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Comparative Foraging Ecology of Sheep and Goats in Caatinga Woodland in Northeastern Brazil

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Comparative Foraging Ecology of Sheep and Goats in Caatinga Woodland in Northeastern Brazil

by

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ABSTRACT

Comparative Foraging Ecology of Sheep and Goats

in Caatinga Woodland in Northeastern Brazil

by

Scott L. Kronberg, Doctor of Philosophy

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Major Professor: Dr. John C. Malechek
Department: Range Science

Small-ruminant production is an important part of the agricultural economy of northeastern Brazil. However, mild-to-severe undernutrition of livestock is an annual occurrence. Goats can tolerate the marginal forage conditions better than sheep, but the mechanisms underlying their superior tolerance are not understood.

An analysis of animal liveweights at the end of the year-long study indicated that reproducing mixed-race goats gained nearly twice ($P<.05$) the weight of reproducing hair-sheep of the Santa Ynez breed, and non-reproducing goats gained about 1.2 times more ($P<.05$) weight than non-reproducing sheep. Daily weight gains of lambs were less ($P<.10$) than those of kids for their first 80 days of life.

In the wet season, reproducing sheep and goats gained similar ($P>.05$) weight, while non-reproducing sheep gained more ($P\leq.05$) than non-reproducing goats. Non-reproducing goats had greater ($P<.05$)

forage organic matter intake (OMI) than the corresponding sheep in the two wet periods. In the late-wet period, non-reproducing goats had greater (P<.05) digestible energy intake (DEI) than corresponding sheep did but had similar (P>.05) digestible protein intake (DPI) as sheep.

In the dry season, reproducing sheep and goats lost similar (P>.05) weight but only the five better performing sheep were weighed at the end of the dry season. The five poorer performers were removed from the study and given supplemental feed to keep them alive. The non-reproducing sheep lost weight during the dry season, while the non-reproducing goats gained weight. Non-reproducing sheep and goats had similar (P>.05) OMI and DEI during the dry periods. In the late-dry period when forage quality was lowest, the animals experienced their greatest weight loss, and both species had greatly reduced DPI; the goats had 83 percent greater (P<.05) DPI than the sheep.

Digestion trials were conducted with actual diet samples selected by free-ranging animals. Goats had greater (P<.05) crude protein apparent digestibility than sheep in the late-dry period trial. This difference may be a key aspect explaining their responses to the dry season.

(153 pages)

INTRODUCTION

There is a growing number of people who believe that livestock are destroying the world's semi-arid and arid lands and would like to see livestock removed from these lands. Simultaneously, there is a growing number of people in developing and developed countries attempting to increase food production from arid and semi-arid lands.

Excessive soil erosion and declining productivity are often associated with attempts to increase food production from these lands. While livestock have certainly contributed to soil erosion problems and the decreasing productivity of many arid and semi-arid lands, the problem does not lie directly with the livestock but with their human managers. This simple but critical concept seems to be misunderstood by many people who seek to remove livestock from the Earth's arid regions.

Also, a growing number of people advocate increasing the proportion of plant-supplied nutrients in the human diet while decreasing the proportion of animal-supplied nutrients. This typically means increasing grain consumption, but these grains are often produced on semi-arid lands. Grain production requires plowing of these lands and therefore destroys the native plant communities that have provided some degree of continuous protection for the soil to wind and water erosion. While poorly managed livestock grazing can lead to increased soil erosion and decreased productivity, soil loss is usually less when the soil and soil-stabilizing vegetation are left unplowed and the vegetation grazed than when the soil is plowed for row crops.

A substantial part of the world's lands is simply unsuited for cultivation by virtue of various physical and climatic limitations. For these areas, livestock provide about the only avenue for food production short of a hunter-gatherer culture.

If our goal is to increase food production from arid and semi-arid lands while conserving their soils and productivity, then we must direct our research to sustainable agricultural practices for these lands. For much of this land, properly managed livestock production will likely provide maximal food production on a sustainable basis. The study discussed in this dissertation was intended to increase our knowledge of livestock interactions on semi-arid land in northeastern Brazil and consequently improve our capacity to manage these livestock for maximum food production on a sustainable basis.

The study was conducted in northeastern Brazil under the auspices of the Small Ruminant Collaborative Research Support Program (SR-CRSP) funded by the U. S. Agency for International Development. The overriding purpose of the SR-CRSP is to offer support for the application of science to solve human nutritional problems in developing countries. The avenues for this support are applied research and education, mainly through graduate training.

The semi-arid portion of northeastern Brazil (the Sertão) is one of the largest areas of poverty in South America. It encompasses a large part of Brazil (1 million km^2). The predominant vegetation of the Sertão is a woodland of small trees with an understory of herbaceous annuals. The vegetation is termed caatinga. The caatinga zone is depicted in Figure 1. The area is characterized by extreme variation in precipitation from year to year, and droughts are frequent and often severe.

Small ruminant production is a very important part of the Sertão's agricultural economy. Thirty percent of Brazil's sheep and 92 percent of its goats are produced in this region (roughly six million head of each species). The erratic precipitation makes small ruminant production a high-risk venture. Mild to severe undernourishment of the livestock population is associated with this climatic situation. When droughts occur, crop failures and livestock losses trigger famine, unemployment and migration of rural people (particularly the poorest) to major cities (Pfister et al. 1983). This large influx of people into urban centers creates major health and social problems because these cities are incapable of absorbing the large increase in residents (McDowell 1984).

Even during years of "average" precipitation, the four- to six-month rainy season (typically beginning about January) is followed by a six- to eight-month dry season. During the long dry season, livestock left on the rangeland typically experience moderate weight losses (15 to 25 percent of body weight (BW)); extreme weight losses and even death are not uncommon in drought years. Reproductive performance is probably compromised in most years. Pfister (1983) studied unsupplemented native hair-sheep and mixed-race goats free-ranging on caatinga rangeland throughout the dry season. He observed that his sheep lost 5.5 kg (20.4 percent of BW) in the late-dry season

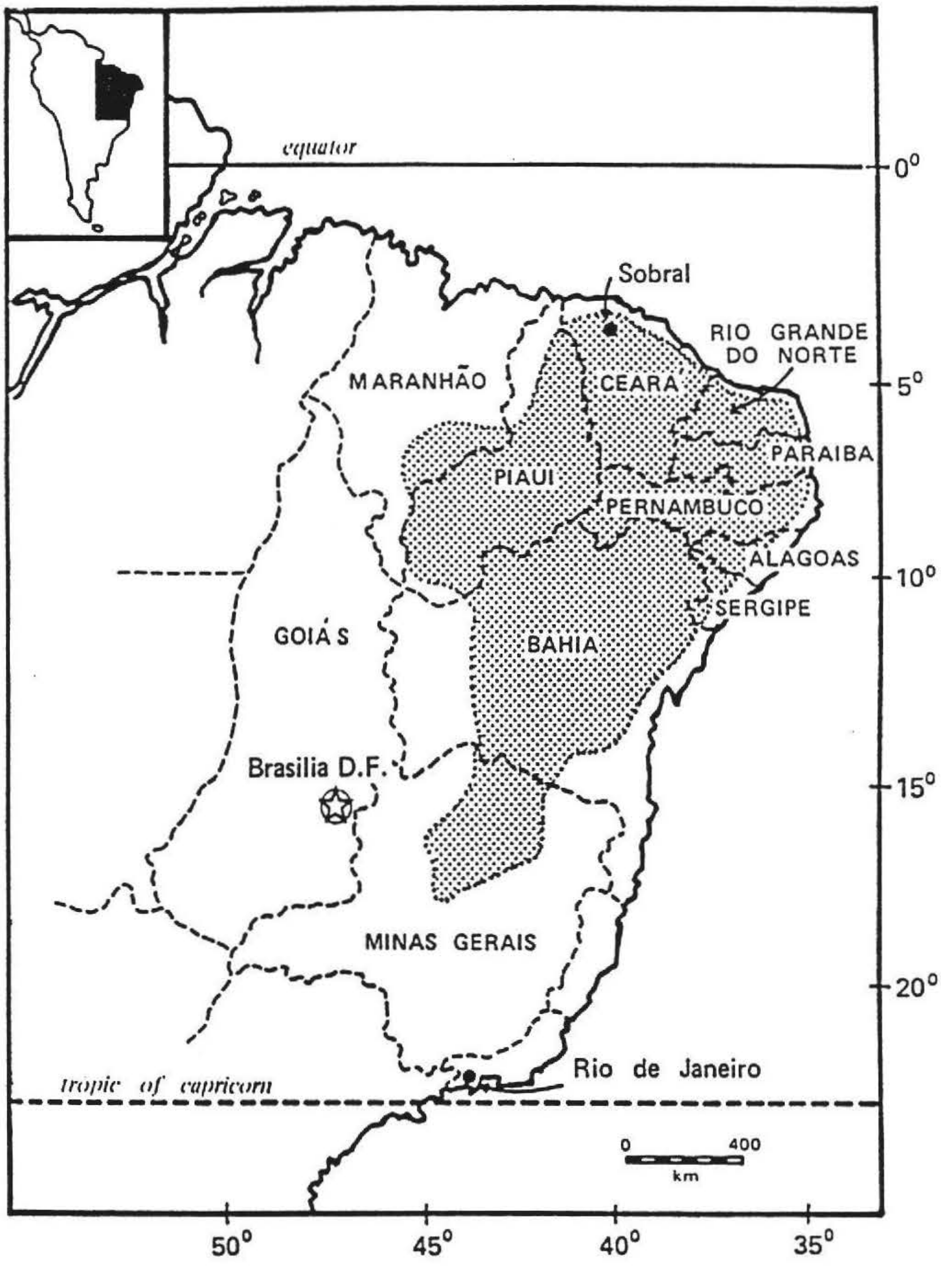


Figure 1. The caatinga vegetation zone of northeastern Brazil.

(October through December), while goats lost only 3.5 kg (15.2 percent of BW). These findings suggest that sheep and goats may respond to the dry season conditions in different ways. Pfister also monitored weight changes and forage intake of unsupplemented, free-ranging sheep and goats from June through April. On average, goats consumed 132 kg of forage per head over the 10-month period to gain about 8.5 kg, while sheep consumed about 174 kg of forage to gain only about 7.0 kg. These estimates suggest that goats may be more efficient producers from this rangeland.

Both sheep and goats are important livestock in northeastern Brazil, yet this region produces a far greater proportion of Brazil's goats than sheep. There are many potential explanations for this situation, but given the marginal forage conditions which regularly plague the Sertão, it is possible that goats may be better adapted to subsisting under these conditions than are sheep. This explanation is supported by several statements in the literature. Queiroz and Gutierrez-Aleman (1985) stated that sheep and goats, especially goats, provide the resiliency necessary to cope with the unpredictable environment. Pfister et al. (1983) noted that goats are looked on as a form of drought insurance because of their survivability. Primov (1982) stated that goats play an important part in the small producer's survival strategy, contributing to the household's cash and consumption needs. In a longitudinal study of livestock producers in the state of Ceara, Queiroz and Gutierrez-Aleman (1985) observed that 85 percent of producers supplemented cattle during the dry season, 50 percent supplemented sheep but only 30 percent supplemented goats. Of the producers that supplemented with high-quality feedstuffs (61 percent), only 18 percent fed this supplement to some of their goats. Primov (1982) concluded that the high reproductive capacity of goats and their ability to perform well with a minimum input make these animals a reliable and inexpensive source of food and ready cash.

If goats are better adapted to subsisting on the forage conditions in the caatinga, then the pertinent question is: What attributes do they have which sheep lack? It is commonly known that goats can assume a bipedal stance and reach forage unavailable to sheep. Goats can also climb into trees and reach forage which sheep cannot. However, these abilities do not appear to offer much advantage to goats during the critical period, since almost all dry-season forage in this deciduous woodland occurs on or near the ground (Pfister et al. 1988).

A review of the literature reveals other differences between sheep and goats that may pertain. Marker (1945 as cited by Huss 1972) noted that goats have a mobile upper lip and prehensile tongue. Huss (1972) suggested that goats tend to eat more browse than grass and forbs. Wilson (1977) suggested that goats may be able to digest more of the nitrogen in tree leaves than can sheep. Goats may also be able to digest cell wall in shrub and tree leaves more completely or faster than do sheep (Doyle et al. 1984; Wilson 1977), and goats may be more efficient ruminators (ruminate more roughage per unit time) than sheep (Welch 1982). Gihad (1976) observed that goats consume more poor quality tropical grass hay with lower water intake and greater crude fiber digestion than do sheep.

Alam et al. (1983) studied the digestion of a low quality hay by lambs and kids over a longer period (16 weeks) than is typically used. They observed that while both species initially digested the hay to a similar extent, the digestive efficiency of the lambs declined while that of the kids was maintained for the entire 16 weeks. Alam et al. (1983) also noted that the lambs drank twice as much water (ml water/kg dry matter (DM) intake) as the kids. Watson and Norton (1982) fed Angora goats and Merino sheep immature and mature Pangola grass (Digitaria decumbens) hay. They found that both species utilized the higher quality (12 percent crude protein and 80 percent neutral detergent fiber) immature grass hay with equal efficiency, whereas the goats digested more of the organic matter and fiber fractions of the lower quality (5 percent crude protein and 77 percent neutral detergent fiber) mature grass hay than the sheep. The authors also noted that when the goats ate the mature grass diet, they had longer rumen fluid retention times, higher rumen ammonia concentrations and higher plasma urea concentrations than did sheep on the same diet. Alam et al. (1985) compared ad libitum digestible organic matter intake of seven forages by sheep and goats. They found that intake by goats was higher than the sheep for forages of less than 60 percent organic matter digestibility (OMD). They also observed that goats maintained higher rumen ammonia concentrations and had less water intake than sheep did. They concluded that the ability of goats to maintain higher rumen ammonia levels is associated with their lower water intake, and their ability to consume more low quality forage (OMD < 60 percent) is partly because of their ability to maintain higher rumen ammonia concentrations. Essentially, higher rumen ammonia levels mean larger rumen microbial populations, greater microbial digestion of plant tissues, higher concentrations of volatile fatty acids (energy-supplying compounds absorbed and used by the ruminant) and greater uptake of amino acids by the ruminant.

Brosh et al. (1986) concluded that infrequent drinking increases feed digestibility and reduces metabolizable energy needs of Bedouin goats on low-quality diets. Silanikove et al. (1980) compared gross energy digestion and urea recycling by Bedouin goats from the Sinai desert to that by Swiss Saanen dairy goats. They found that when forage intake was restricted or when low quality feed was fed, the Bedouin goats recycled higher amounts of urea than did Saanen goats. They also observed that apparent energy digestibility of alfalfa hay and wheat straw was 6 and 33 percent higher, respectively, for the Bedouin goats than the Saanen goats. They concluded that under adverse nutritional conditions, the Bedouin goats possess a high capacity to meet their caloric demands and to economize their nitrogen metabolism.

These studies suggest that goats can utilize forages low in crude protein and high in fiber better than sheep can. Schacht and Malechek (1989) observed goats in caatinga selecting forage of only 8 percent crude protein (CP) and 45 percent neutral detergent fiber (NDF) in the later portion of the dry season. If goats can utilize forage of this quality better than sheep, this advantage may explain why goats are valued for their survivability in the Sertão.

Purpose of the Study

The purpose of this study was to elucidate aspects of sheep and goat behavior, digestive physiology and feeding ecology which may account for their productivity differences.

Primary Hypothesis

The basic hypothesis tested was that sheep exploit wet-season foraging conditions better than goats do; however, dry-season foraging conditions are more critical to year-round animal productivity, and goats exploit the dry-season foraging conditions better than sheep do. Therefore, goats have greater year-round productivity than sheep have.

Specific Hypotheses

1) During the wet season, sheep select diets of higher digestibility and crude protein content than goats do.
2) During the wet season, sheep spend more time foraging than goats do.
3) During the wet season, the retention time of particulate matter through the gastrointestinal tract is similar in sheep and goats.
4) During the wet season, sheep have greater forage, energy and protein intakes than goats do.
5) During the dry season, goats select diets higher in lignin and crude protein content than sheep do.
6) During the dry season, goats spend more time foraging than sheep do.

7) During the dry season, goats spend more time ruminating than sheep do.
8) During the dry season, the retention time of particulate matter in the gastrointestinal tracts of goats is shorter than that in sheep.
9) During the dry season, goats have greater forage, energy and protein intakes than sheep do.

DESCRIPTION OF STUDY AREA

The field study was conducted during 1986 on 150 hectares of land controlled by the Brazilian National Goat Research Center (Centro National de Pesquisa de Caprinos) near the city of Sobral in the state of Ceara in northeastern Brazil. Sobral's elevation is 63 m. It is located at 3.42° south latitude and 42.21° west longitude. The terrain in the study area is flat to slightly undulating. Crystalline bedrock underlies the area, and it is exposed in portions of the pastures.

Generally, two kinds of soils occur on the granitic stock (Queiroz 1985). These are 1) deep (1.5-m +) soils with red subsoils and 2) moderately deep (0.5 to 1.5-m) soils with reddish or yellowish red subsoils. Both of these have horizons of clay accumulation and belong in the Ustalf suborder.

The study area was divided into three 50-hectare (ha) pastures. The divisions were made to facilitate finding the animals at the end of the day and occasionally for other purposes. The stocking rate for the study area was 1.5 ha/animal/year. The year was divided into four defined periods. January through March was defined as the early-wet period. April through June was defined as the late-wet period. July through September was defined as the early-dry period, and October through December was defined as the late-dry period. During each of the three-month periods, all of the study animals were pastured together for one month in each of the three pastures. Consequently, each pasture was grazed a total of four months during the year of the study. This rotational grazing scheme was used in order to maintain equal access to forage in all pastures that was available at different times of the year.

A stream passed through two of the pastures. It contained water into the early-dry period. The third pasture had a small portion of a reservoir which supplied water and moist soil for plant growth into the early-dry period.

The Sertão has a 1- to 6-month wet season, which typically begins between December and February, and a 6- to 8-month dry season, which typically starts in June and lasts until January. Occasionally, droughts extend the dry season for 11 to 12 months (Pfister et al. 1983). Mean annual precipitation in Sobral for the last 30 years is 760 mm. The variation in annual amount and timing of precipitation as well as its spatial distribution is extreme. Figure 2 shows the 30-year average monthly precipitation patterns for Sobral and the study area in 1986. The monthly distribution of rain on the study area followed the normal pattern. The crucial difference between 1986 rainfall and the 30-year average lies in the amount of rain received. The study area received about 77 percent more rain during 1986 than the 30-year average. In 1986, rainfall was near the maximum for a region marked by extreme fluctuations in annual rainfall.

The mean annual temperature in the Sertão ranges from 22 to 28°C, with temperatures varying from 8 to 40°C (Pfister et al. 1983). Relative humidity is usually around 90 to 100 percent during the cooler

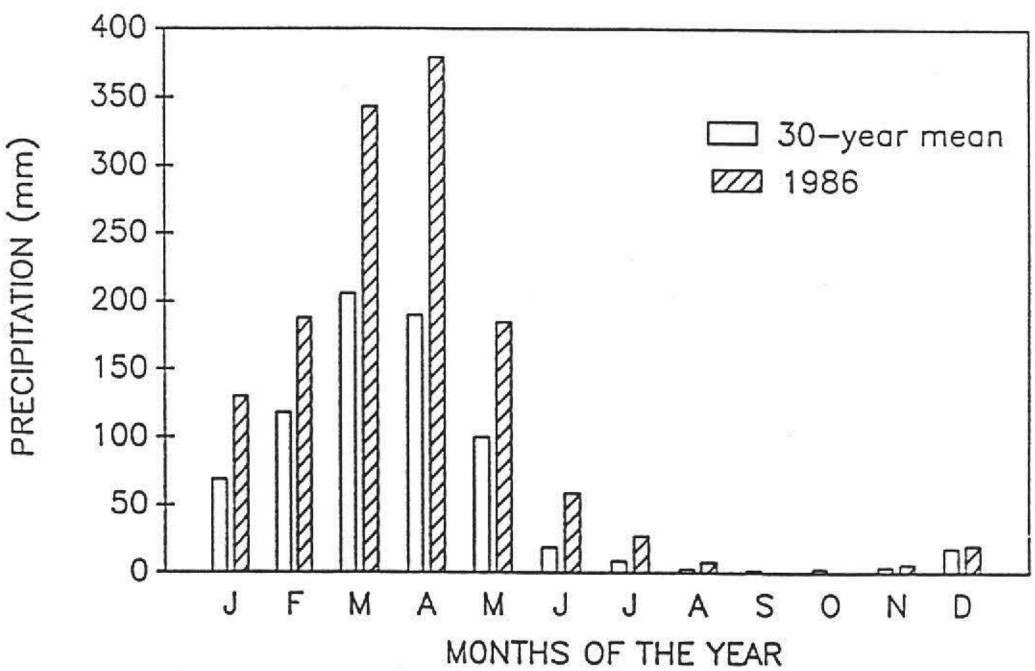


Figure 2. Mean (30-year) monthly precipitation for Sobral and for the study area in 1986.

early morning hours and may drop as low as 35 percent in the afternoon, especially during the dry season (Kirmse 1984).

The vegetation on the study area is deciduous woodland, called caatinga. The complex is composed of a great variety of tree, shrub, annual grass and annual forb species. The trees had been clearcut on the study area in about 1975. Clearcutting is a widely practiced tradition in the caatinga woodland. Trees are often cleared to allow for cultivation of crops (primarily corn and beans) and perennial cotton or they may be cleared, ostensibly to increase forage production for livestock grazing. The woodlands are also cut to obtain lumber, fence posts and firewood.

The principal tree species in the study area are pau branco (Auxemma oncocalyx Taub.), sabia (Mimosa caesalpiniaefolia Benth.), mofumbo (Combretum leprosum Mart.), marmeleiro (Croton hemiargyreus Muell. Arg.), pereiro (Aspidosperma pyrifolium Mart.), jurema branca (Pithecolobium dumosum Benth.) and jurema preta (Mimosa acutistipula Benth.). Tree foliage is an important component of available vegetation during the wet season and early-dry period. During the later portion of the dry season, virtually all of the tree leaves are available as litter covering the ground. Genera of important annual grasses include Andropogon, Brachiaria, Echinochloa and Panicum. Genera of important annual forbs include Bainvillea, Bidens, Canavalia, Chaptalia, Commelina, Crotalaria, Heliotropium, Hyptis, Ipomoea, Phaseolus, Pithecolobium, Ruellia, Stylosantes and Wissadula as well as other minor species that have not been described and classified taxonomically.

