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“ANTONIO NARRO”

UNIDAD LAGUNA

SUBDIRECCIÓN DE POSGRADO

HÁBITOS ALIMENTICIOS DE CABRAS GESTANTES O QUE ABORTAN Y CABRAS MULTÍPARAS O MENORES DE 2 MESES MANTENIDAS EN AGOSTADERO

TESIS

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POR:

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ÍNDICE DE CONTENIDO.

Página

ÍNDICE DE FIGURAS

FIGURAS. **Página**

COMPENDIO

Hábitos alimenticios de cabras gestantes o que abortan y cabras multíparas o menores de 2 meses mantenidas en agostadero

Por:

Leticia Romana Gaytán Alemán

DOCTORADO EN CIENCIAS EN PRODUCCIÓN AGROPECUARIA

UNIVERSIDAD AUTONOMA AGRARIA ANTONIO NARRO

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Torreón, Coahuila, Junio 2013

Se realizaron dos estudios para **1)** describir los hábitos alimenticios de cabras adultas y de cabritos de alrededor de un mes de edad en agostadero y **2)** determinar las diferencias en el contenido de nutrientes de las dietas de las cabras que mantienen su gestación y cabras que abortan en condiciones de escaso forraje en agostadero.

Estudio 1. El objetivo de este estudio fue determinar si la edad (seis semanas de edad, 7.2±0.7 kg *vs* adultas 46.9±5.6 kg) y la estación (lluviosa y seca) afecta el contenido de nutrientes de la dieta seleccionada por las cabras criollas en el norte de México. Se utilizaron dos grupos de cabras, 10 jóvenes y 10 multíparas en condiciones extensivas para evaluar la calidad de la dieta y el consumo de materia seca (DMI) por medio de colecciones repetidas de heces durante 24 h (5 días) y de forraje tomado directamente de la boca del animal. Las cabras portaban una cuerda de plástico corta atada al cuello, con la cual se sujetaban momentáneamente en forma intermitente mientras pastoreaban. El consumo de alimento fue evaluado mediante la colección de muestras fecales (24 horas) en bolsas de lona adheridas al área pineal, las cuales eran sujetadas con arneses que se ajustaban al costado del animal. Los cabras adultas consumieron más forraje (MS) ($P< 0.05$, 28 g kg^{-1} BW ± 8 SD) que las cabras jóvenes (23 g kg^{-1} BW ± 8 SD) a través de las estaciones de pastoreo, pero las muestras de la dieta para digestibilidad *in situ* (DMD) fueron mayores ($P<0.05$) en las jóvenes que en las adultas (67.2 ± 4.2 % *vs* 60.7 ± 4.2 respectivamente) a través de las estaciones. El contenido de ceniza (100 ± 16 g kg^{-1} DM), fósforo (1.40 ± 0.41 *vs* 1.06 ± 0.36 % DM) y proteína cruda (CP, 95 ± 4 *vs* 89 ± 5 g kg^{-1} DM) fue mayor ($P<0.05$) en la dieta seleccionada por las cabras jóvenes comparadas con las adultas. Por otro lado, el forraje seleccionado por las cabras jóvenes durante las estaciones de pastoreo fue más baja la concentración en FDN y FDA que las cabras adultas. En conclusión, la edad y la estación afectaron la calidad de la dieta de las cabras en agostadero, ya que las cabras jóvenes ingirieron una dieta más rica en nutrientes que las cabras adultas. Esto apoya la teoría de que la selección de forraje está determinada por el estado fisiológico y por consiguiente el consumo de nutrientes está dado por mayores requerimientos para el crecimiento. Por otro lado, el desarrollo incompleto de la función ruminal parece explicar el menor consumo de forraje de los cabritos predestete.

Palabras clave: pastoreo, herbívoros, consumo de alimento, selección de forraje, calidad de la dieta, condición corporal.

Estudio 2. El objetivo del presente estudio fue determinar el contenido de nutrientes seleccionado por cabras mestizas que abortaron al final de la gestación y cabras que llevaron a término su gestación. El estudio se llevó a cabo durante los últimos 4 meses de gestación de las cabras en el periodo de intensa sequía en el agostadero del norte de México. Las muestras de la dieta se obtuvieron directamente de la boca del animal durante su trayectoria de pastoreo en un pastizal muy degradado. Se utilizó una cuerda corta y delgada de plástico amarrada alrededor del cuello para inmovilizar al animal y obtener el forraje recogido de la boca de las cabras. Las muestras se utilizaron para los análisis químicos. A través de los meses, las cabras no abortadas seleccionaron una dieta más alta (133 ± 17 *vs* 119 ± 21 g kg^{-1} DM; *P*<0.01) en proteína cruda (CP) que las cabras abortadas, este nutriente no cumplió con los requisitos nutricionales al final de la gestación en las cabras abortadas. Las dietas de ambos grupos de cabras fueron más altos (P<0.01) en PC desde febrero y más bajas en mayo (el último mes de la gestación). Las cabras que no abortaron hicieron menos uso de alimentos fibrosos (a través de los meses NDF= 575 ± 43 g kg^{-1} DM) que las cabras abortadas. Los niveles de ceniza, macro y microelementos de la dieta no fueron diferentes entre los grupos de animales. Los minerales de los forrajes seleccionados por las cabras fueron suficientes para satisfacer las demandas de la preñez. Las cabras que mantuvieron su gestación no seleccionaron forrajes bajos en taninos (1.5 ± 0.2 *vs* 1.6 ± 0.3 g 100 g^{-1} DM) o alcaloides (1.1 ± 0.6 *vs* 1.1 ± 0.5 g kg^{-1} DM) comparadas con las cabras que abortaron. Se concluyó que en las condiciones del presente estudio, las cabras abortadas no son capaces de seleccionar forraje o partes de plantas con alto valor nutritivo para maximizar la ingestión de nutrientes. Lo anterior implica que las cabras que no abortaron tienen mayor habilidad para pastorear selectivamente y una mayor capacidad para buscar partes de las plantas con alto contenido de nutrientes que las cabras que no llevaron a término su gestación.

Palabras clave: Aborto, macrominerales, microminerales, gestación, metabolitos secundarios.

Abstract

Food habits of pregnant goats or aborted and multiparous goats or under 2 months held in rangeland

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Two studies were conducted to **1)** describe the feeding habits of adult goats and kids about a month old in rangeland and **2)** determine differences in the nutrient content of the diets of goats kept their pregnancy and aborted in poor condition rangeland forage.

Study 1. The objectives of this study were to determine the effects of age of goats (six-week-old, 7.2 ± 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 a degraded rangeland. Two groups of goats, 10 juvenile and 10 pluriparous from a commercial goat operation under extensive conditions were used. Diet quality and dry matter intake (DMI) 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 ($P < 0.05$, 28 g kg^{-1} BW ± 8 SD) than young goat kids (23 g kg^{-1} BW ± 8 SD) across grazing seasons, but diet samples for in situ dry matter digestibility (DMD) were greater ($P < 0.05$) for young than mature goats (67.2 ± 4.2% vs. 60.7± 4.2, respectively) across seasons. Ash (100 ± 16 g kg^{-1} DM), phosphorus (1.40 ± 0.41 vs. 1.06 ± 0.36 % DM) and crude protein (CP, 95 ± 4 vs. 89 ± 5 g kg^{-1} DM) content were greater ($P < 0.05$) in diets selected by young compared to mature goats. On the other hand, across grazing seasons herbage selected by young goats had lower ($P < 0.05$) concentration of NDF and ADF than mature goats. In conclusion, both age and season affected diet quality of goats on rangeland, as young goats ingested a diet richer in nutrients than 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.

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

Study 2. Nutrient content of diets selected by aborted and non-aborted crossbred Criollo goats on rangeland were studied during the last 4 month of gestation in the dry period. Dietary samples were obtained directly from the mouth of momentarily restrained goats during their grazing path on a highly degraded rangeland. A short light rope permanently tightened around their neck was used to immobilize goats to obtain the forage collected from the goat's mouth. Samples were used for chemical analyses. Across months, non-aborted goats selected diets higher (133 ± 17 vs. 119 ± 21 g kg^{-1} DM; P<0.01) in crude protein (CP) than aborted goats; this nutrient did not meet the requirements of late gestation in aborted goats. All diets were highest in CP during February (P<0.01) and lowest in May (last month of pregnancy). Non-aborted goats made use of less fibrous feeds (e.g. across months NDF= 575 ± 43 g kg^{-1} DM) than non-pregnant goats (599 ± 34 g kg^{-1} DM; P<0.01). Levels of ash, macro and microelements in the goat diets did not differ between groups of animals; minerals were adequate to meet the demands of pregnancy. Non-aborted goats did not seek forages lower in tannins (1.5 ± 0.2 vs. 1.6 ± 0.3 g 100 g^{-1} DM) or alkaloids (1.1 ± 0.6 vs. 1.1 ± 0.5 g kg^{-1} DM) compared with aborted goats. It was concluded that in this rangeland those goats not able to increase selection of forages or plant parts with high nutritional value to maximize nutrient ingestion aborted. This implies that non-aborted goats have a greater ability to selectively graze/browse and greater capacity to seek out parts of plants or patches of high nutrient content than aborted animals.

Keywords: abortion, macrominerals, microminerals, gestation, secondary metabolites.

Introducción.

En México la mayoría de las cabras son explotadas de manera extensiva. Generalmente las cabras utilizadas en los sistemas extensivos corresponden a genotipos mestizos (autóctonos x razas lecheras) adaptados a los factores limitantes y ecológicos de las zonas áridas de México. En condiciones de pastoreo en agostaderos, los rumiantes seleccionan su alimento con base en los requerimientos para maximizar su balance de energía, sin embargo, cuando la calidad de la vegetación es muy variable, suelen seleccionar nutrientes específicos o evitar toxinas (Bugalho and Milne, 2003; Verheyden-Tixier *et al*., 2008; Villalba *et al*., 2008). Los animales comen plantas nutritivas que contienen toxinas, pero generalmente limitan el consumo de acuerdo a la concentración de aleloquímicos, ya que las toxinas causan malestar que a su vez hace que los animales coman pequeñas cantidades de una variedad de plantas, para aumentar la amplitud de la dieta y así mitigar la toxicidad de ciertos forrajes (Provenza, 1995). Debido al pastoreo continuo y excesivo, la presencia de plantas forrajeras en los agostaderos ha ido disminuyendo, lo que ha provocado un deterioro en gran parte de los pastizales, sin embargo, la capacidad de adaptación de los caprinos en condiciones severas hace que estos animales sean ideales para la producción en áreas marginadas (Ramirez *et al*., 1990). Se ha comprobado en zonas desérticas que la dieta de las cabras no cubre los requerimientos de proteína para la preñez y lactación, y el fosforo y energía necesarios para su mantenimiento son deficientes, aún así la productividad de las cabras en esta zona es aceptable (Mellado *et al*., 1991; Mellado *et al*., 2004). Las cabras tienen mayor preferencia por el follaje de plantas leñosas, cuya cobertura y frecuencia de aparición en los agostaderos es abundante (México: Mellado *et al*., 2004a; España: Sánchez Rodríguez *et al*., 1993). En el desierto del norte de México, los caprinos muestran una marcada selectividad alimenticia, ya que consumen sólo un arbusto de la familia de las leguminosas y más del 65 % de las herbáceas en la época de lluvia, pero en la época de sequía, la baja disponibilidad en los forrajes preferidos conducen a una diversificación en el régimen alimenticio de los caprinos, lo que permite describir los grandes rasgos de las variaciones en la selectividad alimenticia de rumiantes en agostadero (Genin and Pijoan,1993).

