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 during 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 were 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 a greater capacity to seek out parts of plants or patches of high nutrient content than aborted animals.

Keywords: abortion, diet analysis, feeding behaviour, cell wall content, secondary metabolites.

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 when forage is most abundant and climate is mildest. This breeding program allows goats to produce adequate amount of milk for the newborns and extra milk for the market. 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.

Material and methods

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.

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).

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 ($c_{j:i}$ ˜ $N[0, \sigma^2 c]$), 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} ˜ iidN $[0, \sum]$); where $\sum$ 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.

Results and discussion

Abortions in these grazing goats occurred in the last trimester of gestation, with no signs of placentitis or decomposed fetuses, which suggests that undernutrition was the most likely cause of the premature expulsion of fetuses. 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.

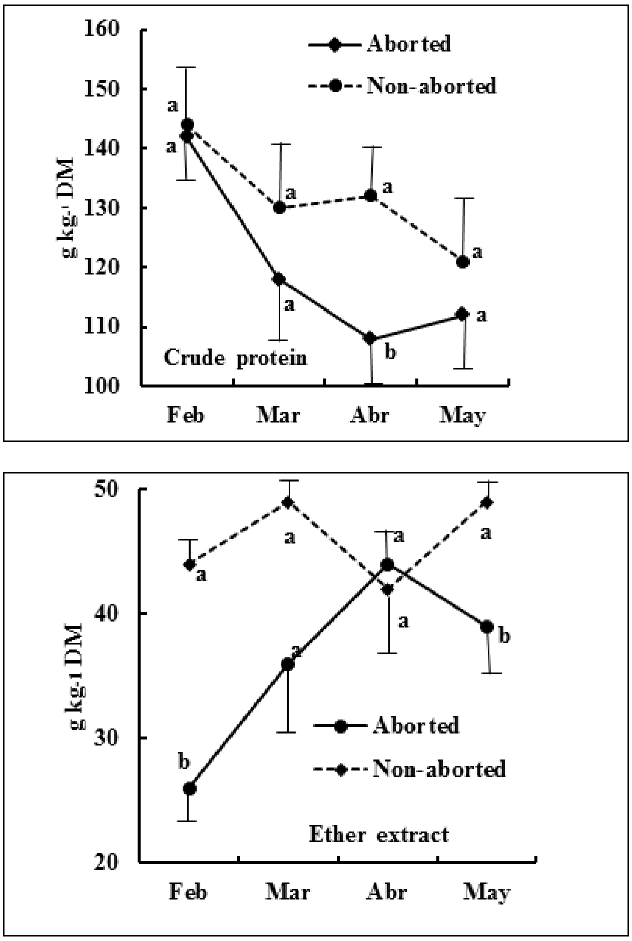

Fig. 1. **Contents of crude protein and ether extract in diets selected by aborted and non-aborted goats on rangeland. February corresponds to second month of pregnancy and May is the last month of gestation. Means within months with dissimilar letters differ ($p<0.05$). Bars indicate standard deviation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

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 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 increase 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).

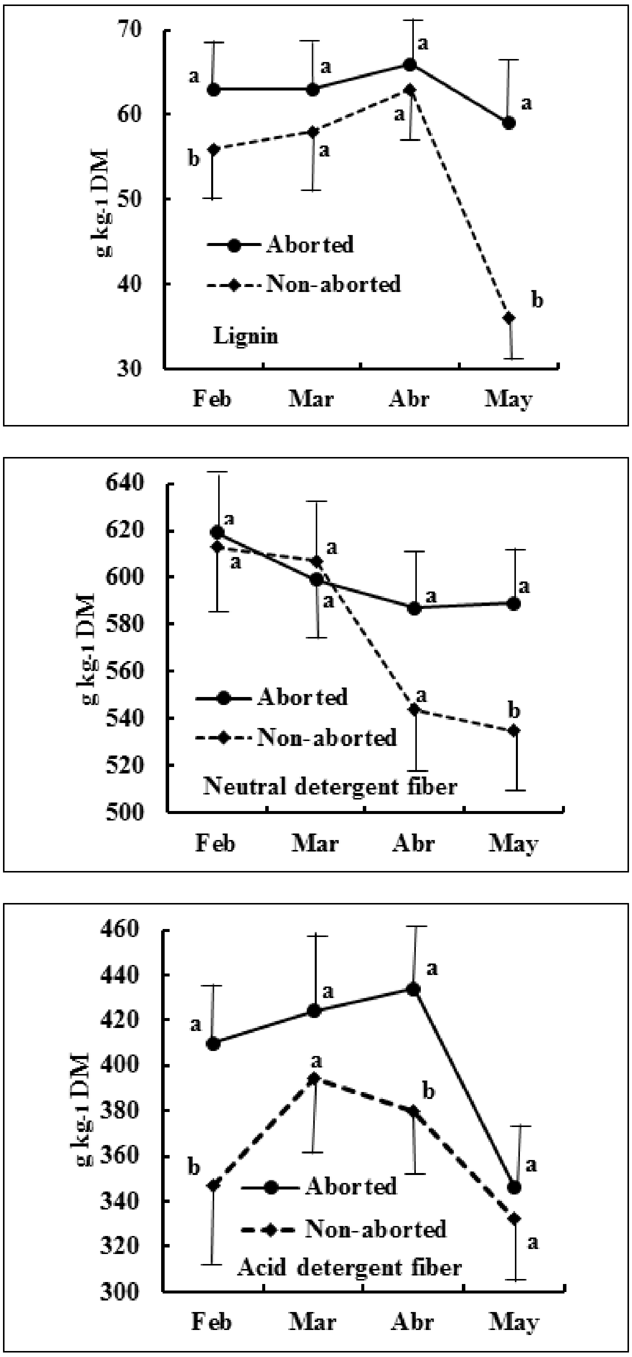

Fig. 2. **Contents of fiber components in diets selected by aborted and non-aborted goats on rangeland. February corresponds to second month of pregnancy and May is the last month of gestation. Means within months with dissimilar letters differ (p<0.05). Bars indicate standard deviation of the mean.**

Forage ADF content in diets selected by non-aborted goats was lower (*P*<0.01) in the second (February) and fourth (April) months 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

Evidence for different foraging behavior of aborted and non-aborted goats Iwas found. 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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