LITERATURE REVIEW

Botanical Selection by and Diet Quality of Sheep and Goats

There are a growing number of comparative studies of intake, digestion and (or) utilization of one or more forages by sheep and goats (El Hag 1976; Gihad 1976; Huston 1976; Wilson 1977; Watson and Norton 1982; Gamble and Mackintosh 1982; Alam et al. 1983; McCabe and Barry 1988; Howe and Barry 1988). These studies are valuable for helping us understand digestive differences between sheep and goats and the nutritive value of the forages for both species. However, these studies have limited value in respect to free-ranging sheep and goats because these two species often select different diets composed of a great variety of plant species from the grasses, forbs, shrubs and trees that are available as forage. This is important to consider when reviewing comparative studies of forage(s) fed to sheep and goats. When sheep and goats graze together they are free to select different diets which may be better matched to the particular digestive capabilities of each species than are the diets fed to them in confinement.

There are only a few reported studies comparing the diet selection of sheep and goats on common range. One of these comparative studies was done in northeastern Brazil by Pfister and Malechek (1986a). They found that sheep and goats selected dissimilar diets during the wet season. Sheep chose mainly grass and forb species, while goats chose varying combinations of grasses, forbs and browse through the wet season. During the dry season, sheep and goats selected similar diets of dried forbs and browse. In this locality, the browse available to the animals exists partly as ground litter in the early portion of the dry season and completely as ground litter during the later portion of the dry season. They concluded that during the dry season there may be severe interspecific competition for preferred forage. However, during the wet season, with the ample supply of nutritious forage, different dietary preferences and the tendency for sheep and goats to select forage from different heights above the ground, interspecific competition appeared to be low.

Wilson et al. (1975) compared the diets of sheep and goats grazing a semi-arid woodland in western New South Wales at different times of the year. They noted that goats selected the major proportion of their diets from trees and shrubs. When the goats selected a high proportion of herbaceous species they selected forbs more than grasses. In contrast, sheep preferred grasses and forbs. When their preferred grasses and forbs were not available they selected a higher proportion of browse, mainly from one tree species.

Wilson et al. (1975) noted that the nitrogen content of goats' diets was generally higher than that of sheep, but the in vitro digestibility of their diets was comparable. Pfister and Malechek (1986b) observed that goats generally selected diets higher in crude protein than sheep, while the two species generally selected diets of similar in vitro digestibility. They also observed that sheep generally selected diets with lower lignin levels than goats, but the two species were roughly equal in terms of total dietary fiber.

Daily Activity Budgets of Free-ranging Sheep and Goats

Free-ranging ruminants expend considerably more energy than confined ruminants. The maintenance energy requirements of ruminants may be 25 to 100 percent higher if they are grazing as compared to fed in confinement (Osuji 1974). Osuji (1974) suggested that the increased requirement may be due to the higher energy costs of eating and traveling.

The energy cost of eating is a direct function of the time spent eating (Osuji 1974), and animals on pasture tend to spend considerably more time eating than animals fed in confinement. Young (1966) found that the energy expenditure per gram of diet ingested by sheep varied with the type of diet. The energy cost of eating an alfalfa or wheat chaff diet (1.2 - 1.9 cal/g ration) was about three times the energy cost of eating a concentrate diet (0.3 - 0.6 cal/g ration). The sheep consumed 40 g/min of the concentrate diet, while they only ate 8 - 12 g/min of the chaff diets. Grazing animals often eat moderate to low quality forage similar to the chaff diets. When concentrate-type forage is available (e.g., seedheads or fruit) it is usually dispersed in the pasture, and the animals must travel between foraging sites.

The energy cost of travel can contribute substantially to the increased energy expenditure of the free-ranging animal. Clapperton (1964) estimated the energy cost to sheep for horizontal walking at

0.59 cal/kg BW/m and the average energy cost of walking on gradients of 1:22 and 1:11 at 6.36 cal/kg BW/vertical m.

Oliveira (1987) estimated the daily energy expenditures of free-ranging sheep and goats with activity budgets and with the carbon dioxide entry rate technique (CERT). His estimates by the two techniques were not statistically different for the sheep. However, his estimates with the activity budget approach were significantly less (39 percent) than the CERT estimates for goats. Because of the lack of energetic values for various activities of goats, he used estimates for other ruminant species to construct an energy budget for goats. His results demonstrated the inaccuracy of that approach. His CERT results indicate that in a free-ranging situation, goats had a higher energy expenditure per unit of metabolic body weight (MBW) than sheep did (127.1 versus 88.4 kcal/kg MBW/day).

While activity budgets may not provide an accurate quantitative approach for estimating and comparing the energy expenditures of free-ranging sheep and goats, they still have value. I used them to help explain how sheep and goats responded to forage conditions during a year on caatinga range.

The literature comparing daily activity budgets and travel distances of sheep and goats is limited. Pfister (1983) studied sheep and goats free ranging on caatinga range in northeastern Brazil but did not systematically quantify daily activities. He noted that during the late-dry period, both species extended their foraging times to virtually all daylight hours plus several hours during the night. He explained that this modification of behavior was likely a reaction to maintain forage intake as forage availability declined. He also speculated that given the dry and fibrous nature of the forage during the late-dry season, foraging time may have been constrained by the time required to ruminate such forage. Numerous investigations have indicated that domestic ruminants seldom ruminate more than ten hours a day (Welch and Smith 1969, 1970; Cammel and Osbourne 1972; Jorgensen et al. 1978). How or why this apparent maximum is set is not understood (Hooper and Welch 1983). In Pfister's (1983) study of free-ranging sheep and goats, during the late-dry period when the animals were not foraging they were ruminating. The large portion of the day spent foraging coupled with the high level of dietary fiber were considered the likely determinants of their rumination behavior.

The existence of fibrous material in the reticulorumen appears to be the major factor controlling rumination (Welch and Smith 1969, 1970). Bines and Davey (1970) observed that cows stopped ruminating when fed an all-concentrate ration. Welch and Smith (1969) studied the effect of forage quality on rumination time in stall-fed sheep. They fed three types of roughage which had different levels of cell wall (CW). While DM intake was constant at 791 g per day for the three roughages fed, CW intake increased. As the percent of CW increased in a ration, the minutes ruminated per g DM increased linearly ($r = 0.99$). As CW content was increased from 50.7 to 67.3 percent of the diet (a 33 percent increase), daily rumination time increased from 5.2 to 8.6 hours (a 64 percent increase). When they held DM intake constant at 927 g per day and increased dietary CW content from 49.5 to 75.6 percent (a 53 percent increase), daily rumination time increased from

7.0 to 12.2 hours (a 75 percent increase). In these experiments, rumination time increased roughly one and one-half to two times the increase in dietary CW content.

Campling (1970) suggested that chewing efficiency (CW intake/mastication time) is important in determining reticulorumen retention time and forage intake. Welch and Smith (1969, 1970) demonstrated strong relationships between CW intake and chewing efficiency. On a high fiber diet a ruminant that can masticate more CW per minute may be able to consume more than another ruminant that masticates CW less efficiently (Hooper and Welch 1983). Hooper and Welch (1983) stated that with mature sheep, goats and cattle, rumination efficiency is generally related to body size, with the large animals having greater efficiency. Within a species, large individuals tend to be more efficient than small ones. Welch (1982) stated that sheep are much less efficient than cattle in the amount of CW ruminated per day. On a daily basis, the sheep he studied could only ruminate about 15 g CW per kg (MBW) (4.9 g CW/kg BW), while the cattle could ruminate up to 40 g CW per kg MBW (8.2 g CW/kg BW). Goats do not fit the general pattern of BW to rumination efficiency (Welch 1982). Goats ruminated 23.7 g CW per kg of MBW (9.4 g CW/kg BW), which was more than sheep on a MBW and BW basis and more than cattle on a BW basis. Goats apparently accomplish this by spending more time ruminating each day. On average, goats spent 1.30 min/g CW, whereas sheep spent 1.18 min/g CW.

Passage Rate of Dietary Fiber Through the Gastrointestinal Tract

There is considerable evidence that reticulorumen capacity and passage rate of particulate digesta through the reticulorumen can affect feed intake in ruminants (Balch and Campling 1962; Baile and Forbes 1974). Campling (1970) found that additions of food into the reticulorumen through a fistula caused an immediate decrease in eating while removal of food from the rumen caused the animal to eat much longer than normal. Grovum (1979) found that when the reticula of sheep were distended with water-filled balloons, their feed intake was depressed. When the balloons were removed, the animal resumed feeding. Conrad et al. (1964) studied the feed intake of lactating dairy cows. The dry matter digestibility (DMD) of their rations ranged between 52 and 80 percent, and their cow weights varied between 283 and 661 kg. They concluded that physical and physiological factors regulating feed intake change in importance with increasing digestibility of the diet. With lower digestibilities, body weight (reflecting reticulorumen capacity), passage rate of particulate digesta and digestibility of the diet appear to regulate intake. At higher digestibilities, intake appears to be regulated by metabolism and production. Nutt et al. (1980) found that among cows grazing lower quality pasture (mean DMD of 55 percent), a positive relationship existed between rumen capacity and forage intake. For cows grazing higher quality pasture (mean DMD of 60 percent), they found no relationship between these two factors. From their results, they also hypothesized that forage intake is regulated by different factors for cows grazing high and low quality pasture.

Blaxter et al. (1961) showed a strong positive association between the apparent digestibility of roughages and the amount consumed by sheep. They noted that voluntary intake of long (not chopped or ground) fodder increases rapidly with the quality of the fodder until its apparent digestibility reaches about 75 percent. At this level of digestibility, intake stabilizes. This suggests that metabolic controls may not regulate the forage intake of sheep consuming typical range forage until dietary digestibility reaches approximately 75 percent (which is unusual).

Balch and Campling (1962) demonstrated that movement of particulate digesta through the alimentary canal is limited by passage of digesta particles through the reticulo-omasal orifice into the omasum. Particles are reduced in size primarily by mastication, digestive action of microbial fermentation in the reticulorumen and mechanical action by particle movement from reticulorumen contractions.

Although little work has been reported on the passage rate of dietary fiber by goats, they may have a somewhat faster passage rate than sheep and cattle (McCammon-Feldman et al. 1981). Castle (1956a) studied passage rates of dye-stained particles through the digestive tracts of goats. Approximately 40 hours elapsed between appearance of five and 80 percent of the stained particles in the feces. Castle noted that excretion of stained particles began about the same time in all goats, but final marker excretion times (when 95 percent of marked particles had been excreted) varied and tended to be characteristic of individual animals. She concluded that initial marker excretion times (appearance of five percent of marked particles in feces) reflected a relatively uniform rate of passage through the intestines of all her goats; whereas, the non-uniform rate of later excretions reflected individual variation in passage rate through the four chambers of their stomachs (Castle 1956b). Castle (1956a) observed a significant relationship between food intake and particle retention time. The animals with higher food intakes had lower retention times.

Uden et al. (1982) used chromium-mordanted fiber to estimate particle passage rates and retention times for sheep and goats fed mature timothy (<u>Phleum pratense</u>) hay. The mean passage rates of their four sheep and three goats were 0.027 and 0.038%/h, respectively. The passage rate of marked particles was 40 percent faster in the goats than in the sheep. The mean retention times of marked particles in their sheep and goats were 57 and 41 h, respectively. The mean retention time of marked particles was about 40 percent shorter in the goats than in the sheep. The work of Uden et al. (1982) suggests that goats may pass dietary fiber faster than sheep when both species are eating a high fiber ration. Whether goats consistently pass dietary fiber faster than sheep when the two species are consuming diets with low to high levels of fiber has not been determined.

Forage, Energy and Protein Intake of Sheep and Goats

McCammon-Feldman et al. (1981) reported DM intake values from studies of sheep and goats fed grass and (or) legumes. Excluding two abnormally high values (5.2 and 7.3 percent of BW/day) and one abnormally low value (0.8 percent of BW/day), the goats had a mean daily DM intake of 2.6 percent of BW and ranged from 1.3 to 3.7 percent of BW. Excluding one abnormally high value (11.8 percent of BW/day), the sheep also had a mean daily DM intake of 2.6 percent of BW and ranged from 1.4 to 3.6 percent of BW. Van Dyne et al. (1980) catalogued 42 observations of dry or organic matter intake of sheep on cultivated pasture and rangeland. They reported values ranging from 1.2 to 4.0 percent of BW/day.

Pfister and Malechek (1986b) estimated the daily forage organic matter intake of two-year-old castrated male hair-sheep and mixed-race goats on caatinga range. In January and February (early-wet period months), the sheep had intakes of 2.6 and 2.2 percent of body weight (BW), respectively, while the goats had intakes of 2.5 and 2.1 percent of BW, respectively. In April (in the late-wet period), the sheep and goats had intakes of only 1.2 percent of BW. In July and August (early-dry period months), the sheep had intakes of 2.8 percent of BW, while the goats had intakes of 2.6 percent of BW. In September (in the later portion of the dry season in that year), the intakes of sheep and goats were only 1.6 and 1.9 percent of BW, respectively. In October and December (late-dry period), the sheep had intakes of 2.5 and 2.1 percent of body weight, respectively, while the goats had intakes of 2.0 percent of BW for each month.

Pfister and Malechek (1986b) also estimated the digestible energy intake (DEI) of their animals. In January, the sheep had greater DEI than the goats (100 and 74 kcal/kg BW, respectively). In February, both species had intakes of about 70 kcal/kg BW. In April, both species had intakes of only about 33 kcal/kg BW. In July and August, both species had intakes near 66 kcal/kg BW, while the goats had greater intake (42 kcal/kd BW) than the sheep (35 kcal/kg BW) in September. In December, the two species had intakes near 48 kcal/kg BW. The authors concluded that digestible energy requirements for maintenance and medium activity of sheep and goats were met in the early-wet and early-dry periods. Their animals gained weight in these periods. The nutrient requirements suggested by Kearl (1982) for livestock in developing countries fit their animal weight responses better than did those suggested for sheep and goats by NRC (1985, 1981).

Pfister and Malechek (1986b) did not estimate digestible protein intake by their animals. However, they reported dietary crude protein levels and suggested that animal performance is probably not limited by crude protein intake unless crude protein digestibility is limited by high lignification.

Summary

Goats tend to eat more browse than sheep, while sheep will select more herbaceous plants; but goats are very flexible foragers and will eat a variety of grasses and forbs. Goats may select diets of higher crude protein content than those of sheep. Free-ranging goats may have higher energy expenditures per kg of MBW than sheep do. Goats can spend more time ruminating per g CW than sheep do and can have faster particle passage rates through their gastrointestinal tracts than sheep have. The daily forage and energy intakes of free-ranging sheep and goats are similar about as often as they differ, but there is not a consistent trend when they differ.

METHODS

Available Vegetation

Vegetation sampling was conducted at the beginning of each of the four periods of the year and just prior to the start of diet sample collections. The vegetation available (kg/ha) in each period was estimated by harvesting all herbaceous vegetation within 200 randomly located $0.3m^2$ quadrants and harvesting all the tree leaves to a browsing height of 1.5 m from 10 randomly located $40m^2$ quadrants. During the dry season, leaf litter was collected from the $0.3m^2$ quadrants along with the herbaceous vegetation.

Body Weight Changes and Progeny Growth

At the start of the study all animals were about one-year of age. Female hair-sheep of the Santa Ynez breed and mixed-race goats were used. Reproducing and non-reproducing animals of both species were weighed. The animals were held off feed and water for a 12-hour nighttime period and weighed in the morning at the beginning of each month from January 1986 until January 1987. Because the four types of animals started the study with different weights, body weight changes across a particular period were expressed as the percentage of change between the beginning and ending weights for the specified period. In a separate analysis, monthly body weights were adjusted for each animal's initial weight with analysis of covariance.

The date of birth and birth weight were recorded for all lambs and kids produced by the reproducing animals in the study. The diets of the lambs and kids were not supplemented during the period in which their growth was measured. The lambs were weighed on October 18th and ranged in age from 81 to 90 days. The kids were weighed on November 3rd, when they varied in age from 73 to 88 days. The lambs were supplemented after October 18 because they were in poor condition. After November 3, the kids were also allowed access to supplement.

Body weight changes during each month and season were determined as well as the weight changes across the entire year. In a separate analysis, monthly measures of body weights were analyzed with analysis of covariance. The covariables were the animals' weights at the beginning of the study. Body weight changes during the months and seasons and across the year were analyzed with analysis of variance. With the exception of the covariate analysis of body weights at the end of the study (January), all weight data were analyzed by a split-plot design with repeated monthly measurements of individuals. The individuals were nested within species and reproductive status. The time unit was the sub-plot treatment. The data for body weight changes across the year were analyzed by a factorial design, with species and reproductive status as treatments. A completely randomized design was used to test for differences between lamb and kid birth weights and average daily weight gains. Birth weights were analyzed with analysis of variance, while average daily weight gains were analyzed with analysis of covariance with birth weights as covariables.

Least-squares analysis of variance procedures (General Linear Models) (SAS 1988) were used for all analyses. The protected LSD procedure was used for comparisons among means. A probability $\leq .05$ was accepted as indicating significant difference for all comparisons except the average daily gains of progeny. A probability <.10 was accepted as indicating significance for this comparison.

Botanical Selection and Diet Quality

Diet samples were collected with 20 to 22 esophageally fistulated non-reproducing females of each species. The animals were about one-year-old at the start of the study. The samples were collected early in the morning on three days spaced evenly through the sampling month for each of the four periods of the year.

The diet samples were collected in closed-bottom bags so that saliva-soluble compounds were not lost from the samples. The fistulated animals were released into a particular 50-ha pasture and allowed to roam freely for 30 to 45 minutes. Excess saliva was separated from the sample if present. Then, each diet sample was hand mixed, divided into two equal portions, placed in a ice-filled cooler and promptly transported to a freezer where, samples were stored at -20°C.

Three half-size samples from each animal (one from each of the three days) were pooled, oven-dried and analyzed for botanical composition. Botanical composition was estimated by the microscope point method of Harker et al. (1964). The plant tissue in each sample was systematically identified by species or recorded as unidentifiable at 100 points per sample at 15x magnification. The remaining 3 half-samples from each animal were pooled, freeze-dried, ground to pass through a 1-mm screen and analyzed for nitrogen, *in vitro* digestibility and fiber components. Nitrogen analysis was by the micro-Kjeldahl procedure (AOAC 1970). Nitrogen values were multiplied by 6.25 to estimate crude protein.

In vitro digestibility was determined through the Moore modification of the Tilley and Terry technique (Harris 1970). The in vitro digestibility analysis was conducted during the same period in which the samples were collected. The rumen fluid inoculum for these analyses was collected from ruminally fistulated sheep and goats (one animal/species/trial) that were free-ranging on the same pasture with the esophageally fistulated animals. The rumen fluid was collected in the morning before the animals began grazing. Samples of known in vivo digestibility were used as standards for the in vitro digestibility analyses.

Dietary samples were analyzed for neutral detergent fiber (NDF) and permanganate lignin with the sequential extraction procedure (Goering and Van Soest 1970; Van Soest and Wine 1968). The reagents decalin and sodium sulfite were omitted as Robertson and Van Soest (1980) recommended. All diet quality characteristics were expressed on an organic matter basis.

A split-plot statistical design with repeated measurements of individual animals was used. Individuals were nested within their species. The period of the year was the sub-plot treatment. Least-squares analysis of variance procedures (General Linear Models of SAS) were used to test for differences. The protected LSD procedure was used for comparison among means. A probability $\leq .10$ was accepted as indicating significant difference for the tests of the particular plant species selected by the animals. I accepted the greater risk of a type I error for these tests because 1) there was large variation among the individuals of a species, 2) I used a relatively large number of individuals for these tests (I believe that I used a considerably larger number of animals than anyone else has ever used) and 3) the consequence of a type I error for any of these tests would not have serious implications for the key aspects of my study. For the tests associated with diet quality characteristics, I accepted a probability $\leq .05$ as indicating a significant difference.

Daily Activity Budgets

In the early-wet period, daily activity budgets were estimated by observing four animals of each species. The number of animals was increased to eight of each species for the other three periods. Gestating females were observed in the late-wet period, and lactating females were observed during the dry periods. Two animals of each species were observed for a 24-hour period for consecutive days (two days for the early-wet period, and four days for the other periods). During the day, there was one observer per animal. During the night, the animals were penned with the rest of the herd and were observed by one person. All observers were trained to follow the same procedure and to define the various activities uniformly. Each animal was observed momentarily at five-minute intervals and its activity recorded (Altmann 1974). Four categories of activities were recorded: traveling, foraging, ruminating and all other activities. An animal was considered to be foraging if at the moment it was observed its feet were stationary and it held its head close to forage to either bite or sniff it. Animals were recorded as traveling if their movements appeared to deliberately transport them to a new location. Occasionally, two animals were involved in a pushing contest. Their behavior was placed in the "other activities" category, although they may have taken a few steps. Ruminating behavior was clear-cut.

Daily travel distances of reproducing sheep and goats were determined for the two dry periods. Ten animals of each species were equipped with digital pedometers of the type described by Anderson and Kothmann (1977). Each pedometer was tightly housed in a leather case and strapped to the right foreleg just above the knee. The pedometers were set at the minimum pace setting, as described by Anderson and Kothmann (1977). During both periods, the animals were walked along a 485 meter alleyway with their pedometers in place to allow calibration of each pedometer individually. Travel distances were measured over two consecutive days in each period. The pedometers were attached in the morning just before the animals were released into a pasture with the remainder of the herd and were removed immediately after the animals returned to the pen in the evening. The same eight animals used to estimate daily activity budgets were equipped with pedometers along with two additional animals of each species. Wet season estimates were not made because the animals were constantly stamping their feet to remove biting insects, and the pedometers recorded the stamps as steps.