Los diferentes estados fenológicos que suceden en forma simultánea en comunidades vegetales y el estado fisiológico de los pequeños rumiantes influyen en su comportamiento de pastoreo. Para las cabras en agostadero es de esperar que las hembras preñadas seleccionen forrajes con alto contenido de nutrientes y de mayor digestibilidad, ya que a medida que el feto aumenta la capacidad del rumen para dar cabida a más alimento disminuye, por lo tanto, durante la época de lluvia las cabras gestantes prefieren el uso de hierbas y pastos y disminuye el consumo de arbustos (Mellado *et al*., 2005). Por otra parte, cabras jóvenes seleccionan mayor proporción de especies con alto valor nutritivo en comparación con cabras adultas, aparentemente con la estrategia de optimizar la ingestión de nutrientes durante la época de humedad y de explotar su ambiente (Mellado *et al*; 2004b).

Las cabras han desarrollado mecanismos de comportamiento que les permite diferenciar forrajes del agostadero en función de su contenido de nutrientes para satisfacer sus necesidades de acuerdo al estado fisiológico (por ejemplo gestación; Mellado *et al*., 2011).

Aún se desconoce la influencia de otros estados fisiológicos de la cabra sobre la selección de su dieta en agostadero. Por ejemplo, no se tienen datos de la habilidad de pastoreo de cabritos de alrededor del mes de nacidos en agostaderos. Se desconoce también porqué algunas cabras, en condiciones de escaso forraje son capaces de llevar su gestación a término, mientras que una gran parte de las cabras abortan a sus crías. De acuerdo a lo anterior, el objetivo de este estudio fue describir los hábitos alimenticios de cabras adultas y de cabritos de alrededor de un mes de edad en agostadero. Otro objetivo fue determinar las diferencias en el contenido de nutrientes de las dietas de las cabras que sostienen su gestación y cabras que abortan en condiciones de escaso forraje en el agostadero del norte de México.

Objetivos:

Determinar los efectos de la edad y época del año (6 semanas de edad, 7.2 ± 0.7 kg vs adultas 46.9 ± 5.6 kg; lluvia vs seca, respectivamente) sobre la calidad de la dieta seleccionada por cabras criollas en el agostadero.

Describir las diferencias del contenido de nutrientes de la dieta de las cabras gestantes o que no mantienen su gestación en condiciones de escaso recurso forrajero de los agostaderos del norte de México.

Hipótesis:

Las cabras pequeñas tendrán mejores habilidades de pastoreo que las cabras adultas que les permitirá seleccionar una dieta más rica en nutrientes para su crecimiento y desarrollo.

Las cabras que logren mantener su gestación serán capaces de seleccionar una dieta más rica en nutrientes aún en condiciones extremas de escases de forraje.

Revisión de literatura

Pastoreo extensivo de cabras

En México, el pastoreo extensivo del ganado caprino se desarrolla básicamente en zonas áridas y semiáridas, donde la alimentación de estos animales depende principalmente de la vegetación en los agostaderos, así como de esquilmos de cultivos de riego y de temporal. En estas áreas, la producción forrajera varía de 300 a 400 kg/ha en los matorrales áridos y de 900 a 1,000 kg/ha en los pastizales de la región semiárida. La importancia ecológica y productiva de estas zonas radica en que sólo son aptas para la ganadería extensiva y el aprovechamiento de fauna silvestre (Echavarría Chairez *et al.,* 2006)

Como consecuencia de un manejo de pastoreo inadecuado por siglos, la presencia de plantas forrajeras en el agostadero ha ido disminuyendo, lo que ha provocado un deterioro en gran parte de los agostaderos en México, sin embargo, la capacidad de adaptación de los caprinos en condiciones de escasez de forraje hace que estos animales sean ideales para la producción de carne y leche en áreas marginadas (Ramírez *et al*., 1990).

Por lo tanto, se necesita un conocimiento profundo del comportamiento de alimentación y la selección de la dieta de éstos animales, para que la utilización de los recursos forrajeros y el impacto animal sobre la vegetación sea eficiente. En zonas áridas aún con poca abundancia de forrajes, las cabras eligen diversos tipos de plantas para complementar su dieta y esto tiene el inconveniente de ingerir gran cantidad de metabolitos secundarios tales como alcaloides, terpenos**,** glucósidos y taninos, pero la conducta exploratoria de estos animales les permite equilibrar la dieta para contrarrestar los efectos perjudiciales de estos compuestos tóxicos. Por ejemplo, se ha observado que en un matorral micrófilo desértico del norte de México las cabras tienen preferencia por las plantas leñosas cuando éstas existen en abundancia, aunque estas plantas contengan espinas o abundantes aleloquímicos (Mellado *et al.,* 1991, 2003, 2004a 2005c). En estas

mismas condiciones, la dieta de las cabras lactantes fue dominada por una mayor proporción de herbáceas y menor proporción de arbustivas comparadas con no lactantes (Mellado et al., 2005b), es de esperar que las necesidades de nutrientes para la lactancia aumenten, lo que explica el mayor consumo de herbáceas por las cabras lactantes, ya que esto se debe a que el contenido de nutrientes y paredes celulares más delgadas de las herbáceas es mayor comparadas con los pastos (Bodmer, 1990).

Los factores limitantes de la producción de las cabras en los sistemas de pastoreo son: la cantidad y calidad de la hierba disponible, la proporción de forraje que el animal ingiere y la eficiencia de la utilización digestiva de los nutrientes, de manera que, cuando la calidad de los forrajes disminuye, la máxima capacidad de ingestión no permite cubrir las necesidades nutritivas de los animales.

Se ha comprobado que el grado de predilección que un animal muestra por cualquier especie vegetal no necesariamente se repite ya que está en constante cambio debido a múltiples factores abióticos y bióticos que influyen sobre ella, siendo uno de los más importantes los diferentes eventos fenológicos que suceden de forma simultánea en comunidades vegetales de gran diversidad de especies dentro de un ecosistema, los que a su vez, influyen en el comportamiento selectivo del herbívoro (Franco-Guerra *et al*., 2008).

Por lo tanto, queda claro que el animal tiene que seleccionar de los alimentos disponibles una ración la cual le permita satisfacer sus necesidades de mantenimiento y producción de leche (Juárez-Reyes *et al.,* 2004, Mellado et al 2003) y, al mismo tiempo impedir la ingestión de sustancias tóxicas (Bugalho and Milne, 2003; Verheyden-Tixier *et al*., 2008; Villalba *et al*., 2008).

La amplia gama de especies consumidas por las cabras en agostaderos desérticos de México, parece ser una estrategia alimenticia para ajustar la dieta de acuerdo a sus necesidades nutricionales y por otro lado neutralizar el efecto negativo de los innumerables metabolitos secundarios que ingieren.

Por lo anterior, las cabras presentan un comportamiento alimentario oportunista ya que son altamente selectivas cuando la vegetación en el

agostadero es abundante y muy generalistas ante la escasez (Sánchez-Rodríguez *et al*., 1993).

Mecanismos de selección de la dieta

El proceso de selección de la dieta en pastoreo es mediante la búsqueda de comida por el animal minimizando lo desagradable hasta llegar al máximo de lo agradable buscando las plantas que aporten alimentos específicos que logren cubrir las necesidades nutricionales (Arnold *et al.*, 1978). Los animales seleccionan su dieta a partir de una amplia gama de alimentos potenciales, algunos de los cuales son apropiados, mientras que otros son nutricionalmente deficiente o incluso perjudiciales, así, los animales en pastoreo se adaptan a su medio ambiente desarrollando su capacidad para reconocer especies de plantas y mejorando sus habilidades de pastoreo mediante el aprendizaje y la memorización de la distribución de los recursos (Dumont y Petit, 1998).

Se cree que la mayoría de la información se transfiere a las crías jóvenes durante el destete (Thorhallsdottir *et al*., 1987), etapa que comprende una matriz de cambios nutricionales, morfológicos y fisiológicos (Martin, 1984) en los cuales, los cabritos aprenden sobre los alimentos de sus madres. Sin embargo, la preferencia de los alimentos se establece mediante un muestreo continuo en función de su valor nutricional. El proceso de aprendizaje a prueba y error (Provenza y Balph, 1987) parece ser el mecanismo dominante. La preferencia de determinadas especies o combinación de éstas por las cabras es el resultado del olfato gustativo heredado, pero sobre todo de su experiencia. De esta manera, los animales desarrollan preferencias por especies nutricionalmente beneficiosos, mientras que desarrollan aversiones a las especies con exceso de aleloquímicos y deficiencia de nutrientes, por lo tanto, los animales muestran mayor preferencia por las especies individuales conocidas que respondan a sus necesidades nutricionales, mientras que las especies nuevas en el agostadero se muestran

solo en pequeñas cantidades con el fin de evaluar su utilidad (Du Toit et al., 1991).

La experiencia dietética, particularmente en la edad temprana, modula el comportamiento de alimentación y selección de la dieta. Por ejemplo, en cabras, ovejas y vacas jóvenes, éstas pueden pastar hasta un 40% menos que los animales con experiencia en el mismo entorno (Provenza y Balph, 1987).

Los factores que determinan la preferencia están relacionados a las características de la comunidad vegetal, el estado fisiológico de los animales, los factores climáticos y el manejo que se realiza del ecosistema. En comparación con otros ungulados domésticos, las cabras son más flexibles en sus hábitos de alimentación adaptándose rápidamente a cambios estacionales. Por ejemplo, se ha observado que las cabras en lactación pueden amortiguar las variaciones estacionales de acuerdo a la composición de la vegetación disponible, ya que, al final de la estación, las cabras buscan especies de plantas relativamente bajas en proteínas y ricas en fibra, probablemente con la intención de seleccionar la vegetación para reducir la variación en la composición de la ingesta tanto como sea posible al inicio de las grandes variaciones estacionales de la composición vegetal (Baumont *et al.,* 2000). Las cabras tienen la capacidad de regular el consumo de alimento dependiendo de la disponibilidad, donde el conocimiento por parte de los animales del tiempo que permanecen bajo similares condiciones de alimentación produce un racionamiento y manejo del forraje tal que asegure la perpetuidad de las fuentes de alimento. Por esta razón, especies muy preferidas no son consumidas en su totalidad en una etapa inicial, sino que son intercaladas con otras especies menos preferidas que se encuentran en mayor abundancia (Ramírez *et al*., 1990).

En el desierto del norte de México, los caprinos muestran una marcada selectividad alimenticia, ya que consumen sólo un arbusto de la familia de las leguminosas y más del 65 % de las herbáceas en la época de lluvia, pero en la época de sequía, la baja disponibilidad en los forrajes preferidos conducen a una diversificación en el régimen alimenticio de los caprinos, lo que permite describir

los grandes rasgos de las variaciones en la selectividad alimenticia de rumiantes en agostadero (Genin and Pijoan,1993).

