EVALUATION OF STOCKING RATE EFFECTS WITH PASTURES THAT CONTAIN VARIOUS FORBS AND GRASSES BEING CO-GRAZED BY GOATS AND SHEEP AND SUBSEQUENT PERFORMANCE WITH AN ENERGY-RICH DIET

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TABLE OF CONTENTS

LIST OF TABLES

Tables Page

CHAPTER III

CHAPTER IV

CHAPTER V

Format of Dissertation

This dissertation is presented in the Journal of Animal Science style and format, as outlined by the Oklahoma State University Graduate College style manual. The use of this format allows for independent chapters to be prepared suitable for submission to scientific journals.

CHAPTER I

INTRODUCTION

In 1996, there were 1325 million cattle, 1057 million sheep, and 677 million goats on the earth, constituting the first, second, and fourth largest livestock groups, respectively (Morand-Fehr and Boyazoglu, 1999). These ruminant species supply the majority of meat and milk for humans of the world. Small ruminants are also raised for their valuable fibers and skins. Most ruminants are produced under extensive or semi-extensive systems in which most nutrients are derived from grazed forage. Hence, levels and efficiencies of production are impacted by seasonal and environmental factors influencing the quantity and quality of forage available for consumption. Another important factor affecting the efficiency and sustainability of production is the manner in which pastures and forage resources are managed.

A range of conditions determine the type of vegetation and its productivity, including climate (precipitation, wind, temperature, humidity), soil, and topography (Holechek et al., 2004). Proper grazing management given these specific conditions should allow for long-term utilization and maintenance of forage resources. FGTC (1991) defined grazing management as “the manipulation of animal grazing in pursuit of a defined objective.” Therefore, grazing management involves the integration of animals, land, forage, and other inputs with the goal of marketing a product at a profit, while maintaining or improving the productivity of the grazing land resources. The four basic components of grazing management are proper stocking rate, time of use, animal distribution, and grazing system (Holechek et al., 2004). Of these, stocking rate has the largest impact on both animal performance and forage resources (Holechek et al., 1995). Determining the most appropriate stocking rate is difficult because of the multitude of entailed considerations (Holechek, 1988; Galt et al., 2000), such as land area, forage mass and demand, distance from water, slope, and harvesting coefficients. Animal species is also an important determination to be made.

In many parts of the world it is not uncommon for different species of herbivores to graze together. Forage species selection varies greatly among herbivores (Dumont, 1997; Penning et al., 1997; Bartolome et al., 1998; Ngwa et al., 2000). Thus, in pastures with diverse plant communities (Dumont, 1997), integrating different species might yield greater production per unit land area compared with mono-species grazing (Holechek et al., 2004). There has been much less study of complementary grazing or co-grazing of sheep and goats compared with cattle and sheep. Although, sequential grazing of sheep after goats in grass/clover swards enhanced lamb growth compared with grazing by sheep alone (del Pozo et al., 1996). Co-species grazing, in addition to increased live weight gain per unit land area, has also had positive effect on pastures conditions including soil properties (Abaye et al., 1994, 1997).

Grazing is associated with an additional energy cost above that of confined animals used for locomotion and forage ingestion, which affects energy available for production. Sahlu et al. (2004) proposed that this activity expense could be projected based on time spent grazing plus walking, distance traveled, forage quality, and ruggedness of the terrain, although other prediction systems such as described by CSIRO

(1990) include direct input of forage availability. Stocking rate influences available forage mass and forage nutritive values, both of which can impact grazing time and distance traveled. Although, because of differences between sheep and goats in factors such as forage selectivity and preferences, it is unclear how stocking rate effects might vary with co-grazing species.

High stocking rates typically yield greater production per unit land area compared with lower rates, but performance per animal can be less. Hence, subsequent feeding of concentrate-based diets after grazing to reach marketable weight and condition and achieve greater economic returns compared with marketing immediately after grazing is a management option. Because of potential differences among ruminant species in factors such as diet selectivity, level of feed intake, nitrogen recycling, etc., effects of previous stocking rate on subsequent compensatory growth of cattle (e.g., Rodel et al., 1981; Dufrasne et al., 1995; Hornick et al., 1998c) may not necessary be directly extrapolated to small ruminants, particularly goats.

With this general background, objectives of this project were to investigate effects of co-grazing by sheep and goats of grass/forb pastures at different stocking rates on performance, diet selectivity, grazing behavior, and energy expenditure. In addition, effects of co-grazing by sheep and goats of grass/forb pastures at different stocking rates on subsequent performance while consuming a 65% concentrate diet were determined.

CHAPTER II

REVIEW OF LITERATURE

Co-Grazing and Diet Selection

Co-grazing of goats and sheep and(or) cattle has been proposed as a method of improving pasture carrying capacity. Snell (1934) reported higher weight gains and carrying capacity by co-grazing sheep and cattle than when the livestock species were grazed separately. Studies conducted on Texas native range also showed higher overall carrying capacities with the co-grazing of cattle, sheep, and goats (Merrill and Miller, 1961; Merrill et al., 1966). It was concluded that the increase in production was related to differences in preferences among the livestock species, with cattle preferring grass, sheep utilizing forbs, and goats utilizing browse. Benefits of co-grazing apparently are dependent on the diversity of botanical types and the stocking rate that ultimately affects the forage masses of these plant species (del Pozo et al., 1996; Gong et al., 1996a; Abaye et al., 1997). In addition, co-grazing can favorably alter soil conditions, such as pH and organic matter concentration, compared with grazing by one species alone (Abaye et al., 1997).

Reynolds et al. (1971) found no effect of co-grazing cattle and sheep with a monoculture of orchardgrass and a low grazing pressure. Rapid growth of grasses that occurs seasonally can also change the botanical composition in favor of grasses and result in considerable overlap between goat and sheep diets (Squires, 1982). Studies have shown goats and sheep to selectively graze grass during periods when forbs and browse decline in the botanical composition relative to grasses (Squires, 1982).

Goats and sheep share a common preference to graze the green herbage of dicotyledonous plants, but their preferences in the growth types they selectively graze differ considerably (Prigge et al., 1985). Sheep have shown to select a diet higher in quality than those selected by other ungulates (Bryant et al., 1980; Squires, 1982). Their selectivity of plant species and structures has been strongly related to leafiness, dry matter concentration (preferring low levels), and crude protein concentration (preferring high levels; O'Reagain, 1993). Conversely, goats selectively graze and utilize a wide variety of low-quality woody plants (Davis et. al., 1974; Merrill, 1975; Sidahmed et. al., 1981). It is for this reason that goats have been used to clear or control trees and brush in areas where this vegetation is competitive with grasses and forbs that are preferably grazed by sheep and cattle (Terrill and Price, 1985; Pompay and Field, 1996). Goats also consume many of the spiny and prickly weeds that sheep do not graze (Pompay and Field, 1996). Balogu et al. (1999) observed that goats grazed at a stocking rate of 40 animals/ha consumed 60% of the available forest vegetation in less than 4 weeks.

In many instances goats have consumed diets relatively lower in clover than grass in mixed swards, resulting in greater subsequent sward levels of clover (del Pozo et al., 1996). However, such differences in selectivity may largely depend on spatial distribution of clover and grass in the sward and biting depth. With a shorter depth of biting by goats than sheep, accompanied by biting of goats horizontally or from the side, clover consumption may be less by goats if most clover leaf biomass is in the basal horizon of mixed swards. Conversely, there may be little or no species differences in selection with a similar vertical clover distribution in the sward, or with a high level of clover leaf biomass in the upper sward stratum (Gong et al., 1996a).

Although goats are classified as browsers, the composition of their diets correlates with the botanical composition of the pastures they are grazing. Grant et al. (1984) found goats to graze rushes (*Juncus effusus*) that were in mixture with various grasses, but the selectivity of rushes decreased as their proportion of the mixture decreased in relation to grasses. Other studies have shown goats to selectively graze grass, particularly during seasonal periods of rapid grass growth (Coblentz, 1977; Squires, 1982). Coblentz (1977) found that diets of feral goats on Catalina Island, California contained 90% browse, 4% forbs, and 6% grass during the winter months when the availability of browse was high relative to forbs and grass, but contained 8% browse, 18% forbs, and 74% grass during the summer when there was rapid growth of grasses and forbs.

Goats preferentially consume reproductive stems, reducing the spread of weeds by seed. Even though mature seeds sometimes survive passage through the digestive tract of most animals and germinate, goats usually consume the seeds in an immature stage that do not survive the digestive tract. Allan and Holst (1996) observed that goats reduced the seed bank of thistles when being used for thistle control. Mayo (2000) observed a reduction in seed production when goats were used to control sericea lespedeza.

Stocking Rate

Stocking rate is defined by FGTC (1991) as the "the relationship between the number of animals and the grazing management unit utilized over a specified time period." Stocking rate has more influence on forage productivity than any other factor

(Holechek et al., 2004). Proper stocking rate is a prerequisite for sustainable livestock grazing, referring to the number of animals that can graze an area of land over time without causing damage to vegetation or related resources and improving areas with undesirable conditions such as unwanted vegetation or poor fertility (Holechek, 1991; Holechek et al., 2004). Unmanaged livestock grazing, on the other hand, is destructive to soil, plant, and water resources (Holechek, 1991). Heavy grazing over extended periods of time degrades pasture conditions, while light or moderate grazing pressure maintains or improves them (Malechek, 1984).

Stocking rate is determined by dividing the total usable forage per unit area by the total forage demand of the grazing animals during the period (Holechek et al., 2004). When the forage supply is inadequate to meet the demand, then stocking rate should be reduced to avoid negative effects on the prevalence of desirable forage plants being consumed by the ruminant species on site. Likewise, high grazing pressure can cause nutritional stress and health problems to animals and increases the likelihood of consumption of poisonous plants (Holechek, 2002). Excessive stocking rates compromise long-term carrying capacity of the land and eventually lead to ecological damage.

Determining the most appropriate stocking rate requires the quantification of available forage, identification of harvesting coefficients, corrections for slope and distance to water, and assessment of accurate animal forage intake allowances (Galt et al., 2000; Holechek et al., 2004). The harvest coefficient is the percentage of total forage produced that is assigned to animals for consumption. Holechek (1988) based harvest coefficient selection on various stocking rate studies with different range types, and suggested a 35% value for most arid and semi-arid areas and 50% for annual grasslands and humid areas. Most reports indicate 50% as a general rule of thumb harvest coefficent on which to select a stocking rate. But, generally actual forage use is 10 to 15% greater than intended because of livestock trampling, wildlife consumption, and weathering (Galt et al., 2000). Troxel and White (1989) allocated 25% of the current year's forage for livestock and another 25% to natural disappearance (i.e., insect, wildlife, weathering), leaving 50% for site protection. Guidelines of adjusting for slope are reductions of 0% for 1 to 10% slope, 30% for 11 to 30%, 60% for 31 to 60%, and 100% for over 60% (Holechek, 1988).

Heavy, moderate, and light grazing are general descriptors of stocking rate or grazing pressure. However, Klipple and Bement (1961) defined heavy grazing as a degree of herbage utilization that does not permit desirable forage species to maintain themselves. Moderate grazing allows palatable species to maintain themselves but usually does not permit herbage-producing ability to improve. Light grazing permits palatable species to maximize herbage-producing ability. Averaging previous stocking rate studies, Holechek et al. (2004) noted that heavy grazing resulted in 57% use of primary forage species compared with 43 and 32% use for moderate and light grazing, respectively.

Daily weight gain by cattle on pasture typically declines linearly as stocking rate increases (Cowlishaw, 1962; Jones and Sandland, 1974). This relationship was demonstrated by results of numerous grazing studies conducted with N-fertilized monocultures of grass (Riewe, 1961; Bransby, 1988; Hart et al., 1988). Heavy grazing of unfertilized grass pastures can result in severe weed encroachment. Overgrazing from heavy stocking has been defined as causing a change in botanical composition that is deleterious to animal production (Wilson and MacLeod, 1991); however, intensive grazing can also encourage emergence and growth of other species that may be higher in quality than the planted species (Roberts, 1980; Rickert, 1996). Aiken et al. (1994) found increasing concentrations of crabgrass in mixture with fertilized small plots of bermudagrass as clipping height decreased and clipping frequency increased. The changes in botanical composition were not to the detriment of forage crude protein concentrations and digestibility.

In comparison with grass monocultures, complex mixtures of grasses and legumes are generally more sensitive to changes in stocking rate and, as a result, weight gain to stocking rate relationships can depart considerably from linearity. Roberts (1980) concluded in a literature review that tall erect growing grasses can suppress lower growing legumes at low stocking rates, but the legume dominates at high stocking rates. This shift in botanical composition, from dominance by stemmy, mature grasses to a dominance by high-quality legumes can greatly reduce the weight gain response to stocking rate. Typically, however, legumes are most abundant with light grazing intensities and will diminish from stands with heavy grazing intensities (Aiken et al., 1994). Partridge (1979) reported that a heavy grazing intensity on a *Dichanthium caricosum-Macroptilium atropurpureum* mixture resulted in loss of the legume and subsequent replacement with native legumes, which substantially reduced animal performance. Similar responses have been reported for heavily grazed mixtures of *Panicum maximum* in mixture with the legumes, *Stylosanthes quianensis* and *Centrosema pubescens* (Eng et al., 1978).

Changes in botanical composition depend on how individual components are affected by the interrelation between the stresses of defoliation, environment, and competition (Grime, 1973). Grime (1977) attributed the ability of a species to be competitive to a (1) tall stature, (2) growth habit that allows extensive exploitation of the above and below ground environment, (3) high maximum growth rate, and (4) tendency to deposit a dense layer of litter on the soil surface.

Stocking rate has a major influence on the ecological and economic sustainability of grazing systems. Maximum sustainable stocking rate, defined by Rickert (1996) as the maximum, long-term stocking rate that does not cause pasture degradation, is relevant information that can be determined from stocking rate grazing trials. Rickert (1996) concluded in a literature review that stocking rates for maximizing profit generally entail moderate grazing intensities that provide sustainable levels of pasture utilization. Inputs of management (e.g., fertilizer, irrigation, rotational grazing) can increase the maximum sustainable stocking rate, but increases in pasture costs will also increase the stocking rate necessary for maximum profit (Riewe, 1981; Bransby, 1989). Furthermore, it is possible for high pasture costs to result in the stocking rate for maximum profit to be higher than the maximum sustainable stocking rate. Aiken et al. (1998) further demonstrated that economic condition of livestock markets has a major impact on the feasibility of increasing pasture inputs to increase stocking rate and profitability.

Grazing Behavior

The grazing ruminant is faced with the task of searching for, harvesting, and ingesting forage to satisfy its nutrient demands one bite at a time. Daily herbage intake has been difficult to determine in grazing animals. Ingestive behavior has been employed as a possible approach to determine daily dry matter (DM) intake by coupling rate of intake and time spent grazing, with intake rate being the product of bite rate and mass (Burns and Sollenberger, 2002).

Ingestive behavior and, hence, herbage intake of grazing animals is strongly influenced by sward structure, such as sward height and density (Gong et al., 1996a,b,c), botanical composition, and distribution of morphological components within the canopy (Burns and Sollenberger, 2002). Gong et al. (1996a,b,c), from turves extracted from field-grown grasses and legume monocultueres at two stages of maturity, showed sward height to be the most important sward variable affecting ingestive behavior of sheep and goats, although bulk density was also important for leguminous swards grazed by sheep. Sward height is positively related with bite weight, but is related negatively with bite rate (Gong et al., 1996b). Gong et al. (1996a,c) noted that forage maturity stage and type impacted ingestive behavior of sheep and goats grazing monoculture turves in confinement differently. Bite weight with vegetative grasses was similar between species, but bite weight for goats was greater with reproductive grasses and was greater for sheep than for goats with legumes (Gong et al., 1996a,c).

While grazing grass swards at two sward heights, sheep had greater bite mass than goats but goats had a higher bite rate than sheep, resulting little difference in intake rate between sheep and goats (Gordon et al., 1996). This ability for goats to compensate for smaller bite masses by having a higher bite rate might reflect their higher chewing efficiency or their readiness to swallow larger particles than sheep (Domingue et al., 1991). But other reports have shown an overall greater bite rate for sheep than for goats (Gong et al., 1996a).

Ingestive mastication plays an important role in particle size reduction of forage (Luginbuhl et al., 1989) and subsequent escape via the reticulo-omasal orifice to the lower tract, thereby facilitating voluntary feed intake (Allen, 1996). In dairy cows, bite rate, bite mass and, thus, intake rate increased but chewing rate decreased as the day progressed under continuous stocking (Taweel et al., 2004). Such change may reflect ample ability to compensate for an increase in the size of swallowed particles with advancing grazing time (Taweel et al., 2004).

Nutrient demand influences grazing behavior. For example, fasting of sheep grazing perennial ryegrass and white clover increased intake rate largely through increases in bite mass and grazing time (Newman et al., 1994). One factor influencing nutrient demand is genotype. Grazing behavior such as time spent for ingestion, walking, eating, and ruminating varied among breeds of goats (Odo et al., 2001). Likewise, bite rate and distance traveled have been shown to vary among different types of cattle (Funston et al., 1991) and sheep (Brand, 2000).

Animal grazing behavior also changes in response to grazing management, such as stocking density and length of stay at pasture (Burns and Sollenberger, 2002). As herbage mass declines with increasing stocking density the amount of time spent by sheep per feeding station decreases (Ruyle and Dwyer, 1985). Moreover, bite weight declines, but bite rate and grazing time will increase up to a point to offset the reduction in bite weight (Burns and Sollenberger, 2002).

Mean daily grazing time was reported to be about 11.5 h in cattle (Funston et al., 1991). Stobbs (1970) estimated that grazing time may be limited by fatigue at approximately 12 h/day. Goats grazing *Acacia nilotica*, *Leucaena Leucocephala*, and *Cenchrus ciliaris* in a semi-arid reconstituted silivipasture of India spent about 54.7, 23.2, 7.4, and 14.7% of their time for foraging, ruminating, walking without grazing, and resting, respectively (Sharma et al., 1998). Fierro and Bryant (1990) noted for sheep grazing native range in southern Peru that 52, 13, 20, and 13% of the time was in grazing, ruminating, walking, and resting, respectively. Lu (1987) reported that average time spent rumination could range 329 to 420 min/day, depending on particle length of forage.

Goats (Sharma et al., 1998) and sheep (Fierro and Bryant, 1990) show a diurnal pattern of foraging, with most of the grazing occurring in the morning and some hours prior to sunset. Goats and sheep also exhibit a distinct diurnal pattern in rumination and spend a greater portion of their time on this activity during the night (Lu, 1988; Fierro and Bryant, 1990). But grazing time can be modified by factors such as forage availability and environmental factors (e.g. heat and rain; Sharma et al., 1998). Ruminants generally tend to avoid grazing during the hotter part of the day and thus reduce their daily grazing time (Shinde et al., 1997; Sharma et al., 1998). However, genotypes of small ruminants vary in their adaptation to harsh climatic conditions. For example, active grazing and resting times differ between breeds of sheep (Ashutosh et al., 2002) and among seasons (Sharma et al., 1998). In addition, bite rate decreases when ambient temperature and humidity increase (Ashutosh et al., 2002).