In the early-dry period, animals were observed for activity budget estimates from the morning of August 26 through the morning of August

30. Travel distances were measured on August 31 and September 1. In the late dry period, animals were observed for activity budgets from November 4 through the morning of November 9. An unusual dry-season rain occurred on November 6; therefore, observations were not made on that day. Travel distances were measured on November 12 and 13. The weather was consistently hot and dry during the dry-season days of animal observation and travel-distance measurement.

Data of activity budgets were analyzed by a factorial design with species and periods as treatments. Analysis by a repeated measures design was not possible for activity budget estimations because different individuals were used in the four periods. Daily travel distances were analyzed by a split-plot design with repeated measurement of individuals. The individuals were nested within their species. Periods were the sub-plot treatment. Least-squares analysis of variance procedures (General Linear Models of SAS) were used to test for differences. The protected LSD procedure was used for comparisons among means. A probability $\leq .10$ was accepted as indicating significant difference. I accepted the greater risk of a type I error for the same reasons stated above.

Retention Time of Dietary Fiber

Retention times were estimated in the late-wet, early-dry and late-dry periods. Technical problems precluded sample collection in the early-wet period. These estimates were made using both reproducing and non-reproducing sheep and goats. In the late-wet period, five gestating and five non-reproducing animals of each species were used.

In both dry periods, nine to ten lactating and nine to ten non-reproducing animals of each species were used. The flow rates of particulate digesta through the animals' gastrointestinal tracts were estimated by marking ingesta particles with chromium and fitting the chromium excretion curve to a model of digesta kinetics.

Diet samples collected by esophageally fistulated sheep and goats were mordanted with chromium, as described by Uden et al. (1980). These samples were not ground before mordanting, and care was taken not to reduce particle size during the mordanting process. Early in the morning, just before the animals were released from their pen into the pasture, the chromium-mordanted fiber was placed down the animals' throats in gelatin capsules. The animals were dosed with ten grams of mordanted fiber in the late-wet period and six grams of mordanted fiber in each of the two dry periods. Fecal samples were collected from each animal immediately before the mordanted fiber was dosed and at about 4, 8, 12, 18, 24, 36, 48, 72 and 96 hours post-dosing. Fecal samples were analyzed for chromium by atomic absorption spectrophotometry, as described by Williams et al. (1962). The concentration of chromium in the feces was expressed on an organic matter basis. The concentrations of the marker in the feces were fitted to a one-compartment model with time delay and gamma two age dependency using the non-linear regression option (Marquardt method) of SAS (Pond et al. 1987). The model was:

$$Y = (K_o \times L_1 (t-a) \times e^{-(L_1 \times (t-a))}) / 0.59635$$

where Y = expected concentration of marker in the feces (ug/g fecal OM), K_o = concentration of the marker if instantaneously mixed in the compartment, L_1 = age-dependent rate parameter, a = time from dose until first appearance of marker in feces and t = time after marker is administered. These parameters were estimated by fitting the model to the concentrations of marker in the fecal samples collected from each animal. The particle retention time (h) was estimated from the equation $2/L_1 + a$. For this equation, L_1 and a are defined as above.

Retention time data were analyzed by a factorial design with species, period and reproductive status as treatments. Least-squares analysis of variance procedures (General Linear Models procedure of SAS) were used to test for differences. The protected LSD procedure was used for comparisons among means. I accepted a probability $\leq .05$ as indicating significant differences.

Digestion Trials

Accurate estimates of forage, energy and protein intake require accurate estimates of forage digestibility because forage intake is typically estimated by dividing fecal output by forage indigestibility. This presents a problem when working with free-ranging animals consuming diets of various tropical browse and herbaceous species, which are often high in fiber. It has not been established that traditional in vitro techniques provide accurate estimates of the digestibility of these forages. Therefore, I attempted to make reliable estimates of dietary digestibility and digestible energy and protein intake by free-ranging animals by collecting large amounts of extrusa and feeding the extrusa to animals in digestion trials.

Three digestion trials were conducted on stall-confined sheep and goats during 1986. The trials corresponded to the late-wet, early-dry and late-dry periods. Technical problems precluded the completion of a trial for the early-wet period. The primary objective of these trials was to estimate the organic matter digestibility of and the digestible energy and protein intake from the diets of free ranging sheep and goats in the caatinga.

Diets tested in these digestion trials consisted of samples of range forage representative of that consumed by sheep and goats free ranging in the caatinga. These diet samples (extrusa) were collected for 20 to 22 esophageally fistulated, non-reproducing females of each species. The animals were hair-sheep and mixed-race goats about one-year-old at the beginning of the study. The samples were collected early in the morning six days per week for about one month of each period (except for the three days of each month when diet samples were collected for other purposes).

The fistulated animals of one species were released in the pasture and allowed to roam freely for 30 to 45 minutes. The order of release of the sheep and goats was alternated daily. Five technicians were employed to hasten the collections. The extrusa were collected in closed-bottom bags to prevent the loss of saliva-soluble compounds. Excess saliva was removed from each sample if necessary. Then all of the material collected from either sheep or goats was mixed together, a small sample was taken for determination of DM and in vitro dry matter digestibility (IVDMD) and the larger remaining portion was placed in large plastic bags and gently pressed into packets each about 3 cm thick for quick cooling and freezing. The extrusa packets were placed in an insulated container between layers of ice and promptly transported to a freezer, where they were stored at -20°C.

During the month of extrusa collections, daily fecal dry matter output (FO) of free-ranging, non-reproducing, female sheep and goats was estimated. Fecal collection bags were placed on approximately 10 individuals of each species and their feces were collected for a four-day period. The bags were emptied daily and the feces weighed and sampled for DM determination. The canvas collection bags had a inner bag of mosquito netting which held the fecal pellets and allowed urine to pass through and collect briefly in the bottom of the outer bag before dripping out.

Samples from the daily extrusa collections were pooled over the month for each species; sub-samples from the pool were taken, freeze-dried and subsequently analyzed for IVDMD for each species. The in vitro digestibility procedure was the same as that described above. The FO and IVDMD estimates were then used to calculate daily dry matter intake (DMI) for each species using the relationship DMI = FO/1-IVDMD.

When the DMI's of the free-ranging animals were estimated for the period and sufficient extrusa were collected to meet their DMI's, the digestion trial was conducted. Four ruminally fistulated animals of each species were used in all digestion trials except in the trial for the late-wet period, when only three individuals were used for the goat portion of this trial. The animals were removed from the pasture and placed in individual metabolism cages (1.2-m^2) 12 hours before the five-day digestion trial began.

Metabolism cages were placed side by side so that individual animals of a species could maintain visual contact. I was unable to collect sufficient extrusa to allow a preliminary adjustment period before the onset of the collection period (Schneider and Flatt 1975). However, the trials were conducted only several days after the month of extrusa collections, and the ruminally fistulated animals were in the same pasture from which the extrusa collections were made. Therefore, I expect that the ruminally fistulated animals were selecting diets very similar to those they received in the trials. Under these circumstances, I felt that a period of adjustment to the diet was not necessary. The trial animals were kept in the cages for a five-day adaption period during the early-wet period.

The animals would not eat the wet extrusa, and I could not freeze-dry the large quantities needed for each trial. Therefore, the frozen extrusa were thawed to 15°C and placed intraruminally into each animal through its rumen fistula. The extrusa were manually inserted at rates equal to estimated DMI (as a percent of BW) for free-ranging animals during the corresponding month of the extrusa collections. The extrusa were inserted in three equal portions at 0830, 1130 and 1430 hours. The portion for each animal was placed in a bucket, which was placed under the rumen fistula. A technician would straddle an animal at its neck while facing its rump. In this manner, the technician had both hands free to insert the extrusa through the fistula. Five technicians were employed to speed the process. No other food was offered to the animals, but water and trace mineral salt were offered daily.

During the five-day digestion trials, samples of the infused extrusa were collected daily. These samples were stored at -20°C until they were freeze-dried. The feces of each animal were weighed and sampled daily. The DM content of each day's output was determined, and 10 percent of each animal's daily output was stored at -20°C. The daily fecal samples from each animal were pooled at the end of the trial, and samples of the pooled feces were dried in a forced-air dryer at 40°C. The dried extrusa and fecal samples were ground to pass through a 1-mm screen. Then the samples were analyzed for nitrogen and converted to crude protein values as described above. The samples were also analyzed for gross energy content by complete oxidation in a Parr adiabatic bomb calorimeter and for organic matter (Harris 1970). The data were analyzed by a factorial design with the period of extrusa collections and the animal species as treatments. Least-squares analysis of variance procedures were used for the analysis. The protected LSD procedure was used for comparisons among means. I accepted a probability $\leq .05$ as indicating significant difference.

The validity of this unusual approach to digestion trials was tested. For sheep, I compared the IVDMD of a diet of cunha hay (Clitoria ternatea) consumed normally or stuffed into the rumen as extrusa. The cunha hay was chopped, air-dried, mixed and divided in half. One portion was stored and the other was fed to 20 esophageally fistulated sheep over a two-week period. Cunha hay was presented to the sheep each morning, and extrusa were collected as they ate the forage. The extrusa were stored as described above until enough was accumulated to conduct a digestion trial.

Two ruminally fistulated sheep were placed in metabolism cages and fed the chopped, air-dried cunha hay for seven days. Dry matter intake, FO and DM digestibility were determined for each animal. Three days after the completion of this trial the second seven-day trial began. In this trial, the two sheep received the cunha as extrusa. The extrusa were stuffed at rates equal to the DMI of the hay (2.6 and 3.1 percent of BW for animals one and two, respectively). The extrusa were stuffed as described above. Fecal DM output and DM digestibility of the extrusa diet were determined for each animal.

A test of the validity of the unusual feeding technique was also made with goats. I compared the OMD and the intakes of digestible energy and protein by goats consuming young leaves and small stems (ca. 1-mm) from the tree species sabia. The sabia was chopped into small pieces (ca. 1-cm^2) and fed normally or introduced into the goats' rumens.

Two five-day trials were conducted with four rumenally fistulated goats. No preliminary period was allowed in these trials. Early in the morning and afternoon of each day of the trials, sabia leaves with attached stems were harvested in the field. In each trial, the sabia was chopped and fed normally to two goats and stuffed into the rumens of two other goats. The sabia was fed or stuffed in three equal portions at 0830, 1130 and 1430 hours. Water and trace mineral salt were offered daily.

All goats were fed the sabia at three percent of BW on a DM basis. The manner of sabia intake was reversed for each animal in the second trial.

The fecal output of each animal was treated as described for the main digestion trials. The sabia forage and fecal samples were analyzed as described for the main digestion trials.

The data were analyzed by a factorial design with feeding manner and trial time (first or second) as treatments. Least-squares analysis of variance was used for the analysis. The protected LSD procedure was used for comparisons among means. A probability $\leq .10$ was required for significant difference.

Forage, Energy and Protein Intake of Free-ranging Sheep and Goats

Forage organic matter intake of free-ranging, non-reproducing sheep and goats was estimated during the four periods of the year. Total fecal collections were conducted as described above with the addition of organic matter determination on the fecal samples. Organic matter intake (OMI) was calculated with the equation:

$$\text{OMI (g/d)} = \frac{\text{Fecal organic matter output (g/d)}}{\text{(1 - organic matter digestibility)}}$$

For the early-wet period, the OMD estimates used to calculate forage intake were <u>in vitro</u> values that were obtained as described above. For the remaining three periods, the OMD values used were <u>in vivo</u> values obtained from the digestion trials described above.

Digestible energy and protein intake were estimated for free-ranging, non-reproducing animals during the late-wet and dry periods. Digestible energy intake was calculated with the equation DEI (kcal/d) = OMI (g/d) x DEI:OMI (kcal/g). The DEI:OMI ratios were determined in the digestion trial for each period. Digestible protein intake was calculated with the equation DPI (g/d) = OMI (g/d) x DPI:OMI (g/g). The DPI:OMI ratios were also determined in the digestion trials.

The data were analyzed by a factorial design with the species of animal and period of the year as treatments. Fecal output was determined on different animals for the various periods; therefore, the data could not be analyzed with a repeated measures design. Least-squares analysis of variance procedures were used to test for differences. The protected LSD procedure was used for comparisons among means. A probability $\leq .05$ indicated significant difference.

RESULTS

Sheep and Goat Survival Through the Study

All of the non-reproducing animals and the reproducing goats that started the study were able to finish the year in adequate body condition. All of these animals were strong enough in the latter part of the dry season to survive the poor forage available to them. In contrast, half of the reproducing sheep (5 head) were in such poor condition by early December that they could barely walk. These five sheep were removed from the study and were fed supplemental feed. They probably would have died before the end of the study had they not been given supplemental feed. These five individuals were not weighed at the end of December. Thus, the mean body weights for reproducing sheep for December, the dry season and the entire year are based on only the weights of the five sheep that remained in the study to its end.

Body Weight Changes During the Year

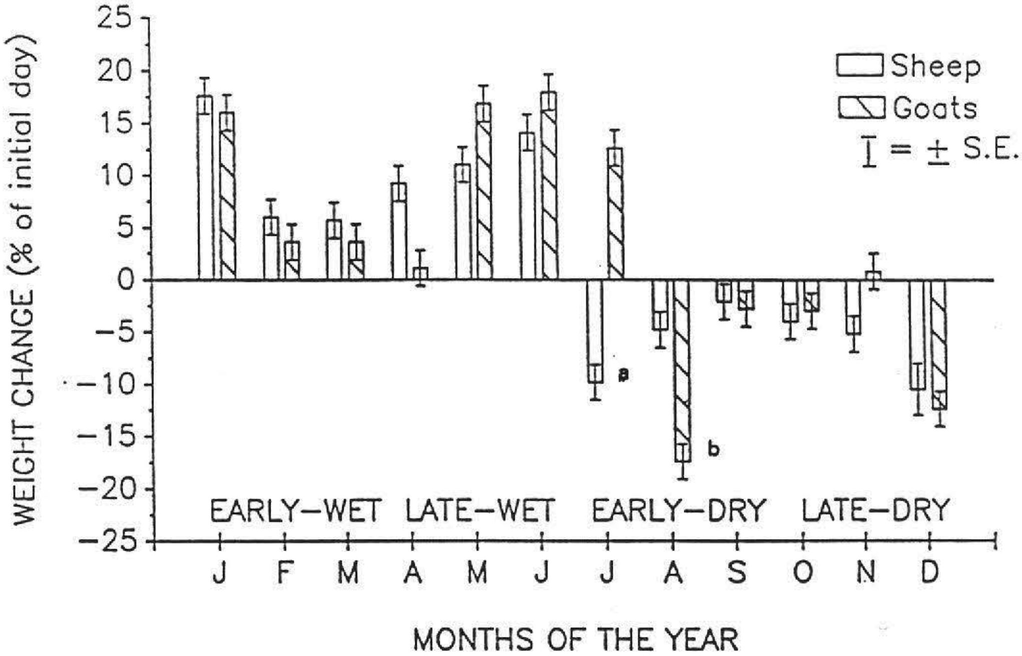
At the beginning of the study, the mean weights of reproducing and non-reproducing sheep were 20.5 and 19.1 kg, respectively. Corresponding weights of reproducing and non-reproducing goats were 19.6 and 18.0 kg, respectively. Animal body weights at the beginning of each month are presented in Appendix Table 1.

The monthly weight changes of sheep and goats were different ($P=.01$), and the reproductive status of the animals influenced ($P<.01$) their weight changes (Appendix Table 2). The various animal classes demonstrated different ($P<.01$) weight changes during the various months. The month-by-species, month-by-reproductive status and month-by-species-by-reproductive status interactions were all significant ($P<.01$).

All four classes of animals showed large weight gains in January, the beginning of the rainy season (Figures 3 and 4). (The values for their percentage of weight change are presented in Appendix Table 3). These high gains may have been partly compensatory after weight losses in the preceding dry season. All classes of animals had small weight gains in February and March. The rainy weather during these months probably depressed weight gains. Weight gains were generally high for all classes of animals in April, May and June, except for the goats in April. Their low weight gains were likely associated with the wet conditions, which peaked in April. By April, herbaceous understory material was quite tall (ca. 1-m), the soil and vegetation were saturated with water and the goats were very reluctant to forage under these conditions.

In July, August and September, some classes of animals began to lose weight. The large weight losses of reproducing sheep in July and reproducing goats in August were from parturition. After parturition, the lactating sheep and goats generally continued to lose weight during the remainder of the year. The non-reproducing sheep did not lose weight until September, while the non-reproducing goats maintained weight until November.

Excluding weight losses from parturition, all classes of animals had their greatest weight losses in December, near the end of the dry



[a]Parturition of sheep
[b]Parturition of goats

Figure 3. Body weight changes (expressed as a percentage of change during the month) for the reproducing animals.

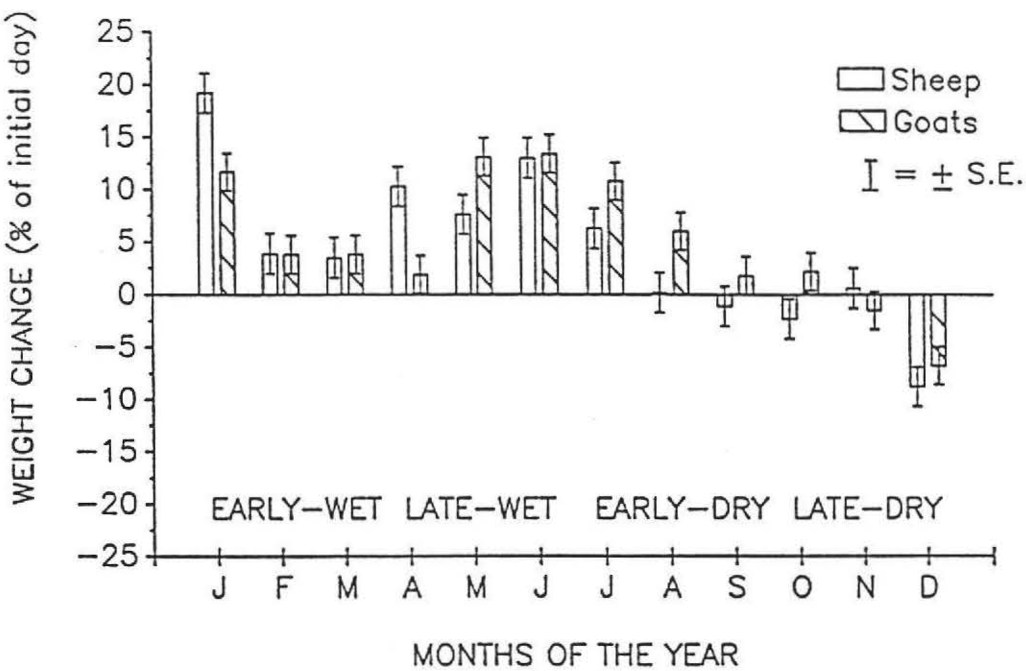


Figure 4. Body weight changes (expressed as a percentage of change during the month) for the non-reproducing animals.

season. During that period, reproducing and non-reproducing sheep lost about eleven and nine percent of their weights, respectively, and reproducing and non-reproducing goats lost about twelve and seven percent.

While the reproducing sheep and goats appear to have had similar weight losses in December, it is important to recall that only the better performing half of the reproducing sheep were weighed at the end of December. The other five sheep, which were removed from the study for reasons discussed above, would have increased the mean weight loss for reproducing sheep even more had they been weighed at the end of the year.

Adjusted body weights from the analysis of covariance are presented in Appendix Table 4. The same means are also presented in Figures 5 and 6. With respect to the analysis of covariance for body weights from the beginning of the study through the beginning of December, the species of animal alone did not ($P=.17$) influence body weights nor did ($P=.16$) reproductive status (Appendix Table 5). The species by reproductive status interaction was not ($P=.25$) significant. However, the month of the year had great ($P<.01$) influence on body weights and all interactions with months were highly ($P<.01$) significant. The analysis of covariance results for animal weights at the end of the study indicate that the species of animals did not ($P>.15$) affect the weights of either reproducing or non-reproducing animals (Appendix Table 6 and 7). During the wet season, reproducing sheep had greater ($P\leq.05$) adjusted body weights than reproducing goats in March, April, May and June. In the dry season, the reproducing

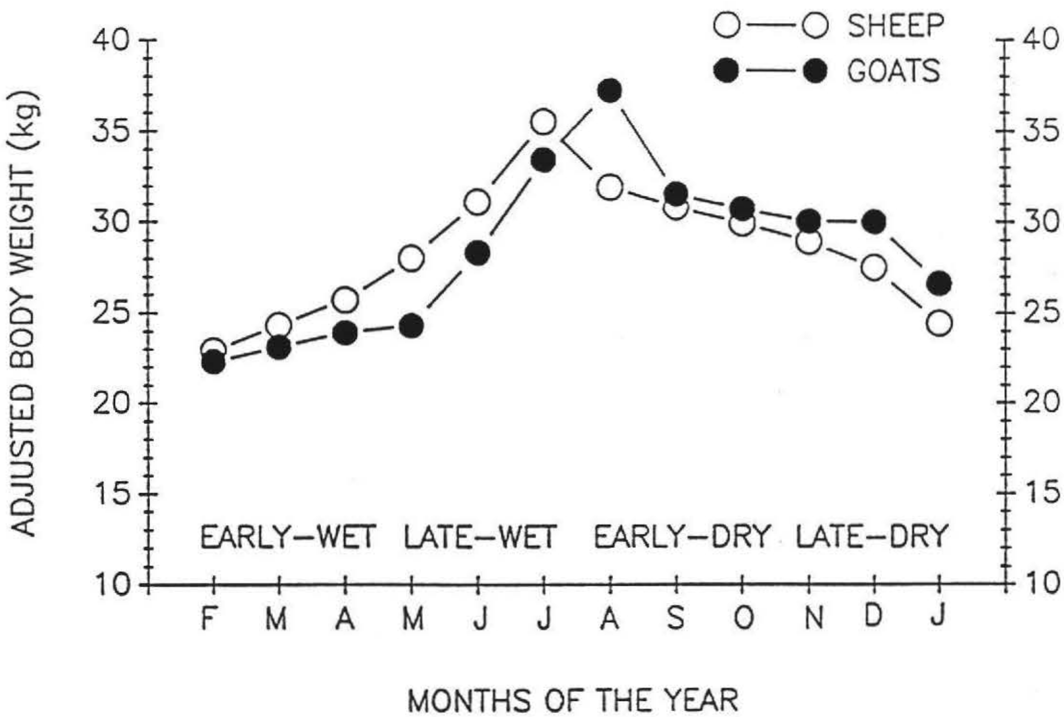


Figure 5. Adjusted body weights of reproducing sheep and goats at the beginning of each month of the study.