Por otra parte, en el desierto Sonorense donde las comunidades vegetales constituyen el 92 % de los arbustos, Ramírez-Orduña *et al.* (2008) reportaron un efecto de sustitución árboles y arbustos no leguminosos por cactáceas y árboles leguminosos durante el final de la primavera e inicio del verano en la dieta de cabras, no obstante, Ramírez *et al.* (1990) reportaron que las dietas de cabras estuvieron compuestas por 81 % de arbustos, 12.3 % de hierbas y tan solo un 6.7 % de pastos en el noreste de México. Silanikove (2000) revisó resultados de estrategias de pastoreo de arbustos por cabras indicando que los arbustos constituyen al menos 50 % del forraje seleccionado por las cabras como una forma de preservar su adaptación a alimentos ricos en taninos, el cual se encuentra disponible en grandes cantidades a lo largo del año.

Comportamiento selectivo y estado fisiológico

El comportamiento del hato a lo largo del día depende fundamentalmente de la actividad del pastoreo y ésta, de las características de la vegetación presente en el medio ambiente, es así que cuanto más heterogénea sea la vegetación, se vuelve más compleja y con mayores variantes el comportamiento asumido por las cabras.

Por ejemplo, se ha demostrado (Papachristou y Nastis 1993) que las cabras muestran cambios muy rápidos entre arbustos, pastos y herbáceas, dependiendo de su disponibilidad y su valor nutritivo estacional. Por lo que en ciertas épocas del año, las cabras consumen altas proporciones de arbustos, para luego incluir en sus dietas básicamente herbáceas. Los pastos siempre son consumidos en bajas proporciones (López-Trujillo and García-Elizondo, 1995; Mellado *et al*., 2004a, 2004c, 2005a). En el desierto del norte de México, durante la estación seca las cabras preñadas seleccionan plantas con altos niveles de Proteína Cruda (PC) comparadas con las cabras sin preñar (14.5 vs 12.8%

respectivamente, Mellado eta al., 2011), además independientemente del estado fisiológico, estos grupos de cabras superaron los valores de PC comparados con otros estudios en el mismas condiciones de forrajes (Juárez-Reyes *et al.,* 2004), lo que demuestra que aún con poca disponibilidad de forraje, las cabras logran seleccionar las partes más nutritivas de las plantas con el fin de maximizar la ingesta de proteínas.

El consumo de materia seca de las cabras en agostadero varía de 58.6 (verano) a 91.7 g $kg^{0.75}$ (invierno; Cerrillo et al., 2005), lo cual les permite ingerir suficientes nutrientes para el mantenimiento de la gestación (Juárez-Reyes *et al.,* 2004). Es probable que hembras preñadas seleccionen forrajes con alto contenido de nutrientes y mayor digestibilidad a fin de llevar a término su gestación, ya que a medida que el feto aumenta, la capacidad del rumen se ve disminuida, por lo que las cabras gestantes prefieren el uso de herbáceas y pastos, y disminuye el consumo de arbustos durante la época de lluvia (Mellado *et al*., 2005b) comparadas con cabras no preñadas. En este estudio antes mencionado, las herbáceas estaban en su última fase de crecimiento vegetativo (al final de la estación de lluvias) lo cual indica que este grupo de forrajes tenían mayor contenido de nutrientes y paredes celulares más delgadas con altos compuestos digestibles comparados con los pastos (Bodmer, 1990). Además, las herbáceas del Desierto Chihuahuense exceden los requerimientos nutricionales de los ungulados (Soltero-Gardea *et al*., 1994). Una de las herbáceas que más utilizan las cabras en los agostaderos del norte de México es *Sphaeralcea angustifolia*, una herbácea que llega a constituir un tercio de la dieta de las cabras (Mellado *et al.*, 2004e).

Las cabras en lactación, presentan este mismo patrón de comportamiento alimenticio al seleccionar mayor proporción de herbáceas y menor consumo de arbustos comparadas con las cabras no lactantes (Mellado *et al.,* 2005b). A pesar de que el tiempo de pastoreo en zonas áridas no sobre pasa las 7 horas diarias, las cabras en lactación deben ser habilidosas para cosechar su alimento de manera que ajusten la dieta necesaria para la lactancia en el mismo periodo de

tiempo que las no lactantes. De esta manera, estos animales parecen mostrar una estrategia alimentaria al sacrificar la velocidad de consumo por calidad de la dieta en estados de mayor demanda de nutrientes (por ejemplo: lactancia y preñez; Mellado *et al*., 2005b). En el caso de hembras preñadas, los requerimientos energéticos se presentan al final de la gestación, etapa en la que las cabras seleccionan los forrajes con menor contenido de carbohidratos estructurales (Mellado *et al.,* 2005b y 2011), ya que éstos se han relacionado negativamente con la digestibilidad (Jung y Vogel, 1986), lo anterior es importante para el esfuerzo reproductivo, porque el consumo de forraje con altos niveles de fibra conduciría a mayores periodos de retención de forraje en el rumen, lo cual reduciría el consumo de alimento de las cabras (Bhatti *et al.,* 2008). Por lo tanto, queda claro que uno de los comportamientos de pastoreo de las cabras gestantes es el evitar plantas con alto contenido de pared celular, con el objetivo de satisfacer los ascendentes requerimientos de nutrientes al final de la gestación.

La gran demanda de Calcio para la formación del esqueleto de los fetos y la secreción de calostro al final de la gestación obliga a las cabras preñadas a ser más selectivas en su dieta, así lo indican datos de Mellado *et al* (2011), donde las cabras gestantes consumieron una dieta con niveles más altos de calcio y potasio comparadas con las cabras no gestantes, ya que el requerimiento de calcio se incrementa al final de la gestación debido al rápido crecimiento fetal (Abdelrahman, 2008). Esta estrategia de alimentación probablemente tiene el propósito de reemplazar las reservas óseas de calcio de la gestación temprana, con el fin de tener suficiente reservas y soportar la reabsorción en el hueso, y debido a la demanda de calcio para la síntesis de leche durante el parto y las primeras semanas de lactancia (Liesegang y Risteli, 2005).

Contrario a lo que se supone, en el sentido de que las cabras gestantes evitarían el consumo de plantas con altos niveles de metabolitos secundarios, por ser dañinos a sus fetos, las cabras gestantes no discriminan las plantas por las fitotoxinas que estas poseen (Mellado *et al.,* 2011).

El estado de crecimiento de las cabras también tiene un efecto marcado sobre sus hábitos alimenticios. En un pastoreo de escasa cobertura de gramíneas y predominio de ramoneo, las cabras jóvenes tienden a explorar su ambiente y seleccionan especies con alto valor nutritivo durante la época de lluvias, haciendo uso en mayor proporción de herbáceas (37.3 vs 28.5) comparada con hembras adultas, aparentemente con la estrategia de optimizar la ingesta de nutrientes y hacer frente a las variaciones estacionales, además las cabras jóvenes consumen una mayor cantidad de *Solanum elaeagnifolium* (14.3 vs 9.2) en comparación con hembras adultas (Mellado et al., 2004b), una herbácea que contiene altos niveles de alcaloides (Pfister *et al.,* 2001), y que a pesar de su toxicidad, las cabras la consumen ávidamente y llega a constituir la mayor parte de la dieta en ciertas épocas del año (Mellado *et al.,* 2003, 2004e). Lo anterior indica que las cabras poseen la capacidad de neutralizar una gran cantidad de fitotoxinas de las plantas en los agostaderos del desierto Chihuahuense.

Habilidades de pastoreo de la cabra

Las cabras presentan amplias diferencias en su capacidad adaptativa para cosechar su alimento en ecosistemas de extrema escasez de forraje, lo que conlleva a explorar la gran diversidad de plantas en agostaderos, de manera que el forraje seleccionado por el animal cumpla con las necesidades fisiológicas y las características morfológicas.

Por ejemplo, en el Norte de México en época de lluvias donde las arbustivas son la principal fuente de forraje disponible de esta comunidad vegetal, las cabras de mayor talla tienen acceso a este forraje. Por lo que cabras con > 77 cm de altura de la cruz incluyen en su dieta 71 % de arbustivas en comparación con 63 % de las cabras de < 71 cm, además las cabras con circunferencia abdominal menor (<92 cm) tienden a seleccionar más gramíneas comparadas con cabras de mayor (>101cm) circunferencia (Mellado *et al.,* 2004d). Estos datos muestran las ventajas del tamaño corporal para seleccionar el forraje presente en

el agostadero y hacer uso de alimentos menos preferidos por las cabras de circunferencia menor.

Dado que las cabras sólo utilizan las puntas de las agaváceas, las cabras de altura reducida consumen mayor cantidad de *Agave lechuguilla*, mientras que las más altas prefieren el *Agave striata*, un agave más alto que el primero (Mellado *et al.,* 2004d).

No obstante, cabras jóvenes evitan el consumo de *Agave lechuguilla* mientras que las cabras adultas hacen uso moderado de este arbusto. Las cabras solo consumen el tejido menos fibroso de esta planta, localizado debajo de la espina terminal, por lo que las cabras con poca experiencia lo desconocen (Mellado *et al.,* 2004b). Además, las cabras adultas muestran mayor consumo de plantas con espinas que las jóvenes, lo que sugiere que éstas son más sensibles a los atributos físicos anti-calidad de las plantas del desierto que las cabras adultas. Otro arbusto de importancia en el desierto del norte de México es *Larrea tridentatea*, consumido en pequeñas proporciones por cabras adultas en temporada de lluvia, sin embargo en temporada de sequía conforme va disminuyendo la cobertura vegetal, está planta fue consumida en mayor proporción por cabras adultas comparada con cabras jóvenes (9.2 *vs* 4.5, respectivamente), aparentemente con la estrategia de optimizar la ingestión de nutrientes durante la época de humedad (Mellado *et al* 2004b). La diferencia en la selección de la dieta entre las cabras jóvenes y adultas, puede estar relacionado con las habilidades de pastoreo de las cabras adultas, ya que éstas tienen mayor alcance, fuerza y destreza física, que les permite seleccionar las especies deseadas.

Cada cabra nace con una disposición distinta para la cosecha de su alimento, para su desplazamiento en el agostadero y para discernir entre las plantas que tiene a su disposición en el agostadero. Así las cabras con alta adaptación a las zonas áridas, como es el caso de las granadinas, consumen básicamente arbustivas, ignorando las gramíneas, en comparación con las nubias (Mellado *et al*., 2004c). Más importante aún, es el hecho de que las cabras

granadinas utilizan muchas arbustivas altamente impalatables para los herbívoros, como es el caso de *Larrrea Tridentata,* lo que indica que las cabras granadinas tienen una mayor tolerancia a los metabolitos secundarios de esta planta del agostadero. (Mellado *et al*., 2004c).

Las cabras poseen un labio superior muy movible que unido a su capacidad de elevarse paradas sobre sus patas traseras hacen que estos animales logren cosechar su alimentos en tipos de escasa y diversa vegetación.