Eating, ruminating, and resting activities can be measured using electronic recordings or approximated by visual observation (Kononoff et al., 2002). The Institute of Grassland and Environmental Research (IGER) behavior monitoring unit (Ultra Sound Advice, London, UK) system has been used to help monitor the jaw movements in free-ranging ruminants (Rutter et al., 1997). Kononoff et al. (2002) compared the eating and ruminating behavior of dairy cattle using the continuous IGER behavior monitoring unit with visual observations every 5-min and noted that total time eating and ruminating were 8.7 and 42.9 min greater for visual observations compared with the electronic method, respectively. The authors suggested the difference could be in part due to the continuous measurement for electronic method compared with 5-min intervals for visual observation and that results from different methods should not be directly compared.

Energy Expenditure of Grazing

Energy expenditure (EE) has been determined from production of carbon dioxide, uptake of oxygen, or comparative slaughter. The production of carbon dioxide can be estimated using doubly labeled water (Midwood et al., 1993) or constant infusion of labeled sodium bicarbonate (Sahlu et al., 1992). Oxygen uptake can be measured in animals by tracheal intubation (Young and Webster, 1963; Shinde et al., 1998) or in respiration chambers. Thus, in penned animals EE can be relatively easily assessed (McDonald et al., 1995). Accurate estimation of EE by grazing animals has been difficult in part because of complications imparted by environmental factors, and it is challenging to quantify feed intake under grazing conditions as well. The carbon dioxide entry rate technique (Havstad and Malechek, 1982; Sahlu et al., 1989; Sahlu et al., 1992) is probably the most common method of determining grazing ruminant EE. However, heart rate measurement has also been employed (Brosh et al., 1998; Arieli et al., 2002; Barkai et al., 2002). Oxygen delivered from the lungs to body tissues is a product of heart rate and O_2 uptake per heart beat, called O_2 pulse. In the use of heart rate to estimate grazing EE, a constant O_2 pulse or EE per heart beat is assumed, although this is typically determined for each animal used rather than applying an average. Brosh et al. (1998) noted that regression equations of oxygen uptake against heart rate differed among individual cattle. Barkai et al. (2002) reported that O_2 pulse in lambs was stable throughout the day. Another method of estimating the grazing activity energy cost is the factorial approach (Fierro and Bryant, 1990; Lachica and Aguilera, 2003), in which the energy cost of each activity, determined by calorimetry, is multiplied by the total time spent for each activity by grazing animals and the total energy cost is calculated by summation.

Energy expenditure attributable to grazing can account for a substantial part of the total energy requirement of ruminants. For example, NRC (1981) suggested that the grazing activity energy cost of goats relative to the cost of maintenance in confinement (ME_m) is 25% with light activity, 50% with semi-arid rangeland and slightly hilly conditions, and 75% with sparsely vegetated rangeland or mountainous transhumace pasture. A 60 to 70% increase above ME_m in daily energy expenditure was noted for grazing vs. penned sheep (Young and Corbett, 1972). For sheep grazing *Cenchrus ciliaris* pasture interspersed with fodder trees, EE of grazing compared with penned sheep in monsoon, winter, and summer was 78, 15, and 33%, respectively (Shinde et al., 1998). Coop and Hill (1962) reported a higher grazing energy activity cost of 92% of ME_m with Romney ewe lambs grazing a perennial ryegrass-white clover sward. Free-ranging cattle expended 46% more energy than did stall fed cattle in a study involving crested wheatgrass range (Havstad and Malechek, 1982). However, Holmes et al. (1978) reported a relatively low grazing activity energy cost, with each hour spent grazing by cattle increasing daily EE by 2%.

The energy cost of grazing can be partitioned into that associated with locomotion and ingestion (Osuji, 1974; Fierro and Bryant, 1990). The daily distance traveled by goats has been noted to vary from 3.5 to 14.3 km (Swain et al., 1986; Lachica et al., 1997b, 1999; Sharma et al., 1998). For sheep, of 4.6 to 10.0 km have been seen (Swain et al. 1986; Fierro and Bryant, 1990). Swain et al. (1986) noted that goats traveled greater distance than sheep in a semi-arid natural range. However, distance traveled depends on many conditions, including season of the year, forage availability, and other animal and environmental conditions (Swain et al., 1986; Sharma et al. 1998). For example, distance traveled was negatively correlated with temperature, humidity, and hours of daylight to a lesser extent for goats than sheep (Swain et al., 1986), reflecting greater adaptability to hotter environments of goats than sheep (Silanikove, 2000).

The energy cost of walking is affected by slope (Lachica et al., 1997a). In goats, 34.8 to 130.9 kJ/kg$^{0.75}$ body weight (BW) per day has been noted for heat production due to locomotion (Lachica et al., 1997b, 1999). For goats under range conditions, grazing, walking, and standing were the primary activities, accounting for 57, 27, and 13% of the day period, respectively (Lachica et al., 1997b). Fierro and Bryant (1990) noted that the energy cost of daily walking was almost equal to energy cost of grazing in sheep. The energy cost of eating varies with diet type, being 9.02 J kg^{-1} BW g^{-1} DM for roughages and 1.55 J kg^{-1} BW g^{-1} DM for concentrates (Lachica and Aguilera, 2003). The energy cost of eating is proportional not to the amount of feed eaten but to the length of time spent feeding and the nature and physical form of the feed consumed (Lachica and Aguilera, 2003). In regards to time spent grazing, Lambourne and Reardon (1963) noted greater EE by free-ranging sheep when forage was scarce compared with when it is abundant. In contrast, Havstad and Malechek (1982) reported that the energy expended by cattle was independent of the quantity of available forage, though the limited sample size and variability in the data was implicated as a probable contributing factor for this finding. Because of the close relationship between grazing time and EE (Osuji, 1974), Sahlu et al. (2004) proposed prediction based primarily on time spent grazing and walking, but also with influence of herbage digestibility, distance traveled, and terrain ruggedness or topography.

Compensatory Growth

Introduction

Growth is an increase in mass of tissues or organs by hyperplasia and(or) hypertrophy (Owens et al., 1993). Growth starts prenatally with the fertilized ovum. Growth is the end-result or the sum effect of synthesis, degradation, and losses of energy, nitrogenous-containing compounds, and minerals. Growth is affected by many factors, including ones genetic in nature and environmental. When not hindered by environmental factors, animal growth is best described by a sigmoidal curve (Owens et al., 1993); however, in many cases growth is restricted and the genetically determined growth curve is not realized.

Feed restrictions, with limited supplies of energy, protein, or both, can profoundly affect animal growth (Poppi and McLennan, 1995; Wester et al., 1995). Restricted nutrient intake is associated with decreased synthesis of body tissues relative to degradation (Hayden et al., 1993). In some cases, tissues are mobilized to meet needs for essential functions (Hovell et al., 1987). However, in not all instances is growth permanently affected. With unrestricted or a higher level of nutrient intake after a period of restriction (i.e., realimentation, repletion, or re-feeding), growth may be greater than expected based on body weight and the nature of the diet, which is termed 'compensatory growth.'

Nutrient restriction period

Restricted nutrient consumption results in coordinated alterations of tissue turnover (Wester et al., 1995; Rossi et al., 2001). With severe restriction, very labile protein stores are mobilized first, followed by metabolism of fat and then muscle (Hornick et al., 2000). Tissue metabolic activity is highly related to use with restricted nutrient intake. Tissues with high activity (e.g., liver) incur relatively large decreases in mass. Drouillard et al. (1991b) and Wester et al. (1995) estimated reductions of 32 to 40% in oxygen uptake by the liver of lambs in response to restricted nutritional planes for 35 to 49 days, which were associated with decreases in whole body oxygen consumption. Conversely, early maturing body components such as bone generally are little affected by feed restriction (Carstens et al., 1991; Kamalzadeh et al., 1998a). But, if impacted, recovery of mass of such tissues during refeeding is less than of other tissues (Kamalzadeh et al., 1998b). In addition to limited growth and perhaps tissue mobilization, other economically important tissues and traits can be affected. For example, Kamalzadeh et al. (1998a,b) reported a decrease in the size of testes due to feed restriction that could compromise reproductive performance. Nutrient restriction has also adversely affected the ovarian cycle, conception, fecundity, and twinning rate (Roberts et al., 1997; Kusina et al., 2001). In Angora goats, mohair growth also can be lessened by low nutritional planes, although for animals selected for fiber growth, with a minimal or moderate degree of nutrient restriction other tissues will be mobilized to fuel and maintain fiber growth (Sahlu et al., 1999).

During the period of feed restriction, resting metabolic rate is reduced, with the magnitude of change depending on the severity of limitation (Drouillard et al., 1991b; Wester et al., 1995; Yambayamba et al., 1996). This is accompanied by shifts in metabolism of nutrients and energy stores. For example, adipose tissues and the liver release non-esterified fatty acids (NEFA) and ketone bodies and muscles release lactate, branched chain keto-acids, alanine, glutamine, and branched chain amino acids (Hornick et al., 2000). During restriction, plasma concentrations of glucose, alpha-amino nitrogen, total protein, and urea nitrogen decrease and plasma creatinine and NEFA levels increase (Hayden et al., 1993; Yambayamba et al., 1996; Hornick et al., 1998b; Sahlu et al., 1999). Such changes are orchestrated by altered endocrine conditions. For example, plasma insulin, triiodothyronine (T3), thyroxine (T4), and IGF-I levels decrease during restriction, while cortisol and somatotropin (GH) concentrations increase (Hayden et al., 1993; Barash et al., 1998; Hornick et al., 2000). Change in IGF-I is presumably due to reduced GH receptors in target tissues, particularly the liver (Wester et al., 1995; Yambayamba et al., 1996; Barash et al., 1998; Hornick et al., 1998b). Daily body weight gain during the energy restriction period was linearly correlated with plasma levels of IGF-I in calves (Barash et al., 1998). Decreased T3 and T4 levels during restriction contribute to the reduced basal metabolic rate (Yambayamba et al., 1996). Daily weight gain during the energy restriction period was linearly correlated with mean plasma concentration of total T4 in calves (Barash et al., 1998).

Realimentation period

The phenomenon of compensatory growth has been long recognized (Wilson and Osbourn, 1960; O'Donovan, 1984; Ryan, 1990). Hornick et al. (2000) defined compensatory growth as "a physiological process whereby an organism accelerates its growth curve after a period of restricted development, usually due to reduced feed intake, in order to reach the weight of animals whose growth was never reduced."

During realimentation, the decrease in energy expenditure during the period of limited nutrient intake continues with a higher plane of nutrition (Drouillard et al., 1991b; Yambayamba et al., 1996). However, the severity and length of the restriction dictate the magnitude and length of this effect (Drouillard et al., 1991b). A decreased metabolic rate during realimentation is commonly thought to decrease the maintenance energy requirement and, thereby, increase energy available for growth. Also, Carstens et al. (1991) estimated a decreased net energy for gain requirement for growth of cattle during a period of compensation. This was explained by a lower energy concentration in tissue being accreted after the period of restriction, as well as possibly an increase in gut digesta mass.

As alluded to above, the composition of tissue being gained during compensatory growth may be different than for animals on a continuous high plane of nutrition. In the first part of compensatory growth, deposited tissue has in some instances been relatively high in protein (Fox et al., 1972; Turgeon et al., 1986), presumably due to an enhanced fractional rate of accretion of skeletal muscle (Rossi et al., 2001) and recycling and reutilization of amino acids and reduced amino acid oxidation (Hornick et al., 2000). High deposition of lean tissue early in the compensation phase may be the product of an elevated GH level (Yambayamba et al., 1996; Hornick et al., 2000). However, after this early phase, composition of gain may be similar to that of continuously fed animals or higher in fat (Hornick et al., 2000). Hence, length of the realimentation period can affect final body composition.

Another factor many times contributing to compensatory growth is increased feed intake relative to the level expected based on body weight and the nature of the diet (Wanyoike and Holmes, 1981; Drouillard et al., 1991a,b; Sainz et al., 1995; Wester et al., 1995; Hornick et al., 1998a; Creighton et al., 2003). Increased feed intake during compensatory growth could be partly attributable to differences in gastrointestinal tract (GIT) capacity. Development of the GIT has not been markedly affected by nutrient deprivation (Carstens et al., 1991; Drouillard et al., 1991b; Wester et al., 1995). Consequently, restricted animals could have larger GIT mass relative to body weight compared with unrestricted animals. However, feed intake does not always contribute to compensatory growth. For example, Kabbali et al. (1992) found no increase in intake of refed lambs, which as attributed to the young age of the animals.

As noted for nutrient restriction, during realimentation blood metabolite and hormonal conditions may be altered. For example, refeeding has increased plasma glucose, alpha-amino nitrogen, and urea nitrogen and decreased plasma NEFA and creatinine levels (Hayden et al., 1993; Hornick et al., 1998b; Sahlu et al., 1999). Higher circulating NEFA levels during restriction are due to lipolysis presumably because of a high blood concentration of GH or a low insulin/GH ratio (Cole et al., 1988).

GH levels generally are decreased during realimentation, other than perhaps in the initial period ring (Hornick et al., 1998b), probably due to inhibition through rumen distension (Tindale et al., 1985) and(or) a higher concentration of insulin that stimulates metabolite uptake by the hypothalamus. Yambayamba et al. (1996), on the other hand, reported an elevated GH level in beef heifers until day 104 of realimentation. Serum IGF-I increased during nutrient repletion (Wester et al., 1995; Yambayamba et al., 1996; Barash et al., 1998; Hornick et al., 1998b), and plasma IGF-I level was positively correlated with empty body protein accretion in compensating steers (Wester et al., 1995). Higher plasma insulin levels during repletion stimulates anabolic processes including fat accretion. The increase in plasma insulin after refeeding presumably is due to higher blood metabolite concentrations, particularly of propionate and gluconeogenic amino acids. Effects of nutrient restriction on concentrations of T3 and T4 during realimentation are not consistent. Whereas Hayden et al. (1993) reported a lack of response of T4 to repletion, others have shown an increased concentration (Barash et al., 1998; Hornick et al., 1998b). Changes in T3 include a continued low level (Yambayamba et al., 1996), inconsistent change (Hornick et al., 1998b), or increase (Hayden et al. 1993; Wester et al., 1995).

Factors affecting compensatory growth

Compensatory growth has been quantified using a compensatory index. This index is the ratio of the difference between continuously fed animals and ones compensating in weight at the end of restriction and compensatory growth periods (Hornick et al., 2000). Values typically range between 50 and 100% (Hornick et al., 2000), reflecting that in many cases compensation at the end of realimentation is incomplete (Barash et al., 1998; Creighton et al., 2003; Nega Tolla et al., 2003).

The degree of compensatory growth is influenced by many factors (Wilson and Osbourn, 1960; O'Donovan, 1984; Ryan, 1990). For example, young animals are more sensitive to restriction than older animals (Thorton et al., 1979). At young ages with hyperplastic growth, malnutrition can impede cell division and limit the extent of compensation (Thorton et al., 1979). Degree of maturity also determines later composition differences (Thorton et al., 1979; Tudor et al., 1980). Restriction of growth at an earlier age can result in a high levels of fat in tissue accreted during compensation, whereas older compensating animals tend to deposit tissue higher in protein than continuously fed animals (Tudor et al., 1980). The severity of the restriction of nutrient intake also impacts the degree of compensatory growth (Barash et al., 1998). Another factor having influence is the length of time nutrient intake is limited, with greater impact when energy rather than protein intake is restricted (Drouillard et al., 1991a). However, the degree to which nutrient intake is limited has had a relatively greater impact than the length of time nutrient intake is low (Drouillard et al., 1991a,b).

After restricted nutrient intake, there may be a delay or period of adaptation before compensatory growth is apparent. Hornick et al. (2000) suggested that this period is 1 month in length, with compensatory growth of bulls reaching a maximum 2 months after refeeding began (Hornick et al., 1998a). Drouillard et al. (1991b) also observed that 1 month was required for lambs to express compensatory growth, but indicated that this delay might have been due to feeding practices employed to minimize digestion upset. Conversely, Barash et al. (1998) observed only a 1-week delay in the body weight gain response to refeeding of bull calves that had previously consumed low energy diets. Also, Hays et al. (1995) observed maximum growth rate and feed efficiency of cattle in the initial 14 days of realimentation.

There are many different types of conditions leading to low nutrient intake and limited growth. Regarding energy limitations, Barash et al. (1998) fed Holstein bull calves at 138 days of age diets containing four levels of metabolizable energy (ME) for 77 days followed by the highest ME diet during realimentation. Mean daily body weight gain during the energy restriction period was linearly related to dietary ME concentration and weight gain during realimentation was correlated negatively with the energy concentration in the diet fed during the restriction period. Drouillard et al. (1991a) noted that in severely energy-restricted steers body weight gain during the subsequent finishing period was 40% more efficient than in unrestricted counterparts. Turgeon et al. (1986) and Sahlu et al. (1999) observed differences with sheep and goats, respectively, after being fed different levels of concentrate. Kamalzadeh et al. (1998a,b) varied the length of nutrient restriction, which involved the withholding of a 17% CP concentrate supplement for 3 or 4.5 months. These different lengths did not impact the rate of weight loss or body dimensions, but the longer period of restriction increased the time of realimentation necessary for animals to reach the same weight as unrestricted counterparts.

With diets to cause mild or severe restrictions of energy intake for 77 to 154 days, Drouillard et al. (1991a) showed that all restricted animals, except those subjected to only a mild and short period of restricted energy intake, exhibited compensatory growth. In beef steers limit fed a 70% concentrate diet with a ME concentration of 2.8 Mcal/kg and crude protein (CP) level of 14% with average daily gain of 0.4 kg/day, Carstens et al. (1991) reported more than a 37% increase in daily body weight gain during realimentation compared with steers consuming the diet ad libitum.

Restricted nitrogen intake also is a common occurrence in practical livestock production settings (Winchester et al., 1957; Abdalla et al., 1988). Protein restriction can result in depletion of body protein (Hovell et al., 1987), which potentially can increase need for protein during repletion. Given the interdependency of protein and energy metabolism within the rumen (Poppi and McLennan, 1995), protein restriction usually elicits both protein and energy deficiencies. Short-term energy and protein restrictions resulted in similar performance during refeeding by lambs and steers, but performance by energy-restricted animals during the period of growth restriction was greater (Drouillard et al., 1991a,b). This may be attributable to an immediate impact of protein restriction on hormonal conditions but not on visceral mass or metabolic activity compared with energy restriction (Wester et al., 1995). When the restriction period was extended, Drouillard et al. (1991a) indicated that finishing gains increased more for energy- than for protein-restricted steers, with the latter requiring a longer duration of realimentation.

Earlier it was stated that compensating animals may have an elevated protein requirement. For example, Hays et al. (1995) reported that increasing levels of dietary protein during refeeding enhanced body weight gain by beef cattle during the initial phase of realimentation concomitant with an increased serum IGF-1 concentration. On the other hand, level of rumen undegraded intake protein (UIP) supplementation of beef steers grazing in the summer did not impact growth regardless of previous management in the winter, which entailed slow (0.24 kg/day) or fast growth (0.65 to 0.71 kg/day;

Creighton et al., 2003), although slow growing steers did undergo growth compensation. It was suggested that differences in microbial protein synthesis and metabolizable protein supply to the animal, changes in microbial protein degradation due to UIP level, and(or) increased efficiency of protein utilization during the summer grazing compensation phase might have accounted for the lack of response to higher UIP levels.