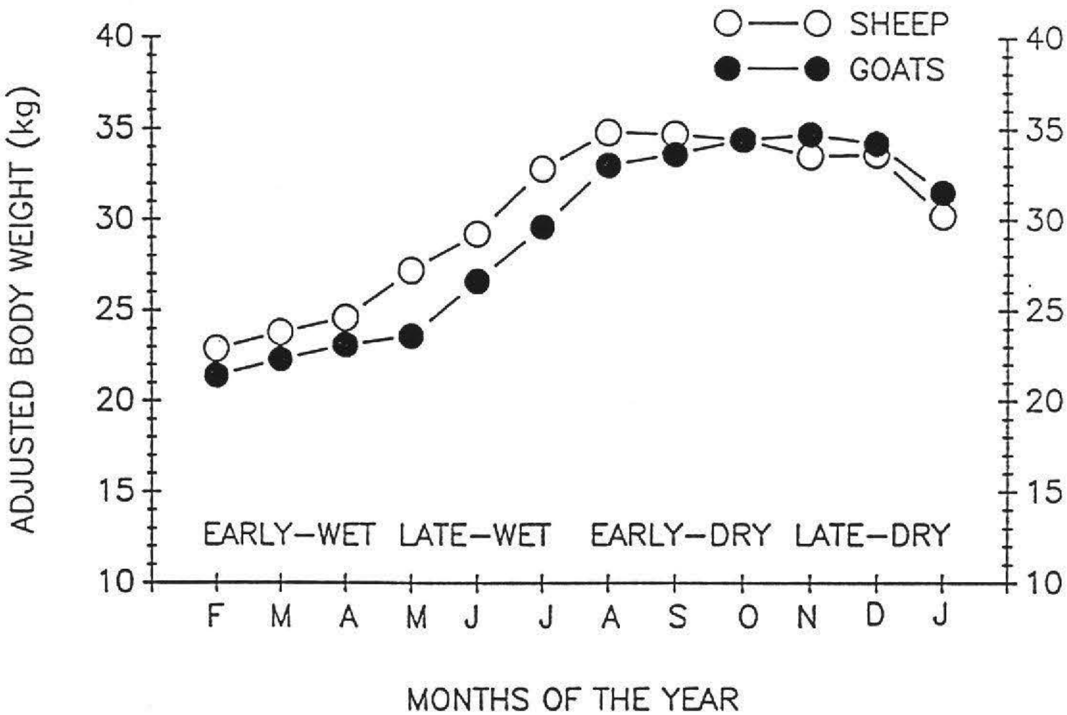


Figure 6. Adjusted body weights of non-reproducing sheep and goats at the beginning of each month of the study.

goats had greater adjusted body weights than their sheep cohorts in August and December. In all other months, the weights of reproducing sheep and goats were similar (P>.05). The non-reproducing sheep had greater (P≤.05) weights than non-reproducing goats in every month from February until July. In September, the non-reproducing goats had greater (P<.05) adjusted weights than similar sheep, but in all other dry season months the adjusted weights of non-reproducing sheep and goats were similar (P>.05).

In the wet season, reproducing sheep and goats gained similar (P>.05) weight (Appendix Table 8 and 9). However, non-reproducing sheep gained more (P ≤.05) weight than the non-reproducing goats in the wet season. In the dry season, reproducing sheep and goats lost similar (P>.05) weight, but only the better performing sheep were weighed at the end of the dry season. Non-reproducing sheep and goats had very different (P≤.05) weight changes in the dry season. Sheep lost weight while goats gained.

During the year, the reproducing goats had nearly twice (P≤.05) the weight gain of the reproducing sheep, and non-reproducing goats had about 1.2 times greater (P≤.05) gain than the non-reproducing sheep (Appendix Table 10 and 11). The year-long weight changes may seem inconsistent with seasonal weight changes, but one must bear in mind that the changes discussed are on a percentage basis rather than absolute. The non-reproducing sheep gained about 3.7 times more (P≤.05) weight than the reproducing sheep, while the non-reproducing goats gained about 2.3 times more ($P \leq .05$) weight than the reproducing goats.

Progeny Birth Dates, Birth Weights and Daily Weight Gains

The sheep conceived earlier than the goats, and lambs were born, on average, 19 days earlier in the dry season than were kids (Table 1). Lambs were born between July 20 and 29. Kids were born between August 7 and 22. All lambs and kids were born as singles. The lambs were heavier ($P < .01$) at birth than the kids (Appendix Table 12), and the kids had greater ($P = .08$) adjusted daily weight gains than the lambs for about their first 80 days of life (Appendix Table 13). The lambs potentially had an important advantage over the kids because of their earlier birth dates. Nutrient availability in the caatinga may have been somewhat higher during the first 80 days of lamb growth as compared to that for the kids.

Available Vegetation During the Four Periods of the Year

The overall amount and botanical composition of available vegetation varied greatly over the year (Table 2). This ranged from a herb-dominated, low-biomass condition in the wet periods to a higher biomass, herb-dominated condition in the early-dry period to a tree-leaf-litter-dominated, high-biomass situation in the late-dry period. The peak amount of available vegetation was recorded at the beginning of the dry season, when the herbaceous vegetation was at peak levels and tree leaves had begun to drop. By the beginning of the late-dry period, all tree leaves had fallen, and tree leaf litter supplied 70

Table 1. Birth dates, birth weights and adjusted daily weight gains for lambs and kids in their first eighty days of life.

Species	Mean Birth Date	Birth Weight (kg) Mean	Birth Weight (kg) SE	Adjusted Daily Weight Gain (kg) Mean	Adjusted Daily Weight Gain (kg) SE
Lambs	25 July	3.5[a]	0.15	0.075[c]	0.007
Kids	13 August	2.4[b]	0.20	0.096[c]	0.007

[a-b]Least-squares means with different superscripts differ ($P \leq .01$).

[c-d]Least-squares means with different superscripts do not differ ($P = .08$).

Table 2. Biomass (kg/ha) of available vegetation at the beginning of the four periods of the year.

	Early-Wet Period[a]		Late-Wet Period[b]		Early-Dry Period[c]		Late-Dry Period[d]	
	kg/ha	SE	kg/ha	SE	kg/ha	SE	kg/ha	SE
Tree species								
Pau banco	65	23	58	30	38	11		
Sabia	37	17	49	23	41	14		
Mofumbo	95	38	31	20	42	22		
Marmeleiro	11	8	35	17	14	9		
Pereira	11	10	43	17	5	5		
Jurema branca	6	6	22	6	--	--		
Jurema preta	6	6	7	6	2	2		
All other species	7	7	3	5	--	--		
Total tree leaves	238		248		142		0	
Tree leaf litter	0		0		839	166	1677	133
Total tree biomass	238		248		981		1677	
Total herbaceous biomass	381	33	681	67	1677	167	705	83
Total biomass	619		929		2658		2382	

[a]The early-wet period comprises the months of January, February and March.
[b]The late-wet period comprises the months of April, May and June.
[c]The early-dry period comprises the months of July, August and September.
[d]The late-dry period comprises the months of October, November and December.

percent of the available vegetation with herbaceous material making up the remainder. The tree species pau branco, sabia, mofumbo, marmeleiro and pereira supplied the majority of the tree foliage. The herbaceous element was composed of about 75 species.

Botanical Selection of Sheep and Goats
During the Four Periods of the Year

The levels of browse, grass and forbs were different ($P \leq .01$) in sheep and goat diets (Appendix Tables 14, 15 and 16). Additionally, the animal species-by-period interaction was significant ($P < .01$) for browse and forb levels but not for grass levels ($P = .19$). For each animal species, the amounts of the three vegetation classes selected varied ($P < .01$) among the four periods (Appendix Tables 17 and 18).

Browse Selection

Goats selected more ($P < .05$) browse than sheep did in the two wet periods and in the early-dry period (Table 3). In the late-dry period, both sheep and goat diets had a large browse component, consisting of tree leaf litter. The analysis of variance results for sheep versus goat use of particular browse species is presented in Appendix Table 19.

The comparative prevalence of each browse species in sheep and goat diets for all periods is presented in Table 4. Sabia was by far the most popular browse species for both sheep and goats. Goats selected more ($P < .05$) sabia than sheep during both wet periods and during the early-dry period, while sheep selected more ($P < .05$) sabia during the late-dry period. With the exception of sabia, sheep

Table 3. Browse, grass and forb composition (least-squares means and S.E.) of sheep and goat diets during four periods of the year.

	Early-Wet Period		Late-Wet Period		Early-Dry Period		Late-Dry Period	
	Sheep	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goats
Browse	$11.8^{a,1}$(2.8)	$36.9^{b,1}$(3.0)	$19.5^{a,1}$(3.0)	$41.7^{b,1}$(3.2)	$39.9^{a,1}$(2.8)	$54.8^{b,1}$(2.9)	$45.4^{a,1}$(3.3)	$40.8^{a,1}$(3.3)
Grass	$47.8^{a,2}$(2.1)	$41.8^{a,1}$(2.2)	$20.0^{a,1}$(2.2)	$5.1^{b,2}$(2.4)	$9.7^{a,2}$(2.1)	$3.1^{b,2}$(2.1)	$27.7^{a,2}$(2.4)	$22.0^{a,2}$(2.4)
Forbs	$40.3^{a,2}$(2.5)	$23.5^{b,2}$(2.7)	$58.9^{a,2}$(2.7)	$53.4^{a,3}$(2.9)	$50.2^{a,3}$(2.5)	$41.3^{b,3}$(2.6)	$26.9^{a,2}$(3.0)	$37.5^{b,1}$(3.0)

$^{a-b}$Least-squares means for the same class of vegetation and period with different superscripts differ ($P<.05$) between species.

$^{1-2}$Least-squares means for the same species and period with different superscripts differ ($P<.05$) between vegetation classes.

Table 4. Browse species (least-squares means percent and S.E.) in sheep and goat diets during four periods of the year.

Species	Early Wet Period		Late Wet Period		Early Dry Period		Late Dry Period	
	Sheep	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goats
Sabia (Mimosa caesalpiniaefolia)	11.8^{a}(2.5)	26.2^{b}(2.6)	15.6^{a}(2.6)	23.8^{b}(2.8)	18.6^{a}(2.5)	29.1^{b}(2.5)	33.9^{a}(2.9)	17.0^{b}(2.9)
Marmeleiro (Croton hemiargyreus)	T^{ac}(0.5)	2.4^{b}(0.5)	0.0^{a}	0.1^{a}(0.5)	T^{a}	0.3^{a}(0.5)	T^{a}	1.0^{a}(0.5)
Mofumbo (Combretum leprosum)	0.0^{a}	1.6^{a}(1.0)	T^{a}	2.5^{b}(1.0)	1.7^{a}(0.9)	7.3^{b}(0.9)	0.3^{a}(1.1)	5.1^{b}(1.1)
Feizão bravo (Capparis cynophallophora)	0.0^{a}	1.3^{b}(0.5)	0.6^{a}(0.5)	3.7^{b}(0.5)	0.1^{a}(0.5)	2.2^{b}(0.5)	0.0^{a}	0.2^{a}(0.5)
Pereiro (Aspidosperma pyrifolium)	0.0^{a}	0.7^{a}(0.3)	0.3^{a}(0.4)	2.3^{b}(0.4)	1.0^{a}(0.3)	1.4^{a}(0.3)	0.0^{a}	0.0^{a}
João mole (species unknown)	0.0	1.1 (0.4)	0.0	0.4 (0.4)	0.2 (0.3)	0.1 (0.4)	0.0	0.0
Pau moco (Luetzelburgia auriculata)	0.0^{a}	0.9^{a}(0.5)	1.1^{a}(0.5)	2.7^{b}(0.5)	0.0^{a}	3.9^{b}(0.5)	0.0^{a}	0.0^{a}
Jurema branca (Pithecolobium dumosum)	0.0^{a}	0.9^{b}(0.3)	0.4^{a}(0.3)	2.2^{b}(0.3)	0.0^{a}	0.3^{a}(0.3)	0.0^{a}	0.1^{a}(0.3)
Jurema preta (Mimosa acutistipula)	0.0	0.5 (0.8)	1.2 (0.8)	2.5 (0.9)	6.7 (0.8)	1.2 (0.8)	7.7 (0.9)	11.1 (0.9)
Marmeleiro branco (Croton sincorensis)	0.0^{a}	0.8^{b}(0.2)	0.0^{a}	T^{a}	0.0^{a}	T^{a}(0.2)	0.0^{a}	0.1^{a}(0.2)
Aroeira (Astronium urundeuva)	0.0^{a}	0.3^{a}(0.2)	0.0^{a}	1.0^{b}(0.2)	0.4^{a}(0.2)	1.0^{b}(0.2)	0.1^{a}(0.2)	0.0^{a}
Jucazeiro (Caesalpinia ferra)	0.0	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.4 (0.1)	0.0	0.1 (0.1)
Camara de chumbo (Lantana camara)	0.0	0.0	0.0	0.3 (0.1)	0.0	0.0	0.0	0.1 (0.1)
Pau branco (Auxemma oncocalyx)	0.0	T	T	0.2 (0.4)	3.0 (0.3)	2.3 (0.3)	0.2 (0.4)	0.9 (0.4)
Maria preta (Cordia salzmanni)	0.0^{a}	0.0^{a}	0.1^{a}(0.3)	0.1^{a}(0.3)	2.8^{a}(0.3)	0.9^{b}(0.2)	0.1^{a}(0.3)	0.6^{a}(0.3)
Catingueira (Caesalpinia pyramidalis)	0.0	0.1 (0.7)	0.2 (0.7)	0.0	3.7 (0.6)	2.6 (0.7)	3.0 (0.8)	5.2 (0.8)
Imburana (Torresea cearensis)	0.0^{a}	0.1^{a}(0.2)	0.0^{a}	0.2^{a}(0.2)	0.0^{a}	1.2^{b}(0.2)	0.0^{a}	0.0^{a}
Juazeiro (Zizyphus joazeiro)	0.0^{a}	T^{a}	0.0^{a}	0.0^{a}	1.5^{a}(0.2)	0.5^{b}(0.2)	0.1^{a}(0.2)	0.0^{a}
Mororo (Bauhinia forficata)	0.0	0.0	0.0	0.0	0.0	0.1 (0.03)	0.0	0.0

[a-b]Least-squares means within a plant species and period with different superscripts differ ($P \leq .10$) between species.
[c]Trace amount (<0.1%) in diet.

virtually ignored browse species during both wet periods. Goats selected considerable amounts of sabia and small amounts of a large number of other browse species in the wet periods. During the dry periods, in addition to sabia, mofumbo, jurema preta, pau branco, maria preta (Cordia salzmanni DC), catingueira and juazeiro (Zizyphus joazeiro Mart.) leaves were important components of sheep diets. For goats, marmeleiro, mofumbo, feizao bravo (Capparis cynophallophora L.), pereiro, pau moco (Luetzellurgia auriculata Ducke) jurema preta, aroeira, pau branco, catingueira and imburana were important dietary components during the dry periods.

Grass and Forb Selection

In the early-wet period, grass was a large component of sheep and goat diets (Table 3). Although sheep selected more ($P<.05$) grass than goats did in the late-wet and early-dry periods, grass was the least ($P<.05$) prevalent of the three forage types in the diets of both animal species in the early-dry period. The prevalence of grass increased in both sheep and goat diets in the late-dry period. Forbs were a larger ($P<.05$) portion of sheep diets than of goat diets in the early-wet and early-dry periods. In the late-wet period forbs formed a large component of sheep and goat diets. In the late-dry period goats selected more ($P<.05$) forbs than sheep did, although forbs remained an important part of sheep diets.

Sheep and goats selected a particularly large number of forb species during the four periods. The analysis of variance results for sheep versus goat use of particular grass and forb species are presented in Appendix Table 19. Comparisons of the prevalence of each of these species in sheep and goat diets are presented in Table 5.

Diet Quality of Sheep and Goats During Four Periods of the Year

Crude Protein

Overall, crude protein (CP) levels in sheep and goat diets were different ($P<.01$) (Appendix Table 20). The period of the year strongly affected ($P<.01$) dietary crude protein levels, and the animal species-by-period interaction was significant ($P<.01$). During the two wet periods, sheep selected diets higher ($P<.05$) in CP than goats (Table 6). However, in the two dry periods, dietary CP content did not differ between sheep and goats ($P>.05$). For sheep and goats, dietary CP content was highest ($P<.05$) in the late-wet period, lowest ($P<.05$) in the late-dry period and intermediate during the early-wet and early-dry periods. The dietary CP levels were relatively high in the wet periods and early-dry period for both animal species. In the late-dry period, they were at moderate levels.

Body weight changes of sheep and goats during the four periods of the year were highly correlated to dietary crude protein content. For sheep, body weight change (as a percentage of initial BW for a particular period) was correlated to dietary crude protein content by the expression $Y = -47.98 + 3.97(CP)$; $r^2=.99$ ($P<.01$). For goats, body weight change was related to dietary crude protein content by the expression $Y = -41.58 + 3.74(CP)$; $r^2=.97$ ($P=.02$).

Table 5. Grass and forb species (least-squares means percent and S.E.) in sheep and goat diets during four periods of the year.

