by goats were higher ($P < 0.01$) in the diet of goat kids than mature goats. On the other hand, Mn and Fe concentrations were higher ($P < 0.01$) in forages selected by mature goats compared with goat kids. With the exception of Fe, significant age by grazing season interactions were detected for all other microelements with differences between ages occurring mostly in the dry season.

Discussion

The total mineral content of goat kids' diet was higher than that of mature goat diets. However, differences between kids and mature goats mostly occurred in the dry season. In the arid areas of northern Mexico goats normally do not lactate in the dry season, because goats subjected to insufficient food supply do not produce enough milk to nurse their kids. Despite the insufficient milk for kids to satisfactorily fulfil their mineral requirements, probably goat kids selected higher dietary mineral levels in their search for higher energy and protein sources and not to improve mineral balance and skeletal growth. This is assumed because of the contribution of milk to the intake of minerals, especially P, and the high Ca and P content of the herbaceous diet, which is above the requirements for bone development, considering the high availability of P from phytic acid to ruminants in this landscape (Mellado *et al*. 2011). Herbivores select diets with high ash levels in response to increased metabolic requirements derived of active growth, pregnancy or lactation (Estevez *et al*. 2010; Mellado *et al*. 2011). Goat kids consumed higher amounts of minerals in the dry season than in the rainy season, which suggests that high mineral ingestion may be crucial to growing goats at times of nutritional stress. Although forage quality decreases during the dry season, goat kid diets were higher in CP content than mature goats during this season. Both groups of goats selected forages with higher CP in the rainy season than in the dry season, however, CP content of forage selected by mature goats declined more sharply than for goat kids, suggesting that goat kids show a greater selectivity for high quality forages during nutritional distress than mature goats. This can be explained by the very low milk yields of dams during the dry season (very low protein ingestion), which do not allow kids to have a good start in life.

The National Research Council (2007) indicates that 14–16% CP is required by young goat kids for optimum growth, thus, diets selected by preweaning goat kids in this study may have been below their CP requirements for optimum growth in both the rainy and dry season. The CP levels in the rainy and dry season seemed to be adequate for non-pregnant and non-lactating mature goats.

Crude protein content of herbage harvested by goats in the present study was much lower than levels found in goat's diet in this type of vegetation (Juárez-Reyes *et al*. 2004, 2008; Mellado *et al*. 2011). This discrepancy was probably due to the overgrazed (much bare ground cover) rangeland used by goats, which lead to a reduction in the quantity or nutritional quality of the vegetation available for goats. Thus, in this particular landscape, preweaning goat kids consumed diets composed of medium quality forages to barely maintain a nutritional status to sustain a modest growth, complementing their protein intake with the milk provided by their mothers. Even though CP availability to goats was at its lowest point during the dry season, goat kids maintained a level of CP very close to that encountered in the rainy season, which suggests that accelerated growth and meagre milk yield from their mothers in the dry season apparently forced goat kids to obtain a mixture of feeds that approached their CP requirement for construction of body tissues (Villalba *et al*. 2002; Mellado *et al*. 2004). The absence of any great reduction in dietary CP in the dry season may be accounted for by the large proportion of woody plants ingested by goat kids (Mellado *et al*. 2004) with a high CP content (Ramírez *et al*. 1991; Pinos-Rodríguez *et al*. 2007) as well as forbs, which maintain a high CP level in arid ecosystems (Frost *et al*. 2008).

Lower values for NDF and ADF were found in diets selected by goat kids than mature goats. These fibre components are negatively correlated with forage digestibility and intake (Casler and Jung 2006). This observation highlights the ability of goat kids to select diets favouring the non-fibrous ingredients, thereby maintaining a high degradability of feed consumed. This ability of goats to avoid fibrous ingredients has been previously documented (Borja *et al*. 2010). The lower cell-wall content of forages selected by goat kids compared with mature goats suggests that these animals used young succulent vegetation available during the summer growing period as well as during the dry season (Mellado *et al*. 2004).

Most common nutrients of diets selected by goats were significantly affected by the interaction between seasons and age. This interaction derived from less variability in plant chemistry and lower structural components in diets of kids during drought compared with adult goats. These results indicate that feed choice of goat kids during periods of climatically related food depletion are less affected than adult goats.

Goat kids were observed to select a diet higher in DMD than that selected by mature goats in both grazing seasons, which is in line with results reported by Provenza and Malechek (1986). Narrow muzzles, small body mass, agility to move around and to kneel to reach plants hidden beneath thorny plants enabled goat kids to be very selective feeders, allowing them to harvest only the most digestible forage or parts of plants from that on offer. The higher DMD of the goat kid's diet is typical of non-grass plant species; these usually constitute ~95% of growing goat diets (Mellado *et al*. 2004). Forb and shrub leaves have much more rapid rates of digestion than grasses (Kothman 1980; McCollum and Galyean 1985), due to their lower cell-wall content (Frost *et al*. 2008) and higher CP concentrations and low fibre levels compared with grasses (Hanley 1982).