Although compensatory growth occurs for many tissues, fiber growth may respond differently in some cases. For example, mohair production by Angora goats limit-fed a 70% concentrate diet was reduced during this time but also remained low throughout the 41-day realimentation period (Sahlu et al., 1999).

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CHAPTER III

EFFECTS OF STOCKING RATE ON PERFORMANCE AND FORAGE SELECTIVITY OF SHEEP AND GOATS CO-GRAZING GRASS/FORB PASTURES

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Abstract

Differences among ruminant species in forage selectivity offer potential for efficient utilization of pastures with diverse arrays of plant species. Therefore, this experiment was conducted to determine effects of stocking rate (SR) on performance and forage selectivity of growing sheep and goat wethers co-grazing grass/forb pastures. Grazing was for 16-week periods in 2002 and 2003. Pastures consisted of various grasses, primarily bermudagrass (*Cynodon dactylon*) and johnsongrass (*Sorghum halepense*), and forbs (e.g., ragweed; *Ambrosia* spp.). Sheep (Khatadin) and goats (75% Boer) averaged 21 ± 4.8 and 21 ± 3.7 kg initial BW, respectively, and were 4 to 5 months of age when grazing began. Stocking rates were four (4), six 6), and eight (8) animals per 0.4-ha pasture, with equal numbers of sheep and goats. The nine pastures (three/treatment) were divided into four paddocks for rotational grazing in 2-week periods. There was a year x SR interaction ($P < 0.05$) in forage DM mass before grazing (year 1: 2937, 3298, and 3351 kg/ha; year 2: 3033, 2928, and 2752 kg/ha for 4, 6, and 8, respectively (SE = 172.7)). Post-grazed forage mass was affected by a SR x year x week (measured at 2-week intervals) interaction ($P < 0.05$), decreased linearly ($P < 0.05$) as SR increased at all but three times, and was greater than 1000 kg/ha at all measurement times in year 1 and at four of the eight times in year 2. In vitro true DM digestibility of quadrat forage samples was 57.4, 54.4, and 53.5% in year 1 and 56.8, 49.0, and 48.3% in year 2 for 4, 6, and 8, respectively (SE = 2.15). Year and SR interacted ($P < 0.05$) in the percentage of grass in pastures post-grazing determined by transect (year 1: 64, 69, and 74%; year 2: 50, 66, and 73% for 4, 6, and 8, respectively (SE = 8.4)). The preference value (10 = highest possible preference; 0 = consumption in proportion to availability; -

10 = no consumption) for grasses was higher and that for total forbs lower for sheep than for goats ($P < 0.05$). The preference value for ragweed measured only in year 2 was lower ($P < 0.05$) for sheep than for goats (-1.6 vs. 0.2) and increased linearly with increasing SR at all but one of the eight times of measurement. Average daily gain tended ($P < 0.10$) to decrease linearly as SR increased (61, 51, and 47 g/day), and total BW gain per ha increased linearly ($P < 0.05$; 610, 759, and 933 g/day for 4, 6, and 8, respectively). In conclusion, post-grazing herbage mass greater than 1000 kg/ha at most times suggests that decreasing forage mass may not have been primarily responsible for the effect of increasing SR on ADG by limiting DM intake. Rather, SR effect on forage mass could have limited the ability of both sheep and goats to compensate for the effect of SR on forage quality.

Key words: Goat, Co-grazing, Stocking rate, Mixed pastures, Average daily gain

Introduction

Cattle, sheep, and goats differ physiologically in many known ways (Van Soest, 1994; Gordon et al., 1996) that, along with less well understood unique characteristics, affect plant species selectivity. In general, goats prefer and spend more time consuming browse plants than grasses and forbs than do sheep (Rodriguez Iglesias and Kothmann, 1998; Ngwa et al., 2000). Bartolome et al. (1998) also noted differences in dietary preferences between sheep and goats grazing rangeland, with sheep selecting primarily grasses throughout the year; goats, however, selected against grasses and preferred certain trees. But, plant species preferences by sheep and goats are influenced by specific plants available. For example, Penning et al. (1997) noted that, with availability of only white clover (*Trifolium repens*) and ryegrass (*Lolium perene*), sheep showed greater preference for clover than did goats.

Because of differences in factors such as herbage preferences and selectivity by cattle, sheep, and goats, multiple species or co-grazing has favorably affected pasture or rangeland conditions and animal performance. For example, grazing sheep and cattle together on pastures containing 29% Kentucky bluegrass, 11% white clover, and 60 % weeds (broad leaf and other grass species) improved animal performance, botanical composition, and soil characteristics compared with grazing cattle or sheep alone (Abaye et al., 1994, 1997). Relatedly, del Pozo et al. (1996) observed enhanced lamb growth rates with grass/clover swards previously grazed by goats compared with ones grazed only by sheep. However, effects of multiple compared with mono-species grazing are affected by conditions influencing the extent to which potential differences in herbage selectivity are expressed (Dumont, 1997; Kitessa and Nicol, 2001). A primary management decision affecting such forage conditions is stocking rate (SR).

SR is well known to impact animal performance and forage conditions (Huston et al., 1993; Davies and Southey, 2001). High SR restrict forage mass and limit potential forage selectivity (Wilson and MacLeod, 1991; Davies and Southey, 2001) and, due to the general preference of animals for highest quality plants and plant parts, lead to a reduction in quality of available forage (Senft, 1989; Chong et al., 1997). For mono-species grazing, increasing SR decreases level of production per animal, although up to a certain SR production per unit land area increases (Sahlu et al., 1989; Aiken et al., 1991b; Huston et al., 1993; Davis and Southey, 2001). However, the nature of these changes depends on preferences of the one ruminant species present for different plants present in the sward, as well as effects of SR on available plant species. With co-grazing and the associated greater diversity in forage preferences compared with grazing by one species, it seems likely that effects of SR cannot be directly extrapolated from findings with mono-species grazing. Furthermore, because perhaps of an accompanying lesser degree of change in availability of particular plant species with the large number being consumed throughout the grazing season with co- vs. mono-species grazing, less adverse effect of high SR with co-grazing on per animal performance and, therefore, a more positive effect on productivity per unit land area seem likely. In this regard, in a study reviewed by Brand (2000), without browse plant species present, dietary preferences of co-grazing Dorper sheep and Boer goats in the Valley Bushveld of South Africa were not influenced by SR (i.e., 6 goats and 6 lambs vs. 42 goats and 59 lambs per 21 ha).

Considerable grazing land in Oklahoma as well as in other areas of the U.S. and the world do not receive intensive management practices such as use of herbicides or fertilizer and, thus, host a variety of grasses and forbs. Means to achieve optimal utilization of such pastures are not well understood. However, because of the diverse arrays of plant species available, co-grazing would seem a logical, preferred practice. Therefore, objectives of this experiment were to evaluate effects of SR on performance and forage selection by sheep and goats co-grazing pastures containing various grasses and forbs.

Materials and Methods

Animals and location

This experiment was conducted at the E (Kika) de la Garza American Institute for Goat Research of Langston University, Langston, Oklahoma, and was approved by the Langston University Animal Care Committee. There were two consecutive years (2002 and 2003) of grazing with each experiment lasting 16 weeks from May to September. In each year, 27 goat and 27 sheep wethers were used. Sheep (Khatadin) and goats (≥ 75% Boer) averaged 21 ± 4.8 and 21 ± 3.7 kg initial body weight, respectively, and were 4 to 5 months of age when grazing began. Animals were obtained from commercial producers. Most sheep were from the same source in the two years. Goats were, however, from two different sources but both were located near Sonora, Texas. Upon arrival, wethers were quarantined for 3 weeks, vaccinated with Covexin 8 (Schering-Plough, Kinilworth, NJ), and treated for internal parasites (Ivomec® orally; Merck Ag Vet Division, Rahway, NJ) before the experiment. Fecal egg counts by the modified McMaster method (Stafford et al., 1994) were made from two goats and two sheep per pasture every 28 d during the grazing period to ascertain need for re-treatment.

Treatments

Nine 0.4-ha (1 acre) pastures were used for the experiment. Pastures were randomly assigned to three stocking rates (SR). Stocking rates were four (4, low), six (6, moderate), and eight (8, high) animals per pasture, with equal numbers of sheep and goats. Pastures were divided into four paddocks, which were sequentially grazed in 2-week periods for two 8-week grazing cycles (2 weeks of grazing and 6 weeks of regrowth). The pastures contained a complex mixture of grasses, though predominantly bermudagrass (*Cynodon dactylon*) and johnsongrass (*Sorghum halepense*), and various forbs, primarily ragweed (*Ambrosia* artemisiifolia) but also included others such as *Lespedeza* cuneata. and nightshade (*Solanum spp.*) (Table 1). Animals were grouped for similar mean body weight and randomly assigned to pastures in accordance with SR.

Measurements

Forage measures were performed at the beginning and end of each grazing period. Pre- and post-grazed forage mass was assessed by clipping herbage at a height of 2.5-cm in four randomly placed 0.25-m^2 quadrats. Mass of dry matter (DM) was determined by drying for 72 h in a forced-air oven at 55 ºC. The four samples from each paddock were then mixed and ground to pass a 1-mm screen for laboratory analysis.

Pre- and post-grazed forage cover of the sward were determined using two 91-m randomly placed transects, with readings made at 0.9-m intervals. Plants that lied on the top of the point were recorded. When bare ground, litter, or rock was encountered, no reading was made. In the first year readings were for grasses and forbs, whereas in the second year forbs were classified as ragweed or others.

Unshrunk body weight (BW) was measured at the beginning of the experiment and at 28-d intervals to determine average daily gain (ADG) per animal and total gain per pasture or hectare. Rectal grab fecal samples were collected from individual animals on weigh days for estimating diet botanical composition by microhistological analysis of plant fragments (Sparks and Malechek, 1968). Fecal samples were dried at 55°C, ground in a Willey mill to pass a 1-mm screen, and used to prepare three slides per sample. Twenty randomly chosen points from each slide were read for the presence and absence of grasses, ragweed, and other forbs with expression as a percentage of the total. Before slides were read, reference slides were prepared by mixing different proportions of grasses and forbs present in the pastures and used for training in recognition. Preference ratings or selectivity ratios of dietary components were developed as described by Durham and Kothmann (1977). A preference value of +10 indicates the highest possible preference, –10 indicates no consumption, and 0 infers consumption in proportion to availability.

Laboratory analysis

Samples of forage were ground to pass a 1-mm screen and analyzed for DM (100°C), ash, Kjeldahl N (AOAC, 1990), NDF, and ADF (filter bag technique; ANKOM Technology Corp., Fairport, NY). Forage samples were also analyzed for in vitro true DM digestibility (IVDMD; filter bag technique; Ankom Technology Corp.) with NDF as the end-point measure. Ruminal fluid for IVDMD was collected from three mature Boer crossbred goats grazing native grass pasture and supplemented with a moderate amount of concentrate.

Statistical analyses

Animal and plant responses to SR treatments were analyzed using mixed model procedures of SAS, assuming a compound symmetry covariance structure (Littell et al., 1996). Year was considered a fixed effect, because effects of SR in the first year of grazing could impact results in the second year. Also, as mentioned later, these pastures were not grazed in the year preceding this experiment. Because growing animals were used, the same animals could not be employed each year. However, there was effort expended to ensure that animals used in the two grazing seasons were similar in genotype, age, and body weight.

The model consisted of SR, year, week of sampling, and their interactions for forage measures; SR, species, year, and their interactions for performance measures; and SR, species, year, week of sampling, and their interactions for forage selectivity. The random effect and repeated measure for forage measurements were animal group (SR) and year x 2-week interval, respectively. For performance measurements, random effects were animal group (SR) and species (group x SR) and the repeated measure was year of grazing (with analyses conducted for 4-week intervals and the 16-week grazing seasons). Random effects were animal group (SR) and species (group x SR) for forage selectivity measures and the repeated measure was year x 4-week fecal sampling period. For variables with models not including species, analyses were conducted by week within year with a significant ($P < 0.10$) three-way interaction or the following two-way interactions: 1) SR x year and SR x week or 2) year x week. For variables with species in the model, analyses were conducted separately for species in each measurement week within year with a significant ($P < 0.10$) three-way interaction or the following two-way interactions: 1) SR x year and SR x week or 2) year x week. Since in most instances interactions justified analysis by year and/or by species, year, and week, in other instances when these interactions were not significant data were also analyzed in this manner. Orthogonal contrasts were performed for linear and quadratic effects of SR.

Results and Discussion

Forage mass

SR x year, SR x week, and year x week interactions were noted ($P < 0.05$) in forage mass before grazing (Table 2). Pre-grazing forage mass for moderate and high SR was less in year 2 compared with year 1 ($P < 0.05$), but values were similar ($P > 0.10$) between years for the low SR (year 1: 2937, 3298, and 3351 kg/ha; year 2: 3033, 2928, and 2752 kg/ha for low, moderate, and high SR, respectively (SE = 172.7)).

SR had relatively little effect on pre-grazed forage mass (Table 2). For year 1, this may be explained by similar SR among pastures in years before this experiment was conducted and these pastures were constructed, with the area as one large pasture. Furthermore, because of the time taken to construct fences for these pastures and to establish tree legumes in others in the same area, the pastures were not grazed in the preceding year. In addition, greater pre-grazed forage mass in the first four measurement times of year 2 than of year 1 may have resulted from differences in weather conditions after grazing ceased in the preceding fall of year 1 and in the spring immediately before both seasons of grazing. Numerically, decreasing pre-grazed forage mass in weeks 10, 12, 14, and 16 of year 2 as SR increased and lower mass at these times in year 2 vs. 1

probably reflect impact of grazing in year 1 and previous grazing in the first cycle of paddock rotations in week 1 to 8 of year 2.

There was a three-way interaction between SR, year, and week of sampling in post-grazed forage mass ($P < 0.05$; Table 2). With the exception of weeks 2, 4, and 12 in the first year ($P > 0.10$), post-grazed forage mass decreased linearly as SR increased ($P < 0.05$). This is in line with the report of Aiken et al. (1991a) with beef steers grazing subtropical grass-legume pastures at three SR (2.0, 3.5, and 5.0 steers/ha in 1987 and 3.0, 5.3, and 7.5 steers/ha in 1988) and that of Davies and Southey (2001) with lambs grazing subterranean clover-based pastures at SR of 4.9, 6.7, and 8.6 lambs/ha. In the present experiment, the magnitude of change in kg/ha of forage mass with increasing SR did not consistently or markedly differ between years or among weeks within years, other than perhaps slightly greater change in year 2 vs. 1 and in the second vs. first four measurement times in year 1.

As expected, post-grazed forage mass was generally less in the second half of the grazing season compared with the first and in year 2 vs. 1 (Table 2). Also, differences between values in the first and second four measurement times appeared slightly greater in year 2 than in year 1. As noted for pre-grazed forage mass, this may be partially a function of no grazing in the season before year 1 compared with grazing before year 2. Forage mass after grazing in weeks 14 and 16 of year 2 for the high SR treatment was quite low, below levels that may limit feed intake and performance by other ruminant species. For example, Redmon et al. (1995) and Lippke et al. (2000) reported thresholds in herbage mass of wheat forage of 1250 and 850 kg/ha, respectively, for beef steers.

Pre- minus post-grazed forage mass, or change in forage mass, was affected by SR x year, year x week ($P < 0.05$), and SR x week ($P < 0.06$) interactions (Table 2). Although the difference in forage mass before and after grazing periods is impacted by forage growth within the grazing period, it would be largely influenced by consumption by the grazing animals. Increasing SR linearly increased change in forage mass at most times. In this regard, change in forage mass was similar ($P > 0.10$) between years for moderate (101 kg/(ha x d)) and high SR (124 and 128 kg/(ha x d)), but differed between years ($P < 0.05$) for the low SR (29 and 72 kg/(ha x d) in year 1 and 2, respectively). Other than for some 2-week intervals in the second half of grazing in year 2, change in post-grazed forage mass was relatively greater than the difference in number of animals per pasture, which could reflect increasing forage selectivity with decreasing SR that lessened plant regrowth. Factors responsible for the interaction in change in forage mass between year and week include differences in forage growing conditions such as due to precipitation and temperature. Relatively low values in year 1, including a small number of negative values, reflect high forage growth compared with consumption as well as variability in measurement of forage mass.

Sward composition

Contributions of grass and forbs to the sward in years 1 and 2 and that of ragweed to total forbs in year 2 are shown in Table 3. The pre-grazed contribution of grass was affected by year, being 7 percentage units less in year 2 compared with year 1 (62 vs. 55% in year 1 and 2, respectively; SE = 4.1), and week ($P < 0.05$). The difference between years may relate to pasture management before the experiment compared with grazing in two sequential seasons during the trial. SR and year interacted ($P < 0.05$) in the contribution of grass to the post-grazed sward (year 1: 64, 69, and 74%; year 2: 50, 66, and 73% for low, moderate, and high SR, respectively (SE = 8.4)), with a tendency for a linear effect of SR in year 2 ($P = 0.13$). The analysis by week within year likewise included a linear increase in the post-grazed grass contribution to the sward with increasing SR in weeks 8 and 16 of year 2 ($P < 0.05$), though SR did not have effect at other times ($P > 0.10$). The contribution of grasses to the sward post-grazing was lower ($P < 0.05$) in year 2 vs. 1 for the low SR but was similar between years for the medium and high SR ($P > 0.05$). This may have been due to limited defoliation of ragweed that resulted in a higher proportion of ragweed at the end of the grazing cycle in pastures stocked with four animals.

The pre-grazed forb contribution of ragweed in year 2 was only influenced by week of sampling ($P < 0.05$; Table 3). However, there was a trend ($P < 0.08$) for a linear decrease in the contribution of ragweed to forbs in pre-grazed samples (74, 57, and 48% for low, moderate, and high SR, respectively; SE = 8.5). When analyzed by week of sampling, a linear decrease as SR increased was noted in weeks 4, 12 ($P < 0.05$), and 14 ($P < 0.08$). The post-grazed ragweed percentage, similar to that pre-grazed, tended ($P < 0.08$) to linearly decrease as SR increased (88, 82, and 49% for low, moderate, and high SR, respectively; SE = 12.6). Analysis by week also revealed a linear decrease with increasing SR in weeks 4 ($P < 0.07$), 6 ($P < 0.06$), 12 ($P < 0.03$), and 14 ($P < 0.10$).