	Early Wet Period		Late Wet Period		Early Dry Period		Late Dry Period	
	Sheep	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goats
Grasses								
Capim pe de galinha (Echinochloa spp.)	3.7^{a}(0.6)	3.8^{a}(0.6)	2.2^{a}(0.6)	0.1^{b}(0.6)	2.0^{a}(0.6)	0.2^{b}(0.6)	7.6^{a}(0.7)	4.5^{b}(0.7)
Capim rabo de raposa (Andropogon spp.)	7.9 (0.7)	10.1 (0.7)	4.1 (0.7)	1.8 (0.8)	2.7 (0.7)	0.3 (0.7)	10.2 (0.8)	10.5 (0.8)
Capim milha branca (Branchiaria plantaginea)	9.4 (0.9)	14.4 (0.9)	6.9 (0.9)	0.3 (1.0)	0.3 (0.9)	0.7 (0.9)	3.3 (1.0)	0.9 (1.0)
Capim milha vermelha (Panicum spp.)	23.9^{a}(1.1)	12.7^{b}(1.2)	4.1^{a}(1.2)	0.7^{b}(1.3)	T^{a}(1.1)	0.4^{a}(1.2)	2.4^{a}(1.3)	2.0^{a}(1.3)
Other grasses	0.0	0.0	0.9 (0.6)	2.2 (.06)	4.7 (0.5)	1.5 (0.6)	4.2 (0.6)	4.2 (0.6)
Forbs								
Amendoin de caracara (Arachis spp.)	0.1^{a}(0.2)	T^{ac}	T^{a}(0.2)	1.9^{b}(0.2)	0.0	0.0	0.0	0.0
Azedinho (Oxalis spp.)	0.0 (0.2)	T (0.02)	0.0	0.0	0.0	0.1 (0.02)	0.0	0.0
Bambural branco (Bainvillea spp.)	2.2 (0.2)	0.2 (0.2)	0.0	1.4 (0.3)	0.0	0.4 (0.2)	T	0.1 (0.3)
Bambural verdadeiro (Hyptis spp.)	1.8^{a}(0.5)	1.2^{a}(0.6)	1.2^{a}(0.6)	3.6^{b}(0.6)	7.1^{a}(0.5)	2.4^{b}(0.6)	3.6^{a}(0.6)	2.6^{a}(0.6)
Barba de bode (Cyperus compressus)	3.0^{a}(0.3)	0.9^{b}(0.4)	1.8^{a}(0.4)	0.0^{b}	0.0	0.0	0.2^{a}(0.4)	0.1^{a}(0.4)
Canafistula brava (Pithecolobium spp.)	0.0	0.1 (0.1)	0.0	0.4 (0.1)	0.0	0.0	0.0	0.0
Canafistula de lagoa (Pithecolobium cauliflorum)	0.0^{a}	2.6^{b}(0.6)	2.7^{a}(0.6)	11.7^{b}(0.7)	0.1^{a}(0.6)	0.0^{a}	0.6^{a}(0.7)	0.0^{a}
Carrapicho de agulha (Bidens spp.)	4.7^{a}(0.6)	1.1^{b}(0.6)	5.4^{a}(0.6)	2.6^{b}(0.7)	5.8^{a}(0.6)	1.3^{b}(0.6)	2.3^{a}(0.7)	3.6^{a}(0.7)
Casco de burro (Dioscorea laxiflora)	0.0	0.1 (0.1)	0.1 (0.1)	0.2 (0.1)	0.0	0.0	T	0.0
Cebola brava (Amaryllis belladonna)	0.0	0.0	0.0	0.6 (0.2)	0.0	0.0	0.0	0.0
Centrosema (Centrosema spp.)	0.0	0.0	0.4 (0.2)	0.4 (0.2)	0.0	0.1 (0.2)	0.0	0.0
Cuandu (Cajanus indicus)	T	0.2 (0.2)	1.1 (0.2)	1.5 (0.2)	0.0	T	0.0	0.1 (0.2)
Desconhecida (species unknown)	5.8 (0.6)	4.3 (0.6)	3.9 (0.6)	5.6 (0.6)	2.8^{a}(0.5)	5.8^{a}(0.5)	4.5^{a}(0.6)	3.2^{a}(0.6)
Erva de ovelha (Stylosanthes humilis)	15.8^{a}(1.1)	1.6^{b}(0.2)	8.3^{a}(1.2)	1.7^{b}(1.2)	0.4 (1.1)	0.3 (1.1)	3.8 (1.3)	5.4 (1.3)
Ervango (Froelichia lanata)	0.0	0.0	0.7 (0.2)	0.4 (0.2)	0.3 (0.1)	0.4 (0.2)	0.1 (0.2)	0.1 (0.2)
Espoleta (species unknown)	0.1^{a}(0.6)	0.0^{a}	7.2^{a}(0.7)	2.0^{b}(0.7)	2.6^{a}(0.6)	3.0^{a}(0.7)	1.5^{a}(0.7)	3.3^{b}(0.7)
Fava de boi (Vanavalia obtusifolia)	0.0	0.1 (0.3)	0.0	0.7 (0.3)	1.2 (0.3)	0.8 (0.3)	1.1 (0.4)	1.0 (0.4)
Fedegoso (Heliotropium indicum)	1.4 (0.2)	1.4 (0.2)	0.1 (0.2)	0.1 (0.3)	0.0	T	0.0	0.1 (0.3)
Feizão de rola (Phaseolus lathyroides)	3.4 (0.5)	2.5 (0.5)	2.3 (0.5)	3.4 (0.5)	T	0.0	0.0	0.0
Gergelim bravo (Crotalaria spp.)	0.0^{a}(0.4)	0.2^{a}(0.4)	1.7^{a}(0.4)	1.3^{a}(0.4)	5.3^{a}(0.4)	1.4^{b}(0.4)	0.0^{a}	0.2^{a}(0.5)
Jitorana lisa (Quamoclit rochae)	0.6 (0.2)	0.4 (0.2)	T (0.2)	0.6 (0.3)	0.4 (0.2)	0.3 (0.2)	T	0.2 (0.2)
Jitirana peluda (Ipomoea pentaphylla)	1.5 (0.3)	0.2 (0.3)	0.5 (0.3)	1.0 (0.3)	0.7 (0.3)	0.5 (0.3)	0.1 (0.4)	0.2 (0.4)
Lingua de vaca (Chaptalia spp.)	0.0^{a}	0.1^{a}(0.8)	5.0^{a}(0.8)	3.7^{a}(0.8)	1.9^{a}(0.7)	1.6^{a}(0.7)	1.0^{a}(0.9)	13.7^{b}(0.9)
Malicia (Mimosa spp.)	0.0	1.4 (0.4)	0.0	0.4 (0.4)	0.0	0.0	0.0	0.0
Malva (Sida spp.)	0.0^{a}	0.0^{a}	0.2^{a}(0.2)	T^{a}	0.4^{a}(0.2)	T^{b}	0.8^{a}(0.2)	0.1^{b}(0.2)
Maracujo de estralo (Passiflora spp.)	0.0^{a}	0.1^{a}(0.6)	0.0^{a}	0.0^{a}	9.0^{a}(0.6)	0.0^{b}	0.0^{a}	T^{a}
Maracuja rasteiro (Passiflora spp.)	T^{a}	0.2^{a}(0.2)	0.3^{a}(0.2)	0.2^{a}(0.3)	0.0^{a}	2.0^{b}(0.2)	T^{a}	T^{a}
Mariana (Commelina spp.)	0.5^{a}(0.2)	0.2^{a}(0.2)	1.9^{a}(0.2)	0.4^{b}(0.2)	0.2^{a}(0.2)	0.4^{a}(0.2)	T^{a}	0.0^{a}
Mata pasto (Cassia sericea)	0.0	0.0	0.1 (0.1)	0.0	0.1 (0.1)	0.1 (0.1)	T	T
Melosa (Ruellia asperula)	0.5^{a}(1.0)	1.1^{a}(1.1)	2.8^{a}(1.1)	2.4^{a}(1.2)	4.7^{a}(1.0)	13.1^{b}(1.1)	1.2^{a}(1.2)	1.5^{a}(1.2)
Melosa brava (Cassia hispidula)	0.2^{a}(0.4)	0.0^{a}	2.6^{a}(0.4)	0.3^{b}(0.4)	0.2^{a}(0.4)	4.9^{b}(0.4)	T^{a}	0.0^{a}
Milho de cobra (Dracontium asperum)	0.3 (0.3)	0.0	0.5 (0.3)	0.4 (0.3)	0.0	0.7 (0.3)	0.0	0.2 (0.3)
Mirasol (species unknown)	0.3^{a}(0.7)	0.1^{a}(0.7)	6.1^{a}(0.7)	0.6^{b}(0.7)	1.8^{a}(0.7)	0.3^{b}(0.7)	0.0^{a}	0.0^{a}
Paco paco (Wissadula spp.)	0.2 (0.8)	2.1 (0.9)	T	0.6 (0.9)	2.2 (0.8)	0.0	4.4 (0.9)	1.7 (0.9)
Pescoco de ganso (Stachytarpheta gardneriana)	0.0	0.0	0.2 (0.1)	0.0	0.0	T	0.0	T
Pimentinha (species unknown)	0.3^{a}(0.3)	0.5^{a}(0.4)	2.5^{a}(0.4)	0.2^{b}(0.4)	1.2^{a}(0.3)	0.3^{b}(0.3)	0.1^{a}(0.4)	0.6^{b}(0.4)
Quebra panela (Telanthera spp.)	0.7 (0.4)	1.0 (0.4)	1.1 (0.4)	2.7 (0.4)	0.6 (0.4)	T	0.6 (0.5)	0.4 (0.5)
Relogio (Sida rhombifolia)	0.0	1.0 (0.1)	0.0	0.3 (0.1)	0.0	0.0	0.0	0.0
Urtiga (Ureara spp.)	0.0^{a}	0.4^{b}(0.1)	0.0^{a}	0.2^{a}(0.1)	0.0^{a}	0.2^{a}(0.1)	0.0^{a}	0.0^{a}
Vassourinha (Stylosanthes spp.)	0.0^{a}	0.1^{a}(0.3)	T^{a}	0.1^{a}(0.3)	1.0^{a}(0.3)	1.0^{a}(0.3)	1.5^{a}(0.3)	0.0^{b}

$^{a-b}$Least-squares mean within a plant species and period with different superscripts differ ($P \leq .10$) between species.
^{c}Trace amount (<0.1%) in diet.

Table 6. Dietary crude protein content and _in vitro_ organic matter digestibility (least-squares means and S.E.) for sheep and goats in the four periods of the year.

Period	Crude Protein[a]		In-vitro digestibility[a]	
	Sheep	Goats	Sheep	Goats
Early-Wet	$19.3^{b,2}$(0.3)	$17.4^{c,2}$(0.3)	$55.5^{b,1}$(1.2)	$52.7^{b,1}$(1.3)
Late-Wet	$21.0^{b,1}$(0.3)	$19.0^{c,1}$(0.4)	$46.1^{b,3}$(1.2)	$44.7^{b,2}$(1.3)
Early-Dry	$14.7^{b,3}$(0.3)	$15.2^{b,3}$(0.3)	$51.8^{b,2}$(1.2)	$36.6^{c,3}$(1.3)
Late-Dry	$10.6^{b,4}$(0.4)	$9.6^{b,4}$(0.4)	$41.0^{b,4}$(1.4)	$35.2^{c,3}$(1.3)
Average	16.4	15.3	48.6	42.3

[a]Percent of organic matter.

[b-c]Least-squares means for a particular diet characteristic and period with different superscripts differ (P<.05) between species.

[1-4]Least-squares means for a particular diet characteristic and species with different superscripts differ (P<.05) over periods.

In Vitro Organic Matter Digestibility

The *in vitro* organic matter digestibilities (IVOMD) of sheep and goat diets were different (P<.01), the period of year affected (P<.01) dietary IVOMD and there was a significant (P<.01) animal species-by-period interaction (Appendix Table 21). The IVOMD of sheep and goat diets did not differ (P>.05) in the two wet periods (Table 6), but sheep diets had higher (P<.05) IVOMD than goat diets in the two dry periods. For both animal species, IVOMD was highest (P<.05) in the early-wet period and lowest (P<.05) during the late-dry period. Their early-wet period diets had only moderate IVOMD for both species. The sheeps' diets for the remainder of the year had low to moderate IVOMD; whereas, the goats' diets had low to very low levels. The poor relationship between IVOMD and lignin levels for goats suggests that higher CP levels or other factors besides lignin level are important determinants of IVOMD.

Neutral Detergent Fiber

The NDF levels of sheep and goat diets were different (P<.01), the period of the year influenced (P<.01) NDF levels and the animal species-by-period interaction was significant (P<.01) (Appendix Table 22). The NDF levels for sheep and goat diets were not different (P>.05) during the early-wet and late-dry periods. They were different (P<.05) during the late-wet and early-dry periods, with the sheep levels higher than those of the goats in these periods (Table 7). The NDF levels were surprisingly high for both animal species in the early-wet period, when the animals were eating relatively young vegetation.

Table 7. Dietary neutral detergent fiber and lignin contents (least-squares means and S.E.) for sheep and goats in the four periods of the year.

	Neutral Detergent Fiber[a]		Lignin[a]	
Period	Sheep	Goats	Sheep	Goats
Early-Wet	$64.6^{b,2}$(1.5)	$62.7^{b,2}$(1.6)	$10.4^{b,3}$(0.5)	$12.8^{c,2}$(0.6)
Late-Wet	$58.3^{b,3}$(1.5)	$42.8^{c,4}$(1.7)	$13.1^{b,2}$(0.5)	$9.3^{c,3}$(0.6)
Early-Dry	$53.5^{b,4}$(1.5)	$47.7^{c,3}$(1.6)	$12.6^{b,2}$(0.5)	$12.4^{b,2}$(0.6)
Late-Dry	$\underline{85.6}^{b,1}$(1.7)	$\underline{86.2}^{b,1}$(1.7)	$\underline{15.0}^{b,1}$(0.6)	$\underline{16.1}^{b,1}$(0.6)
Average	65.5	59.9	12.8	12.7

[a]Percentage of organic matter.

[b-c]Least-squares means for the same diet characteristic and period with different superscripts differ ($P<.05$).

[1-4]Least-squares means for the same diet characteristic and species with different superscripts differ ($P<.05$).

The late-dry period levels were also quite high, but the animals were eating leaf litter and matured herbaceous material.

Lignin

Overall, the species of the animals alone were not significant ($P=.77$) influences on lignin levels during the year (Appendix Table 23). The period of the year affected ($P<.01$) dietary lignin levels, and the animal species-by-period interaction was significant ($P<.01$). Goat diets had higher ($P<.05$) lignin levels than did sheep diets in the early-wet period (Table 7). In the late-wet period the situation was reversed. Lignin levels were similar ($P>.05$) for sheep and goats during both of the dry periods. Sheep diets were lowest ($P<.05$) in lignin level in the early-wet period and highest ($P<.05$) in the late-dry period. Goat diets were lowest ($P<.05$) in lignin in the late-wet period and highest ($P<.05$) in the late-dry period.

Daily Activity Budgets of Sheep and Goats in Four Periods of the Year

The species of the animals alone did not affect ($P=.70$) the percent of a 24-hour day spent traveling by the animals, but the period of year did ($P<.01$) (Appendix Table 24). The species-by-period interaction was significant ($P<.01$). In the wet periods and the late-dry period, traveling time did not differ ($P>.10$) between sheep and goats (Table 8). In the early-dry period, sheep spent more ($P\leq.10$) of their day traveling than goats did. Except for sheep in the early-dry period, both species consistently devoted about 4.5 to 6.5 percent of their days to traveling.

Table 8. Percent of day (mean and S.E.) spent in various activities.

	PERIODS							
	Early-Wet		Late-Wet		Early-Dry		Late-Dry	
	Sheep	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goats
Traveling	$4.5^{a,1}$ (0.5)	$5.2^{a,1}$ (0.7)	$6.4^{a,2}$ (0.9)	$6.7^{a,1,3}$ (0.4)	$8.3^{a,3}$ (0.6)	$5.2^{b,1,4}$ (0.5)	$4.0^{a,1}$ (0.6)	$5.3^{a,1,3,4}$ (0.8)
Foraging	$23.9^{a,1}$ (2.2)	$19.6^{b,1}$ (2.2)	$22.3^{a,1,2}$ (1.1)	$16.1^{b,1}$ (1.3)	$27.1^{a,1,3}$ (0.9)	$28.8^{a,2}$ (1.0)	$33.2^{a,4}$ (0.5)	$31.3^{a,2}$ (1.9)
Ruminating	$28.8^{a,1}$ (2.1)	$34.3^{b,1}$ (1.4)	$26.5^{a,1}$ (1.7)	$27.1^{a,2}$ (2.3)	$37.0^{a,2}$ (1.8)	$41.9^{b,3}$ (1.5)	$36.3^{a,2}$ (0.9)	$36.4^{a,1}$ (1.0)
All Other Activities	$42.9^{a,1}$ (2.7)	$35.9^{b,1}$ (3.0)	$44.4^{a,1}$ (1.9)	$50.2^{b,2}$ (2.9)	$27.6^{a,2}$ (2.1)	$24.2^{a,3}$ (1.9)	$26.6^{a,2}$ (0.9)	$27.0^{a,3}$ (1.9)

$^{a-b}$Means for the same period and activity with different superscripts differ ($P \leq .10$) between species.

$^{1-4}$Means for the same species and activity without common superscripts differ ($P \leq .10$) among periods.

The species of the animals influenced ($P<.01$) the percent of a 24-hour day spent foraging (Appendix Table 25), as did ($P<.05$) the period of year. The species-by-period interaction was significant ($P<.05$). Sheep spent 22 percent more ($P\leq.10$) time foraging than goats did in the early-wet period (Table 8) and 39 percent more ($P\leq.10$) time in the late-wet period. However, in the dry periods, the two species did not differ ($P>.10$). For sheep, foraging times were not different ($P>.10$) in the two wet periods, but they spent about 23 percent more time foraging in the late-dry period than in the early-dry period. Sheep spent more ($P\leq.10$) time foraging in the late-dry period than in any other period. In the wet periods, foraging times of the goats did not differ ($P>.10$). Goats spent about 68 percent more ($P\leq.10$) time foraging in the dry periods than in the wet periods. The foraging times of goats were not different ($P>.10$) in the two dry periods.

The species of the animals affected ($P=.03$) the percent of a 24-hour day spent ruminating, and the period of the year also affected ($P<.01$) ruminating times (Appendix Table 26). The species-by-period interaction was not significant ($P=.26$). The goats spent about 19 percent more ($P\leq.10$) time ruminating in the early-wet period than sheep did (Table 8). In the late-wet period, sheep and goats had similar ($P>.10$) ruminating times. Goats spent 13 percent more ($P\leq.10$) time ruminating than sheep in the early-dry period, while the two species had similar ($P>.10$) ruminating times in the late-dry period. The sheep had similar ($P>.10$) ruminating times in the two wet periods and similar ($P>.10$) ruminating times in the two dry periods. However, the sheep spent more ($P\leq.10$) time ruminating in the dry periods than they did in the wet periods. The goats spent about 27 percent more time ruminating in the early-wet period than they did in the late-wet period, when their ruminating time was the lowest ($P \leq .10$) of the year. The goats spent more ($P \leq .10$) time ruminating in the early-dry period than in any other period.

The time spent ruminating by goats in the four periods of the year was highly correlated to the NDF and lignin contents of their diets; $Y = 2.94 - 0.70(\%NDF) + 5.85(\% \text{ lignin})$; $r^2 = .99$ ($P = .05$). In contrast, the time spent ruminating by sheep was highly correlated to OMD and lignin contents of their diets; $Y = 70.66 - 0.52(\% \text{ OMD}) -1.23(\% \text{ lignin})$; $r^2 = .99$ ($P = .08$).

The species of the animal influenced ($P < .01$) the percent of the day spent for "other activities" (Appendix Table 27), but period of year did not ($P = .51$). The species-by-period interaction was significant ($P < .05$). Both species used more ($P \leq .10$) time for "other activities" in the wet periods than in the dry periods (Table 8). The allocation of time to "other activities" did not differ ($P > .10$) between sheep and goats in the dry periods. Sheep devoted about 40 percent of their time in "other activities" in the wet periods, while using about 25 percent of their time in these activities in the dry periods. Goats spent 35 to 50 percent of their time in "other activities" in the wet periods, then used about 25 percent of their time for these activities in the dry periods.

Although the sheep and goats traveled similar ($P > .60$) distances during the two dry periods, both species traveled farther ($P \leq .06$) in the early-dry period than they did in the late-dry period (Appendix Table 28 and Table 9).

Particle Retention Time in the Gastrointestinal Tracts of Free-ranging Sheep and Goats

Overall, the species of the animal did not influence ($P=.08$) particle retention time in the gastrointestinal tract (Appendix Table 29). However, the period of the year and the reproductive status of the animal did influence ($P\leq.05$) retention time. The species-by-period interaction was highly significant ($P<.01$). The other interactions were not significant ($P=.10$ or greater). In the late-wet period, the reproducing goats retained particles in their gastrointestinal tracts 20 percent longer ($P\leq.05$) than reproducing sheep (Table 10). In the late-dry period, the situation was reversed, and the reproducing sheep retained particles 12 percent longer ($P\leq.05$) than the reproducing goats. In this period, the reproducing sheep had 12 percent longer retention time than the reproducing goats. The retention times of all animals were longest ($P\leq.05$) in the late-dry period.

Validation of Forage Insertion Technique

To support the unusual style of forage intake in digestion trials, I conducted trials comparing insertion versus normal ingestion.

The in vivo dry matter digestibility of cunha hay was the same regardless of whether it was fed normally or inserted into sheep rumina as extrusa (Table 11). Likewise, trials with goats showed no differences attributable to route of ingestion (i.e., consumed normally versus manually inserted into the rumen) (Appendix Tables 30, 31 and

Table 9. Distance traveled (m/d) by sheep and goats during the early-dry and late-dry periods.

		Periods			
		Early-Dry		Late-Dry	
Species	n	Mean	SE	Mean	SE
Sheep	10	5072[a]	384	4006[b]	192
Goats	10	5231[a]	402	4222[b]	532

[a-b]Means in the same row or column with different superscripts differ (P<.10).

Table 10. Retention time (h) of dietary fiber in the gastrointestinal tract (least-squares means and S.E.) for reproducing and non-reproducing sheep and goats during three periods of the year.

Period	Species	Reproductive Status	Retention Time
Late-Wet	Sheep	Reproducing	38.5[a,1] (2.2)
Late-Wet	Goats	Reproducing	46.2[b,2] (2.2)
Late-Wet	Sheep	Non-reproducing	40.9[a,1] (2.2)
Late-Wet	Goats	Non-reproducing	45.0[a,1] (2.2)
Early-Dry	Sheep	Reproducing	35.4[a,1] (1.7)
Early-Dry	Goats	Reproducing	39.7[a,1] (1.8)
Early-Dry	Sheep	Non-reproducing	41.2[a,1] (1.6)
Early-Dry	Goats	Non-reproducing	44.3[a,1] (1.5)
Late-Dry	Sheep	Reproducing	58.6[a,2] (1.6)
Late-Dry	Goats	Reproducing	52.3[b,3] (1.7)
Late-Dry	Sheep	Non-reproducing	56.8[a,2] (1.7)
Late-Dry	Goats	Non-reproducing	55.4[a,2] (1.6)

[a-b]Least-squares means in the same period and for the same reproductive status with different superscripts differ ($P<.05$) between species.

[1-3]Least-squares means for the same species with the same reproductive status without a similar superscript differ ($P<.05$) across periods.

Table 11. Dry matter digestibility (DMD) of two sheep that were fed cunha hay or received it as extrusa inserted into their rumina.

	DMD	
Manner of Intake	Animal 1	Animal 2
	---------- %	----------
Normal	60.0%	59.9%
Inserted into Rumen	60.0%	59.6%

32). The three variables measured, OMD, DEI and DPI, all showed slight but uniformly higher levels during the second replication of the experiment (Table 12).

Digestibility and Energy and Protein Intake by Sheep and Goats in Three Digestion Trials

Daily Extrusa Intake

The quantity of extrusa stuffed in the animals each day was based on estimates of daily intake by the free-ranging, non-reproducing animals during the corresponding period. The estimate of their mean intake, expressed as a percentage of BW, was used for all individuals of the corresponding species for the corresponding trial; therefore, no statistical analysis of extrusa input was possible. The quantities of extrusa stuffed into the individuals of each species per day are presented in Table 13.

Gross Energy Intake

Because the amount and caloric density of the extrusa stuffed did not vary among individuals of a species for a period, the gross energy intake, as a percentage of BW, did not vary among individuals of a species in a period either (Table 13).

Digestible Energy Intake

The period of the trial strongly influenced ($P<.01$) DEI, but the species of the animals did not ($P>.05$) (Appendix Table 33). The species-by-period interaction was not significant ($P=.70$).

Sheep had their highest ($P<.05$) DEI in the early-dry period trial and their lowest ($P<.05$) DEI in the late-dry period trial (Table 13).

Table 12. Organic matter digestibility (OMD), digestible energy intake (DEI) and digestible protein intake (DPI) by goats consuming sabia normally or receiving it directly into their rumina through a fistula (least-squares mean and S.E.).

	OMD		DEI	
Trial	Normal	Inserted	Normal	Inserted
	---------- % ----------		----kcal/kg body wt----	
1	48.4[a](2.1)	49.4[a](2.1)	60.8[a](2.8)	62.8[a](2.8)
2	50.9[a](2.1)	54.6[a](2.1)	66.8[a](2.8)	74.3[a](2.8)

	DPI	
	Normal	Inserted
	----g/kg body wt ----	
1	1.8[a](0.1)	1.8[a](0.1)
2	2.1[a](0.1)	2.3[a](0.1)

[a]Least-squares means for the same trial and parameter with the same superscript do not differ (P>.10).

Table 13. Organic matter intake (OMI), daily gross energy intake (GEI), daily digestible energy intake (DEI), DEI:organic matter intake (OMI) ratio, gross energy apparent digestibility coefficients (GED) and organic matter digestibility (least-squares means and S.E.) by sheep and goats in three digestion trials.