La estructura de la mandíbula y la cavidad oral, tienen también una marcada influencia sobre la selección de la dieta de las cabras. Por ejemplo, las cabras con dientes más largos prefieren el uso de arbustos poco suaves, como *S. Leucopila* (Mellado *et al*, 2007) una especie con amplia resistencia estructural, lo que corrobora que la integridad de los incisivos constituye un mecanismo eficiente que desempeña un papel importante para cortar las plantas, es por eso que las cabras con dientes desgastados evitan consumir este tipo de forrajes (Mellado *et al*, 2005a). Por otro lado, las cabras con mandíbula corta seleccionan una mayor proporción de arbustos de hoja pequeña, como *A. Triplex canecens y Flourencia cernua,* que las cabras con mandíbulas más largas (Mellado *et al*., 2007), además los animales con mandíbulas cortas mastican más rápido que las cabras con mandíbulas largas (Perez-Barbería and Gordon, 1998), lo que les permite tener un mayor consumo de forraje (Druzinky, 1993).

Palatabilidad de los forrajes en agostadero.

La palatabilidad resulta de la interacción de varios componentes (sabor, olor y textura) y esta característica determina la aceptabilidad de las plantas por los herbívoros, por lo tanto, las propiedades sensoriales estimulan el comportamiento hedónico del alimento.

Existen diferentes definiciones que describen el término de palatabilidad. Forbes (1986) afirma que la palatabilidad no puede considerarse únicamente como la calidad del alimento, si no que ésta, depende de la experiencia y el

estado metabólico del animal en cuestión, así pues, la palatabilidad de un alimento no es absoluto y depende del grado de saciedad del animal.

En un estudio realizado con ovejas, el consumo total fue de sólo 0.4 kg/día cuando consumían paja y recibían pasto en el rumen, pero aumentó a 0.9 kg/día en la situación inversa, aunque la digestibilidad de la dieta total fue similar (Greenhalgh y Reid, 1971). Las sensaciones desagradables previamente de cuando consumían paja pueden explicar su bajo valor hedónico. Así mismo, el comportamiento hedónico puede explicar el alto consumo voluntario del exceso de requerimientos en borregos castrados alimentados con forrajes de buena calidad (Baumont *et al*., 1997). La motivación sensorial inducida por una segunda distribución de heno fresco anulará las señales de saciedad asociadas con la primera distribución (Baumont *et al*., 1990). Sin embargo, el tamaño de la segunda ración depende de la calidad relativa de los dos henos distribuidos (Fig. 1). Además, los animales utilizan sus sentidos para aprender a asociar los efectos postingestivos del alimento con las características sensoriales, ya que se ha demostrado que, después de 10 días de adaptación, los borregos muestran una fuerte preferencia por sabores no nutritivos asociados con glucosa comparados con los mismos sabores asociados con sacarina (Burrit y Provenza, 1992), lo que indica que los rumiantes, como otros mamíferos, desarrollan preferencias por los alimentos que proporcionan mayor energía (Provenza, 1995). Para el caso de cabras en agostadero, las características físicas del forraje tales como la altura, las espinas y la resistencia a la fractura entre otras, tienen una marcada influencia en la selectividad de los animales, ya que las cabras utilizan el sentido del tacto para consumir o evitar ciertos tipos de plantas. Generalmente los rumiantes desarrollan preferencias por alimentos que proporcionan un alto nivel de saciedad rápidamente, así los alimentos que son altamente digestibles son muy aceptables. Sin embargo, a largo plazo (varios días o semanas), la preferencia de un alimento determinado parece estar relacionado generalmente a modificaciones digestivas (Baumont, 1996; Fig 2). Las cabras en pastoreo consumen una amplia variedad de plantas y algunas de ellas contienen fitotoxinas que causan malestar, lo que

provoca que coman pequeñas cantidades de estas plantas para aumentar la ingesta de otras y así poder contrarrestar la toxicidad de ciertos forrajes (Provenza, 1995). Sin embargo, la escasez de forraje obliga a las cabras a aumentar el consumo de ciertas especies, como es el caso de *Solanum elaeagnifolium* (Mellado *et al*., 2005) que contiene el alcaloide tropano solanina y un alcaloide esteroidal que afecta el sistema nervioso (Buck *et al*., 1960). A pesar de la toxicidad de esta planta, las cabras la consumen ávidamente y llega constituir la mayor parte de la dieta en ciertas épocas del año (Mellado *et al*., 2003), lo que hace suponer que éstos animales logran contrarrestar los efectos negativos de esta planta.

Los mecanismos del cerebro pueden inducir el comportamiento hedónico del alimento donde intervienen factores fisiológicos controlando la ingesta. Por ejemplo, el consumo o rechazo de un determinado alimento en las cabras, puede ser explicado por este comportamiento, incluso cuando esta selectividad les impide satisfacer sus necesidades energéticas (Morand-Fehr *et al*., 1991), como en el caso de ciertas plantas con poco valor forrajero que en determinadas circunstancias son altamente consumidas por las cabras (*Agave lechuguilla* /Mellado *et al.,* 1991; *Opuntia spp* /Mellado *et al*., 2011; y *Larrea tridentata* /Mellado *et al*., 2004), tal parece que las cabras logran conciliar entre calidad y cantidad de forraje seleccionado, para terminar con una dieta de calidad intermedia, con el objeto de maximizar la tasa de asimilación de nutrientes.

El siguiente diagrama resume la principal relación entre las características del forraje, control de consumo a corto plazo, comportamiento de alimentación y finalmente la ingesta de forraje en rumiantes.

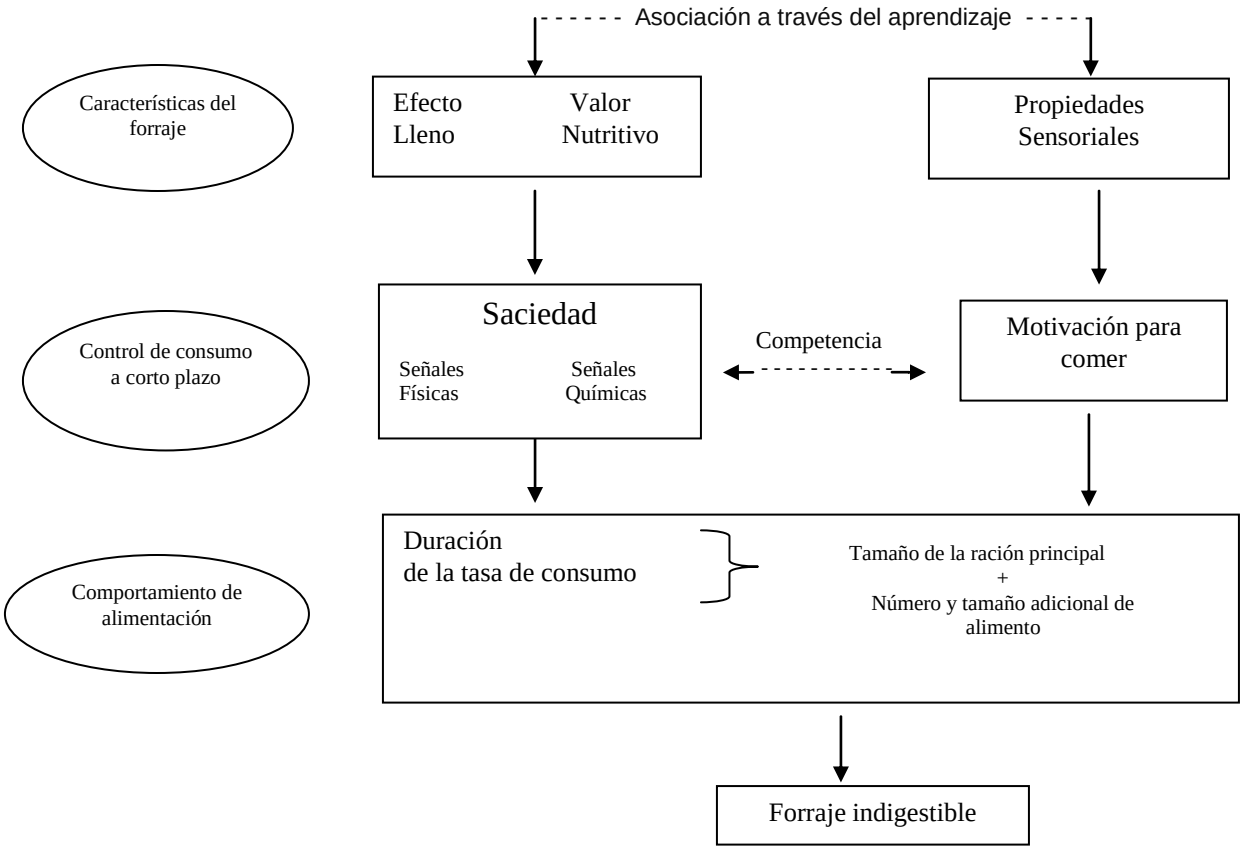

Fig 1. Relación entre las características, control de consumo a corto plazo, comportamiento de alimentación y la digestibilidad del forraje (Baumont *et al*, 2000).

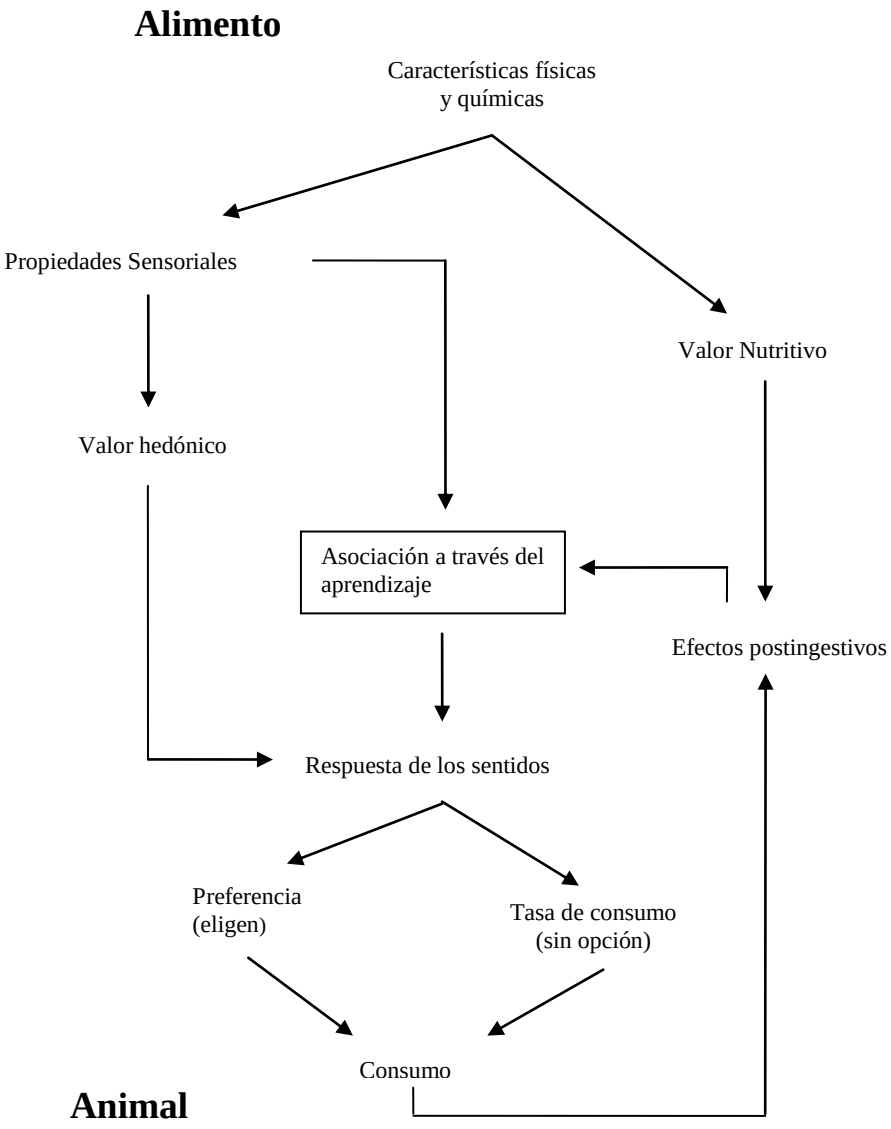

Fig 2. Respuesta de los sentidos con las características de los alimentos. Las propiedades sensoriales influyen en el comportamiento hedónico y son asociados con el valor nutritivo después del aprendizaje. La palatabilidad medida como respuesta de los sentidos integra ambos aspectos (Baumont, 1996).