Sheep and goats consume more forbs than cattle (Rodriguez Iglesias and Kothmann, 1998). Diets of goats likewise often consist more of forbs compared with sheep diets, although there is a relatively greater difference in preference for browse (Bartolome et al., 1998; Rodriguez Iglesias and Kothmann, 1998). Results of this experiment depict how SR can affect botanical composition of available forage, although the effect of SR on the percentage of grass in the sward was only significant after 2 and not 1 year of grazing. With the low SR, there appeared relatively greater removal of grass than forbs on a percentage of the sward basis, resulting in a lower grass level in the pre- and post-grazed sward in year 2 vs. 1, compared with similar levels between years for moderate and high SR. With the differences in levels of grass and forbs in the diet based on microhistology to be noted later, as well as grass and forb preference values, with mono-species grazing at the same SR results would presumably differ.

For goats, ragweed, the primary forb in pastures of this experiment, is not highly preferred (Bauni, 1993). Although impacted also by consumption by sheep, these results suggest that with low and moderate SR, animals consumed relatively more forbs other than ragweed compared with ragweed. But with the highest SR, grazing pressure was high enough and forage mass adequately limited to lessen forb selectivity against ragweed to a point at which the contribution to forbs in the sward pre- and post-grazing was similar for ragweed and other forbs.

Nutrient composition of the sward

Pre- and post-grazed N concentrations in forage were affected by a year x week interaction ($P < 0.05$; Table 4). Pre-grazed N concentration also tended to be affected ($P < 0.06$) by a SR x year interaction (year 1: 1.28, 1.05, and 1.23%; year 2: 1.33, 1.25, and 1.22% for low, moderate, and high SR, respectively (SE = 0.066)). Overall, post-grazed N concentration in forage linearly decreased ($P < 0.05$) with increasing SR (1.20, 0.98, and 0.99% for low, moderate, and high SR, respectively; SE = 0.060). Analysis by week within year indicated influence of SR on the pre-grazed forage N concentration only in the very latter part of the grazing season, with slightly more frequent impact on the post-grazed level. When effects were significant, they entailed a higher concentration for the low than for moderate and high SR. Hence, these findings, along with the relatively low N concentration in post-grazed forage compared with requirements for growth of sheep and goats (NRC, 1975; AFRC 1998), suggest a greater potential for impact and a possibly greater magnitude of effect of N intake at performance on moderate and high SR compared with the low SR. In this regard, in year 1 there was considerable change in both pre- and post-grazed forage N levels as week advanced. This was generally also true in year 2 for moderate and high SR, although magnitudes of change were less than in year 1. Changing forage N concentration with advancing time would, in addition to preferential selection by sheep and goats for relatively high quality forage, involve increasing stage of maturity of the various plant species.

Pre- and post-grazed NDF concentrations were affected by year x week interactions ($P < 0.05$; Table 4). SR did not affect ($P > 0.10$) pre- or post-grazed NDF concentration, although numerically ($P < 0.11$) NDF concentration in post-grazed samples increased as SR increased (61.7, 66.8, and 68.9% for low, moderate, and high SR, respectively; SE = 2.68). Similarly, there was only one sampling time when SR affected ($P < 0.05$) pre-grazed forage NDF concentration, compared with linear increases ($P < 0.05$) as SR increased for post-grazed samples in weeks 6, 12, and 14. Overall, forage NDF concentrations are in accordance with levels of N; however, there appeared relatively greater differences in level of NDF vs. N between moderate and high SR. Another difference is the generally increasing forage NDF concentration as week of the experiment advanced for moderate and high SR in both years rather than only in year 1 in forage N concentration.

The ADF concentration in pre-grazed forage samples was affected by SR and a year x week of sampling interaction (P < 0.05; Table 4). The effect of SR (P < 0.05) was quadratic (42.9, 45.2, and 44.4% for low, moderate, and high SR, respectively; SE = 0.49). Analysis by week within year, however, resulted in linear SR effects on pre-grazed ADF concentration in weeks 14 of year 1 and week 4, 12, and 14 of year 2 (P < 0.05). The post-grazed forage ADF concentration was affected by week and a SR x year interaction (P < 0.05). Regarding this interaction, the concentration was higher in year 2 compared with year 1 and was affected relatively less by SR in year 1 vs. 2 (year 1: 40.4, 41.8, and 43.0%; year 2: 45.4, 50.4, and 50.5% for low, moderate, and high SR, respectively (SE = 0.68)). As noted for levels of N and NDF, forage ADF concentration generally increased as week advanced. Although magnitudes of change with advancing time were not discernibly different between years, the level of ADF was in most cases greater in year 2 than in year 1. At least for post-grazed forage, this was not as evident in NDF concentration.

The ash percentage in pre- (year 1: 8.0, 8.1, and 8.0%; year 2: 7.9, 7.3, and 7.0% (SE = 3.0)) and post-grazed forage samples (year 1: 8.2, 8.2, and 8.0%; year 2: 8.0, 6.9, and 6.5% (SE = 0.34)) was affected by a SR x year interaction (P < 0.05; Table 4). Year and week also interacted in the percentage ash in pre- and post-grazed forage (P < 0.05). Analysis by week within year resulted in only a small number of significant SR effects, largely in year 2 when the ash concentration in post-grazed samples decreased linearly (P < 0.05) with increasing SR (6, 14, and 16 weeks).

Pre-grazed forage IVDMD (Table 5) was affected by a year x week interaction ($P < 0.05$) and tended to be influenced ($P < 0.06$) by an interaction between SR and year (year 1: 60.5, 56.9, and 59.5%; year 2: 59.6, 52.9, and 53.7% for low, moderate, and high SR, respectively (SE = 1.66)). Analysis by week within year revealed linear decreases ($P < 0.05$) in IVDMD of pre-grazed forage in week 14 of year 1 and weeks 6, 12, and 14 of year 2. SR x year and year x week interactions were noted ($P < 0.05$) in post-grazed forage IVDMD. Regarding the former interaction, IVDMD was 57.4, 54.4, and 53.5 in year 1 and 56.8, 49.0, and 48.3 in year 2 for low, moderate, and high SR, respectively (SE = 2.15). For the analysis by week within year, SR did not have effect ($P > 0.10$) in year 1, whereas in year 2 in weeks 6, 8, 14, and 16 IVDMD decreased linearly with increasing SR ($P < 0.05$).

Forage IVDMD are in general agreement with concentrations of N and NDF. SR had considerably more impact on forage nutritive value in year 2 than 1. Furthermore, effects of SR in year 2 on forage nutritive value appeared slightly greater in the latter part of the 16-week grazing season than earlier. Also, although there was not a large number of times at which quadratic effects of SR were significant, numerically the effect of SR on forage nutritive value indices (i.e., N and NDF concentrations and IVDMD) was greater between the low vs. moderate and high SR compared with the moderate vs. high SR.

Grass and forb composition of the diet

The percentage of grass in the diet determined from fecal microhistological analysis was influenced by SR x year (year 1: 62.5, 59.4, and 62.5%; year 2: 56.4, 62.4, and 55.1% for low, moderate, and high SR, respectively (SE = 1.63)), species x year

(year 1: 51.9 and 71.1%; year 2: 50.7 and 65.2% for goats and sheep, respectively (SE = 1.12)), year x week of sampling, and SR x species x week of sampling interactions ($P < 0.05$; Table 5). Analysis by week within year did not reveal consistent differences among SR with goats or sheep. Factors responsible for an overall similar percentage of grass in the diet between years for the low and high SR but a slightly greater level of grass for the moderate SR in year 2 vs. 1 are unclear. The year by species interaction reflects the higher preference of goats for forbs compared with sheep to be noted later, with the botanical composition of the diet of goats perhaps more resistant to change in response to varying proportions of grasses and forbs in the sward. The lower dietary level of grasses in the diet of sheep in year 2 than in year 1 could have resulted from the generally lower level of grass available in year 2. The magnitude of difference in the level of grass in the diet between goats and sheep was similar to results of Bartolome et al. (1998) in Mediterranean heath woodland range, but greater compared with results of Pfister and Malechek (1986) in a deciduous woodland area of Brazil. In slight contrast, with grass/clover pasture Angora goats selected more grass and less clover than did Merino sheep (Gurung et al., 1994), similar to findings of Penning et al. (1997). In the present experiment the size of the difference between species in dietary level of grass was fairly consistent throughout the grazing season of both years 1 and 2, which is in line with results of Pfister and Malechek (1986) for 2 years of grazing deciduous woodland.

The dietary proportion of ragweed was affected by SR x species x week of sampling, species x year x week ($P < 0.05$), and SR x species x year interactions ($P < 0.06$; Table 5). SR did not linearly influence the dietary percentage of ragweed at any time in year 1, although the percentage increased and then decreased (quadratic) as SR increased in week 12 for both goats ($P < 0.05$) and sheep ($P < 0.08$). Values averaged over SR were greater ($P < 0.05$) for goats vs. sheep at week 8 and were also numerically greater for goats at other times. There was a greater number of significant SR effects in year 2. For goats, the dietary percentage of ragweed increased linearly and changed quadratically ($P < 0.05$; lowest for moderate SR) in weeks 4 and 8, and in week 16 the percentage was less for moderate vs. low and high SR (quadratic; $P < 0.05$). Effects for sheep were similar to those for goats in weeks 8 and 16. For species means averaged over SR, goat diets were higher ($P < 0.05$) in ragweed than diets of sheep at each time of sampling. Neither the absolute dietary level nor the magnitude of difference between species in the dietary level of ragweed markedly varied among weeks of sampling. Factors responsible for quadratic effects of SR on the dietary proportion of ragweed are unclear, particularly that in year 2 the direction of effect differed from that in year 1. Nonetheless, these results reflect a greater preference for, or perhaps less aversion to, ragweed by goats than sheep, as noted later for preference values. Though growth stage of ragweed was not monitored, no consistent change in the dietary percentage of ragweed with advancing time and values for each year not markedly different suggest fairly steady plant characteristics that influence consumption.

The dietary percentage of forbs other than ragweed consumed was affected by SR x species x year, SR x year x week of sampling, and species x year x week of sampling interactions ($P < 0.05$; Table 5). In agreement with ragweed data, in year 1 SR had little impact on the dietary percentage of other forbs, with a slightly greater number of significant effects in year 2. However, effects in year 2 were not consistent among weeks of sampling or between species. But, other forbs made up a higher percentage of the diet of goats than sheep in both years at all times of sampling. When comparing dietary levels of ragweed with other forbs, it appears that in year 1 goats preferentially consumed other forbs, with only slightly greater ingestion of other forbs in year 2. For sheep, other than in week 12 of year 2, dietary levels of ragweed and other forbs were fairly similar. Hence, although goats consumed diets with a higher level of ragweed than did sheep, this might be thought of as a greater preference for forbs vs. grasses rather than one for ragweed. As was the case for ragweed, the dietary level of other forbs did not markedly vary among times of sampling within or between years. Therefore, as suggested for ragweed, plant characteristics of other forbs affecting dietary preference may not have markedly changed with advancing week of the experiment or greatly differed between years.

Forage preference values

The preference value for grasses was affected by species and a SR x year x week of sampling interaction ($P < 0.05$; Table 5). The overall preference value for grass was 0.01 and 1.03 (SE = 0.217) for goats and sheep, respectively. In accordance, grass preference values were lower ($P < 0.05$) for goats vs. sheep at all times of sampling except one, with goat means ranging from -1.0 to 1.5 and sheep means of 0.5 to 2.3. Hence, goats were not highly selective for or against grass and sheep only slightly preferred grass. Values did not consistently vary with advancing week or markedly differ between years. There were no SR effects ($P > 0.10$) other than in week 16 of year 2, at which time the grass preference value decreased linearly as SR increased for both species ($P < 0.05$). This may in part relate to relatively low forage mass at this time compared with earlier ones and decreasing forge nutritive value and an increasing percentage of grass in the sward as SR increased. Thus, it appears that the linear decrease in grass preference was primarily because the low amount of forage mass primarily consisted of grass of relatively low quality, presumably with availability of forbs of relatively higher nutritive value.

The preference value for total forbs was affected by species and a SR x year x week of sampling interaction ($P < 0.05$; Table 5). The preference value for total forbs averaged 0.5 and -1.6 (SE = 0.34) for goats and sheep, respectively. As noted for grass, SR affected the forb preference value only in week 16 of year 2, with values increasing linearly as SR increased for goats ($P < 0.07$) and sheep ($P < 0.09$). This may have been due indirectly to decreasing selectivity for grass but also to a decreasing contribution of forbs to the sward as well as an increasing percentage of forbs other than ragweed. The preference value for forbs was greater ($P < 0.05$) for goats than for sheep at all times of sampling. In year 1 for both species and in year 2 for goats, the forb preference value appeared to increase as the grazing period advanced. This might in part involve lesser change with advancing maturity in nutritive value of forbs vs. grasses (Long et al., 1999). Ragweed preference values do not indicate that this change with time was solely due to ragweed. There appeared to be larger differences among preference values for forbs vs. grasses, perhaps reflecting the greater number of forbs than grasses in the pastures whose availabilities during the grazing season changed more with time than of the few species of grasses present.

The preference value for ragweed in year 2 was affected by species and a SR x week of sampling interaction ($P < 0.05$; Table 5). The preference value for ragweed was lower ($P < 0.05$) for sheep vs. goats (-1.6 vs. 0.2; SE = 0.58) and increased linearly (P <

0.05) with increasing SR in all sampling weeks except week 4. The preference value for forbs other than ragweed was affected by a species x week of sampling interaction ($P < 0.05$), with an effect of species ($P < 0.05$) in all weeks but 12, and tended ($P < 0.11$) to decline linearly as SR increased (3.63, 2.01, and 1.16 for low, moderate, and high SR, respectively; SE = 0.912).

The preference value for ragweed was not markedly different from that for other forbs in weeks 4 and 8 (Table 5). In week 12 both goats and sheep strongly selected for other forbs and against ragweed. Factors responsible for this finding are unclear. Preference values were also greater in week 16 for other forbs vs. ragweed, but differences were less than in week 12. Overall, it does not appear that ragweed was a forb highly preferred or averted compared with others available in these pastures, and neither goats nor sheep displayed a clear pattern of change in preference for ragweed or other forbs as the grazing period advanced. Results of this experiment suggest that preference for ragweed is somewhat more subject to modification by SR than that of other forbs both by goats and sheep. Hence, although goats consumed more ragweed than sheep, management factors such as SR should affect ragweed consumption by sheep and goats in a similar manner.

Average daily gain

Initial BW was similar among SR and between species and years ($P > 0.10$; Table 6). Final BW was not influenced by SR or year ($P > 0.10$), but was greater ($P < 0.05$) for sheep vs. goats. In both years ADG decreased as the grazing season progressed, but was greater in year 2 vs. 1 in the first two 28-day segments and lower in the second.

A number of factors probably contributed to overall ADG by sheep nearly twice as great ($P < 0.05$) as that by goats. First, growth rate is typically greater for sheep than for goats because of factors such as different selection histories. Although, Boer goats were developed for attributes including large size, muscularity, and rapid growth. Another factor that may have had influence is previous nutritional plane. Since animals were purchased and it was only possible to obtain them after weaning near when grazing in the experiment was to begin, previous nutritional plane may have differed. In fact, over 50% of the difference in overall ADG was attributable to the first 28 days of grazing. Furthermore, ADG was greater ($P < 0.05$) for sheep vs. goats in the first two 28-day segments of grazing but was similar between species in the last two segments. This suggests differences in compensatory growth potential, for which exhibition may have been feasible in the first part of the grazing season when forage mass and nutritive value were highest. But, no species difference in ADG late in the grazing season when forage nutritive value and mass were lowest could relate to suggestions that performance by goats is less adversely affected by low nutritional planes compared with other ruminant species (Silanikove, 2000).

SR did not influence ADG in any 4-week period ($P > 0.10$; Table 6). However, ADG in the entire 16-week experiment tended to decrease linearly ($P < 0.10$) as SR increased, with the difference numerically greater between low vs. moderate and high SR than between moderate and high SR. This is in accordance with differences among SR in forage nutritive value indices such as the concentration of N and IVDMD. Similarly, a linear decrease in ADG with increasing SR was reported for beef steers grazing a mixture of tropical legumes and bahiagrass (*Paspalum notatum* Flugge; Aiken et al., 1991b). Also for sheep grazing smooth bromegrass pasture at SR of 15 or 30 lambs/ha (Sahlu et al., 1989) and light and heavy beef calves grazing Plains Old World bluestem at three SR (Ackerman et al., 2001), ADG linearly decreased with increasing SR.

The lack of interaction between SR and species presumably indicates that, overall, availabilities of the various grass and forb species with all SR were relatively greater than differences in preferences for, or aversions to, particular plant species. Forage preference values were not greatly different from 0 and, thus, limited availability of a particular preferred plant should have simply resulted in increased consumption of a slightly lesser preferred or more averted one.

The most obvious factors potentially responsible for the decrease in ADG by both sheep and goats with increasing SR are decreasing forage mass and nutritive value. Although, there are certainly other factors that may have had influence, such as differences in energy expenditure due to grazing that would impact energy available for growth (Chapter IV). Though it is not possible to conclusively discern the relative importance of these factors from measures reported here, forage nutritive value may deserve greatest attention. Pre-grazed forage mass in all instances, and post-grazed forage mass in nearly all cases, was greater than 1000 kg/ha, which suggest that forage mass did not markedly restrict DM intake. However, decreasing forage mass with increasing SR could have accentuated potential impact of decreasing forage nutritive value on digestible nutrient consumption. As forage mass declines, biting rate and grazing time increase, although these changes are many times not completely compensatory for the decrease in bite size (Stobbs, 1973; Jamieson and Hodgson, 1979; Burns and Sollenberger, 2002). Furthermore, the degree to which plants and plant parts highest in quality can be selected declines with increased rate of biting, apart from the decrease in nutritive value of forage available as SR increased in this experiment. In this regard, these results suggest that goats were no more able to cope with the challenge of selecting and ingesting a sufficient quantity and quality of forage under these conditions to attain a moderate to high level of growth than were sheep.

Total BW gain per hectare increased linearly ($P < 0.05$) with increasing SR (Table 6). Hence, the magnitude of change in ADG per animal with increasing SR was much less than differences in SR. Similar findings were noted by Ackerman et al. (2001) with beef steers grazing Plains Old World bluestem at three SR. Phillips and Coleman (1995), comparing three grazing systems, also noted increased gain per ha with greater SR despite lower ADG. Conversely, with very high SR that severely limit the quantity of available forage, thereby markedly reducing ADG, increased BW gain per unit land area can be minimal or even absent. For example, with a simulation model Seman et al. (1991) proposed that gain/ha increased to about 200 kg/ha with a SR of 22 steers per hectare and then declined.

Summary and Conclusions

Overall, increasing SR decreased forage mass after grazing, increased percentage of grass in the sward, contribution of ragweed to total forbs (variable), and decreased forage nutritive value, although effects varied with year and week of sampling. Goats were not highly selective for or against grass and sheep only slightly preferred grass. Preference values for forbs varied with time of the grazing season more than for grasses. Grasses generally made up a greater proportion of the diet of sheep vs. goats. Goats exhibited a greater preference for or less aversion to ragweed than sheep. Dietary levels of ragweed and other forbs did not markedly vary between years or among weeks of sampling. It did not appear that ragweed was a forb highly preferred or averted compared with others available, and preference for ragweed by both sheep and goats was increased more by SR than for other forbs. ADG decreased slightly as SR increased regardless of species, and was greater for sheep than for goats. In conclusion, post-grazing herbage mass greater than 1000 kg/ha at most times suggests that decreasing forage mass may not have been primarily responsible for the effect of increasing SR on ADG by limiting DM intake. Although, the SR effect on forage mass could have limited the ability of both sheep and goats to compensate for the adverse effect of SR on forage nutritive value.