Period	OMI		GEI	
	Sheep	Goats	Sheep	Goats
	--- % of body wt ---		--- kcal/kg of body wt ---	
Late-Wet	2.06	2.09	120.4	127.3
Early-Dry	2.89	2.54	178.8	153.4
Late-Dry	2.31	1.91	131.1	110.6

Period	DEI			
	Sheep	Goats	Sheep	Goats
	---------- kcal ----------		--- kcal/kg body wt ----	
Late-Wet	1552.5(81.1)	1254.1(93.6)	61.8^{a,2}(2.2)	60.2^{a,1}(2.6)
Early-Dry	2127.7(81.1)	1627.6(81.1)	69.9^{a,1}(2.2)	64.4^{a,1}(2.2)
Late-Dry	1065.1(81.1)	851.2(81.1)	38.2^{a,3}(2.2)	34.5^{a,2}(2.2)

Period	DEI:OMI		GED	
	Sheep	Goats	Sheep	Goats
	-------- kcal/g -------		---------- % -----------	
Late-Wet	3.0^{1} (0.1)	2.9^{1} (0.1)	51.3^{1} (1.6)	47.3^{1} (1.8)
Early-Dry	2.4^{2} (0.1)	2.5^{2} (0.1)	39.1^{2} (1.6)	42.0^{2} (1.6)
Late-Dry	1.7^{3} (0.1)	1.8^{3} (0.1)	28.7^{3} (1.6)	31.2^{3} (1.6)

Period	OMD	
	Sheep	Goats
	----------- % ------------	
Late-Wet	52.3^{a,1} (1.5)	49.8^{a,1} (1.7)
Early-Dry	33.3^{a,2} (1.5)	37.7^{b,2} (1.5)
Late-Dry	30.4^{a,2} (1.5)	35.5^{b,2} (1.5)

$^{a-b}$Least-squares means for the same period and parameter with different superscripts differ ($P<.05$) between species.

$^{1-3}$Least-squares means for the same species and parameter with different superscripts differ ($P<.05$) among periods.

Goats had similar (P>.05) DEI in the late-wet and early-dry period trials, while their DEI in the late-dry period trial was much lower (P<.05) than that in the other two trials.

Gross Energy Apparent Digestibility

There was no difference (P=.72) in the apparent digestibilities of gross energy (GED) for sheep versus goats in any of the three trials (Appendix Table 34). However, the period of the trial affected (P<.01) GED. The species-by-period interaction was not significant (P>.05) (Table 13). Both species had their greatest (P<.05) GED--near 50 percent--in the late-wet period trial. Their GED was near 40 percent in the early-dry period trial and near 30 percent in the late-dry period.

Digestible Energy Intake:Organic
Matter Intake Ratio

The DEI:OMI ratio is an indicator of the efficiency by which the gross energy of dietary organic matter is converted to digestible energy. This ratio was used to calculate the DEI by free-ranging animals.

The DEI:OMI ratio did not differ (P=.55) between sheep and goats in the three trials, but the period of the trial strongly affected (P<.01) the ratio (Appendix Table 35). The species-by-period interaction was not significant (P=.35). The animals had their highest (P<.05) ratio in the late-wet period when forage quality was higher and their lowest (P<.05) ratio in the late-dry period trial when forage quality was lowest.

Organic Matter Digestibility

Overall, dietary digestibility was not influenced (P>.05) by animal species, but it was affected (P<.01) by period of the year (Appendix Table 36). The species-by-period interaction was significant (P<.05). Sheep and goats digested organic matter similarly (P>.05) in the late-wet period (Table 13), but goats had greater (P<.05) OMD than the sheep in both dry-period trials. While the OMD of sheep diets was similar (P>.05) in both dry periods, it was much lower (P<.05) then than during the late-wet period. OMD of goat diets was also similar (P>.05) for the dry periods, and, like for sheep, it was much lower (P<.05) then than during the late-wet period.

Crude Protein Intake

Within a species, each individual received the same amount of extrusa and crude protein (as a percentage of BW) in each trial (Table 14).

Apparent Digestible Protein Intake

The apparent daily digestible crude protein intake (DPI) was not influenced (P>.05) by the species of animals alone, but it was strongly influenced (P<.01) by the period of the trial (Appendix Table 37). The species-by-period interaction was also highly significant (P<.01).

Sheep had greater ($P\leq.05$) DPI (g/kg BW) than did goats in the late-wet period trial (Table 14). In the other two trials, the DPI of sheep and goats was similar (P>.05). Sheep had their highest (P<.05) DPI in the late-wet period trial and their lowest (P<.05) in the late-dry period trial. Their DPI in the late-dry period was less than about

Table 14. Daily crude protein intake (CPI), daily apparent digestible protein intake (DPI), DPI:organic matter intake (OMI) ratio and crude protein apparent digestibility coefficient (CPD) (least-squares means and S.E.) by sheep and goats in three digestion trials.

Period	CPI		DPI	
	Sheep	Goats	Sheep	Goats
	g/kg body wt		g	
Late-Wet	4.18	3.83	50.3 (2.0)	32.5 (2.4)
Early-Dry	4.59	4.20	42.2 (2.0)	35.9 (2.0)
Late-Dry	2.43	2.00	15.3 (2.0)	16.9 (2.0)

Period	DPI		DPI:OMI	
	Sheep	Goats	Sheep	Goats
	g/kg body wt		g/g	
Late-Wet	2.0[a,1] (0.1)	1.6[b,1] (0.1)	0.10[a,1] (0.003)	0.07[b,1] (0.003)
Early-Dry	1.4[a,2] (0.1)	1.4[a,1] (0.1)	0.05[a,2] (0.003)	0.06[b,2] (0.003)
Late-Dry	0.6[a,3] (0.1)	0.7[a,2] (0.1)	0.02[a,3] (0.003)	0.04[b,3] (0.003)

Period	CPD	
	Sheep	Goats
	%	
Late-Wet	47.9[a,1] (1.8)	40.9[b,1] (2.1)
Early-Dry	30.3[a,2] (1.8)	33.8[a,2] (1.8)
Late-Dry	22.5[a,3] (1.8)	34.0[b,2] (1.8)

[a-b]Least-squares means for the same period and parameter with different superscripts differ ($P \leq .05$) between species.

[1-3]Least-squares means for the same species and parameter with different superscripts differ ($P < .05$) among periods.

a third of their late-wet-period DPI. The goats had similar (P>.05) DPI in the late-wet- and early-dry-period trials, and goats had their lowest (P<.05) DPI in the late-dry period. This was about half of their DPI in the other trials.

Crude Protein Apparent Digestibility

The crude protein apparent digestibility (CPD) was not affected (P>.05) by the species of the animals, but it was affected by the period of the trial (P<.01) (Appendix Table 38). The species-by-period interaction was highly significant (P<.01).

Sheep had greater (P≤.05) CPD than did goats in the late-wet period trial (Table 14). In the early-dry period trial, sheep and goats had similar (P>.05) CPD, while in the late-dry period trial the goats had greater (P≤.05) CPD. The sheep had their highest (P<.05) CPD in the late-wet period trial and had their lowest (P<.05) CPD in the late-dry period trial. Interestingly, while goats also had their highest (P<.05) CPD in the late-wet period trial, their CPD levels were the same (P>.05) in the dry-period trials and not that much lower than their late-wet-period levels.

Digestible Protein Intake:Organic Matter Intake Ratio

The DPI:OMI ratio is an indicator of the efficiency by which the CP in the organic matter is converted to digestible protein. This ratio was used to calculate the DPI by free-ranging animals.

While the ratio was not influenced (P=.67) by the species of animals alone, the period of the trial had a great effect (P<.01) on the ratio (Appendix Table 39). The species-by-period interaction was also highly significant ($P<.01$).

Sheep had greater ($P\leq.05$) DPI per g of OMI than goats in the late-wet-period trial (Table 14). In the other two trials, goats had slightly larger ($P\leq.05$) DPI:OMI ratios than sheep. The sheep had their highest ($P<.05$) ratio in the late-wet-period trial. Their ratio dropped by one-half in the early-dry-period trial and again by more than one-half in the late-dry-period trial. The goats also had their highest ($P<.05$) ratio in the late-wet-period trial. Their ratio was only slightly smaller ($P<.05$) in the early-dry period. Their ratio in the late-dry-period trial was still smaller, but the decrease from late-wet to late-dry periods was not as drastic as it was for the sheep.

Relationships Between Nitrogen Intake and Fecal Nitrogen Output

Increases in crude protein digestibility are simply reflections of decreased losses of nitrogen (N) in the feces. When N intake decreased to low levels in the late-dry period, the goats were able to reduce fecal N losses (in proportion to N intake) more ($P<.05$) than the sheep were (Figure 7 and Appendix Tables 40 and 41). Figure 8 illustrates the relationship between N intake and fecal-N output for both species in the three digestion trials. Fecal N decreased with decreased N intake for both species. However, while sheep had minimal fecal N losses near nine g/day, goats had minimal losses, near 5 g/day.

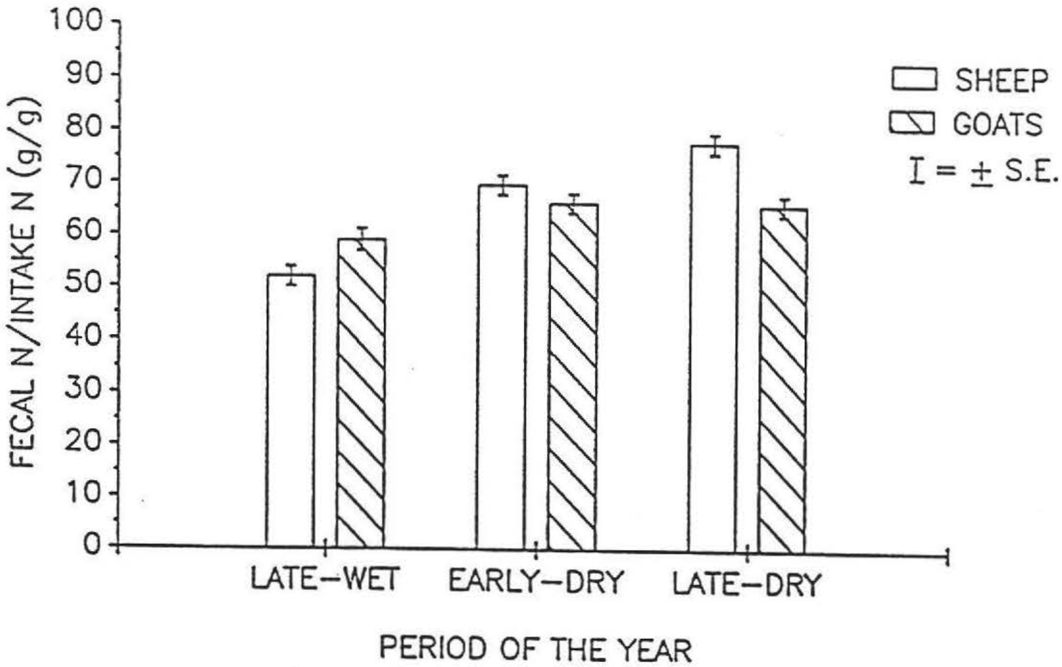
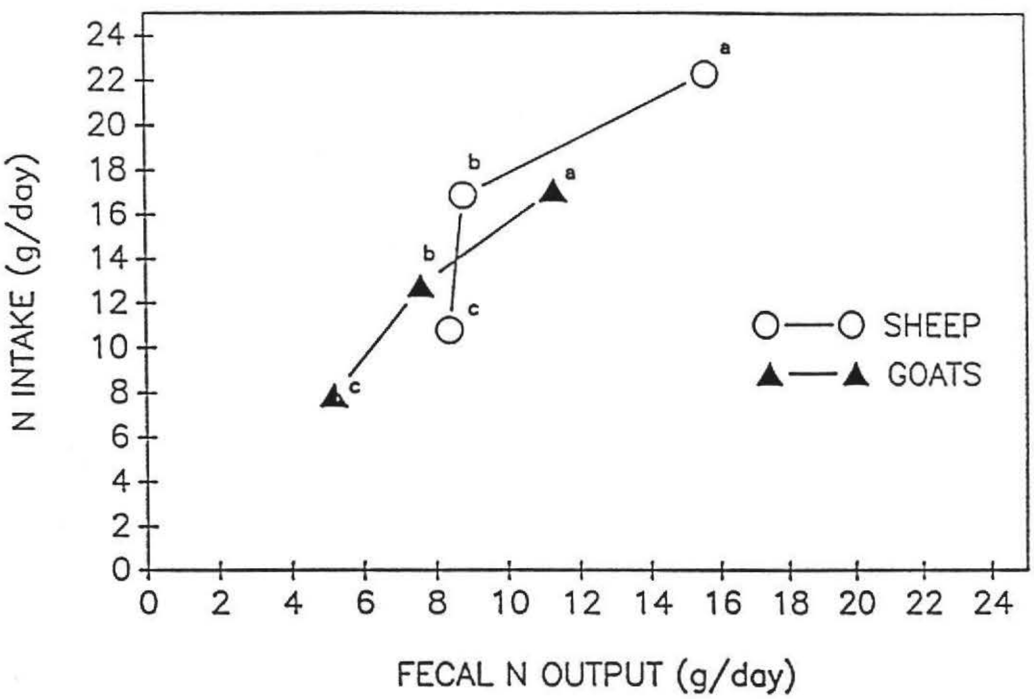


Figure 7. Fecal-N output:N intake ratios for sheep and goats in three digestion trials.



[a]Late-wet period
[b]Early-dry period
[c]Late-dry period

Figure 8. Relationships between N intake and fecal-N output for sheep and goats in three digestion trials.

Body Weight Changes of Sheep and Goats During the Three Trials

The sheep lost weight in all trials, while the goats gained small amounts of weight in the late-wet- and early-dry-period trials and lost weight in the late-dry-period trials (Table 15).

Forage, Energy and Protein Intake of Free-ranging, Non-reproducing Sheep and Goats

Forage Intake

The free-ranging, non-reproducing sheep and goats consumed different ($P<.01$) amounts of forage organic matter, and their OMI varied ($P<.01$) among the periods of the year (Appendix Table 42). The species-by-period interaction was also significant ($P<.01$). In the early-wet period, the OMI by goats (as a percentage of BW) was about 19 percent greater ($P<.05$) than that of sheep (Table 16). In the late-wet period, the goats consumed 31 percent more ($P<.05$) forage than did sheep. In the two dry periods, the sheep and goats consumed similar ($P>.05$) amounts of forage. Both sheep and goats had their greatest ($P<.05$) forage intakes in the early-wet period.

Digestible Energy Intake

Sheep and goats had different ($P<.02$) levels of DEI (kcal/kg BW), and DEI varied ($P<.01$) among the periods of the year (Appendix Table 43). The species-by-period interaction was also significant ($P<.01$). While goats had 27 percent greater ($P<.05$) DEI than sheep in the late-wet period, the DEI of sheep and goats was similar in the dry periods (Table 16). While the goats had greater ($P<.05$) DEI in the late-wet

Table 15. Body weight changes of sheep and goats during the three digestion trials (means and S.E.).

Period	Sheep	Goats
	------------ kg	-------------
Late-wet	-1.4 (0.2)	0.3 (0.1)
Early-dry	-2.1 (0.2)	0.05 (0.6)
Late-dry	-2.6 (0.3)	-1.0 (0.6)

Table 16. Daily forage, digestible energy and digestible protein intake by free-ranging, non-reproducing sheep and goats during the four periods of the year (least-squares means and S.E.).

Period	Forage Organic Matter Intake			
	Sheep (g)	Goats (g)	Sheep (% body wt)	Goats (% body wt)
Early-Wet	739 (36.6)	798 (29.3)	2.73[a,1] (.12)	3.26[b,1] (.10)
Late-Wet	628 (26.2)	641 (25.4)	1.91[a,2] (.09)	2.51[b,2] (.09)
Early-Dry	724 (32.1)	708 (32.1)	2.12[a,2] (.11)	2.17[a,3] (.11)
Late-Dry	633 (33.9)	600 (38.4)	2.12[a,2] (.11)	1.93[a,3] (.13)

Period	Digestible Energy Intake			
	Sheep (kcal)	Goats (kcal)	Sheep (kcal/kg body wt)	Goats (kcal/kg body wt)
Late-Wet	1885 (61.5)	1861 (59.6)	57.4[a,1] (2.5)	73.0[b,1] (2.4)
Early-Dry	1738 (75.4)	1770 (75.4)	51.0[a,1] (3.1)	54.3[a,2] (3.1)
Late-Dry	1076 (79.4))	1058 (75.4)	36.0[a,2] (3.2)	34.5[a,3] (3.1)

Period	Digestible Protein Intake			
	Sheep (g)	Goats (g)	Sheep (g/kg body wt)	Goats (g/kg body wt)
Late-Wet	62.9 (1.6)	44.9 (1.6)	1.91[a,1] (.07)	1.76[a,1] (.07)
Early-Dry	36.2 (2.0)	42.5 (2.0)	1.06[a,2] (.09)	1.30[a,2] (.09)
Late-Dry	12.7 (2.1)	23.5 (2.0)	0.42[a,3] (.09)	0.77[b,3] (.09)

[a-b]Least-squares means for a particular period with different superscripts differ ($P<.05$) between species.

[1-3]Least-squares means for a species with different superscripts differ ($P<.05$) over periods.

period than in either dry period, the sheep had similar (P>.05) DEI in the late-wet and early-dry periods. Both species had their lowest (P<.05) DEI in the late-dry period. Figure 9 illustrates DEI (kcal/d) for both species in three periods.

Digestible Protein Intake

The sheep and goats consumed different (P<.01) amounts of digestible protein (g/kg BW), and DPI varied (P<.01) among the periods (Appendix Table 44). The species-by-period interaction was significant (P<.01). The two species had similar (P>.05) levels of DPI in the late-wet and early-dry periods (Table 16). However, while the DPI of sheep and goats was very low in the late-dry period, the goats had about 83 percent greater (P<.05) DPI than the sheep in this period.

As expected, the DPI by sheep and goats was lowest (P<.05) in the late-dry period. Figure 10 shows DPI (g/d) for both species in three periods.

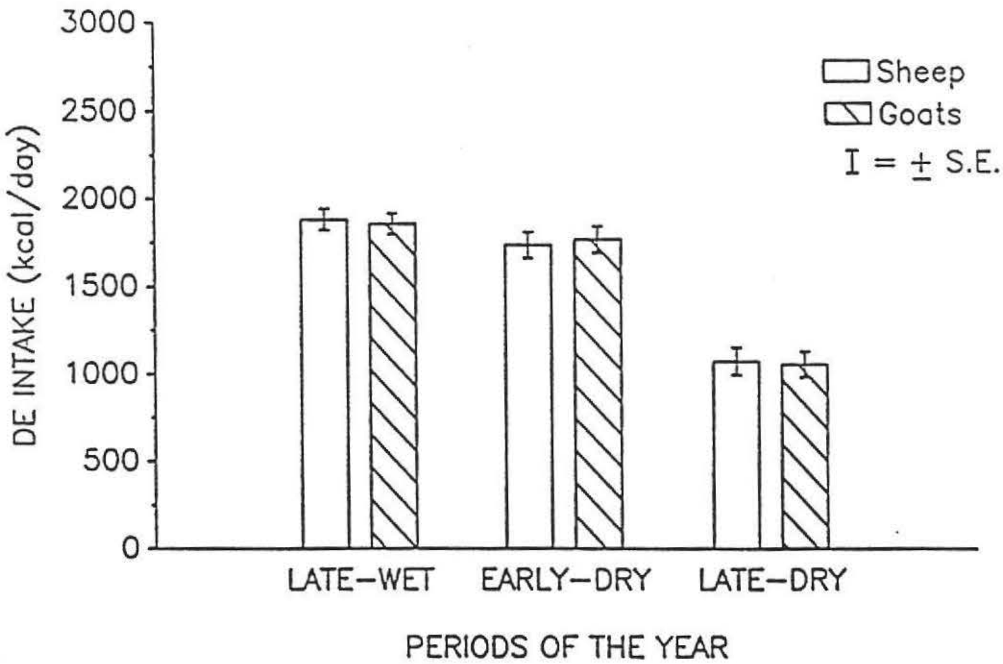


Figure 9. Daily digestible energy intake by free-ranging, non-reproducing animals during three periods of the year.

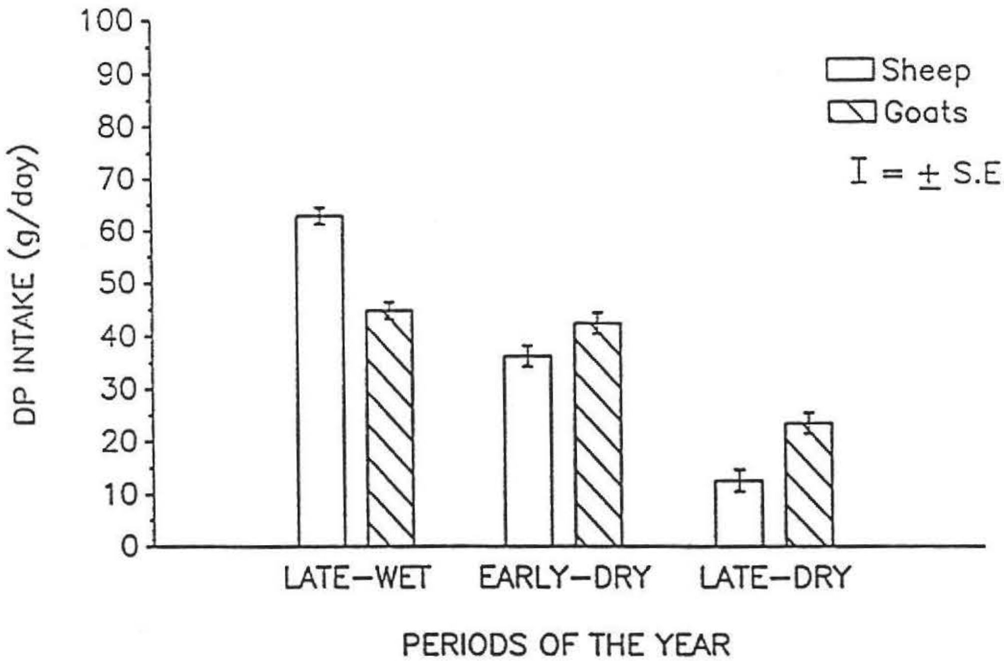


Figure 10. Daily digestible protein intake by free-ranging, non-reproducing animals during three periods of the year.