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

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Running title: Diet quality of goat kids on rangeland

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Implications

Six-week-old goat kids on rangeland rapidly become experienced grazers, because nutrient content and digestibility of the herbage selected is greater in goat kids than mature goats. Young goat kids also select a more energy-dense diet (low fibre content) than mature goats. However feed intake is limited apparently by the reduced capacity of their digestive system, low body mass and diminute muzzle. Protein content of spring and winter diets were inadequate for maximum growth rate of preweaning goat kids in a depleted rangeland, but milk ingestion from their mothers may complement their protein requirement. Criollo crossbred goat kids proved to have the grazing/brawsing capacity to utilize forage resources of the Chiuahuan desert rangeland, although dry conditions hinders dry matter intakes and potentially growth rates.

Abstract

The objectives of this study were to determine the effects of age of goats (six-week-old, 7.2 ± 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 a degraded rangeland. Two groups of goats, 10 juvenile and 10 pluriparous from a commercial goat operation under extensive conditions were used. Diet quality and dry matter intake (DMI) 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 ($P < 0.05$, 28 g kg^{-1} BW ± 8 SD) than young goat kids (23 g kg^{-1} BW ± 8 SD) across grazing seasons, but diet samples for in situ dry matter digestibility (DMD) were greater ($P < 0.05$) for young than mature goats (67.2 ± 4.2% vs. 60.7± 4.2, respectively) across seasons. Ash (100 ± 16 g kg^{-1} DM), phosphorus (1.40 ± 0.41 vs. 1.06 ± 0.36 % DM) and crude protein (CP, 95 ± 4 vs. 89 ± 5 g kg^{-1} DM) content were greater ($P < 0.05$) in diets selected by young compared to mature goats. On the other hand, across grazing seasons herbage selected by young

goats had lower ($P < 0.05$) concentration of NDF and ADF than mature goats. In conclusion, both age and season affected diet quality of goats on rangeland, as young goats ingested a diet richer in nutrients than 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.
Keywords: foraging, herbivore, feed intake, forage selection, diet quality, body size.

1. Introduction

Most goats in the arid and semi arid ecosystems of northern Mexico are kept in harsh and resource poor environments. A common practice in these pastoral systems is to keep the goat kids indoor during the first days of life, because they are unable to keep pace with mature goats while grazing (about five km journey away from the pen). After about four weeks of age female goat kids (males remain indoor until about 40 d of age when they are slaughtered) are moved to the rangeland to graze/browse together with the mature animals, in order for the kids to complement their milk diet. This practice prevents diseases that thrive in damp unroofed corrals, encourage physical activity and allow the 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 metabolize toxins, lower gut capacity and reduced capacity of mobilization while grazing, probably young goat kids are not fully capable of effectively utilize the different forage species and vegetation types. This is so because in young ungulates the social influences of maternal and peer example are important contributors to the shaping of an animal's dietary selection (Thorhallsdottir *et al*., 1990) and foraging skills improve with age (Flores *et al*., 1989). An animal is born with a set of behavioral patterns, which affect behavioral decisions (Launchbaugh and Howery, 2005), but as goats mature, their

experiences drive modifications to these behavioral patterns, from environmental factors and the influence of parents and conspecifics (Searle *et al*., 2010). Therefore, feeding behavior is shaped from a complex and permanent interaction between the genotype and environmental conditions. On the other hand, early in life goat kids possibly can discern between a variety of forages because compounds and flavors of herbage ingested by their mothers are transferred to the fetus through the blood reaching the placenta (Wiedmeier *et al*., 2012) and throughout the milk (Babcock, 1983). Given that ungulate herbivores select nutrients in amounts to meet their needs (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 in a landscape with scarce and patchy natural resources. In the arid zones of northern Mexico goat kids normally are born early in the growing season when vegetation 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 (Juarez-Reyes *et al*., 2004) has 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 utilize the forage resources of rangelands. Therefore, this study was conducted to test the hypothesis that preweaning goat kids display a good foraging behaviour in a rangeland with scares and patchy resources with vegetation in different phenological phases, but constraints due to body mass (i.e. metabolism and digestive constraints, size of the feeding apparatus) lead to variations in grazing patterns.

2. Material and methods

2.1. Study site

The study was conducted in a rural community of northeast Mexico (101° 59' W, 25° 23'N). Mean annual rainfall (322 mm) is erratically distributed throughout the year, although summer and autumn rainfall is higher and more reliable. Most of the area's precipitation falls during high-intensity thunderstorms during the growing season (June to October). Average maximum daily temperatures range from 28° C in January to 37.2° C in July. Average minimum daily temperatures range from -7° C in January to 12.3° C in July. The topography of the grazing area is relatively flat. The most commonly encountered shrub species were *Acacia farnesiana* (L.) Willd, *Acacia greggii* Gray, and *Dalea bicolor*. The principal perennial grasses were Bouteloua curtipendula (Mich.) Torr. and *Aristida arizonica* Vasey. The most abundant forb species were *Sphaeralcea angustifolia* (Cav.) D. Don., *Tiquilia canescens* (DC.) A. Rich. and *Solanum elaeagnifolium* Cav. Mean above-ground standing crop at the beginning of the study was about 2100 kg ha^{-1}. Shrubs, forbs and grasses constituted 71%, 19% and 10% of total standing crop, respectively (Mellado *et al*., 2005).

2.2. Animals and management

This research adheres to the Guidelines of the Autonomous Agrarian University Antonio Narrow for the use of animals in research. A commercial flock of approximately 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) during the rainy season.

Goats were penned in an unroofed corral adjacent to the household at night without access to water. 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. To evaluate the effect of animal age, ten pluriparous non-pregnant goats (46.9 ± 5.6 kg; x□ and SD) and ten 6-week-old female goat kids (7.2 ± 0.7 kg; x□ and SD) were selected for the study. During the dry period both mature and kids were not the same than those used during the rainy season. Goats grazed on open range, driven by a herdsman, during 7 h day^{-1} (1100 to 1800 h),

2.3. Feed and feces sample collection

Goats included in the study were fitted with a short plastic rope (1.5 m in Length 0.5 cm in diameter) tightened around their neck. A bowline knot was used in order to avoid tightening around the goat's neck. This light 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 forage from their oral cavity. Plants selected by goats were obtained from the goat's mouth, by separating the mandibles of goats by hand, immediately after feeding bouts. Given that goats rapidly learned to swallow their feed as soon as they felt restrained, some feed samples were collected from the esophagus. This operation was repeated approximately every 5 min during a 3-h period, using one person per goat. Collections were made during the morning grazing when goats were grazing most intensely after 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 use these samples 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 d to adapt to them followed by total collection of feces for four consecutive days. Fecal-collection bags were emptied twice daily. The daily fecal output of each sheep was weighed and recorded. About 5% of fresh feces for each animal

was 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-d fecal output.

2.4. Analytical procedures and other measurements

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

Forages collected during a 4-day period were pooled and these samples were oven-dried and then ground to pass through a 1-mm-mesh sieve. Dry matter (DM) 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 (EE) was analyzed 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 x 6.25; AOAC, 1996).

Fibre fractions – neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) 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 analyzer. Cellulose was calculated as ADF–ADL.

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 colorimetry (AOAC, 1996). All analyses were performed in triplicate.

The disappearance of DM from nylon bags (7 x 15 cm; 40-mm pore size, three bags per sample) was determined as described by Orskov *et al.* (1980). Three grams 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 streer fed oat hay. The disappearance of dry matter (dry weight difference between bags before and after incubation) was expressed as

percentage. Dry matter intake (DMI) was calculated as follows: DMI= DM fecal production/ (1- diet DM digestibility) (Handl and Rittenhouse, 1975).

2.5. Statistical analysis

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

The statistical model used was $Y_{ijk} = \mu + A_i + S_j + (GS)_{ij} + e_{ijk}$, 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), Sj= season effect (j=1,2) $(GS)_{ij}$ =age by 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 (HSD) *post hoc* test comparing age categories within grazing season. Data on feed intake are presented as g day^{-1}, percentage of body weight or as g $kg^{-0.75}$ day^{-1} for comparison with other studies. Animal was considered a random effect. Significance was declared at $P < 0.05$.

3. Results

The chemical composition, dry matter intake and digestibility of herbage selected by goats are presented in Table 1. Across seasons forage selected by goat kids had greater (age x season; $P < 0.05$) concentrations of ash than pluriparous goats, but ash content of herbage ingested by goats did not differ between grazing seasons. Crude protein content of forages selected by young goat kids was greater than mature goats (age x season; $P < 0.05$). This nutrient was higher in forages harvested by goats in the rainy season compared with the dry season. Protein content of spring and winter diets were inadequate for maintenance of maximum growth rate in this depleted rangeland.

Juvenile goats showed a greater ability ($P < 0.05$) to select forages with higher digestibility than mature goats. Digestibility of forage selected by goats was much lower ($P<0.05$) in the dry season compared with the rainy season. DMI (g kg^{-1} BW) was greater in mature ($P < 0.05$) than young goats across grazing seasons, with a marked decrease in food intake during the dry season.

The data in Table 2 indicate that across grazing seasons both NDF and ADF were lower ($P < 0.01$) in diets selected by young goat kids than mature goats. Forages selected by goats in the rainy season were lower in cell wall components than those consumed by goats in the dry season. Across grazing seasons young goat kids selected forages richer ($P < 0.01$) in phosphorus (Table 3) than mature goats. Levels of this mineral did not differ in herbage consumed by goats in both grazing seasons. Levels of potassium, copper and zinc in forages selected by goats (irrespective of age) were greater ($P < 0.01$) in the rainy season than the dry season (Table 4). Concentration of these minerals was adequate to satisfy the **needs** of growing goats.

4. Discussion

The total mineral content of goat kids diet was higher than that of mature goat diets. The ash levels in forages selected by goats were similar to that found in goat's diet in this landscape (Mellado *et al.*, 2011). Goats are able to graze close to ground level and pick up soil particles. In the present study dietary samples destined for mineral analysis were thoroughly rinsed with distilled water immediately after collection, therefore the ash values reported are free of contamination from saliva or soil. Given that in the arid areas of northern Mexico goats depend solely on forages resources from the rangeland for their mineral requirements, probably juvenile goats selected higher dietary mineral levels to improved mineral balance and skeletal growth. 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).