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Table 1
Plants encountered in pastures co-grazed by goats and sheep

Latin Name	Common Name
Grasses	
Cynodon dactylon	Bermudagrass
Sorghum halepense	Johnsongrass
Bromus tectorum	Cheat grass
Tridens flavus	Purpletop
Dichanthelium oligosanthes	Scribner's panicum
Forbs	
Ambrosia artemisiifolia	Common ragweed
Cirsium carolinianum	Purple thistle
Cirsium spp.	Thistle
Solanum elaeagnifolium	Silverleaf nightshade
Solanum carolinense	Carolina horsenettle
Trifolium campestre	Plains clover
Trifolium spp.	Clover
Vicia sativa	Narrow leaved vetch
Medicago sativa	Alfalfa
Medicago spp.	
Lespedeza cuneata	
Rudbeckia hirta	Blackeyed susan
Oenothera laciniata	Cutleaf evening primrose
Baptisia australis	Blue wild indigo
Plantago aristata	Bracted plantain
Melilotus officinalis	yellow sweet clover
Rumex crispus	Curly dock
Castilleja indivisa	Indian paintbrush
Achillea millefolium	Common yarrow
Lactuca canadensis	Wild lettuce
Conza canadensis	Marestail
Asclepias syriaca	Milkweed
Schrankia uncinata	Sensitive brier

Table 2
Means of pre-grazed and post-grazed forage mass for mixed grass/forb pastures as influenced by different stocking rates of co-grazing goats and sheep

			Treatment[1]				Effect[2]	
Item	Year	Week	4	6	8	SE	L	Q
Pre-grazed forage mass (kg/ha)[3]	1	0	2057	2400	2434	324.1	0.44	0.71
		2	2568	3187	2996	245.3	0.26	0.23
		4	2783	3668	3605	228.4	0.04	0.14
		6	3627	4171	4568	436.3	0.18	0.90
		8	3532	3331	4090	417.5	0.38	0.38
		10	3374	3496	3666	458.2	0.67	0.97
		12	2564	3015	2465	220.8	0.76	0.11
		14	2989	3120	2987	241.8	0.99	0.67
	2	0	3106	2782	2484	185.8	0.06	0.96
		2	3474	3389	3842	289.4	0.40	0.48
		4	3096	3706	3589	182.6	0.10	0.16
		6	3155	3110	3215	298.4	0.89	0.84
		8	3261	2769	2792	336.3	0.36	0.55
		10	2966	2410	2131	251.2	0.06	0.67
		12	2998	2968	2045	320.6	0.08	0.30
		14	2206	2288	1915	249.3	0.44	0.48
Post-grazed forage mass (kg/ha)[4]	1	2	1703	1547	1352	140.3	0.13	0.91
		4	2454	1836	1926	189.0	0.10	0.18
		6	3183	2035	1555	265.3	0.01	0.34
		8	3154	2211	2201	296.5	0.02	0.12
		10	2929	2105	1846	154.5	0.01	0.19
		12	2166	1639	1655	180.3	0.09	0.27
		14	2667	2094	1216	321.8	0.02	0.71
		16	2023	1562	1121	225.1	0.03	0.97
	2	2	2563	1579	1413	227.6	0.01	0.19
		4	2158	1431	798	78.5	0.01	0.64
		6	2116	2055	1285	220.7	0.04	0.24
		8	2484	2007	1384	164.1	0.01	0.73
		10	1793	1331	896	161.3	0.01	0.95
		12	2074	1448	1075	158.7	0.01	0.54
		14	1314	1198	453	91.9	0.01	0.03
		16	1680	1006	428	187.7	0.01	0.84

Table 2, Continued

Item	Year	Week	Treatment[1] 4	6	8	SE	Effect[2] L	Q
Pre- minus post-grazed forage mass (kg/(ha x d))[5]								
	1	2	25	61	77	15.3	0.06	0.62
		4	8	97	76	19.3	0.05	0.06
		6	-29	117	146	16.2	0.01	0.03
		8	34	140	169	31.9	0.03	0.36
		10	43	88	160	24.3	0.02	0.65
		12	86	133	144	23.2	0.13	0.56
		14	-7	66	89	22.1	0.03	0.39
		16	69	111	133	14.1	0.02	0.58
	2	2	39	86	77	21.8	0.27	0.33
		4	94	140	217	18.5	0.01	0.51
		6	70	118	165	16.4	0.01	0.98
		8	48	79	131	19.0	0.03	0.67
		10	105	103	135	22.1	0.37	0.54
		12	64	69	75	21.4	0.71	0.97
		14	120	126	114	22.2	0.84	0.74
		16	38	92	106	6.9	0.01	0.06

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Pre-grazed = significant effects ($P < 0.05$) of year, week, treatment x year, treatment x week, and year x week.

[4]Post-grazed = significant effects ($P < 0.05$) of treatment, year, week, year x week, and treatment x year x week.

[5]Pre- minus post-grazed = significant effects of treatment ($P < 0.05$), year ($P < 0.05$), week ($P < 0.05$), treatment x year ($P < 0.05$), year x week ($P < 0.05$), and treatment x week ($P < 0.06$).

Table 3
Means of pre-grazed and post-grazed contributions of grass to the sward and the contribution of ragweed (*Ambrosia aratemisiifolia*) to forbs as influenced by different stocking rates of co-grazing goats and sheep

			Treatment[1]				Effect[2]	
Item	Year	Week	4	6	8	SE	L	Q
Pre-grazed grass composition (%)[3]	1	0	50	55	57	12.1	0.68	0.90
		2	57	53	48	8.4	0.51	0.99
		4	57	54	54	8.5	0.81	0.87
		6	69	71	63	5.9	0.53	0.53
		8	59	69	69	12.5	0.59	0.77
		10	61	59	65	8.7	0.77	0.73
		12	55	73	78	7.9	0.09	0.52
		14	69	77	75	7.3	0.56	0.61
	2	0	55	58	62	8.1	0.56	0.94
		2	46	50	47	11.6	0.94	0.79
		4	37	39	38	10.5	0.95	0.93
		6	53	60	65	9.4	0.39	0.94
		8	46	55	68	14.9	0.33	0.94
		10	54	60	56	9.5	0.89	0.72
		12	45	64	70	10.3	0.14	0.61
		14	46	74	72	5.5	0.01	0.07
Post-grazed grass composition (%)[4]	1	2	55	65	73	15.9	0.44	0.97
		4	66	56	65	8.9	0.90	0.42
		6	67	59	72	7.2	0.62	0.29
		8	73	75	75	8.4	0.85	0.91
		10	62	77	73	12.6	0.56	0.53
		12	61	60	67	9.7	0.68	0.79
		14	63	74	82	9.8	0.21	0.89
		16	69	82	86	5.4	0.07	0.51
	2	2	50	63	72	12.2	0.24	0.90
		4	47	59	58	10.8	0.50	0.64
		6	42	65	74	13.7	0.15	0.68
		8	47	76	88	8.4	0.02	0.43
		10	50	60	69	14.8	0.40	0.98
		12	61	63	68	9.5	0.64	0.89
		14	44	65	71	12.9	0.20	0.65
		16	55	79	80	5.0	0.02	0.11

Table 3, Continued

Item	Year	Week	Treatment[1] 4	6	8	SE	Effect[2] L	Q
Pre-grazed ragweed composition (% total forbs)[5]								
	2	0	43	39	47	13.0	0.86	0.72
		2	65	43	41	13.0	0.22	0.56
		4	69	42	23	11.5	0.03	0.78
		6	71	28	61	12.0	0.61	0.04
		8	90	90	63	18.3	0.32	0.57
		10	89	92	76	10.6	0.41	0.50
		12	88	71	33	16.1	0.05	0.62
		14	77	51	42	11.8	0.08	0.57
Post-grazed ragweed composition (% total forbs)								
	2	2	79	84	62	19.4	0.56	0.79
		4	88	70	66	16.5	0.39	0.74
		6	88	84	30	18.1	0.07	0.31
		8	87	81	52	10.4	0.06	0.39
		10	91	97	63	18.3	0.31	0.40
		12	97	96	64	16.3	0.21	0.47
		14	95	85	29	17.0	0.03	0.31
		16	80	60	24	20.3	0.10	0.76

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Pre-grazed grass = significant effects ($P < 0.05$) of year and week.

[4]Post-grazed grass = significant effects ($P < 0.05$) of year, week, and treatment x year.

[5]Pre-grazed ragweed = significant effect ($P < 0.05$) of week.

Table 4
Means of pre-grazed and post-grazed forage nutrient composition for mixed grass/forb pastures as influenced by different stocking rates of co-grazing goats and sheep

			Treatment[1]				Effect[2]	
Item	Year	Week	4	6	8	SE	L	Q
Pre-grazed N (% DM)[3]	1	0	2.10	1.60	2.02	0.241	0.82	0.17
		2	1.81	1.48	1.71	0.218	0.76	0.33
		4	1.30	1.09	1.33	0.164	0.92	0.31
		6	1.05	0.98	0.96	0.121	0.64	0.88
		8	0.91	0.87	0.88	0.126	0.89	0.86
		10	0.91	0.85	1.01	0.158	0.69	0.59
		12	1.00	0.80	1.13	0.174	0.64	0.26
		14	1.12	0.74	0.81	0.070	0.03	0.05
	2	0	1.40	1.40	1.37	0.054	0.65	0.87
		2	1.29	1.40	1.29	0.139	0.99	0.54
		4	1.20	1.19	1.13	0.066	0.48	0.77
		6	1.20	1.10	1.00	0.099	0.21	0.98
		8	1.44	1.41	1.41	0.110	0.89	0.90
		10	1.29	1.21	1.40	0.056	0.21	0.11
		12	1.45	1.28	1.12	0.080	0.03	0.91
		14	1.36	1.00	1.01	0.049	0.01	0.03
Post-grazed N (% DM)[4]	1	2	1.99	1.52	1.59	0.159	0.13	0.23
		4	1.32	1.10	1.15	0.086	0.22	0.24
		6	1.19	0.92	1.00	0.046	0.03	0.02
		8	0.63	0.55	0.55	0.076	0.47	0.68
		10	0.69	0.70	0.66	0.093	0.83	0.88
		12	1.06	0.89	0.98	0.111	0.65	0.36
		14	1.01	0.88	0.80	0.075	0.09	0.82
		16	0.87	0.70	0.66	0.069	0.08	0.44
	2	2	1.30	1.28	1.02	0.154	0.26	0.55
		4	0.99	0.98	1.20	0.142	0.36	0.54
		6	1.30	0.92	0.88	0.073	0.01	0.10
		8	1.15	0.75	0.70	0.049	0.01	0.03
		10	1.22	1.25	1.26	0.158	0.85	0.97
		12	1.36	1.16	1.26	0.153	0.68	0.45
		14	1.54	1.01	1.07	0.157	0.09	0.18
		16	1.57	1.02	1.08	0.169	0.09	0.19

Table 4, Continued

Item	Year	Week	Treatment[1] 4	6	8	SE	Effect[2] L	Q
Pre-grazed NDF (% DM)[5]	1	0	50.2	57.6	54.2	3.67	0.47	0.28
		2	55.5	56.9	57.8	1.85	0.43	0.92
		4	59.7	60.3	59.9	2.20	0.95	0.86
		6	64.7	66.5	69.8	2.49	0.20	0.83
		8	69.9	69.2	70.7	3.05	0.87	0.78
		10	63.7	69.8	61.7	7.48	0.86	0.47
		12	62.4	66.3	59.7	6.85	0.79	0.55
		14	60.7	70.7	71.7	5.54	0.07	0.34
	2	0	61.1	63.1	64.1	2.18	0.36	0.85
		2	59.0	63.0	61.0	1.99	0.49	0.26
		4	59.8	64.6	62.0	2.31	0.51	0.24
		6	59.2	69.0	67.2	1.83	0.02	0.04
		8	57.7	59.5	59.9	4.50	0.74	0.90
		10	55.1	63.4	60.1	3.04	0.29	0.17
		12	54.2	62.5	68.7	3.21	0.02	0.81
		14	61.7	70.9	70.8	2.27	0.03	0.14
Post-grazed NDF (% DM)[6]	1	2	57.4	63.3	63.5	4.85	0.41	0.65
		4	57.3	61.1	62.3	3.42	0.34	0.77
		6	58.9	65.0	66.9	3.43	0.15	0.63
		8	71.4	76.2	75.9	1.46	0.07	0.21
		10	67.3	63.1	66.0	4.35	0.83	0.44
		12	66.9	68.1	70.6	3.14	0.43	0.87
		14	64.9	68.6	73.4	2.30	0.04	0.84
		16	67.9	72.1	75.6	2.38	0.06	0.90
	2	2	63.3	60.2	66.8	4.40	0.60	0.40
		4	62.7	67.7	62.3	4.32	0.95	0.36
		6	54.6	67.9	70.5	3.15	0.01	0.22
		8	61.5	70.4	71.4	3.65	0.10	0.41
		10	63.3	62.5	66.6	7.07	0.76	0.78
		12	59.7	64.9	65.3	5.51	0.50	0.73
		14	51.4	64.7	68.1	5.51	0.08	0.49
		16	58.5	72.4	76.4	2.78	0.01	0.20

Table 4, Continued

Item	Year	Week	Treatment[1] 4	6	8	SE	Effect[2] L	Q
Pre-grazed ADF (% DM)[7]	1	0	34.0	39.2	34.2	1.50	0.94	0.03
		2	39.0	40.2	41.1	1.06	0.22	0.94
		4	40.3	41.8	40.8	0.71	0.66	0.20
		6	41.3	44.2	43.2	1.13	0.29	0.22
		8	39.6	40.7	40.1	1.05	0.77	0.52
		10	40.6	44.8	41.1	2.89	0.91	0.30
		12	42.6	44.0	41.1	2.03	0.64	0.42
		14	41.0	45.7	45.5	1.01	0.02	0.10
	2	0	44.4	44.8	43.9	0.43	0.45	0.29
		2	52.0	51.6	53.8	2.12	0.57	0.63
		4	48.1	51.1	50.7	0.64	0.03	0.08
		6	45.9	48.7	46.2	1.55	0.90	0.22
		8	41.1	41.4	40.8	1.91	0.93	0.86
		10	43.9	49.0	44.8	1.06	0.54	0.01
		12	45.9	47.4	51.6	0.85	0.01	0.26
		14	46.0	48.3	52.0	1.78	0.06	0.76
Post-grazed ADF (% DM)[8]	1	2	37.9	40.4	41.5	1.51	0.14	0.73
		4	38.1	38.9	40.1	1.10	0.23	0.88
		6	38.9	42.2	43.0	0.58	0.01	0.13
		8	42.1	43.1	43.7	1.02	0.33	0.90
		10	40.1	42.0	41.0	0.44	0.19	0.03
		12	41.0	40.4	43.6	0.93	0.11	0.14
		14	41.3	42.5	44.5	0.95	0.06	0.75
		16	43.9	45.2	46.6	1.08	0.12	0.97
	2	2	44.1	47.7	46.4	1.44	0.31	0.26
		4	45.9	49.5	45.3	3.07	0.90	0.34
		6	46.0	50.0	51.1	2.12	0.14	0.61
		8	45.1	50.0	52.0	2.34	0.08	0.64
		10	45.6	47.8	45.2	1.73	0.85	0.30
		12	48.3	51.8	50.9	3.01	0.56	0.58
		14	42.9	52.6	56.9	2.39	0.01	0.40
		16	45.2	53.7	56.1	1.95	0.01	0.24

Table 4, Continued

Item	Year	Week	Treatment[1] 4	6	8	SE	Effect[2] L	Q
Pre-grazed ash (% DM)[9]	1	0	8.3	7.5	7.9	0.58	0.59	0.45
		2	8.3	9.3	8.3	0.33	0.96	0.06
		4	8.0	8.1	8.0	0.40	0.94	0.84
		6	8.2	8.0	7.9	0.24	0.30	0.97
		8	7.7	8.2	8.0	0.54	0.74	0.63
		10	6.4	7.6	8.0	0.64	0.13	0.62
		12	8.1	8.2	8.2	0.38	0.85	0.95
		14	8.6	7.8	8.2	0.43	0.53	0.31
	2	0	7.2	7.5	6.8	0.51	0.58	0.46
		2	8.0	7.2	7.3	0.46	0.34	0.49
		4	7.0	6.8	6.8	0.41	0.67	0.76
		6	7.4	5.7	6.9	0.22	0.16	0.01
		8	8.7	8.5	7.6	0.76	0.36	0.76
		10	8.4	7.6	7.5	0.49	0.24	0.55
		12	8.8	8.2	7.1	0.40	0.02	0.64
		14	7.3	7.3	6.4	0.50	0.21	0.50
Post-grazed ash (% DM)[10]	1	2	8.8	8.0	8.3	0.56	0.50	0.50
		4	8.5	8.7	8.6	0.59	0.92	0.87
		6	9.2	8.4	8.4	0.42	0.26	0.46
		8	7.4	7.2	7.3	0.26	0.80	0.71
		10	7.8	8.4	8.1	0.61	0.78	0.54
		12	7.3	8.1	7.3	0.27	0.91	0.06
		14	8.3	8.1	7.6	0.37	0.26	0.72
		16	8.2	8.3	8.1	0.45	0.87	0.85
	2	2	8.0	8.3	7.2	0.63	0.37	0.43
		4	7.7	6.6	7.3	0.47	0.60	0.16
		6	9.4	6.6	7.1	0.61	0.04	0.07
		8	8.1	6.6	6.9	0.73	0.26	0.36
		10	7.3	7.4	6.7	0.83	0.60	0.73
		12	7.8	7.3	6.5	0.59	0.18	0.81
		14	7.8	6.2	5.4	0.40	0.01	0.46
		16	8.0	6.1	5.3	0.43	0.01	0.33

Table 4, Continued

Item	Year	Week	Treatment[1] 4	6	8	SE	Effect[2] L	Q
Pre-grazed IVDMD (% DM)[11,12]	1	0	69.6	61.8	69.9	2.44	0.94	0.04
		2	66.0	67.4	65.9	1.32	0.98	0.40
		4	64.1	63.6	63.9	1.18	0.88	0.77
		6	60.6	58.9	58.5	1.33	0.31	0.70
		8	57.0	57.0	58.1	2.99	0.80	0.90
		10	55.6	49.1	55.4	6.30	0.98	0.44
		12	53.0	50.7	57.2	5.20	0.59	0.52
		14	58.0	46.5	47.2	3.04	0.05	0.15
	2	0	62.8	62.3	61.5	1.83	0.62	0.96
		2	61.5	59.1	59.9	2.23	0.63	0.57
		4	68.7	58.8	58.9	4.09	0.14	0.36
		6	51.8	42.2	45.8	1.37	0.02	0.01
		8	55.4	54.2	54.5	4.30	0.88	0.89
		10	63.6	53.6	59.2	1.72	0.11	0.01
		12	59.9	49.2	47.9	2.27	0.01	0.15
		14	53.0	44.0	42.3	2.58	0.03	0.29
Post-grazed IVDMD (% DM)[13]	1	2	67.7	62.4	61.1	3.16	0.19	0.62
		4	64.7	63.1	62.0	2.43	0.46	0.94
		6	61.3	53.6	54.8	2.60	0.12	0.21
		8	54.3	50.9	52.5	1.12	0.30	0.12
		10	54.6	53.9	55.0	3.00	0.92	0.82
		12	51.5	53.4	47.5	1.67	0.14	0.10
		14	52.3	51.9	48.1	2.16	0.22	0.56
		16	49.8	45.9	46.8	2.89	0.49	0.52
	2	2	62.2	60.9	58.1	4.06	0.49	0.88
		4	59.3	54.5	58.6	4.05	0.91	0.40
		6	58.2	42.9	43.1	2.93	0.01	0.07
		8	47.7	41.2	37.3	2.95	0.05	0.73
		10	57.3	55.9	55.6	5.38	0.83	0.94
		12	57.9	53.2	55.7	4.32	0.73	0.52
		14	60.1	47.2	43.5	4.48	0.04	0.44
		16	52.0	36.2	34.5	2.81	0.01	0.09

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Pre-grazed N = significant effects ($P < 0.05$) of year, week, and year x week.