DISCUSSION

Botanical Selection

The most obvious difference in sheep and goat diets is the consistently high preference for browse by goats in all four periods. Sheep consumed large amounts of browse only during the dry season, when tree leaf litter was a major component of available vegetation and was readily available at ground level. Pfister et al. (1988) studied the foraging behavior of sheep and goats in the same general area of this study and observed that sheep spent 36 percent of the time feeding at or near ground level, compared with 18 percent for goats.

McCammon-Feldman (1980) studied goats in Nicaragua's tropical savanna and noted that they show distinct changes in foraging habits between wet and dry seasons. They eat more grass than either forbs or browse during the wet season but select mainly leguminous browse during the dry season. Other studies of goat diet preferences, catalogued by Van Dyne et al. (1980), indicate that goats are often very flexible with respect to the vegetation classes they utilize. The goats observed for this study exhibited considerable flexibility in selecting forage from all vegetation classes. The same was true for the sheep, especially in the dry season. These findings support the conclusion of Pfister and Malechek (1986a) that neither animal species conforms to rigid characterization as grazers or browsers.

Dietary Crude Protein Content

The estimates of CP content of sheep and goat diets in this study are somewhat different from those observed by Pfister and Malechek (1986b). While they observed peak dietary CP levels in January (early-wet period) for both species, my animals had their highest dietary CP levels in the late-wet period. Perhaps the increased browse and (or) forb selection and decreased grass selection of both animal species in the late-wet period account for the higher CP levels. While they found no differences in CP levels of sheep's and goats' wet-season diets, my sheep selected diets higher in CP than did goats during both wet periods. In the dry periods, I found no differences in the CP levels of sheep and goat diets. In contrast, Pfister and Malechek (1986b) found that their goats selected diets of higher CP levels in July (early-dry period) and September (between early and late-dry periods) than their sheep did. During the other dry season months, they found no differences in dietary CP levels of sheep and goats.

As expected, the late-dry period yielded the lowest CP levels for both animal species. My late-dry period values were somewhat lower than the corresponding December values reported by Pfister and Malechek (1986b). An herbaceous vine called jiterana (Ipomoea spp.), with high CP levels, was an important component of late-dry period diets (about 15-20 percent) in Pfister and Malechek's study. However, there was very little jiterana available to the animals in this study, and it represented less than 0.5% of their diets during the late-dry period. Also, their study was conducted during a dryer year than my study. Range forage quality can be higher in dry years because lower moisture availability can lead to lower biomass production and higher nutrient concentrations (Van Soest 1982). In addition, dry conditions can cause cessation of plant growth before complete maturation is attained, and consequently, plants die with higher nutrient concentrations in their above-ground tissues (Anderson and Scherzinger 1975).

Diet Digestibility

The IVOMD values for sheep and goats were considerably lower than comparable values reported by Pfister and Malechek (1986b) but similar to values reported by Schacht (1987) for goats. The higher CP and lower NDF levels in samples collected by Pfister and Malechek (1986b) likely account for their higher IVOMD values. Schacht's (1987) study of goats grazing caatinga range was conducted in a high-rainfall year, as was my study. In addition, Pfister and Malechek's IVOMD values were determined in trials where rumen inocula were obtained from animals on an alfalfa hay diet. This may have artificially elevated their IVOMD estimates, especially for dry-season samples, given that the microbes in the rumen inocula developed in a more nutritious environment than did microbes in rumen inocula from donor animals on dry-season caatinga forage. Schacht's and my IVOMD values were determined in trials where rumen inocula were obtained from animals eating caatinga forage.

While the _in vitro_ OMD values determined from extrusa samples collected on three days during each sampling month and the corresponding _in vivo_ OMD values from the digestion trials were similar for goats, they were not always similar for sheep. For instance, the values were reasonably close for the late-wet period but very different (ca. 45 percent) for the two dry periods. The *in vitro* values are based on samples collected on three days of each sampling month. In contrast, the *in vivo* values are based on samples collected almost every day of the sampling month. I also determined the *in vitro* OMD of the actual extrusa given to the sheep in the digestion trials. These *in vitro* estimates are very similar (eight percent difference) to the *in vivo* values from the trials. The *in vivo* values are likely the most accurate estimates. Perhaps botanical selection by the goats was more consistent during the sampling month of each dry period than that of the sheep.

While the dry period diets of sheep and goats were similar in CP, NDF and lignin, goats had greater OMD in both periods than did sheep. The higher OMD of the goats' diets in the dry periods is consistent with observations of Gihad (1976), Wilson (1977) and Doyle et al. (1984) that the capacity of goats to digest low quality forages is greater than that of sheep.

Dietary Fiber Levels

The NDF levels in sheep and goat diets were considerably higher than corresponding values that Pfister and Malechek (1986b) reported. Their animals had the lowest NDF levels (ca. 35 percent) in the early-wet period and the highest NDF levels (ca. 50 percent) in the late-dry period. In contrast, Schacht's (1987) comparable NDF values (for goats on caatinga with low to moderate tree density) and the NDF values of this study were higher in the early-wet period than in the late-wet and early-dry periods. NDF levels in all three studies were at their annual highs in the late-dry period. The NDF values reported in this study are on an organic matter basis, whereas those reported by Pfister and Malechek and Schacht are on a dry matter basis (DMB). My values would be about 25 percent lower if reported on a DMB. If the NDF values are expressed on a DMB, they are similar to the values reported by Schacht in all periods except the late-dry period, where they were about 64 percent in contrast to Schacht's values near 45 percent. The fiber analyses for this study and Schacht's study were conducted in the same laboratory with the same process and by the same technician. Differences in late-dry-period NDF levels between this study and Schacht's are likely a consequence of different late-dry period diets selected by the goats in the two studies.

My late-dry period NDF values, near 64 percent (DMB), are similar to values reported by McCammon-Feldman (1980), who reported values as high as 62 percent (DMB) in tropical grasses in Nicaragua. Barton et al. (1976) reported NDF levels between 60 and 71 percent (DMB) for tropical grasses. In the late-dry period, my sheep and goats selected dried grass for about 25 percent of their diets. Additionally, Schacht (1987) analyzed leaves from sabia in the late-dry period and observed NDF levels near 60 percent. Herbaceous leaves and stems from the same period averaged 44 and 75 percent NDF, respectively. My animals ate large amounts of sabia and other browse species in this period. However, no NDF analysis was conducted on the constituent species of sheep's and goats' diets for this study.

The high early-wet-period NDF levels that Schacht and I observed may have been artificially elevated by tannin interference. In the early-wet period, extrusa samples from both sheep and goats had a definite reddish appearance, suggesting the presence of tannins. Gobena (1988) analyzed sabia foliage for proanthyocyanidin tannins and found high levels of condensed tannins (about 30% of dry weight). In the early-wet period, about 12 and 26% of the sheep's and goats' diets, respectively, consisted of sabia. McArthur (1988) studied the histology of NDF in tannin-rich foliage and determined that tannins can contribute substantially to the NDF fraction. Similarly, Reed (1986) reported that NDF from browse with high levels of insoluble proanthocyandidins contains condensed tannins and tannin-protein complexes. He stated: "The assumption that NDF represents cell wall carbohydrates and lignin in these plants is incorrect" (p. 7). In the early-wet period, diet samples for this study were high in protein and probably high in tannins. An interaction between tannins and protein and perhaps other compounds could have elevated NDF values in both my and Schacht's studies. Differences in the growing conditions during my study and Schacht's (high precipitation) versus Pfister and Malechek's (slightly below average precipitation) may account for the discrepancy in NDF values.

In this study, sheep selected diets either higher than or equivalent to goats in terms of NDF content. In contrast, Pfister and Malechek (1986b) found no difference in NDF levels in sheep and goat diets for their entire study, but this may have been a function of the smaller number of animals they sampled.

The dietary lignin levels in this study are similar to those reported by Pfister and Malechek (1986b) when both sets of data are compared on a DMB. Pfister and Malechek found that sheep selected diets with lower lignin levels than goats during the earlier months of the wet season and attributed this difference to the higher levels of browse selected by their goats. I did not find such clear-cut differences. In the early-wet period, sheep had lower lignin levels than goats and sheep selected lower amounts of browse. However, in the late-wet period, sheep had higher lignin levels than goats, yet selected much lower levels of browse than goats. During the dry season sheep and goats selected diets with similar lignin levels. At that time, the botanical composition of sheep and goat diets was similar with respect to vegetation classes selected but not necessarily with respect to the species selected within each vegetation class. Apparently, the similarity in vegetation classes selected accounts for the similarity in dry-season dietary-lignin levels.

While I found that sheep selected diets of higher CP content during the wet season, as I predicted, I did not find that goats selected diets of higher CP content in the dry season, as I also predicted. Sheep diets did not have higher digestibility in the wet season and goat diets did not have higher levels of lignin as I predicted.

Daily Activity Budgets

Traveling, foraging and ruminating are all behaviors associated with the acquisition or processing of forage. In the dry periods, especially in the late-dry period, sheep and goats devoted considerably less time to the "other activities" (i.e., those not related to forage acquisition and processing) and greater time to foraging and (or) ruminating. During wet periods, the animals, especially goats, attempted to reduce their contact with the muddy ground and wet vegetation often present. They often waited on higher, dryer areas of the pasture until about mid-morning before they began foraging. During rainfall, the goats would usually seek shelter under trees or they would return to their covered pen. On days when they returned to their pen in mid-afternoon, they seldom ventured out again to forage that day. This behavior substantially reduced their foraging times during the rainy periods. Biting flies and mosquitos were a nuisance to the animals during the wet periods, but they did not appear to have the major impact on behavior that Schacht (1987) noted in his study. Another factor increasing the time spent in "other activities" during wet periods was the greater amount of time the animals spent playing or in dominance-determining behaviors. In general, the animals appeared to have more time and energy for these activities in the wet periods than they did in the dry periods.

Perhaps the sheep spent more time foraging than the goats did in the wet periods as I predicted because of their greater tolerance for the wet conditions. When the caatinga was dry, the two species spent equivalent times foraging. Foraging time was at its annual peak during the late-dry period. While the availability of nutrients was the lowest then, nutrient requirements for the young lactating animals were high. These factors combined likely account for the generally greater times used for foraging and ruminating by both species in the dry season.

The time spent ruminating by goats in the four periods of the year was highly correlated to the NDF and lignin contents of their diets. In contrast, the time spent ruminating by sheep was not related to dietary NDF levels but was highly related to OMD and lignin contents of their diets. Organic matter digestibility is generally inversely related to dietary NDF; therefore, it follows that ruminating times of sheep should also be related to their dietary NDF levels. If their NDF values do not represent their actual levels of dietary NDF as discussed above, this may account for the relationship with OMD but not NDF. If condensed tannins existed in sheep extrusa, they may have elevated NDF values artificially while not hindering digestion if sheep or rumen microbes produced compounds which bound these tannins or if digestion was not impacted by the tannins.

While sheep spent more time traveling in the early-dry period than goats, they did not travel farther. Apparently, sheep moved slower while traveling than goats did in this period. In the late-dry period, sheep and goat travel times and distances were consistently similar.

Relationships between foraging time and forage intake were not directly proportional as I expected. The forage intake of sheep was about two percent of BW in the late-wet through late-dry periods, but foraging time varied from 22 to 33 percent of the day. Also, forage intake was highest in the early-wet period, when their foraging time was low. The forage intake of goats was highest in the early-wet period when their foraging time was low. In the late-dry period, their foraging time was high while their forage intake was low.

Retention Time of Particulate Digesta in Free-ranging Sheep and Goats

During the late-dry period, when forage quality was lowest, lactating goats had shorter retention time of digesta particles than the lactating sheep did. However, when forage quality was higher in the late-wet and early-dry periods, the digesta retention times for the two species were similar or shorter in sheep.

Uden et al. (1982) found that the particle retention time of goats was 39 percent shorter than that of sheep when both species were fed mature timothy grass having a CP content of eight percent and cell wall and lignin content of 67 and eight percent, respectively (Uden and Van Soest 1982). In the late-dry period, when my sheep and goats consumed diets containing about 10 percent CP, 85 percent cell wall and 15 percent lignin, the particle retention time for reproducing goats was about 30 percent shorter than that of the sheep.

The shorter particle retention time of lactating goats in the late-dry period was not simply a function of their ruminating time. Sheep and goat ruminating times were similar in the late-dry period. Perhaps the reduction of digesta particles size was greater per minute of rumination for goats than for sheep, or perhaps larger particles can move through the gastrointestinal tracts of goats in comparison to sheep. Alternatively, digesta particles may have moved through the goats faster because particle size was reduced faster in their rumina by greater microbial activity associated with greater N availability in goat as compared to sheep rumina. Additional work is necessary to clarify these relationships.

I predicted that in the dry season, retention time of particulate matter in the gastrointestinal tracts of goats is shorter than in sheep. This prediction was only partially correct. I expected that goats would have greater forage intake than sheep in the dry season and that this would be related to shorter retention times of digesta fiber in goats. However, they had similar forage intakes in the dry season.

Digestibility of Gross Energy and Crude Protein

While there were no differences in the GED of sheep and goat diets during the three periods studied, there were differences in CPD. The goats had about 50 percent greater CPD than the sheep did in the late-dry period when DPI was at its lowest. This large difference suggests that goats had greater capacity to reduce fecal N excretion than did sheep. A greater capacity to reduce fecal N excretion indicates an increased ability to maintain N balance. The study of Doyle et al. (1984) suggested that goats can recycle and conserve nitrogen better than sheep can when both species consume low-quality forages. Watson and Norton (1982) found that goats had higher rumen ammonia and plasma urea levels than sheep did when both ate the same diet of mature grass (43 and 106 mg N/l of rumen fluid for the sheep and goats, respectively). These authors noted that the ammonia levels of the sheep were likely inadequate for normal microbial growth in the rumen. This observation is supported by Satter and Slyter's (1974) finding that rumen ammonia levels below 50 mg N/l limited microbial activity. Watson and Norton's study also suggests that goats may conserve nitrogen better than sheep when both species consume low-quality forages. Oliveira (1987) found that goats had 20 percent greater CPD than sheep while they had similar GED. He also concluded that goats appeared to have a greater capacity to meet their protein needs than sheep had. The greater CPD by goats in the dry periods may partly or completely account for their smaller weight losses.

Body Weight Changes of Sheep and Goats During the Digestion Trials

I expected both species to gain weight during the late-wet and early-dry period trials and lose weight during the late-dry period trial. The weight changes of the goats followed this pattern, but the sheep lost weight in all trials. The extrusa-introduction technique required frequent animal handling. While the goats appeared to habituate to this handling, the sheep did not. The sheep would rise and move around in their cages when we entered the room; whereas, the goats usually remained undisturbed by our activities. When we stuffed extrusa into the animals, the sheep were unwilling to be caught, and they were very tense during the stuffing. In contrast, the goats were easy to catch and were calm while we stuffed the extrusa. I suspect that all or much of the sheep's weight loss is associated with higher energy expenditures related to their reaction to the trials.

Productivity of Free-ranging, Non-reproducing Sheep and Goats and their Forage, Energy and Protein Intakes

Sheep gained more weight than goats did in the wet season, but they lost weight during the dry season, when the goats gained weight. These different weight responses to seasons were very important for overall weight changes during the year. Across the year, the goats gained more weight than the sheep did. Pfister's (1983) sheep and goats on caatinga had similar weight changes.

In the wet season, the sheep spent more time foraging than the goats did, but the goats had greater forage intake. Apparently, goats consumed more forage per hour of foraging than the sheep did.

Estimates of DEI and DPI were not made for the early-wet period. In the late-wet period, the goats had greater DEI than the sheep did while the two species had similar DPI. At that time, the two species had similar weight gains. Perhaps, the sheep had lower energy expenditures than the goats did as Oliveira (1987) found.

In the early-dry period, the goats gained considerably more weight than the sheep did; however, the two species had similar forage intakes and DEI's. The goats had greater DPI in this period than the sheep, and this may explain why the goats had greater weight gains.

In the late-dry period, the sheep and goats had similar weight losses, forage intakes and DEI's. However, the goats had greater DPI than the sheep did in this period. My DEI estimates for this period were very similar to those of Schacht and Malechek (1989) for goats on caatinga vegetation in December.

The animals weighed about 30 kg in the late-wet and early-dry periods. At this weight, the sheep's daily maintenance requirements for digestible energy and protein were 1930 kcal and 38 g (NRC 1985), and the goats' were 1590 kcal and 35 g (NRC 1981). According to these requirements, the sheep were slightly deficient in DEI during these periods, while the goats had excess DEI for some activity but not for growth. Given that these animals grew during the late-wet period, the NRC requirements for digestible energy are apparently excessive for these hair-sheep and mixed-race goats. With respect to digestible protein, both species had adequate DPI for maintenance and growth during the late-wet period. In the early-dry periods, sheep had slightly inadequate DPI for maintenance, while goats had adequate DPI for maintenance and some growth. During the late-dry period, the animals had inadequate DEI and DPI to simply meet their maintenance requirements.

In the latter half of the dry season (mid-September through December), Schacht (1987) compared body weight gains of four-month old mixed-race goats with four different diets. The diets were 1) caatinga vegetation, 2) caatinga vegetation plus 5 g urea/day, 3) caatinga vegetation plus 140 g molasses/day and 4) caatinga vegetation plus 5 g urea and 140 g molasses/day. Only the group receiving urea and molasses gained weight in the final six weeks of the study, while the other groups maintained weight. Schacht concluded that the lack of weight responses to the caatinga-only, urea-only and molasses-only diets during the final six weeks of the study indicated that the caatinga forage was deficient for growth in both CP and energy. However, he did not measure the daily intake of caatinga forage by any of his goats. Therefore, we cannot determine if the weight responses of his various goat groups were influenced by their forage intake. Assuming that his goats had similar forage intake during the study, his conclusion that both protein and energy intake were inadequate during the late-dry period is consistent with my conclusion.

Productivity of Free-ranging, Reproducing Sheep and Goats

Unfortunately, the organic matter, digestible energy and digestible protein intakes by the reproducing sheep and goats were not estimated. I attempted to estimate fecal output of these animals using a pulse-dose of chromium-mordanted fiber. I also applied this technique to non-reproducing sheep and goats, whose fecal output was also measured by total fecal collections. Using data from the total fecal collections as my standards, the pulse-dose technique provided neither accurate nor precise estimates of fecal output. The pulse-dose estimates varied from being nearly identical to the total collection estimates to as much as 100 percent less than the total collection estimates. Krysl et al. (1988) also reported poor results using the pulse-dose technique with sheep.

While sheep and goats had similar weight changes during the dry season and their offspring had similar daily weight gains during their first 80 days of life, the young reproducing goats had greater weight gains across the entire year than the young reproducing sheep. These differences were especially significant given that only the five best performing sheep were weighed at the end of the dry season. Had the five poorer performing sheep been included in the average, the dry season and yearly weight changes of the reproducing sheep would have appeared even worse. The young, reproducing goats were clearly more productive animals in the harsh conditions of the caatinga.

CONCLUSIONS AND RECOMMENDATIONS

The purpose of my study was to elucidate aspects of sheep and goat behavior, digestive physiology and feeding ecology which could account for their productivity differences in caatinga. Although the year in which my study was conducted was a particularly wet year with high forage production, the goats still performed better than the sheep. The non-reproducing goats gained more weight than the non-reproducing sheep. The kids had greater average daily weight gains than the lambs did, and the reproducing goats gained almost twice the weight of the reproducing sheep.

The animals' response to the dry season was critical to their year-long productivity because the sheep had greater or equal weight gains compared to the goats until the end of the wet season, but this productivity relationship changed by the end of the dry season.

The greater productivity of the goats through the dry season as compared to the sheep was apparently not a function of higher diet quality. Their CP, NDF and lignin levels were not different from those of the sheep. In the dry period, the goats did not spend more time foraging than the sheep nor did they have greater forage or digestible energy intakes than the sheep. However, they had greater DPI than the sheep in the late-dry period. Apparently the goats were able to reduce fecal N losses to a greater extent than the sheep did. These findings are supported by other comparative work on sheep and goat energy and protein nutrition. I suspect that the greater DPI of the goats with respect to the sheep was critical to their lower weight losses in the dry season.

Further work is needed to confirm this conclusion or elucidate other aspects of sheep and goat foraging ecology in caatinga woodland which would explain the generally greater capacity of goats to survive the poor forage conditions during the dry season. In particular, the energy expenditures of these animals needs to be studied as well as their mineral nutrition, fat accumulation in the wet season and fat and muscle protein cataboloism in the dry season.

While my reproducing animals were bred in the early-wet period, the end of the early-dry period may be a better time for breeding in "normal" precipitation years. Late gestation, parturition and lactation would then occur during the wet season, when forage quality is higher. This strategy might require some supplemental feeding during the late-dry period to avoid abortion and might fail in years when the wet season starts late (i.e., February, March or later) or if the dry season starts early. In these years, few if any breeding times would be ideal.

Further research on improving forage quality in the late-dry season is also needed. Management strategies involving rotating areas for coppice and wood production show promise in this respect. Research on introducing trees which retain palatable and nutritious foliage through the dry season should also be pursued.

Given the great variability of precipitation from year to year, stocking rates based on available vegetation rather than land area would probably be more suitable. Long-term research on this seems advantageous. Finally, research on feeding relatively less expensive and available energy and (or) N supplements in the late-dry season may prove valuable, especially for reproducing sheep.

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A P P E N D I C E S

Appendix Table 1. Monthly body weights in kilograms (means and S.E.) for reproducing and non-reproducing sheep and goats.