Although forage quality decreases during the dry season, goat kid diets were

higher in CP than mature goats during this season. Considering the DMI of young goats in the current study, 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. These results indicate that provided a suboptimum forage quality, young goat kids could no grow adequately on forage alone, requiring additional nutrients from their mother's milk. The CP levels in the rainy and dry season seemed to be adequate for nonpregnant and nonlactating mature goats.

Crude protein content of herbage harvested by goats in the current study was much lower than levels found in goat's diet in this type of vegetation (Juarez-Reyes *et al.,* 2004; Mellado *et al.*, 2011). This discrepancy was probably due the degraded condition of the rangeland grazed by these 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 diet provided by their mothers. It is worth mentioning that even though protein availability to goats was at its lowest point during dry season, goat kids maintained a level of protein very close to that encounter in the rainy season, which indicates that accelerated growth apparently forced goat kids to diversified their diet and select from a range of different crude protein levels to obtain a mixture of feeds that approached their crude protein requirement for construction of body tissues (Villalba *et al.*, 2002; Mellado *et al.* 2004). The absence of any great reduction in dietary CP as plants matured and moved into dormancy may be accounted for by the fact that a large proportion of the food ingested by juvenile goats comes from woody plants (Mellado *et al.*, 2004) with a high CP content (Pinos-Rodriguez *et al.*, 2007) as well as forbs, which maintain a high protein content (Frost *et al.*, 2008).

Goat kids were observed to select a diet higher in DMD than that selected by mature goats in both grazing seasons. The higher disappearance of the juvenile goat's diet is typical of nongrass plant species; these usually constitute about 95% of growing goat diets (Mellado *et al.*, 2004). Forb and shrub leaves have much more rapid rates of digestion than grasses (McCollum and Galyean, 1985), due to their lower cell wall content (Frost *et al.*, 2008) and higher crude protein concentrations and low fibre levels compared to grasses (Hanley, 1982).

Note that despite a difference of 7 percentage points in DMD (across grazing seasons) in forage selected by young goat kids, feed intake estimates were lower in growing goats compared to 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. This 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 species, but also smaller absolute gut sizes and necessarily faster rates of food passage (Illius and Gordon, 1992). The selection of more digestible forage by growing goats underline the importance of herbage with low cell wall as a major currency for foraging decisions in these animals.

Estimated voluntary feed intake (g kg^{-1} BW dry matter basis) was lower in juvenile than mature goats for both grazing periods. Young goat kids were just 15% of the mature, non-reproductive female's body mass and they ingested 13% as much DM (g day^{-1}) forage as did the mature goats, although young goat kids ingested some milk from their mothers. On an allometric basis (i.e. per $kg^{-0.75}$), DMI by mature females was 1.8–times that by young goat kids. Forage intake was seemingly regulated more by quantity than quality of available forage, because fecal output was higher in the rainy season indicating that goats were not eating to a constant fill of indigestible forage. If herbage availability had not restricted feed intake, fecal output would not have been depressed.

It was clear that in 6-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 is fluctuations in forage availability feed intake is maintained by altering the grazing time, the bites per minute and the amount of feed ingested per minute. In the first case all goats spent the same time grazing due to a preestablished grazing period of the flock. Six-week-old goat kids present a much lower chewing time (Hooper and Welch, 1983) and rumen development (Abou-Ward, 2008) than older kids, which apparently lead to a lower eating efficiency compared to mature goats.

An additional factor probably limiting forage intake of young 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 (Juarez-Reyes *et al.*, 2004).

Lower values for NFD and ADF were found in diets selected by juvenile goats than mature goats. NDF is the least digestible fraction of forage nutrients and therefore NDF is negatively correlated with forage digestibility and intake. This observation highlight the ability of young goat kids to select diets favoring 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 to mature goats suggests that these animals used young succulent vegetation available during summer growing period as well as during the dry season. Mellado *et al.* (2004) observed that forbs provide up to 37% of the young goat diet during the rainy season and 12%when conditions dried out. Dietary NDF and ADF declined as time progressed from the rainy to the dry season.

Changes in dietary ADF were primarily due to lignin levels, apparently contributed by the maturing shrubs and lignified forb components of the diets.

During the rainy and dry season mean P content of diets selected by young goat kids was greater than that found in diets of mature goats. Changes in availability of forage and associated dietary shifts did not induced 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), which indicate that young goats showed a selective tendency toward a more P-rich diet, probably to enhance bone and teeth mineralization.

Given that distribution of P within a plant is relatively uniform (Suttle, 2010), goat kids probably did not select particular parts of a plant in the search for P, rather focused on more phosphorus-rich plants. Selection of forages with high content of P has been documented. Grazing animals prefer phosphorus-fertilized pasture when given a choice (Jones and Betteridge, 1994) or select forage components that are richer in phosphorus than the whole sward (Engels, 1981).

Young goat kid diets showed higher increases in Cu and Zn content compared to mature goats during the dry season. Given that leaves contain 35% higher Cu concentrations than stems in forages (Minson, 1990) it seems that young goats consumed a large 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 other study in a drier area of northern Mexico (Ramirez-Orduña *et al*., 2006). These results are not in line with the view that young herbivore are most sensitive to learning around the time of weaning (Provenza and Balph, 1987) and that the reliance on available forage increasing the influence from other conspecifics (Provenza and Burrit, 1991). Young goat kids in this study showed good foraging skills with a total independence from their mothers while grazing.

Conclusion

Goat kids in this 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.

Narrow muzzles, small body mass, agility to move around and to knee to reach plants hidden beneath thorny plants enabled young goat kids to be very selective feeders, allowing them to harvest only the highest quality forage or parts of plants from that on offer. However, small mouths and not fully developed reticulum-rumen presumably also restricted young goat kids to taking large bites, thereby achieving low rates of dry matter intake when feeding on this resource-poor habitat**.**

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Table 1 *Ash, crude protein, ether extract and dry matter intake and digestibility in diets selected by goat kids or mature goats during the rainy or dry season in a Chihuahuan desert rangeland.*

Item	Rainy season		Dry season		SEM	Age	Season	Age x
	Kids	Matures	Kids	Matures		effect	effect	season
Ash, g kg^{-1}	94^{a}	86^{b}	105^{a}	71^{b}	6.7	**	NS	**
Crude protein, g kg^{-1}	98^{a}	96^{a}	91^{a}	81^{b}	6.8	**	**	*
Ether extract, g kg^{-1}	26^{a}	22^{a}	23^{a}	23^{a}	3.6	NS	NS	NS
DM digestibility, %	70^{a}	66^{b}	64^{a}	55^{b}	4.3	**	**	NS
DDMI, g	168	1379	159	1108	94			
DDMI, g kg^{-1} BW	23^{a}	29^{b}	22^{a}	27^{b}	5.3	*	*	NS
DDM I % BW	2.4^{a}	3.0^{b}	2.3^{a}	2.4^{a}	0.47	*	**	NS
DDMI g/kg $BW^{0.75}$ d^{-1}	40	78	37	62	3.1	**	**	*

DDMI= Daily dry matter intake; NS= Non-significant; *P < 0.05; **P < 0.01

^{a,b}Means in rows with different superscripts, by season, differ (P < 0.05).

Table 2 *Fibre fractions (g kg^{-1} dry matter) in diets selected by goat kids or mature goats during the rainy or dry season in a Chihuahuan desert rangeland.*

Item	Rainy season		Dry season		SEM	Age	Season	Age x
	Kids	Matures	Kids	Matures		effect	effect	season
Neutral detergent fibre	522^{a}	540^{b}	448^{a}	521^{b}	27	**	**	**
Acid detergent fibre	403^{a}	365^{b}	317^{a}	410^{b}	30	**	*	**
Lignin	265^{a}	271^{a}	345^{a}	368^{a}	42	NS	**	NS
Cellulose	654^{a}	688^{b}	607^{a}	609^{a}	29	NS	**	NS
Hemicellulose	119^{a}	175^{b}	131^{a}	116^{a}	24	**	**	**

NS= Non-significant; *P < 0.05; **P < 0.01

^{a,b}Means in rows with different superscripts, by season, differ (P < 0.05).

Table 3 *Macromineral (% dry matter) content of dietary samples of goat kids and mature goats grazing a Chihuahuan desert rangeland during the rainy or dry period.*

Item	Rainy season		Dry season		SEM	Age	Season	Age x
	Kids	Matures	Kids	Matures		effect	effect	season
Calcium	0.42[a]	0.41[a]	0.39[a]	0.39[a]	0.04	NS	*	NS
Phosphorus	1.40[a]	1.06[b]	1.31[a]	1.19[a]	0.28	**	NS	NS
Potasium	1.28[a]	1.05[b]	1.01[a]	0.85[b]	0.24	**	**	NS
Sodium	0.15[a]	0.14[a]	0.13[a]	0.13[a]	0.03	NS	NS	NS

NS= Non-significant; *P < 0.05; **P < 0.01

[a,b]Means in rows with different superscripts, by season, differ (P < 0.05).

Table 4 *Micromineral content (mg kg^{-1}) of dietary samples of goat kids and mature goats grazing a Chihuahuan desert rangeland during the rainy or dry period.*

Item	Rainy season		Dry season		SEM	Age	Season	Age x
	Kids	Matures	Kids	Matures		effect	effect	season
Copper	10.4^{a}	11.2^{a}	12.0^{a}	9.6^{b}	0.81	**	NS	**
Zinc	73.7^{a}	72.3^{b}	76.4^{a}	65.6^{b}	4.39	**	NS	**
Manganese	42.7^{a}	40.4^{b}	34.6^{a}	48.5^{b}	2.94	**	NS	**
Iron	434^{a}	452^{b}	420^{a}	466^{b}	25.40	**	NS	NS

NS= Non-significant; *P < 0.05; **P < 0.01

^{a,b}Means in rows with different superscripts, by season, differ (P < 0.05).

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Nutritive content of aborted and non-aborted goat diets on rangeland

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Abstract

Nutrient content of diets selected by aborted and non-aborted crossbred Criollo goats on rangeland were studied during the last 4 month of gestation in the dry period. Dietary samples were obtained directly from the mouth of momentarily restrained goats during their grazing path on a highly degraded rangeland. A short light rope permanently tightened around their neck was used to immobilize goats to obtain the forage collected from the goat's mouth. Samples were used for chemical analyses. Across months, non-aborted goats selected diets higher (133 ± 17 vs. 119 ± 21 g kg^{-1} DM; P<0.01) in crude protein (CP) than aborted goats; this nutrient did not meet the requirements of late gestation in aborted goats. All diets were highest in CP during February (P<0.01) and lowest in May (last month of pregnancy). Non-aborted goats made use of less fibrous feeds (e.g. across months NDF= 575 ± 43 g kg^{-1} DM) than non-pregnant goats (599 ± 34 g kg^{-1} DM; P<0.01). Levels of ash, macro and microelements in the goat diets did not differ between groups of animals; minerals were adequate to meet the demands of pregnancy. Non-aborted goats did not seek forages lower in tannins (1.5 ± 0.2 vs. 1.6 ± 0.3 g 100 g^{-1} DM) or alkaloids (1.1 ± 0.6 vs. 1.1 ± 0.5 g kg^{-1} DM) compared with aborted goats. It was concluded that in this rangeland those goats not able to increase selection of forages or plant parts with high nutritional value to maximize nutrient ingestion aborted. This implies that non-aborted goats have a greater ability to selectively graze/browse and greater capacity to seek out parts of plants or patches of high nutrient content than aborted animals.