[4]Post-grazed N = significant effects ($P < 0.05$) of year, week, and year x week.

[5]Pre-grazed NDF = significant effects ($P < 0.05$) of week, and year x week.

[6]Post-grazed NDF = significant effects ($P < 0.05$) of year, week, and year x week.

[7]Pre-grazed ADF = significant effects ($P < 0.05$) of year, week, and year x week.

[8]Post-grazed ADF = significant effects ($P < 0.05$) of treatment, year, week, and treatment x year;

[9]Pre-grazed ash = significant effects ($P < 0.05$) of year, week, treatment x year, and year x week;

[10]Post-grazed ash = significant effects ($P < 0.05$) of year, week, treatment x year, and year x week.

[11]Pre-grazed IVDMD = significant effects ($P < 0.05$) of year, week, and year x week.

[13]Post-grazed IVDMD = significant effects ($P < 0.05$) of year, week, treatment x year, and year x week.

[12]%; filter bag technique with NDF as the end point measure.

Table 5
Means of dietary contributions of grass, forb, and ragweed consumed and forage preference of goats and sheep co-grazing mixed grass/forb pastures at different stocking rates

				Treatment[1]				Effect[2]		Species		
Item	Year	Week[3]	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
Dietary contribution												
Grass (%)[4]	1	4	Goat	46.8	48.3	50.0	2.65	0.49	0.97			
			Sheep	73.4	61.1	70.6	4.07	0.64	0.07			
			Mean	60.1	54.7	60.3	2.37	0.97	0.11	48.4a	68.4b	1.94
		8	Goat	58.1	55.5	55.5	4.83	0.73	0.84			
			Sheep	73.8	70.7	71.3	2.35	0.49	0.55			
			Mean	66.0	63.1	63.4	2.90	0.57	0.68	56.4a	72.0b	2.19
		12	Goat	54.2	43.7	50.4	2.17	0.28	0.02			
			Sheep	71.3	68.1	71.7	1.69	0.90	0.16			
			Mean	62.8	55.9	61.0	1.37	0.42	0.02	49.4a	70.4b	1.13
		16	Goat	47.3	56.8	55.8	2.54	0.07	0.14			
			Sheep	74.7	71.1	74.5	3.28	0.96	0.43			
			Mean	61.0	64.0	65.1	2.36	0.28	0.76	53.3a	73.4b	1.72
	2	4	Goat	55.3	55.2	48.3	1.38	0.02	0.10			
			Sheep	69.2	67.5	64.4	2.89	0.30	0.86			
			Mean	62.3	61.4	56.3	1.93	0.08	0.42	52.9a	67.0b	1.37
		8	Goat	52.3	55.3	47.4	1.66	0.09	0.04			
			Sheep	63.0	69.9	59.0	2.92	0.37	0.05			
			Mean	56.7	62.6	53.2	1.71	0.12	0.02	51.7a	64.0b	1.40
		12	Goat	50.2	51.9	48.0	4.90	0.77	0.67			
			Sheep	59.0	67.7	59.7	5.59	0.94	0.27			
			Mean	54.6	59.8	53.8	5.13	0.92	0.42	50.0a	62.1b	3.06

Table 5, Continued

				Treatment[1]				Effect[2]		Species		
Item	Year	Week[3]	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
		16	Goat	38.2	59.4	46.7	2.53	0.06	0.01			
			Sheep	63.7	71.8	67.0	3.36	0.52	0.17			
			Mean	51.0	65.5	56.8	2.74	0.19	0.02	48.1a	67.5b	1.81
Ragweed (%)[5]	1	4	Goat	18.0	18.0	19.8	2.17	0.60	0.74			
			Sheep	10.9	18.2	15.7	2.67	0.26	0.19			
			Mean	14.5	18.1	17.7	1.72	0.24	0.39	18.6	14.9	1.36
		8	Goat	21.4	20.1	15.2	2.87	0.18	0.62			
			Sheep	12.9	10.0	15.0	1.83	0.46	0.13			
			Mean	17.2	15.0	15.0	1.71	0.43	0.63	18.9b	12.6a	1.39
		12	Goat	16.2	23.9	18.7	1.64	0.34	0.02			
			Sheep	16.3	20.5	16.8	1.56	0.85	0.08			
			Mean	16.3	22.2	17.8	1.18	0.42	0.02	19.6	17.9	0.92
		16	Goat	27.1	17.1	17.7	3.31	0.10	0.24			
			Sheep	14.0	19.5	15.2	2.58	0.78	0.18			
			Mean	20.6	18.3	16.4	2.01	0.21	0.94	20.6	16.2	1.64
	2	4	Goat	21.6	16.9	27.8	0.97	0.01	0.01			
			Sheep	14.8	14.2	19.6	1.79	0.11	0.23			
			Mean	18.2	15.5	23.7	1.15	0.02	0.01	22.1b	16.2a	0.87
		8	Goat	18.9	13.5	28.3	0.93	0.01	0.01			
			Sheep	13.9	9.3	24.0	2.04	0.02	0.01			
			Mean	16.4	11.4	26.1	1.24	0.01	0.01	20.2b	15.8a	0.93
		12	Goat	19.4	22.2	29.0	3.62	0.11	0.67			
			Sheep	9.9	11.8	16.0	3.44	0.26	0.80			
			Mean	14.6	17.0	22.5	3.26	0.14	0.71	23.5b	12.6a	2.02

Table 5, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		16	Goat	31.0	15.7	28.9	1.45	0.36	0.01			
			Sheep	19.3	14.1	19.1	1.68	0.92	0.05			
			Mean	25.2	14.9	24.0	1.21	0.52	0.01	25.2b	17.5a	0.91
Other forbs (%)[6]	1	4	Goat	35.1	33.8	30.2	2.87	0.28	0.77			
			Sheep	15.6	20.8	13.7	2.59	0.63	0.11			
			Mean	25.4	27.3	21.9	1.93	0.27	0.18	33.0b	16.7a	1.59
		8	Goat	20.5	24.3	29.3	2.52	0.06	0.87			
			Sheep	13.3	19.3	13.7	2.26	0.91	0.08			
			Mean	16.9	21.8	21.4	2.25	0.21	0.37	24.7b	15.4a	1.48
		12	Goat	29.6	32.5	30.9	1.61	0.60	0.30			
			Sheep	12.3	11.4	11.6	1.14	0.66	0.68			
			Mean	21.0	21.9	21.2	1.07	0.88	0.56	31.0b	11.8a	0.84
		16	Goat	25.6	26.1	26.5	1.98	0.75	1.00			
			Sheep	11.3	9.4	10.4	1.98	0.78	0.57			
			Mean	18.4	17.7	18.5	1.33	0.99	0.68	26.1b	10.3b	1.09
	2	4	Goat	23.1	28.0	23.9	1.30	0.67	0.03			
			Sheep	16.1	18.0	16.0	2.69	1.00	0.59			
			Mean	19.6	23.1	20.0	1.62	0.87	0.15	25.0b	16.8a	1.11
		8	Goat	28.8	31.2	24.3	1.98	0.17	0.11			
			Sheep	23.0	20.8	17.0	1.35	0.03	0.63			
			Mean	25.9	26.0	20.6	1.21	0.03	0.12	28.1b	20.3a	0.99
		12	Goat	30.4	26.0	23.0	1.67	0.03	0.75			
			Sheep	31.2	20.5	24.4	3.03	0.17	0.10			
			Mean	30.8	23.3	23.7	2.37	0.08	0.22	26.4	25.4	1.49

Table 5, Continued

				Treatment[1]				Effect[2]		Species		
Item	Year	Week[3]	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
		16	Goat	30.8	24.9	24.4	2.45	0.12	0.41			
			Sheep	16.9	14.0	13.9	2.20	0.38	0.62			
			Mean	23.9	19.6	19.2	2.09	0.17	0.49	26.7b	15.0a	1.37
Preference value[7]												
Grass[8]	1	4	Goat	-0.2	0.3	0.9	0.83	0.37	0.96			
			Sheep	1.5	1.2	2.2	0.60	0.47	0.40			
			Mean	0.6	0.7	1.6	0.71	0.40	0.68	0.3a	1.6b	0.42
		8	Goat	-0.4	-0.7	-0.2	0.38	0.67	0.49			
			Sheep	0.5	0.2	0.9	0.48	0.64	0.41			
			Mean	0.1	-0.2	0.3	0.40	0.63	0.41	-0.4	0.5	0.25
		12	Goat	0.0	-0.3	-0.5	0.74	0.68	0.96			
			Sheep	1.1	1.0	0.8	0.68	0.77	0.92			
			Mean	0.6	0.4	0.2	0.70	0.72	0.99	-0.3a	1.0b	0.41
		16	Goat	-0.9	-0.9	-1.0	0.44	0.81	0.98			
			Sheep	0.7	-0.2	0.1	0.41	0.38	0.36			
			Mean	-0.1	-0.5	-0.5	0.43	0.58	0.66	-1.0a	0.2b	0.25
	2	4	Goat	2.1	1.2	1.4	1.14	0.67	0.69			
			Sheep	2.8	1.9	2.3	1.09	0.73	0.64			
			Mean	2.5	1.5	1.8	1.11	0.70	0.66	1.5a	2.3b	0.64
		8	Goat	0.9	0.2	-0.4	0.90	0.34	0.99			
			Sheep	1.6	1.3	0.3	0.80	0.28	0.76			
			Mean	1.3	0.7	-0.1	0.83	0.30	0.89	0.2a	1.0b	0.49
		12	Goat	-0.5	-0.1	0.3	0.46	0.33	0.95			
			Sheep	-0.1	1.0	1.1	0.46	0.14	0.37			
			Mean	-0.3	0.5	0.7	0.46	0.21	0.62	-0.1a	0.7b	0.27

Table 5, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		16	Goat	0.8	-0.7	-1.0	0.45	0.03	0.32			
			Sheep	2.2	0.2	0.1	0.41	0.02	0.10			
			Mean	1.5	-0.3	-0.5	0.42	0.02	0.18	-0.3a	0.8b	0.25
Forbs[9]	1	4	Goat	0.5	-0.1	-0.8	1.02	0.42	0.96			
			Sheep	-2.6	-1.4	-3.1	0.55	0.61	0.08			
			Mean	-1.1	-0.8	-2.0	0.74	0.45	0.44	-0.2b	-2.4a	0.47
		8	Goat	0.8	1.4	0.5	0.74	0.76	0.43			
			Sheep	-1.3	-0.1	-1.7	0.97	0.79	0.30			
			Mean	-0.2	0.6	-0.6	0.80	0.76	0.32	0.9b	-1.0a	0.50
		12	Goat	0.4	0.8	1.1	1.23	0.69	0.97			
			Sheep	-1.9	-1.4	-1.4	1.10	0.76	0.86			
			Mean	-0.8	-0.3	-0.2	1.15	0.72	0.92	0.7b	-1.6a	0.67
		16	Goat	2.2	2.5	2.2	1.38	1.00	0.87			
			Sheep	-0.7	0.5	-0.4	1.35	0.89	0.53			
			Mean	0.8	1.5	0.9	1.36	0.95	0.69	2.3b	-0.2a	0.80
	2	4	Goat	-1.6	-1.2	-1.1	1.06	0.75	0.89			
			Sheep	-3.4	-2.7	-3.0	0.86	0.75	0.67			
			Mean	-2.5	-1.9	-2.0	0.96	0.75	0.77	-1.3b	-3.0a	0.57
		8	Goat	-0.8	0.1	1.2	1.35	0.35	0.93			
			Sheep	-2.2	-2.2	0.0	1.26	0.27	0.51			
			Mean	-1.5	-1.1	0.6	1.23	0.30	0.71	0.2b	-1.5a	0.75
		12	Goat	-0.1	-0.6	0.1	0.99	0.92	0.64			
			Sheep	-0.7	-2.7	-1.3	0.80	0.61	0.14			
			Mean	-0.4	-1.7	-0.6	0.89	0.87	0.33	-0.2b	-1.6a	0.52

Table 5, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		16	Goat	-0.6	1.6	2.0	0.80	0.07	0.38			
			Sheep	-3.0	-0.4	-0.5	0.85	0.09	0.24			
			Mean	-1.8	0.7	0.7	0.78	0.07	0.27	1.0b	-1.3a	0.48
Ragweed[10]	2	4	Goat	-1.8	-0.8	2.1	1.88	0.20	0.71			
			Sheep	-3.7	-1.6	0.6	1.96	0.18	1.00			
			Mean	-2.8	-1.2	1.4	1.90	0.18	0.84	-0.2b	-1.6a	1.10
		8	Goat	-2.5	2.2	5.0	1.23	0.01	0.54			
			Sheep	-3.9	0.6	4.2	1.31	0.01	0.82			
			Mean	-3.2	1.4	4.6	1.25	0.01	0.67	1.6b	0.3a	0.73
		12	Goat	-3.4	-3.1	-0.2	1.27	0.13	0.42			
			Sheep	-6.0	-5.8	-3.8	0.65	0.06	0.33			
			Mean	-4.7	-4.4	-2.0	0.78	0.05	0.29	-2.2b	-5.2a	0.57
		16	Goat	-1.4	1.5	4.4	1.08	0.01	0.99			
			Sheep	-3.6	0.9	2.6	1.23	0.02	0.38			
			Mean	-2.5	1.2	3.5	1.12	0.01	0.64	1.5b	-0.1a	0.66
Other forbs[11]	2	4	Goat	1.5	0.2	-0.8	1.95	0.44	0.96			
			Sheep	-0.2	-2.1	-2.7	1.52	0.28	0.74			
			Mean	0.7	-0.9	-1.8	1.73	0.36	0.88	0.3b	-1.6a	1.01
		8	Goat	3.6	0.7	0.8	1.91	0.35	0.53			
			Sheep	2.7	-1.2	-0.7	1.78	0.24	0.35			
			Mean	3.1	-0.3	0.1	1.82	0.28	0.43	1.7b	0.3a	1.06
		12	Goat	7.5	7.6	5.6	1.13	0.27	0.49			
			Sheep	7.5	7.0	5.6	1.23	0.32	0.80			
			Mean	7.5	7.3	5.6	1.18	0.30	0.64	6.9	6.7	0.68

Table 5, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		16	Goat	4.6	3.5	2.2	1.44	0.30	0.98			
			Sheep	1.8	1.0	-0.7	1.32	0.23	0.79			
			Mean	3.2	2.3	0.8	1.37	0.26	0.87	3.4b	0.7a	0.81

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Week of the 16-week grazing period.

[4]Grass percentage = significant effects ($P < 0.05$) of species, year, week, treatment x year, treatment x week, species x year, species x week, year x week, and treatment x species x week.

[5]Ragweed percentage = significant effects of species ($P < 0.05$), year ($P < 0.05$), week ($P < 0.05$), treatment x year ($P < 0.05$), treatment x week ($P < 0.05$), species x year ($P < 0.05$), treatment x species x week ($P < 0.05$), species x year x week ($P < 0.05$), treatment ($P < 0.06$), year x week ($P < 0.07$), and treatment x species x year($P < 0.06$).

[6]Other forbs percentage = forbs other than ragweed; significant effects ($P < 0.05$) of species, year, week, treatment x year, treatment x week, species x year, species x week, year x week, treatment x species x year, species x year x week, and treatment x year x week.

[7]Preference values were calculated using percentages in the diet obtained from microhistological analysis and available forage from transect measures as follows: ((% diet - % available)/(% diet + % available)) x 10

[8]Grass preference value = significant effects ($P < 0.05$) of species, year, week, treatment x year, treatment x week, year x week, and treatment x year x week.

[8]Forb preference value = total forb; significant effects of species ($P < 0.05$), year ($P < 0.05$), week ($P < 0.05$), treatment x year ($P < 0.05$), treatment x week ($P < 0.05$), treatment x year x week ($P < 0.05$), and species x year ($P < 0.09$).

[9]Ragweed preference value = year 2; significant effects of treatment ($P < 0.05$), species ($P < 0.05$), week ($P < 0.05$), treatment x week ($P < 0.05$), and species x week ($P < 0.07$).

[10]Other forbs = forbs other than ragweed in year 2; significant effects ($P < 0.05$) of species, week, and species x week.

Table 6
Means of initial and final BW and ADG of goats and sheep as influenced by different stocking rates of goats and sheep co-grazing mixed grass/forb pastures

		Treatment[1]				Effect[2]		Species			Year[3]		
Item	Species	4	6	8	SE	L	Q	Goat	Sheep	SE	1	2	SE
Initial BW (kg)	Goat	20.1	21.6	20.6	1.07								
	Sheep	21.2	21.3	21.5									
	Mean	20.6	21.5	21.0	0.76	0.72	0.51	20.7	21.3	0.62	20.8	21.3	0.62
Final BW (kg)	Goat	25.0	25.2	24.3	0.94								
	Sheep	29.9	29.1	28.2									
	Mean	27.5	27.1	26.3	0.66	0.25	0.93	24.8a	29.1b	0.55	26.5	27.3	0.55
ADG (g/d)													
0-28 d	Goat	96	40	93	27.9								
	Sheep	157	147	143									
	Mean	127	94	118	21.4	0.78	0.31	76a	149b	16.1	84a	142b	13.9
29-56 d	Goat	79	73	57	20.6								
	Sheep	114	81	88									
	Mean	96	77	73	18.5	0.40	0.74	70	94	11.9	69a	95b	11.7
57-84 d	Goat	17	27	33	10.4								
	Sheep	49	59	31									
	Mean	33	43	32	7.3	0.96	0.29	26	46	6.0	57b	15a	6.0
85-112 d	Goat	-15	-13	-51	17.9								
	Sheep	-8	-9	-22									
	Mean	-12	-11	-36	15.5	0.31	0.51	-26	-13	10.4	-5b	-34a	10.4

Table 6, continued

Item	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE	Year[3] 1	2	SE
Overall	Goat	44	32	33	6.3								
	Sheep	78	69	60									
	Mean	61	51	47	5.1	0.10	0.62	36a	69b	3.7	51	54	3.7
Total gain													
(g/ha x d)	Goat	440	476	664	94.6								
	Sheep	780	1041	1203									
	Mean	610	759	933	70.6	0.02	0.88	527a	1008b	55.0	746	789	53.8

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Year = comparison of the two years of grazing; means with different letters differ ($P < 0.05$).