Species	Reproductive Status	Early-Wet Period		
		February	March	April
Sheep	Reproducing	24.1 (0.9)	25.5 (0.9)	26.9 (1.0)
Sheep	Non-reproducing	22.7 (0.6)	23.6 (0.5)	24.4 (0.6)
Goats	Reproducing	22.7 (0.5)	23.5 (0.7)	24.4 (0.8)
Goats	Non-reproducing	20.1 (0.8)	20.8 (0.9)	21.6 (0.9)
		Late-Wet Period		
		May	June	July
Sheep	Reproducing	29.4 (1.2)	32.4 (1.0)	36.9 (0.8)
Sheep	Non-reproducing	26.9 (0.8)	28.8 (0.9)	32.5 (1.0)
Goats	Reproducing	24.7 (0.9)	28.8 (1.0)	33.9 (1.3)
Goats	Non-reproducing	22.0 (1.0)	24.9 (1.2)	28.2 (1.2)
		Early-Dry Period		
		August	September	October
Sheep	Reproducing	33.2 (1.0)	31.5 (0.9)	30.8 (0.7)
Sheep	Non-reproducing	34.5 (1.0)	34.5 (1.2)	34.2 (1.2)
Goats	Reproducing	38.1 (1.2)	31.5 (1.0)	30.5 (0.9)
Goats	Non-reproducing	31.1 (1.2)	32.8 (0.9)	33.3 (1.2)
		Late-Dry Period		
		November	December	January
Sheep	Reproducing	29.6 (0.7)	27.9 (0.5)	24.8 (0.6)
Sheep	Non-reproducing	33.3 (1.0)	33.5 (1.0)	30.5 (0.9)
Goats	Reproducing	29.6 (1.0)	29.8 (1.0)	25.9 (0.7)
Goats	Non-reproducing	34.0 (1.0)	33.5 (1.2)	31.2 (1.1)

Appendix Table 2. Analysis of variance for body weight change of reproducing and non-reproducing sheep and goats during each month of the year.

Source	d.f.	SS	P>F
Species	1	55.6	0.0119
Reproductive Status	1	438.8	0.0001
Species x RS	1	0.6	0.7897
Animal(S x RS) (Error a)	33	258.7	------
Month	11	22991.2	0.0000
Month x Species	11	3003.3	0.0001
Month x RS	11	2407.6	0.0001
Month x Species x RS	11	1879.6	0.0001
Error b	358	10600.9	------

Appendix Table 3. Monthly body weight change (expressed as the percentage of change during each month) (least squares means and S.E.) for reproducing and non-reproducing sheep and goats.

Species	Reproductive Status	Early-Wet Period		
		January	February	March
Sheep	Reproducing	17.6^{a} (1.7)	6.0^{a} (1.7)	5.7^{a} (1.7)
Sheep	Non-reproducing	19.2^{a} (1.9)	3.9^{a} (1.9)	3.5^{a} (1.9)
Goats	Reproducing	16.0^{ab} (1.7)	3.6^{a} (1.7)	3.6^{a} (1.7)
Goats	Non-reproducing	11.7^{b} (1.8)	3.8^{a} (1.8)	3.8^{a} (1.8)
		Late-Wet Period		
		April	May	June
Sheep	Reproducing	9.2^{a} (1.7)	11.0^{a} (1.7)	14.1^{a} (1.7)
Sheep	Non-reproducing	10.3^{a} (1.9)	7.6^{a} (1.9)	13.0^{a} (1.9)
Goats	Reproducing	1.1^{b} (1.7)	16.8^{a} (1.7)	17.9^{a} (1.7)
Goats	Non-reproducing	1.9^{b} (1.8)	13.1^{b} (1.8)	13.4^{a} (1.8)
		Early-Dry Period		
		July	August	September
Sheep	Reproducing	-9.8^{a} (1.7)	-4.8^{a} (1.7)	-2.1^{a} (1.7)
Sheep	Non-reproducing	6.3^{b} (1.9)	0.2^{a} (1.9)	-1.1^{a} (1.9)
Goats	Reproducing	12.6^{b} (1.7)	-17.4^{b} (1.7)	-2.8^{a} (1.7)
Goats	Non-reproducing	10.8^{b} (1.8)	6.0^{c} (1.8)	1.8^{a} (1.8)
		Late-Dry Period		
		October	November	December
Sheep	Reproducing	-4.0^{a} (1.7)	-5.2^{a} (1.7)	-10.5^{a} (2.5)
Sheep	Non-reproducing	-2.3^{ab} (1.9)	0.6^{b} (1.9)	-8.8^{ab} (1.9)
Goats	Reproducing	-3.0^{a} (1.7)	0.8^{b} (1.7)	-12.4^{a} (1.7)
Goats	Non-reproducing	2.2^{b} (1.8)	-1.5^{b} (1.8)	-6.8^{b} (1.8)

$^{a-c}$Least squares means for the same month and species or for the same month and reproductive status without a common superscript differ ($P \leq .05$).

Appendix Table 4. Adjusted monthly body weights in kilograms (least-squares means and S.E.) for reproducing and non-reproducing sheep and goats.

Species	Reproductive Status	Early-Wet Period		
		February	March	April
Sheep	Reproducing	22.9^{a}(0.3)	24.3^{a}(0.3)	25.7^{a}(0.4)
Sheep	Non-reproducing	22.9^{b}(0.3)	23.8^{a}(0.4)	24.6^{a}(0.5)
Goats	Reproducing	22.3^{a}(0.3)	23.1^{b}(0.3)	23.9^{b}(0.4)
Goats	Non-reproducing	21.4^{b}(0.3)	22.3^{b}(0.4)	23.1^{b}(0.5)
		Late-Wet Period		
		May	June	July
Sheep	Reproducing	28.0^{a}(0.5)	31.1^{a}(0.7)	35.5^{a}(0.8)
Sheep	Non-reproducing	27.2^{a}(0.6)	29.2^{a}(0.7)	32.8^{a}(0.9)
Goats	Reproducing	24.3^{b}(0.5)	28.3^{b}(0.6)	33.4^{a}(0.8)
Goats	Non-reproducing	23.6^{b}(0.6)	26.6^{b}(0.8)	29.6^{b}(0.9)
		Early-Dry Period		
		August	September	October
Sheep	Reproducing	31.9^{a}(1.0)	30.8^{a}(0.9)	29.9^{a}(0.8)
Sheep	Non-reproducing	34.8^{a}(1.0)	34.7^{a}(0.9)	34.4^{a}(0.9)
Goats	Reproducing	37.2^{b}(0.9)	31.5^{a}(0.8)	30.7^{a}(0.7)
Goats	Non-reproducing	33.0^{a}(1.1)	33.6^{a}(1.0)	34.4^{a}(0.9)
		Late-Dry Period		
		November	December	January
Sheep	Reproducing	28.9^{a}(0.9)	27.5^{a}(0.9)	24.4^{a}(1.1)
Sheep	Non-reproducing	33.3^{a}(0.9)	33.6^{a}(1.0)	30.2^{a}(0.8)
Goats	Reproducing	30.0^{a}(0.8)	30.0^{b}(0.8)	26.6^{a}(0.7)
Goats	Non-reproducing	34.7^{a}(0.9)	34.2^{a}(1.0)	31.5^{a}(0.8)

$^{a-b}$Least-squares means for the same month and for animals of the same reproductive status with different superscripts differ ($P \leq .05$).

Appendix Table 5. Analysis of covariance for adjusted body weights of reproducing and non-reproducing sheep and goats from the beginning of the study until December 1.

Source	d.f.	SS	P>F
Species	1	54.0	0.1683
Reproductive Status	1	55.5	0.1626
Species x RS	1	36.8	0.2529
Covariate	1	1590.3	0.0001
Error a	32	869.3	------
Month	10	6773.5	0.0000
Month x Species	10	381.3	0.0001
Month x RS	10	929.8	0.0000
Month x Species x RS	10	101.3	0.0002
Error b	330	934.4	------

Appendix Table 6. Analysis of covariance for adjusted body weights of reproducing sheep and goats at the end of the study.

Source	d.f.	SS	P>F
Species	1	5.3	0.0006
Covariate	1	3.9	0.4168
Error	13	71.4	------

Appendix Table 7. Analysis of covariance for adjusted body weights of non-reproducing sheep and goats at the end of the study.

Source	d.f.	SS	P>F
Species	1	6.8	0.2776
Covariate	1	51.5	0.0082
Error	13	69.1	------

Appendix Table 8. Analysis of variance for body weight change of reproducing and non-reproducing sheep and goats during the two seasons of the year.

Source	d.f.	SS	P>F
Species	1	29.0	0.6177
Reproductive Status	1	577.6	0.0341
Species x RS	1	125.2	0.3024
Animal(Species x RS) (Error a)	33	3763.3	------
Season	3	97148.9	0.0001
Season x Species	3	1410.5	0.0031
Season x Repstat	3	5592.1	0.0001
Season x Species x RS	3	484.3	0.0685
Error b	28	3778.7	------

Appendix Table 9. Body weight change (least squares means and S.E.) during the two seasons of the year (expressed as the percentage of change between beginning and ending body weights for the season) for reproducing and non-reproducing sheep and goats.

Species	Reproductive Status	Seasons	
		Wet	Dry
Sheep	Reproducing	81.4[a] (3.7)	-22.7[a] (6.4)
Sheep	Non-reproducing	70.9[a] (4.1)	-5.8[b] (4.1)
Goats	Reproducing	73.1[a] (3.7)	-23.0[a] (3.7)
Goats	Non-reproducing	57.0[b] (3.9)	11.1[c] (3.9)

[a-c]Least squares means for the same season and species or for the same season and reproductive status without a common superscript differ ($P \leq .05$).

Appendix Table 10. Analysis of variance for body weight change of reproducing and non-reproducing sheep and goats across the entire year.

Source	d.f.	SS	P>F
Species	1	1705.42	0.0037
Reproductive Status	1	13826.2	0.0001
Species x RS	1	9.3	0.8172
Error	33	4769.4	------

Appendix Table 11. Body weight change across the entire year (expressed as the percentage of change between beginning and ending body weights) for reproducing and non-reproducing sheep and goats.

Species	Reproductive Status	Least Squares Mean	S.E.
Sheep	Reproducing	16.4[a]	5.8
Sheep	Non-reproducing	60.5[b]	4.6
Goats	Reproducing	32.6[b]	4.1
Goats	Non-reproducing	74.5[c]	4.4

[a-c]Least squares mean for the same species or reproductive status with different superscripts differ ($P \leq .05$).

Appendix Table 12. Analysis of variance for birth weights of lambs and kids.

Source	d.f.	SS	P>F
Species	1	5.3	0.0006
Error	15	4.3	------

Appendix Table 13. Analysis of covariance for adjusted daily weight gains of lambs and kids.

Source	d.f.	SS	P>F
Species	1	0.0008	0.0846
Covariate	1	0.0002	0.2943
Error	14		------

Appendix Table 14. Analysis of variance for total browse composition of sheep and goat diets during four periods of the year.

Source	d.f.	SS	P>F
Species	1	8262.9	0.0001
Animal (Species) (Error a)	44	9909.4	------
Period	3	14304.4	0.0001
Species x Period	3	4763.4	0.0001
Error b	113	20496.0	------

Appendix Table 15. Analysis of variance for total grass composition of sheep and goat diets during four periods of the year.

Source	d.f.	SS	P>F
Species	1	2151.6	0.0001
Animal (Species) (Error a)	44	3622.4	------
Period	3	33883.6	0.0001
Species x Period	3	473.7	0.1949
Error b	113	11199.4	------

Appendix Table 16. Analysis of variance for total forb composition of sheep and goat diets during four periods of the year.

Source	d.f.	SS	P>F
Species	1	1491.7	0.0128
Animal (Species) (Error a)	44	9737.7	------
Period	3	15152.3	0.0001
Species x Period	3	4186.9	0.0001
Error b	113	16504.0	------

Appendix Table 17. Analysis of variance for composition of browse, grass and forbs in goat diets for four periods of the year.

Source	d.f.	SS	P>F
Period	3	35.4	0.97
Vegetation Type	2	31173.5	0.0001
Period x Vegetation Type	6	31022.6	0.0001

Appendix Table 18. Analysis of variance for composition of browse, grass and forbs in sheep diets for four periods of the year.

Source	d.f.	SS	P>F
Period	3	11.8	0.99
Vegetation Type	2	19406.7	0.0001
Period x Vegetation Type	6	41545.2	0.0001

Appendix Table 19. Analysis of variance results for browse, grass and forb composition of sheep versus goat diets during the year.

Source	Probability Level of Significance	Source	Probability Level of Significance
<u>Browse Species</u>		<u>Forb Species</u>	
Sabia	0.0710	Amendoin de caracara	0.0059
Marmeleiro	0.0121	Azedinho	0.3504
Mofumbo	0.0001	Bambural branco	0.9064
Feizão bravo	0.0001	Bambural verdadeiro	0.0443
Pereiro	0.0116	Barba de bode	0.0011
João mole	0.1715	Canafistula brava	0.1389
Pau moco	0.0001	Canafistula de lagoa	0.0001
Jurema branca	0.0038	Carrapicho de agulha	0.0001
Jurema preta	0.9142	Caso de burro	0.8410
Marmeleiro branco	0.0721	Cebola brava	0.2666
Aroeira	0.0081	Centrosema	0.8416
Jucazeiro	0.1197	Cuandu	0.1524
Camara de chumbo	0.2479	Desconhecida	0.3444
Pau branco	0.8353	Erva de ovelha	0.0001
Maria preta	0.0665	Ervanco	0.7616
Catingueira	0.7104	Espoleta	0.0941
Imburana	0.0504	Fava de boi	0.8631
Juazeiro	0.0521	Fedegoso	0.7003
Mororo	0.4255	Feizão de rola	0.9182
		Gergelin bravo	0.0016
<u>Grass species</u>		Jitirana lisa	0.4844
Capim pe de galinha	0.0009	Jitirana peluda	0.2770
Capim rabo de raposa	0.2770	Lingua de vaca	0.0001
Capim milha branca	0.1809	Malicia	0.1979
Capim milha vermelha	0.0009	Malva	0.0123
Capim barba de bode	0.0011	Maracuja de estralo	0.0001
		Maracuja rateiro	0.0071
		Mariana	0.0144
		Mata pasto	0.6903
		Melosa	0.0085
		Melosa brava	0.0771
		Milho de cobra	0.4947
		Mirasol	0.0001
		Paco paco	0.3560
		Pescoco de granso	0.5433
		Pimentinha	0.0238
		Quebra panela	0.2956
		Relogio	0.2742
		Urtiga	0.0240
		Vassourinha	0.1023

Appendix Table 20. Analysis of variance for crude protein content of sheep and goat diets.

Source	d.f.	SS	P>F
Species	1	44.7	0.0005
Animal (Species) (Error a)	42	131.0	-----
Period	3	2087.7	0.0000
Period x Species	3	45.4	0.0003
Error b	113	249.0	------

Appendix Table 21. Analysis of variance for _in_ _vitro_ digestibility of sheep and goat diets.

Source	d.f.	SS	P>F
Species	1	1561.1	0.0001
Animal (Species) (Error a)	42	1030.4	------
Period	3	5041.3	0.0001
Period x Species	3	1217.3	0.0001
Error b	113	3457.7	------

Appendix Table 22. Analysis of variance for neutral detergent fiber (NDF) in sheep and goat diets.

Source	d.f.	SS	P>F
Species	1	197.5	0.0008
Animal (Species) (Error a)	42	639.2	------
Period	3	2958.0	0.0001
Period x Species	3	463.9	0.0001
Error b	113	1736.2	------

Appendix Table 23. Analysis of variance for lignin content of sheep and goat diets.

Source	d.f.	SS	P>F
Species	1	0.5	0.7743
Animal (Species) (Error a)	42	232.6	-----
Period	3	408.0	0.0001
Period x Species	3	211.2	0.0001
Error b	113	709.9	-----

Appendix Table 24. Analysis of variance for percent of day spent traveling by sheep and goats.

Source	d.f.	SS	P>F
Species	1	0.5	0.70
Period	3	51.1	0.003
Period x Species	3	46.7	0.005
Error	48	153.5	-----

Appendix Table 25. Analysis of variance for percent of day spent foraging by sheep and goats.

Source	d.f.	SS	P>F
Species	1	92.2	0.009
Period	3	1568.2	0.0001
Period x Species	3	131.8	0.021
Error	48	590.7	-----

Appendix Table 26. Analysis of variance for percent of day spent ruminating by sheep and goats.

Source	d.f.	SS	P>F
Species	1	99.7	0.027
Period	3	1436.6	0.0001
Period x Species	3	79.3	0.259
Error	48	916.9	------

Appendix Table 27. Analysis of variance for percent of day spent in activities other than traveling, foraging and ruminating.

Source	d.f.	SS	P>F
Species	1	14.3	0.0001
Period	3	4939.5	0.509
Period x Species	3	278.4	0.045
Error	48	1545.8	-----

Appendix Table 28. Analysis of variance for distance traveled by sheep and goats.

Source	d.f.	SS	P>F
Species	1	333892.6	0.67
Error (a)	18	32557006.8	----
Period	1	10197052.4	0.01
Period x Species	1	7675.8	0.93
Error b	17	18977323.0	----

Appendix Table 29. Analysis of variance for mean retention time of particulate material in the digestive tracts of reproducing and non-reproducing sheep and goats in three periods of the year.

Source	d.f.	SS	P>F
Species	1	80.5	0.077
Period	2	5039.4	0.0001
Species x Period	2	411.8	0.0006
Reproductive Status	1	99.8	0.050
Species x RS	1	0.02	0.978
Period x RS	2	120.1	0.098
Species x Period x RS	2	73.4	0.238
Error	84	2110.8	

Appendix Table 30. Analysis of variance for organic matter digestibility of sabia consumed normally or introduced into the rumina of goats.

Source	d.f.	SS	P>F
Style of Intake	1	11.5	0.32
Trial	1	29.6	0.14
Style x Trial	1	3.6	0.56
Error	4	36.9	----

Appendix Table 31. Analysis of variance for digestible energy intake of sabia consumed normally or introduced into the rumina of goats.

Source	d.f.	SS	P>F
Style of Intake	1	45.6	0.16
Trial	1	154.0	0.03
Style x Trial	1	15.4	0.37
Error	4	61.7	----

Appendix Table 32. Analysis of variance for digestible protein intake of sabia consumed normally or introduced into the rumina of goats.

Source	d.f.	SS	P>F
Style of Intake	1	0.05	0.19
Trial	1	0.31	0.02
Style x Trial	1	0.02	0.34
Error	4	0.08	----

Appendix Table 33. Analysis of variance for digestible energy intake (as a percent of body weight) by sheep and goats in three digestion trials.

Source	d.f.	SS	P>F
Species	1	73.7	0.0705
Period	2	4196.6	0.0001
Species x Period	2	14.4	0.7002
Error	17	336.3	------

Appendix Table 34. Analysis of variance for gross energy apparent digestibility coefficient by sheep and goats in three digestion trials.

Source	d.f.	SS	P>F
Species	1	1.2	0.7296
Period	2	1398.0	0.0001
Species x Period	2	53.8	0.0900
Error	17	164.4	-----

Appendix Table 35. Analysis of variance for the ratio of digestible energy intake organic matter intake by sheep and goats in three digestion trials.

Source	d.f.	SS	P>F
Species	1	0.01	0.5532
Period	2	5.6	0.0001
Species x Period	2	0.08	0.3550
Error	17	0.59	------

Appendix Table 36. Analysis of variance for in vivo organic matter digestibility by sheep and goats in three digestion trials.

Source	d.f.	SS	P>F
Species	1	31.5	0.0724
Period	2	694.6	0.0001
Species x Period	2	63.3	0.0466
Error	17	145.7	------

Appendix Table 37. Analysis of variance for apparent digestible protein intake (as a percent of body weight) by sheep and goats in three digestion trials.

Source	d.f.	SS	P>F
Species	1	0.05	0.0935
Period	2	5.39	0.0001
Species x Period	2	0.34	0.0008
Error	17	0.26	------

Appendix Table 38. Analysis of variance for crude protein apparent digestibility coefficient by sheep and goats in three digestion trials.

Source	d.f.	SS	P>F
Species	1	40.6	0.0953
Period	2	1027.5	0.0001
Species x Period	2	316.5	0.0005
Error	17	221.2	------

Appendix Table 39. Analysis of variance for the ratio of apparent digestible protein intake (g) to organic matter intake (g) by sheep and goats in three digestion trials.

Source	d.f.	SS	P>F
Species	1	0.000005	0.6713
Period	2	0.01	0.0001
Species x Period	2	0.001	0.0001
Error	17	0.0005	------

Appendix Table 40. Analysis of variance for the ratio of fecal nitrogen output to nitrogen intake by sheep and goats in three digestion trials.

Source	d.f.	SS	P>F
Species	1	46.2	0.0846
Period	2	1048.2	0.0001
Species x Period	2	329.0	0.0006
Error	17	234.0	------

Appendix Table 41. Fecal nitrogen output (FNO):nitrogen intake (NI) ratio (least squares means and S.E.) for sheep and goats in three digestion trials.

Period	Sheep	Goats
Late-Wet	52.1^{a} (1.9)	59.0^{b} (2.1)
Early-Dry	69.7^{a} (1.9)	66.2^{a} (1.9)
Late-Dry	77.8^{a} (1.9)	65.9^{b} (1.9)

$^{a-b}$Least squares means in the same row with different superscripts differ (P<.05).

Appendix Table 42. Analysis of variance for forage organic matter intake (as a percentage of body weight) for free-ranging, non-reproducing sheep and goats during the four periods of the year.

Source	d.f.	SS	P>F
Species	1	1.2	0.0002
Period	3	11.1	0.0001
Species x Period	3	2.2	0.0008
Error	79	9.5	------

Appendix Table 43. Analysis of variance for digestible energy intake (kcal/kg BW) for free-ranging, non-reproducing sheep and goats during three periods of the year.

Source	d.f.	SS	P>F
Species	1	557.5	.017
Period	2	10572.1	.0001
Species x Period	2	981.9	.0076
Error	64	5965.9	----

Appendix Table 44. Analysis of variance for digestible protein intake (g/kg BW) for free-ranging, non-reproducing sheep and goats during three periods of the year.

Source	d.f.	SS	P>F
Species	1	0.3	0.0046
Period	2	18.7	0.0001
Species x Period	2	0.9	0.008
Error	64	5.3	-----

VITA

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