Keywords: abortion, macrominerals, microminerals, gestation, secondary metabolites

1. Introduction

In arid zones with rainfall in summer and fall, goat producers under extensive conditions schedule their breeding season in early winter, in order for the births to cluster at the beginning of summer, so that the period of lactation coincides with the beginning of the rainy season, during which time there are the most abundant forage and mildest climate. This breeding program allows goats to produce adequate milk for the newborn and extra milk for marketing it. In addition, newborn kids begin grazing/browsing at around 4 weeks of age, therefore the young present an adequate growth rate before the next winter.

This breeding program is highly risky, because the substantial increase in nutrient requirements for the late pregnant goat occurs when forage quantity and quality decrease during the winter dormant season, which prevents adequate digestible nutrient intake to support fetal growth (Mellado et al., 2005a). This results in a high proportion of fetal losses; in fact, stress resulting from poor nutrition is the most important cause of abortion in goats raised on arid communal rangelands (Mahanjana and Cronjé, 2000; Mellado et al., 2004b).

Thus, nutritional challenges placed upon the gestating goat can be extreme in xeric landscapes and usually it is not possible to entirely prevent weight loss during the gestation period (Mellado et al., 2001). The question of what governs the capacity of goats to maintain gestation under limited nutrients has not been adequately addressed. It is believed that aspects such as individual variation in the grazing animal's ability to select and consume a diet supplying enough nutrients to meet daily requirements for maintenance of pregnancy is partially involved in maintenance of pregnancy in resource-poor environments, where forage resources are restricted in quantity and quality.

Therefore, it was considered important to find out if animals capable to produce viable offspring are more selective and choose diets richer in nutrients than aborted goats on degraded communal rangelands, because if this is so, this information could be used to select the most appropriate type of animal to be grown in landscapes with scarce forage. In a highly overgrazed rangeland it was

tested (1) whether crossbred Criollo goats capable to sustain their pregnancy during the dry season use forage with higher quality than goats incapable to carry their pregnancy to term, and (2) whether diet selection differs among months of pregnancy.

2. Material and methods

2.1. Study site

The study was conducted from February to May 2011 in a highly degraded rangeland of northern Mexico (25°07´N, 101°40'W; altitude 2150 m). The climate of the area is semiarid with an average annual precipitation of 299 mm, 75% occurring from June to October. The mean annual temperature is 16°C. The vegetation of the study area is dominated by creosotebush (*Larrea tridentata* (DC.) Cov., lechuguilla (*Agave lechuguilla* Torr), tarbush (*Flourensia cernua* DC.) and fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.). Some suffrutescents, including desert zinnia (*Zinnia acerosa* DC) and mariola (*Parthenium incanum* H.B.K.) are present. Principal perennial grasses are fluffgrass (*Erioneuron pulchellum* (Kunth) Tateoka), Bouteloua karwinskii (E. Fourn) Griffiths.), and creeping muhly (*Muhlenbergia repens* (J. Presl) Hitchc.). Copper globemallow (*Sphaeralcea angustifolia* (Cav.) G. Don) and *Nerisyrenia camporum* are common forbs. The rangeland has been continuously grazed at high intensity by multiple large flocks of goats, bovines and equines for several decades, which has led to poor forage productivity.

2.2. Animals

A commercial flock of approximately 200 crossbred Criollo (dairy x Criollo) goats was used. Mean condition score (1= extremely thin; 5= extremely fat; palpation over lumbar vertebrae, ribs and sternum) was 2.2 and adult goats range in weight from 34 to 45 kg. At the beginning of January non-lactating goats had been exposed to four adult active bucks of proven fertility during four weeks. Transrectal real time B mode ultrasound scanning (Aloka SSD 500 Echo camera, Overseas

Monitor Corp. Ltd., Richmond, BC, Canada) was used for the diagnosis of early pregnancy (around 30 days post-mating). Based on this diagnosis, sixteen 3-4-year-old pregnant goats were selected. Ultrasound examinations on days 60 and 90 post mating were performed in order to confirm pregnancy. Six of these pregnant goats aborted in the last trimester of gestation, thus, these goats formed the aborted group, whereas six goats which carried their pregnancy to term formed the non-aborted group.

Goat diets were obtained from these 12 goats (6 goats per group, from the second month of pregnancy onwards) by direct collection of plants from the goat's mouth before swallowing them, by opening the mandibles of goats by hand, immediately after feeding bouts. This operation was repeated approximately every five minutes during a 3 h period, using one person per goat. For this procedure goats were momentarily restrained by holding them using a permanent plastic rope (0.5 cm in diameter and 1.5 m in length) tightened to their necks with a bowline knot. This light rope allowed the goats to walk in all kinds of terrain without hindering their motion or feeding activity.

Dietary collections were made during the first hours of grazing when goats grazed/browsed most intensely after an overnight fasting. Following forage collection, samples were separated into two sub-samples. One portion of the sample was thoroughly rinsed, first with tap water and then with distilled water to remove saliva and dust, and was used for mineral analyses. The other subsample was used to determine other chemical analyses.

Goats were freely grazed on open range driven by a herdsman for 7 h per day (from 1100 to 1800 hours) all year round. Animals were penned at night without access to extra feed and water. No food supplements or salt mineral mixes were provided to goats throughout the year, and animals had access to water only once a day. Goats were not vaccinated against endemic diseases and were not subjected to an anthelmintic drenching program. The flock was free of brucellosis (card test). Four sampling periods during the dry season, each four-day long, were

conducted from February (second month of pregnancy) to May (last month of pregnancy).

2.3. Analytical procedures

Forages collected during the 4-d period were pooled and these samples were oven-dried and then ground to pass through 1–mm sieve. Dry matter (DM) was determined by drying at constant weight at 60ºC for 48 h in a forced-air oven, ash (procedure 942.05) by incineration at 600ºC for 2 h, ether extract (EE; procedure 920.39) and crude protein (CP; procedure 954.01) by the micro-Kjeldahl procedure (N x 6.25) (AOAC, 1997). All analyses were done in triplicate. Fibre fractions: neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), and cellulose were determined by the procedures described by Van Soest et al. (1991) and Van Soest and Wine (1968). Hemicellulose was calculated as ADF-ADL.

Phosphorus (P) was determined on a UV-vis spectrophotometer (Model UV-2101 PC; Shimadzu Scientific Instruments, Columbia, MD) at 650 nm (procedure 3.4.11; AOAC, 2000). 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. Total phenols were determined by the procedure of Swain and Hillis (1959) and condensed tannins (extractable, bound to protein and fiber; CT) in feed collected by goats were determined according to Makkar et al. (2003). The alkaloid content was determined gravimetrically using the technique described by Haborne (1973).

Statistical methods

The effects of physiological state, month of sampling and the physiological state x month interaction on nutrient content of diets were analyzed by ANOVA using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) accounting for repeated measures. The model was $Y_{ijk} = \mu + G_i + c_{j:i} + M_k + (GM)_{ik} + ßx_{ijk} + e_{ijk}$; where Y_{ijk} is the observation (dependent variable) of the j^{th} goat in the i^{th} group at the k^{th} month, μ is the overall mean, G_i is the i^{th} group, $c_{j:i}$ is the random effect of the j^{th} goat within

the i^{th} group ($c_{j:i} \sim N[0, \sigma^2 c]$), M_k is the k^{th} month, $(GM)_{ik}$ is the group by month interaction term, ßx$_{ijk}$ = initial body weight of goats as a covariate and e_{ijk} = the residual error term ($e_{ijk} \sim$ iidN [0, Σ]); where Σ is the variance-covariance of the residual errors with a first-order utoregressive structure for repeated measures within goats. Significant differences detected by ANOVA were further investigated using a Tukey's Honest Significant Differences (HSD) *post hoc* test comparing goat groups within month.

3. Results and discussion

Diets of aborted and non-aborted goats were similar in CP at the beginning of gestation, but during the last trimester of pregnancy mean CP content of diets selected by the aborted goats was lower (P<0.05) than values observed in non-aborted goats (Fig. 1). Dietary CP levels in forages selected by goats was higher than those reported in other studies in this type of vegetation in winter (Mellado et al., 1991;Juárez-Reyes et al., 2008), despite the fact that goats faced a severe shortage of forage throughout the study period.

In the present study feed intake of goats was not estimated because techniques for estimation of forage dry matter intake (e.g. total fecal collection) under grazing conditions would have caused additional stress in goats already subjected to nutrient limitations, and this could have triggered abortion or may have altered grazing behavior (Lippke et al., 2002). Thus, this results show nutrient density of grazed plants, but not nutrient balance of goats.

Considering that the average DM intake of adult pregnant mixed breed grazing goats in this landscape in winter is 1.2 kg per goat per day (Juárez-Reyes et al., 2004; Cerrillo et al., 2006), the levels of this nutrient in the aborted goats did not meet late pregnancy requirements (National Research Council, 2007), based on high physical activity and extra nutrients for late pregnancy. Thus, it seems that, in this particular environment, aborted goats were not capable to select enough high-protein forage to sustain their fetuses. It is worth noting that even though protein availability to goats was at its lowest point during the annual growing cycle, goats

that carried their pregnancy to term maintained a fairly high level of protein in their diet, which suggests that these animals increase their selectivity on the more profitable forages and possibly they diversified their diet according to their nutritional needs (Villalba et al., 2002). Additionally, higher levels of protein intake are highly correlated with daily energy intake (Wilmshurst and Fryxell, 1995; Olson et al., 2008) and organic matter digestibility in ruminants (Olson et al., 2008).
In this landscape, pregnant goats select twice as much forbs as non-pregnant animals (Mellado et al., 2005b); probably non-aborted goats increased forbs consumption, which promote forage intake via a more rapid early digestion rate and physical behavior in the gut which allowed the animals to simultaneously increase intake and accommodate more gut fill. These results are similar to those obtained previously (Mellado et al., 2011) and reinforce the conclusion reached then, in the sense that goat grazing behaviour is plastic, so that goats implement feeding tactics for acquiring greater amount of nutrients with increased nutrient demands by the growing fetuses.

Apparently, changes in availability and quality of forage as winter progressed induced a marked monthly fluctuations ($P<0.01$) in the levels of CP for each category of animal. These variations are probably a function of different stages of plant maturity in May resulting from different growing conditions. Usually, structural carbohydrates increased and percent CP decreases with increased plant maturity (Wilson et al., 2011).

Non-aborted goats selected diets higher ($P<0.05$) in ether extract than did aborted goats (Fig. 1). The implication of ether extract on the occurrence of abortions is not clear. The reduced lipid content of forages and the fact that forages contain no triglycerides and leaf galactolipids contain less energy than triglycerides does not seem to influence the reproductive process. It is unknown if other waxy compounds recovered in the ether extract could be involved in the maintenance of pregnancy. No variability in ether extract content of forages was found throughout the study period.