Cell-wall constituents in the diet selected by both kids and mature goats during the rainy season were higher than those of the dry season, even though DMD in the rainy season was higher and not lower, as expected. The causes for these results are unclear; significant correlations have been found between various components of cell-wall lignification and feed digestibility, although the actual components of lignification recognised as key predictors of digestibility have varied among studies, forage species, plant part, and maturity (Jung and Allen 1995). Possibly NDF of forages selected by goats in the rainy season had high rate of digestion as it been observed in forages consumed by goats in this type of vegetation (Pinos-Rodríquez *et al.* 2007), and DMI increased with increased NDF digestibility (Oba and Allen 1999).

Note that despite a difference of 3.5 percentage points in DMD (across grazing seasons) in forage selected by young goat kids, feed intake estimates per BW were lower in growing goats compared with mature goats. This sounds contradictory because digestibility of herbage has a large influence on voluntary feed intake as it determines the rate that plant material can be cleared through the rumen (Allen 1996). This apparent paradox is possibly related to the lower capacity of preweaning goat kids on rangeland to collect and process forages. Additionally, very young animals have higher mass-specific metabolic rates than larger animals, but also smaller absolute gut sizes and necessarily faster rates of food passage (Demment and Van Soest 1985; Illius and Gordon 1992). Additionally, goat kids possibly spent more time grazing (searching, selecting and tasting the different food items) and took smaller bites than mature goats. Thus, kids were able to get a diet richer in nutrient concentration, but DMI per BW (and even more per metabolic BW) was lower. Goat kids apparently were ingesting low quantities of milk, particularly during the dry season and probably they could not make up for the reduced milk ingestion by suddenly increasing herbage intake. The selection of more digestible forage by growing goats underline the importance of herbage with low cell-wall content as a major currency for foraging decisions in these animals.

It was clear that in 4-week-old kids whose diet shifted from milk-based to forage during the first few weeks of life, incomplete development of rumen function and body size limited feed intake (Hooper and Welch 1983). The capacity of the foregut in goats does not scale isometrically with body mass across a wide range of age/size (Abou-Ward 2008).

When there are fluctuations in forage availability animals try to maintain feed intake by altering the grazing time, the bites per minute and the amount of feed ingested per minute. Goats spent the same time grazing due to a pre-established grazing period of the flock. Four-week-old goat kids present a much lower chewing time (Hooper and Welch 1983) and rumen development (Abou-Ward 2008) than older goats, which apparently lead to a lower eating efficiency compared with mature goats.

An additional factor probably limiting forage intake of goat kids was physical limitations for grazing, such as travel time between feeding patches and time required to ingest plants (Lundberg and Astrom 1990), due to their small body mass (basically structural body mass; no energy reserves). Feed intake values of mature goats are well within the range observed in several other studies in the same type of vegetation (Ramírez *et al*. 1991; Juárez-Reyes *et al*. 2004, 2008).

During the rainy and dry season mean P content of diets selected by goat kids was greater than that found in diets of mature goats. Changes in availability of forage and associated dietary shifts did not induce seasonal fluctuations in the levels of P for each kind of animal. P ingested by goats was far above the requirement for growing goats (Suttle 2010). It was unlikely that goat kids searched for P-rich forages in a situation in which P contents of the diet was above 1%.

Young goat kid diets showed higher increases in Cu and Zn content compared with mature goats during the dry season. Given that leaves contain 35% higher Cu concentrations than stems in forages (Minson 1990), it seems that goat kids consumed a larger proportion of leaves of the brush and forb species than mature goats. Forage Cu and Zn concentrations were at adequate levels for growing goats, which is not in line with another study in a drier area of northern Mexico (Ramírez-Orduña *et al*. 2008).

These results are not in line with the view that young herbivores are more sensitive to learning around the time of weaning (Provenza and Balph 1987) and that the reliance on available forage increases the influence from other conspecifics (Provenza and Burritt 1991). Young goat kids in this study showed good foraging skills, although kids need to complement their herbage intake with milk to meet their nutrient requirements, so their growth and performance is partially dependent on their mothers.

Conclusions

Goat kids in this overgrazed, patchy and heterogeneous rangeland consistently selected a higher quality diet than did mature goats, which indicates that Criollo crossbred goats at an early age are remarkably adapted at selecting forage in this resource-poor rangeland. These differences in diet may reflect differences in selection of forage species or plant parts, or subtle spatial separation of age groups while grazing, despite the remarkable flock cohesiveness, so that they forage in spots with different feeding opportunities, resulting in a more nutrient-dense diet. However, small mouths and not fully developed reticulum-rumen presumably also restricted young goat kids to take large bites, thereby achieving low rates of DMI when feeding on this habitat.

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