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CHAPTER IV

EFFECTS OF STOCKING RATE ON GRAZING BEHAVIOR AND ENERGY EXPENDITURE BY SHEEP AND GOATS CO-GRAZING GRASS/FORB PASTURES

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Abstract

A study was conducted to assess effects of stocking rate (SR) on grazing behavior and energy expenditure (EE) by growing sheep and goat wethers co-grazing grass/forb pastures. Grazing was for 16-week periods in 2002 and 2003. Pastures consisted of various grasses, primarily bermudagrass (*Cynodon dactylon*) and johnsongrass (*Sorghum halepense*), and forbs (e.g., ragweed; *Ambrosia spp.*). Sheep (Khatadin) and goats (≥ 75% Boer) averaged 21 ± 4.8 and 21 ± 3.7 kg initial BW, respectively, and were 4 to 5 months of age when grazing began. Stocking rates were four (4), six, (6), and eight (8) animals per 0.4-ha pasture, with equal numbers of sheep and goats. The nine pastures (three/treatment) were divided into four paddocks that were rotationally grazed in 2-week periods. In weeks 3, 9, and 13 of both years, EE was determined on one goat and one sheep in each pasture via heart rate. In the same weeks, behavioral observations (position and activity) were made every 30 min of 13.5 h of daylight on two goats and two sheep in each pasture. Grazing behavior using IGER Grazing Behavior monitoring system units was also measured over 24-h periods on animals used for EE measurement. Based on visual observation, there were interactions ($P < 0.05$) between year and SR in daylight time spent grazing (year 1: 57.3, 57.8%, and 62.3; year 2: 48.0, 56.4, and 60.5% (SE = 1.54)) and idle (year 1: 18.7, 20.9, and 16.3%; year 2: 29.7, 21.4, and 15.5% for 4, 6, and 8, respectively (SE = 1.95)). Standing time (daylight) increased linearly ($P < 0.05$) as SR increased. Species interacted ($P < 0.05$) with week of measurement in daylight time spent grazing and with year in time spent standing, ruminating, and idle. Grazing time during daylight was similar between species (56.1 and 58.0% for sheep and goats, respectively), although idle time was greater (P < 0.05) for goats (23.6 vs. 17.2% (SE = 1.36)). Time spent ruminating in daylight was similar among SR but was greater for sheep (25.0 vs 17.0% (SE = 1.22)). Based on the IGER units, the number of steps increased linearly (P < 0.05) with increasing SR (2279, 2707, and 2788 for 4, 6, and 8, respectively (SE = 96.4)), but was similar for the two species. As SR increased, time spent eating increased (7.4, 8.4, and 9.6 h) and time spent lying (11.0, 10.2, and 8.9 h), ruminating (7.9, 7.7, and 6.8 h), and idle (8.6, 8.0, and 7.6 h for 4, 6, and 8, respectively) decreased (P < 0.05). Goats spent less time eating (1.1 h) and more time idle (0.9 h) than did sheep (P < 0.05). SR, species, and year (P < 0.05) and SR, year, and week of sampling interacted (P < 0.06) in EE of wethers (year 1, sheep: 516, 569, and 572 kJ/kg $BW^{0.75}$; year 2, sheep: 572, 597, and 648 kJ/kg $BW^{0.75}$; year 1, goat: 524, 524, and 624 kJ/kg $BW^{0.75}$; year 2, goat: 499, 496, and 551 kJ/kg $BW^{0.75}$ for 4, 6, and 8, respectively (SE = 17.0)). In summary, influences of SR on grazing time and EE can vary with grazing season. With forage conditions of this study, SR had similar effects on grazing behavior of sheep and goats when co-grazing. Effects of SR on EE may contribute to impact on ADG by small ruminants.

Key Words: Goat, co-grazing, energy expenditure, behavior, stocking rate

Introduction

The majority of domesticated ruminants are raised solely or partially in semi-extensive or extensive production systems in which most nutrients are derived from grazed herbage. Grazing is associated with daily activities considerably different than for confined animals, such as time spent eating and distances traveled (Osuji, 1974; Lachica and Aguilera, 2003). These activities result in greater energy expenditure (EE) than in confinement, which can limit energy available for maintenance and production.

Perhaps because of the difficulty of study, there is a poor understanding of factors influencing the grazing activity energy expense by ruminants. Relatedly, there are at present no universally accepted methods of prediction. For available methods pertaining to goats, NRC (1981) recommended the addition of 25% of the suggested metabolizable energy (ME) requirement for maintenance (ME_m) with light activity, 50% with semi-arid rangeland and slightly hilly conditions, and 75% with sparsely vegetated rangeland or mountainous transhumace pasture. Although, Coop and Hill (1962) reported a higher grazing energy activity cost of 92% of ME_m for sheep grazing perennial ryegrass-white clover pasture. AFRC (1998) recommended estimating the activity energy expense of grazing for goats from additional costs above confinement attributable to horizontal and vertical distances traveled and number of changes in position, based on specific activity costs of ARC (1980) with sheep and of Lachica et al. (1997) with goats on a treadmill placed at different slopes. CSIRO (1990) presented a prediction equation for cattle, sheep, and goats with independent variables of DM digestibility, terrain score, availability of green or total forage, and BW. Because of the close relationship between grazing time and EE (Osuji, 1974), Sahlu et al. (2004) proposed prediction based primarily on time spent grazing and walking, but also with influence of herbage digestibility, distance traveled, and terrain ruggedness or topography.

One of the conditions impacting aforementioned factors used to predict the activity energy cost of grazing is nutrient demand of the animal and, thus, herbage intake (Fierro and Bryant, 1990). Forage availability can influence both grazing time and the quality of ingested forage (Seman et al., 1991; Krysl and Hess, 1993; Herselman et al., 1999). As forage availability decreases, bite size declines, which results in at least partially compensatory changes in grazing time and rate of biting (Davies and Southey, 2001). Decreased forage nutritive value also increases time spent in ingestive mastication (Sahlu et al., 1989; Lachica and Aguilera, 2003).

Stocking rate (SR), or the number of animals of a certain body weight per unit land area, is a common management decision that determines forage mass and nutritive value, with high SR having negative impacts (Senft, 1989; Seman et al., 1991; Wilson and MacLeod, 1991). SR has had expected effects on time spent grazing and resting with mono-species grazing (Birrell, 1991; Seman et al., 1991; Ackerman et al., 2001). However, how SR affects grazing behavior and EE by co-grazing ruminant species is unclear. Because of differences among ruminant species, such as sheep and goats, in preferences and selectivity for different plants and plant parts, with heterogeneous grass/forb mixtures it is possible that such effects may be dissimilar. Therefore, objectives of this experiment were to investigate effects of SR on grazing behavior and EE of sheep and goats co-grazing grass/forb pastures.

Materials and Methods

Animals and location

This experiment was conducted at the E (Kika) de la Garza American Institute for Goat Research of Langston University, Langston, Oklahoma, and was approved by the Langston University Animal Care Committee. There were two consecutive years (2002 and 2003) of grazing with each experiment lasting 16 weeks from May to September. In each year, 27 goat and 27 sheep wethers were used. Sheep (Khatadin) and goats (≥ 75% Boer) averaged 21 ± 4.8 and 21 ± 3.7 kg initial body weight respectively, and were 4 to 5 months of age when grazing began. Both sets of animals were purchased from commercial sources. Most sheep were from the same source in the two years. Goats were, however, from two different sources but were both located near Sonora, Texas. Upon arrival, wethers were quarantined for 3 weeks, vaccinated with Covexin 8 (Schering-Plough, Kinilworth, NJ), and treated for internal parasites (Ivomec® orally; Merck Ag Vet Division, Rahway, NJ) before the experiment. Fecal egg counts by the modified McMaster method (Stafford et al., 1994) were made with samples from two goats and two sheep per pasture every 28 d during the grazing period to ascertain need for re-treatment. These same animals were used for behavioral observations.

Treatments

Nine 0.4-ha (1 acre) pastures were used. Pastures were randomly assigned to three SR. Stocking rates were four (4; low), six (6; moderate), and eight (8; high) animals per pasture, with equal numbers of sheep and goats. Pastures were divided into four paddocks that were rotationally grazed in 2-week periods for an 8-week grazing cycle (2 weeks of grazing and 6 weeks of regrowth). Pastures contained a complex mixture of grasses, predominantly bermudagrass (*Cynodon dactylon*) with a lesser amount of johnsongrass (*Sorghum halepense*), and various forbs, primarily ragweed (*Ambrosia artemisiifolia*) but also including others such as *Lespedeza cuneata* and nightshade (*Solanum spp*.). Animals were allocated to nine groups for similar mean body weight and variation in body weight within group and species in accordance with SR and randomly assigned to pastures. Pastures were subjected to the same SR in both years. Water and trace mineralized salt were freely available, and a shelter was situated in each pasture as well.

Measurements

After close visual observation of animals grazing, hand-plucked samples of forage similar to that being selected were collected around 0830 h from each pasture at 2-week intervals on day 6 of the 2-week periods separately for sheep and goats. The clipped plant material was later dried at 55ºC for 48 h in a forced-air oven, ground to pass a 1-mm screen and analyzed for Kjeldahl N (AOAC, 1990), ash, and NDF (filter bag technique; ANKOM Technology Corp., Fairport, NY).

Two sheep and two goats from each pasture were randomly selected for use in behavioral observations. In addition, one of these animals of each species was randomly selected to determine EE during grazing, body composition via urea space, and grazing behaviors using IGER Grazing Behavior monitoring system units (Ultrasound advice, London, UK). In week 3, 9, and 13, behavioral observations were made every 30 min during daylight for position (i.e., standing vs. lying) and activity (i.e., grazing, ruminating, and idle or not grazing or ruminating). Behavioral observations were made using binoculars so as not to influence behavior. Observations were averaged over time to determine percentage of total daylight. Grazing behaviors determined in week 3 of year 1 and weeks 3 and 9 of year 2 with the IGER units induced number of steps and time spent lying, ruminating, eating (i.e., grazing), and idle in the 24-h period.

EE and body composition were determined with animals used for IGER unit measures (i.e., one animal of each species in each pasture). Before placing animals in the pastures, heat production or EE was determined over a 24-h period for each animal based on O_2 consumption and production of CO_2 and CH_4 (Brouwer, 1965) with a headbox respiration calorimetry system (Sable Systems, Henderson, NV) while simultaneously measuring heart rate (HR) with a Polar S610 monitor (Polar, Woodbury, NY). Coarsely ground alfalfa hay was consumed ad libitum during this period. The average ratio of EE:HR over the 24-h period for each animal was then used to predict EE from HR while grazing. HR were measured in weeks 3, 9, and 13. Body composition was determined at the beginning and end of the experiment based on urea space and shrunk BW. Procedures for sheep were similar to those of Galloway et al. (1996) and Goetsch (1999) and for goats were similar to those of Wuliji et al. (2003a,b).

Statistical analyses

Animal and plant responses to SR treatments were analyzed using mixed model procedures of SAS, assuming a compound symmetry covariance structure (Littell et al., 1996). Year was considered a fixed effect, because effects of SR in the first year of grazing could impact results in the second year. Also, as mentioned later, these pastures were not grazed in the year preceding this experiment. Because growing animals were used, the same animals could not be employed each year. However, there was effort expended to ensure that animals used in the two grazing seasons were similar in genotype, age, and body weight.

The model consisted of SR, species, year, week of sampling or measurement, and their interactions for the composition of hand-plucked forage samples, visual behavioral observations, HR, and EE. Because of a lesser number of IGER units in year 1 vs. 2, behavioral measurements were taken only once in year 1 and twice in year 2. As a result IGER unit measures in year 2 were averaged across week of measurement and associated interactions were excluded from the model. For body composition, there were unreasonable initial body composition values for sheep; therefore, these data are not presented. In addition, one set of blood samples from year 2 for urea N analysis was inadvertently discarded. Hence, only goat data for year 1 are presented. Random effects were animal group within SR and species within group x SR (forage composition, visual behavioral measures, HR, EE, and IGER unit behavior measures). The repeated measure was year x week for forage composition, visual behavioral observations, EE, and HR and year for IGER unit behavior measures. Body composition of goats in year 1 was analyzed with the random effect of animal group within SR. Analyses were conducted separately for the two species in each measurement time or period within year with a significant ($P < 0.10$) three-way interaction or the following two-way interactions: 1) SR x year and SR x week or 2) year x week. Since in most instances interactions justified analysis by week within year or by species, year, and week, in some other cases (forage, visual behavior, and EE) when these interactions were not significant, data were analyzed similarly. Orthogonal contrasts were performed for linear and quadratic effects of SR.

Results and Discussion

Composition of simulated grazed forage

The N concentration hand-plucked forage samples was affected by two three-way interactions: SR, year, and week of sampling, and species, year, and week ($P < 0.05$; Table 1). However, there were no linear effects of SR and only one quadratic effect significant at $P < 0.10$. Overall, N concentration was greater in year 2 vs. 1, and in both years most values were lower in the second 8-week grazing cycle than in the first. The level of N was greater ($P < 0.05$) for goats than for sheep (means averaged over SR) at three sampling times in year 1 but at only one time in year 2. Levels at other times were either similar between species or numerically greater for goats, with smaller and less frequent differences in year 1 than 2. These species differences may relate to the higher content of forbs in the diet of goats than sheep (Chapter III), with forbs presumably higher in N concentration than grasses. In accordance, Pfister and Malechek (1986) observed selection by goats of a diet higher in N than consumed by sheep in a semi-arid woodland community in Brazil. Conversely, Gurung et al. (1994) noted that Merino sheep selected forage with a higher N concentration than ingested by Angora goats grazing annual grass/clover pastures in Australia. Lower N levels in year 2 vs. 1 of the present experiment and fewer and smaller differences between species in year 2 suggest that the ability of goats to select forage with relatively high N concentration is less with available forage of low vs. moderate or high N concentration.

CP concentrations in hand-plucked forage at the different sampling times ranged from 3.4 to 10.2% CP (Table 1). The concentrations averaged across weeks was 9.0 and 7.1% CP in year 1 and 5.6 and 5.2% CP in year 2 for goats and sheep, respectively.

Hence, assuming that these samples reasonably well mimicked actual forage being ingested, it seems likely that CP intake limited performance alone or was co-limiting with intake of ME (NRC, 1975, 1981).

There were SR x year, SR x week of sampling, and species x year x week of sampling interactions ($P < 0.05$) in NDF concentration in hand-plucked forage samples (Table 1). As noted for N concentration, SR had little effect on level of NDF. Averaged over week of sampling and species, NDF concentration was 60.5, 55.8, and 62.9% in year 1 and 68.7, 71.6, and 69.8% in year 2 for low, moderate, and high SR, respectively (SE = 3.15). The concentration of NDF was markedly less for goats than for sheep in week 7, 9, and 11 of year 1 ($P < 0.05$) but was similar between species at other times, which is in partial agreement with differences in N concentration. In contrast, Gurung et al. (1994) observed selection of forage by goats relatively higher in fiber than consumed by sheep. The NDF concentration in hand-plucked forage samples for sheep was similar between years though for goats was generally greater in year 2 compared with year 1. This may be explained by the preference of sheep for grass, which contributed over 50% of the sward, compared with greater forb ingestion by goats. This probably relates to the decreased percentage of the sward in palatable forbs in year 2 vs. 1 that limited the ability of goats to select forbs in year 2, thus increasing the NDF level in ingested forage compared with year 1.

There was a three-way interaction of species, year, and week of sampling in the ash content in hand-plucked forage samples ($P < 0.05$; Table 1). Although, SR did not significantly affect ash concentration at any time ($P > 0.10$) other than a quadratic effect ($P < 0.05$) for sheep in week 15 of year 1. Likewise, the overall effect of SR was not significant ($P < 0.10$; 7.2, 7.7, and 7.4% for low, moderate, and high SR, respectively; SE = 0.28). Averaged over SR, ash concentration in week 9, 11, and 13 of year 1 was greater ($P < 0.05$) for goats vs. sheep, but values were similar between species at other times.

As noted earlier, hand-plucked forage samples were collected on day 6 of the first week of the 2-week grazing periods. Greater potential for differences between species in selectivity would be expected with sampling at this time than later in the second week. Though there were some species differences in chemical composition, overall, differences were not consistent. Earlier in Chapter III, differences between species in botanical composition of the diet were addressed. That these differences were not accompanied by corresponding ones in chemical composition of hand-plucked forage may reflect the ability of both sheep and goats to select specific plant parts in addition to differentiation among plant species.

Forage nutritive value has an obvious impact on digestible nutrient intake. Effects of forage nutritive value on grazing behavior and, thus, EE, may occur via influence of the amount of time spent in ingestive mastication, increasing with decreasing quality (Beauchemin, 1991; Susenbeth et al., 1998), as well as the amount of herbage that must be consumed to reach a particular level of digestible nutrient intake, also increasing with decreasing forage nutritive value. Based on the observed chemical composition of hand-plucked forage samples of this experiment, it would not appear that effects of SR on forage nutritive value had a marked involvement in any effects of SR on grazing behavior or EE.

Visual observation of behavior

Time spent grazing was affected by SR x year, species x week of measurement, and year x week interactions ($P < 0.05$), and there was a trend for a three-way interaction involving SR, year, and week ($P < 0.06$; Table 2). Averaged over week of measurement and species, grazing time was 57.3, 57.8, and 62.3% of daylight in year 1 and 48.0, 56.4, and 60.5% in year 2 for low, moderate, and high SR, respectively (SE = 1.54), with tendencies for linear change in years 1 ($P < 0.12$) and 2 ($P < 0.04$) as SR increased. For the analysis by species at each measurement week within year, in year 1 grazing time by sheep linearly increased ($P < 0.09$) with increasing SR in week 3 and by goats in week 13. Grazing time increased linearly ($P < 0.05$) as SR increased in year 2 for goats in weeks 3 and 13 and for sheep at all times. These findings and the lack of interaction between species and SR indicate similar effects of SR on grazing time for both species and may reflect consumption of both grass and forb plants present by goats and sheep and similar overall effects of SR on availability of forbs and grass. In agreement with the effect of SR on grazing time in this experiment, increased SR lengthened grazing time by beef steers (Seman et al., 1991; Ackerman et al., 2001). The greater prevalence and larger magnitude of SR effects on grazing time in year 2 vs. 1 of the present experiment probably involve generally greater forage mass in year 1 and larger differences among SR in year 2, as addressed in Chapter III. Averaged over SR, grazing time was similar between species at all but one time of measurement. This is in contrast with findings of Herselman et al. (1999), which entailed longer grazing time for sheep vs. goats grazing warm season grass-based pastures.