Similar values for NFD were found in diets selected by aborted and non-aborted goats from the second to forth month of pregnancy, but non-aborted goats selected diets with much lower (P<0.05) content of NDF in the last month of pregnancy than did aborted goats (Fig. 2). There was a significant interaction between groups of goats and months of sampling for this variable. Also, although in this landscape forage quality decreases during the dry season, forage NDF content declined (P<0.01) as the season progressed. This seems contradictory but goats in this type of vegetation greatly depend on dormant forbs in winter (up to one third of their diet; Mellado et al., 2005b), and forbs are characterized by their low cell wall content compared to grasses and shrubs (Frost et al., 2008).

Forage ADF content in diets selected by non-aborted goats was lower (P<0.01) in the second (February) and fourth (April) month of pregnancy compared to aborted goats (Fig. 2). Hemicellulose content did not differ in diets selected by both groups of goats, but this component of the cell wall was higher (P<0.01) in forage selected during the last month of pregnancy than forage selected in the middle of gestation. Both NDF and ADF are the least digestible fraction of forage nutrients and therefore these variables are negatively correlated with forage digestibility and intake (Owens et al., 2010). Given that non-aborted goat selected diets favoring the non-fibrous ingredients, apparently they consumed forages of higher degradability. This ability of goats to avoid fibrous ingredients has been previously documented (Mellado et al., 2011; Sebata and Ndlovu, 2011). The lower cell wall content of forages selected by non-aborted goats compared to aborted goats suggests that changes occurred in botanical composition of diet selected (e.g., shifts in the amount of forbs consumed). Dietary ADF and lignin declined in forages selected by goats as winter progressed. Changes in these dietary components probably were due to a greater use of forbs as the drought intensified, despite the fact that forbs are not readily available for consumption during the dormant season, due to physical losses following frost or senescence.

Ash in aborted (11.5 ± 1.6 g 100 g^{-1} DM) and non-aborted (11.4 ± 1.9 g 100 g^{-1} DM) goat diets did not differ among months of pregnancy, but mineral content of

forages steadily declined (from 12.6 ± 0.9 to 9.4 ± 1.7 g 100 g^{-1} DM; *P*<0.01) as season progressed. Concentrations of calcium (Ca) in diets selected by goats was similar between groups of goats, but this mineral increased (*P*<0.01) as winter progressed (0.74 g 100 g^{-1} DM in February and 1.14 g 100 g^{-1} DM in May). P concentration in forages selected by aborted and non-aborted goats did not differ, but this mineral was higher (0.43 vs. 0.37 g 100 g^{-1} DM; *P*<0.01) at the beginning of gestation compared with late pregnancy. This reduction in P has been documented in forages as they mature (Mountousis et al., 2009; Cline et al., 2010). Even so, forage P concentrations were adequate to meet the nutritional requirements for winter-pregnant goats under the grazing management practices in the current study (NRC, 2007), assuming 1.2 kg DM intake of goats in this type of vegetation (Juarez-Reyes et al., 2004). P is the most deficient macromineral in grasses used by cattle in rangelands of arid zones of North America (Kawas et al., 1997; Ganskopp and Bohnert, 2003), but goats in this study used forages with sufficient P to keep the adequate development of their fetuses, which suggest that goats selected a variety of plants and made use of live tissue to obtain maximum P concentrations (Wilson et al., 2011), in order to meet their P requirements for all phases of gestation.

Aborted goats selected diets with similar levels of Mg, Na and microelements than non-aborted goats. Mean Mg (0.15 ± 0.04 g 100 g^{-1} DM), Na (0.14 ± 0.12 g 100 g^{-1} DM), Cu (10.9 ± 3.6 mg kg^{-1}), Zn (22.2 ± 10.4 mg kg^{-1}), Mn (98.6 ± 24.6 mg kg^{-1}), and Fe (384 ± 87 mg kg^{-}1) forage concentrations were within adequate ranges reported for goats (NRC, 2007). In other studies certain mineral deficiencies cause abortion in goats. Cu deficiency has been identified as an important cause of fetal losses (Unanian and Feliciano-Silva, 1984; Moeller 2001). Other element deficiencies involved in abortion in grazing goats are iodine (Anke et al., 1977, Moeller, 2001), Mn (Anke et al., 1977; Unanian and Feliciano-Silva, 1984), Zn (Aytekin and Aypak, 2011) and Mg (Unanian and Feliciano-Silva, 1984; Mellado et al., 2004). Foraging theory predicts that herbivores are able of assessing the nutrient content of forages, including minerals (Ceacero et al.,

2010), and adjusting their diet according to their physiological needs. Goats in this lanscape were able to select forages with levels of microminerals above the requirements for the reproductive process. In general all microelements decreased as winter progressed, which is in line with findings of Ganskopp and Bohnert (2003) in this type of vegetation.

Aborted goats did not select forage with higher CT content than non-aborted goats. The levels of tannins found in goat diets (1.6 ± 0.3 vs. 1.5 ± 0.2 g 100 g^{-1} DM for aborted and non-aborted goats, respectively) were far below the 5 g 100 g^{-1} DM considered negative for decreasing food intake (Niderkorn and Baumont, 2009). CT content in diets selected by goats increased as winter progressed (range 1.4 to 1.8 g 100 g^{-1} DM; P<0.01). The low level of CT in forages used by goats probably was beneficial for these animals because proteins of forages with low levels of these secondary compounds decrease ruminal degradability of CP, increasing the amount of CP that reaches the abomasums and small intestine (Waghorn, 2008). On the other hand, goats in this study possibly did not require higher levels of tannins to alleviate the impact of gastrointestinal parasites (Hoste et al., 2006), as internal nematode parasitism do no constitute a problem for these animals in this zone (Mellado et al., 2004a).

Non-aborted goats selected forages with the same levels of alkaloids (1.1 ± 0.5 vs. 1.1 ± 0.6 g kg^{-1} DM) as did non-aborted goats. These alkaloid levels are far below the average alkaloids content of major classes of plant rich in compounds of this landscape (Pfister et al., 2001). Although the ingestion of alkaloid-containing plants can harm the goats, apparently they still consume them because of the plant's nutritional quality or availability or addictive chemical properties. In fact, in this landscape alkaloid-containing plants sometimes constitute the major portion of the goat diets (e.g. *Solanum elaeagniifolium*; Mellado et al., 2003). Goats are somewhat physiologically adapted to cope with alkaloid concentrations in their diet (Kronberg and Walker, 2007), which makes them resistant to alkaloid toxicity (Petzinger, 2011).

Conclusions

It was found evidence for different foraging behavior of aborted and non-aborted goats. Aborted goat diets on rangeland in poor condition appeared to contain levels of CP insufficient for maintenance of pregnancy. Also, aborted goats used forages with higher cell wall content which apparently led to less extraction of nutrient per day from high fibre forages**.** Under the conditions of the present study both macro and microelements did not play an important role in the etiology of abortion in goats. Likewise, levels of tannins and alkaloids in diets selected by goats in this type of vegetation do not seem to alter the outcome of pregnancy in goats. These results indicate that goat producers would benefit from selecting goats suited to marginal lands and economically marginal conditions, which would result in higher odds of maintaining pregnancy in rangelands with scarce forage resources.

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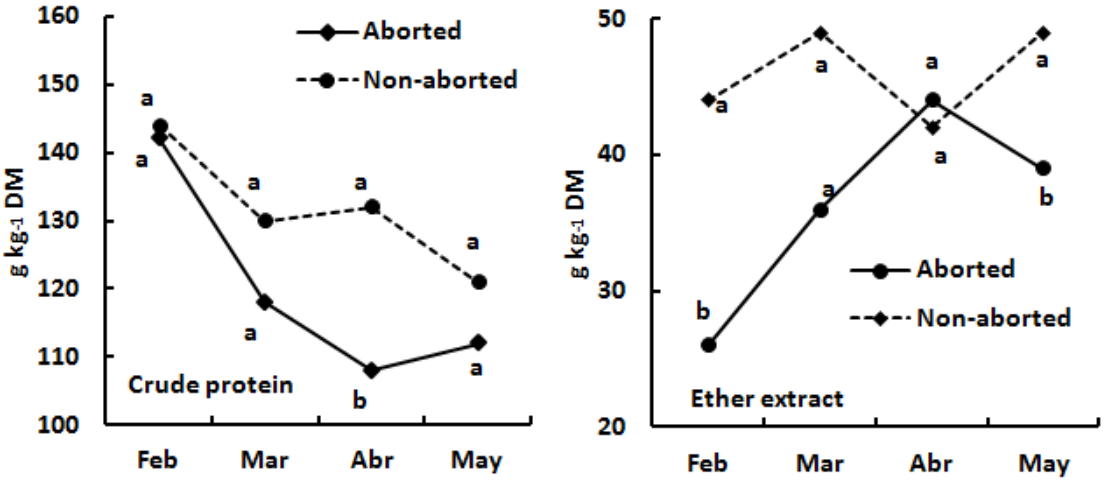

Fig. 1. Contents of crude protein and ether extract in diets selected by aborted and non-aborted goats on rangeland. February corresponds to second month of pregnancy and May is the last month of gestation. Means within months with dissimilar letters differ (P<0.05).

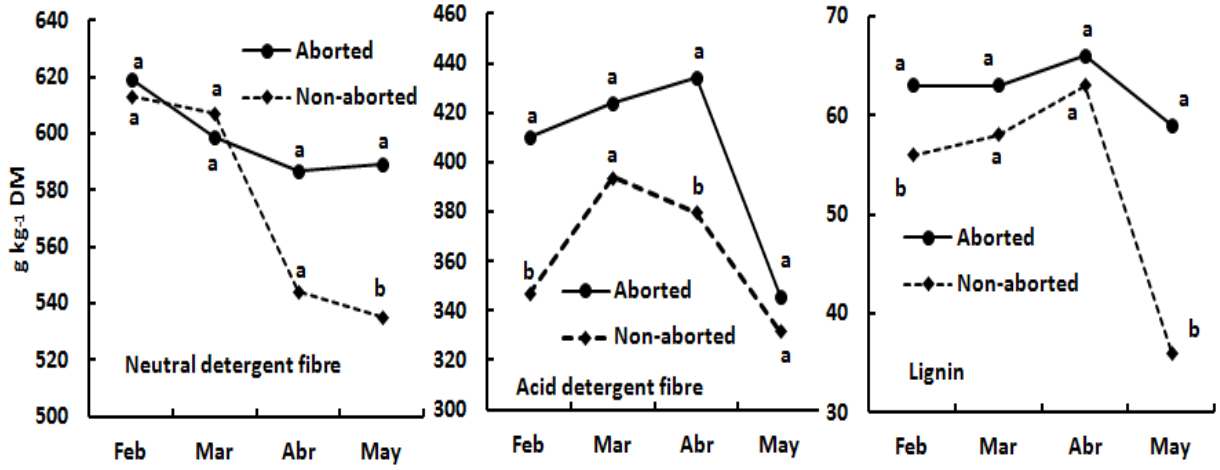

Fig. 2. . Contents of fibre components in diets selected by aborted and non-aborted goats on rangeland. February corresponds to second month of pregnancy and May is the last month of gestation. Means within months with dissimilar letters differ (P<0.05).