There were interactions (P < 0.05) in time spent standing (Table 2) between species and year (year 1: 69.8 and 66.6% of daylight; year 2: 60.2 and 66.3% for sheep and goats, respectively (SE = 1.26)), species and week of measurement (week 3: 60.4 and 67.9%; week 9: 62.1 and 60.4%; week 13: 72.4 and 71.0% for sheep and goats, respectively (SE = 1.52)), and year and week of sampling (year 1: 61.7, 64.7, and 78.1%; year 2: 66.6, 57.8, and 65.3% in week 3, 9, and 13, respectively (SE = 1.52)). Overall, time spent standing increased linearly with increasing SR (61.1, 66.3, and 69.8% of daylight for low, moderate, and high SR, respectively (SE = 1.27; P < 0.05)). Analysis by species for each week within year revealed a linear increase in time spent standing as SR increased in week 9 of both years (P < 0.05). Though time spent standing would be expected to be affected by SR in a manner similar to grazing time, the SR by year interaction was not significant (P > 0.10). This could reflect a relatively lower proportion of time standing spent grazing in year 1 vs. 2. In agreement to findings of the present experiment, Herselman et al. (1999) noted less time lying by sheep compared with goats, and also reported less time standing without grazing by sheep compared with goats.

Ruminating time (Table 2) was affected by interactions (P < 0.05) of SR and week of measurement (week 3: 18.4, 20.7, and 20.1% of daylight; week 9: 31.5, 24.2, and 28.7%; week 13: 17.0, 15.3, and 13.6% for low, moderate, and high SR, respectively (SE = 2.25)), species and year (P < 0.05) (year 1: 22.3 and 19.0%; year 2: 27.8 and 15.1% for sheep and goats, respectively (SE = 1.41)), year and week (P < 0.05) (year 1: 22.4, 25.5, and 14.0%; year 2: 17.0, 30.8, and 16.6% for week 3, 9, and 13, respectively (SE = 1.57)), and species and week (P < 0.06) (week 3: 25.4 and 14.0%; week 9: 31.5 and 24.8%; week 13: 18.2 and 12.3% for sheep and goats, respectively (SE = 1.59)).

Overall, SR did not affect time spent ruminating ($P > 0.10$) (22.3, 20.1, and 20.8% for low, moderate, and high SR, respectively (SE = 1.88)). However, analysis by species for each week of measurement within year showed a decrease in ruminating time as SR increased in week 13 of year 1. At one measurement time in year 1 and at all times in year 2, means for sheep averaged over SR were greater than for goats ($P < 0.05$).

Time spent idle (Table 2) was affected ($P < 0.05$) by interactions of SR and year (year 1: 18.7, 20.9, and 16.3% of daylight; year 2: 29.7, 21.4, and 15.5% for low, moderate, and high SR, respectively (SE = 1.95)), species and year (year 1: 16.7 and 20.6%; year 2: 17.8 and 26.7% for sheep and goats, respectively (SE = 1.59)), SR and week of measurement (week 3: 31.3, 22.2, and 17.6%; week 9: 21.1, 23.6, and 16.8%; week 13: 20.2, 17.6, and 13.3% for low, moderate, and high SR, respectively (SE = 2.20)), and year and week (year 1: 22.2, 22.1, and 11.5%; year 2: 25.2, 18.9, and 22.5% for week 3, 9, and 13, respectively (SE = 1.63)). The overall decline in idle time with increasing SR is in accordance with increased grazing time. When analyzed by species and week within year, SR had effect only in weeks 3 and 13 of year 2 ($P < 0.05$), and goats spent more time idle than sheep in weeks 9 and 13 of year 2 ($P < 0.05$).

IGER unit measurement of behavior

There were no significant interactions among year, species, or SR in the number of steps (Table 3). Overall, the number of steps linearly increased with increasing SR (2279, 2707, and 2788 for low, moderate, and high SR, respectively; SE = 96.4), tended ($P < 0.07$) to be greater in year 1 vs. 2 (2667 vs. 2515; SE = 66.6), and was similar between goats and sheep. Similar findings were observed for the analysis by species and year. Factors responsible for the difference between years are unclear. The number of steps observed in the present experiment was less than reported by Herselman et al. (1999). The most likely factor responsible for this difference is larger pastures employed by Herselman et al. (1999). Swain et al. (1986) determined and Lu (1988) summarized that goats travel longer distances than sheep. However, results of the present experiment suggest that, assuming a similar distance traveled per step, such findings would depend on experimental conditions. That is, with fairly small pastures consisting of forages not highly preferred or averted by either species (Chapter III), the number of steps and distance traveled will not vary between goats and sheep and are affected by SR similarly.

Species and year interacted ($P < 0.05$) in time spent lying (year 1: 9.04 and 10.07 h; year 2: 10.91 and 10.17 h (SE = 0.313)) and ruminating (year 1: 7.36 and 8.18 h; year 2: 7.25 and 7.02 h for sheep and goats, respectively (SE = 0.25; Table 3)). Factors responsible for these interactions are unknown. Time spent lying (10.96, 10.24, and 8.95 h for low, moderate, and high SR, respectively; SE = 0.303) and ruminating (7.92, 7.66, and 6.78 h for low, moderate, and high SR, respectively; SE = 0.195) decreased linearly with increasing SR ($P < 0.05$). Similarly, linear effects of SR ($P < 0.05$) on time lying were noted for goats in year 1 and for both species in year 2. Time ruminating decreased linearly with increasing SR for goats ($P < 0.05$) and sheep ($P < 0.07$) in year 2, with similar numerical trends for both species in year 1.

The year effect was significant for time spent eating ($P < 0.07$) and idle ($P < 0.05$) (eating: 8.84 and 8.09 h (SE = 0.258); idle: 7.39 and 8.72 h for year 1 and 2, respectively (SE = 0.195; Table 3). Time spent eating (i.e., grazing; $P < 0.05$; 7.38, 8.37, and 9.65 h for low, moderate, and high SR, respectively; SE = 0.316) linearly increased and idle time decreased ($P < 0.06$; 8.62, 7.97, and 7.57 h for low, moderate, and high SR, respectively; SE = 0.239) as SR increased. Likewise, linear effects ($P < 0.05$) of SR on grazing time occurred for goats in year 1 and for both species in year 2, although idle time was linearly influenced by SR only in year 1 for goats ($P < 0.05$). Similar effects of SR on grazing and resting times of sheep grazing mixed pastures dominated by perennial ryegrass and subterranean clover at SR of 10, 15, 20, and 25 sheep per hectare were reported by Birrell (1991). As noted previously, with decreased forage mass grazing time increases to compensate for decreased bite size, and rate of biting increases as well (Burns and Sollenberger; 2002). The degree of limitation in forage mass determines the degree of compensation.

Averaged over year, goats spent less time eating ($P < 0.05$; 9.00 and 7.93 h; SE = 0.258) and more time idle than did sheep ($P < 0.05$; 7.70 and 8.41 h for sheep and goats, respectively; SE = 0.190; Table 3). Similarly, eating time was greater ($P < 0.05$) for sheep vs. goats in year 2, and a similar numerical difference was observed in year 1. Opposite differences were noted in time spent idle. Factors responsible for less time spent eating by goats than sheep are unknown. However, botanical composition of the diet (Chapter III) may have been involved. For example, goats consumed more forbs and less grass compared with sheep. Although comparisons of ingestion time differences among the specific plants present in these pastures are not available, ingestion time is less for legumes vs. grasses (Galyean and Goetsch, 1993). Also, the lower rate of growth of goats than sheep (Chapter III, Table 6) implies lower DM intake relative to BW of goats.

Behavioral measures with the two methods employed in this study generally agree. For example, eating or grazing time increased and time spent ruminating decreased with increasing SR based on visual observation and IGER units. With both methods idle time increased with increasing SR, and idle time was greater for goats than for sheep. One exception, however, is the species difference in eating time determined with IGER units but not from visual observation. Likewise, visual observation suggested greater rumination time for sheep than for goats, but this was not evident based on IGER unit data. Because values obtained using IGER units were for a 24-h period compared with 13.5 h of daylight with visual observation, some differences would be expected. For example, ruminants generally spend more time grazing during daylight than nighttime (Birrell, 1991; Krysl and Hess, 1993) and time ruminating and idle during nighttime (Lu, 1988; Fierro and Bryant, 1990) is greater than in daylight hours. However, environmental conditions such as temperature, humidity, and precipitation can modify general daily patterns in behavior (Beverlin et al., 1989; Champion et al., 1994).

Heart rate and energy expenditure

HR is known to be related to oxygen consumption and heat production and, thus, has been used as an indirect measure of EE for cattle and sheep (Brosh et al., 1998, 2002; Arieli et al., 2002; Barkai et al., 2002). To do so, it is necessary to determine the quantity of heat produced or EE per heart beat, which can vary among individual animals (Brosh et al., 1998). The EE:HR ratio measured for individual animals before grazing began ranged from 5.2 to 6.7 kJ/kg $BW^{0.75}$ per heart beat (5.9 ± 0.34; Table 4). There was a tendency for a three-way interaction among SR, species, and year ($P < 0.10$), although magnitudes of difference among means were relatively small. Furthermore, means for each species in both years were similar among SR, and values did not differ between species either.

HR measured during grazing tended to be affected by a SR x species interaction ($P < 0.10$) (sheep: 91, 97, and 101; goats: 89, 89, and 100 for low, moderate, and high SR, respectively (SE = 1.4; Table 4)). There was a trend for an interaction between year and week of sampling ($P < 0.06$) (year 1: 107, 88, and 89; year 2: 104, 91, and 87 in week 3, 9, and 13, respectively (SE = 1.43)). Also, species and year interacted ($P < 0.05$) (year 1: 93 and 96; year 2: 99 and 88 for sheep and goats, respectively (SE = 1.16)). For the analysis by species at each week within year, there were linear effects of SR on HR for goats and sheep in weeks 3 ($P < 0.05$) and 9 ($P < 0.08$) of year 1, for sheep in week 13 of year 1 ($P < 0.05$), and for goats in weeks 9 ($P < 0.05$) and 13 ($P < 0.06$) of year 2. HR was greater ($P < 0.05$) for goats vs. sheep in week 13 of year 1 but lower ($P < 0.05$) for goats at all times in year 2.

Because of relatively small magnitudes of treatment effects on the EE:HR ratio, differences in EE were similar to those in HR (Table 4). There was a three-way interaction in EE involving SR, species, and year ($P < 0.05$) and a tendency ($P < 0.06$) for an interaction involving SR, year, and week of measurement. EE linearly increased with increasing SR for goats in weeks 3 and 9 of year 1 and in weeks 9 ($P < 0.05$) and 13 ($P < 0.07$) of year 2. EE for sheep linearly increased with increasing SR in all weeks of year 2 ($P < 0.05$); values in year 1 also numerically increased as SR increased. Averaged over SR, EE was similar between species in year 1 but was greater ($P < 0.05$) for sheep vs. goats in year 2 at all times of measurement. This finding agrees with previous observations of Herselman et al. (1999) of higher heat production by grazing sheep compared with goats.

Factors responsible for greater HR and EE in week 3 vs. 9 and 13 of each year are unknown. However, this difference might be at least partially attributable to week 3 being the first measurement time, when animals were perhaps not fully accustomed to the HR monitoring equipment. Although, the equipment had been used previously to determine the EE:HR ratio. Forage mass was greater at this measurement time than at others, with week 9 and 13 being in the second 8-week grazing cycle. Nonetheless, differences among SR and between species in week 3 were in accordance with those noted in later weeks of measurement.

It is not possible to definitively discern the factor(s) responsible for change in EE as SR increased. ME intake influences EE, but based on measures of performance in Chapter III and in Table 5, any increase in ME intake with increasing SR was accompanied by change in EE of at least equal magnitude. However, Osuji (1974) reviewed literature indicating a close relationship between time spent grazing and the activity energy cost of grazing, and noted physiological processes contributing to this relationship such as skeletal muscle work for locomotion and energy use by the gastrointestinal tract and liver. The increasing number of steps and presumably distance traveled with increasing SR in the present experiment probably contributed to increasing EE as SR rose. In fact, distance traveled is a primary input of some systems used to predict the grazing activity energy cost (e.g., CSIRO, 1990; AFRC, 1998; NRC, 2000, 2001). In this regard, Sahlu et al. (2004) proposed a method to predict the grazing activity energy cost of goats. The most important condition on which prediction is based is grazing plus walking time, but with adjustments for distance traveled, forage digestibility, and terrain score. The terrain score input is to address greater EE with travel on sloped than level land and that for digestibility is to consider potential effects of forage quality on energy use by splanchnic tissues as suggested by Osuji (1974) and Goetsch (1998).

Common recommendations of ME_m for sheep (NRC, 1975) and goats (AFRC, 1998) are 410 and 438 kJ/kg $BW^{0.75}$, respectively. These values do not include an allowance for the activity energy cost. AFRC (1998) proposed an activity energy cost for goats in confinement of 10% of ME_m. However, it is likely that the low plane of nutrition, as reflected by relatively low ADG, decreased the ME_m requirement (e.g., CSIRO, 1990; NRC, 2000; Sahlu et al., 2004). Hence, it is assumed that the ME requirement for maintenance and activity (ME_{m+a}) is ME_m (i.e., 410 and 438 kJ/kg $BW^{0.75}$ for sheep and goats, respectively). To account for EE associated with tissue gain, the AFRC (1998) equation for energy concentration in BW gain (MJ/kg) of 4.972 + (0.3274 x BW, kg) can be used, along with assuming a forage ME concentration of 9 MJ/kg DM and k_g from the AFRC (1998) equation of 0.006 + (0.0423 x forage ME concentration, MJ/kg DM). Based on these assumptions, expected EE was 521, 498, and 501 kJ/kg $BW^{0.75}$ for goats and 555, 539, and 522 kJ/kg $BW^{0.75}$ for sheep at low, moderate, and high SR, respectively. Therefore, measured EE was -2, 3, and 20% greater than ME_{m+a} for goats and -3, 11, and 22% greater for sheep at low, moderate, and high SR, respectively. Though these estimates are based on numerous assumptions, they do suggest that ME_{m+a} of goats was not impacted by the moderate SR compared with the low SR, even though eating time increased with each increase in SR. Conversely, each of the two increases in SR elicited an increase in ME_{m+a} of sheep. Factors responsible for this difference are unknown, but it suggests that EE by goats attributable to grazing activity per unit time spent eating may not necessarily be constant as assumed by Sahlu et al. (2004).

Using the approach of Sahlu et al. (2004) to predict the grazing activity energy cost, based on the IGER estimates of eating time and number of steps, 0.5 m per step, a forage ME concentration of 9 MJ/kg DM, and terrain score of 1, the estimated ME requirement for grazing activity was 12, 18, and 22% of ME_m for goats and 16, 22, and 32% for sheep at low, moderate, and high SR, respectively. All but one value is greater than estimated in this experiment, which suggests need for refinement of the method of Sahlu et al. (2004). However, accuracy of assumed ME_m requirements on which measurement of the grazing activity energy cost was based is unknown.

Tissue gain

SR did not significantly affect initial or final BW, body composition, or daily gain of shrunk BW, water, fat, protein, ash, or energy (Table 5). However, numerically shrunk BW gain decreased with increasing SR, as was also observed for unshrunk BW in Chapter III. The relatively small number of observations and values only for goats in year 1 limited the ability to evaluate SR effects on these measures. Nonetheless, even though shrunk BW gain was not great, a considerable proportion of tissue accretion was of fat. For example, initially fat was 13.7 ± 0.82% of shrunk BW, whereas the concentration of fat was considerably greater at the end of grazing (18.4 ± 1.68%), with fat being 37.3 ± 6.64% of tissue gain. Concentrations of water, protein, and fat were in accordance with results of Wuliji et al. (2003b) with growing goats and forage-based diets. Conversely, with a lower plane of nutrition Ghosh and Moitra (1992) noted a much lower fat concentration of 6% in Black Bengal goats.

The sum of EE and recovered energy can be used as an estimate of ME intake, which was 6.71, 6.45, and 7.57 MJ/day for goats in year 1 on low, moderate, and high SR, respectively. Therefore, it would appear that goats on the high SR were able to compensate to some degree for high EE by elevating ME intake. Although most of this additional energy was used to fuel EE associated with the long grazing time and greater distance traveled compared with low and moderate SR, intake was adequate for some tissue accretion of energy. It is speculated that with lower forage mass such as in the latter part of year 2, further increases in grazing time and distance traveled resulting from increased SR would coincide with a steady decline in the extent to which ME intake could compensate for increased EE attributable to grazing activity. It is suggested that grazing time and distance traveled would increase with increasing SR and decreasing forage mass up to a point at which the increment of change in EE equals that in ME intake.

Summary and conclusions

SR had little impact on the chemical composition of hand-plucked forage samples, and differences between species were inconsistent. Grazing time and the number of steps by sheep and goats increased and time spent ruminating and idle decreased with increasing SR, with greater effects in the second year when forage mass was lower. Eating time was greater for sheep vs. goats, and EE increased with increasing SR. However, relative to assumed ME requirements for maintenance plus activity in confinement, the grazing activity energy cost rose with each increment of change in SR with sheep but was only greater for the high vs. low and moderate SR with goats. Factors likely responsible for increased EE and the grazing activity energy cost with increasing

SR are decreased forage mass that elicited increased grazing time and number of steps or distance traveled.

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Table 1
Means of simulated grazed forage nutrient composition for mixed grass/forb pastures as influenced by different stocking rates of co-grazing goats and sheep

				Treatment[1]				Effect[2]		Species		
Item	Year	Week[3]	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
N (% DM)[4]	1	3	Goat	1.53	1.06	1.40	0.180	0.62	0.12			
			Sheep	1.24	1.23	1.41	0.137	0.40	0.61			
			Mean	1.39	1.15	1.41	0.135	0.92	0.18	1.33	1.29	0.092
		5	Goat	1.26	1.42	1.68	0.156	0.11	0.81			
			Sheep	1.25	1.53	1.39	0.185	0.61	0.40			
			Mean	1.25	1.48	1.54	0.146	0.22	0.68	1.45	1.39	0.100
		7	Goat	1.53	1.30	1.69	0.249	0.67	0.35			
			Sheep	0.95	0.81	0.96	0.100	0.91	0.29			
			Mean	1.24	1.06	1.33	0.141	0.68	0.24	1.51b	0.91a	0.109
		9	Goat	1.20	1.60	1.61	0.346	0.43	0.66			
			Sheep	0.84	1.05	1.02	0.129	0.37	0.48			
			Mean	1.02	1.33	1.32	0.209	0.36	0.56	1.47b	0.97a	0.151
		11	Goat	1.80	1.58	1.51	0.389	0.63	0.88			
			Sheep	1.07	0.86	0.88	0.187	0.50	0.64			
			Mean	1.43	1.22	1.20	0.271	0.56	0.79	1.63b	0.94a	0.176
		13	Goat	1.95	1.87	1.04	0.380	0.15	0.46			
			Sheep	1.55	2.08	0.87	0.328	0.20	0.08			
			Mean	1.75	1.98	0.96	0.338	0.15	0.19	1.62	1.50	0.205
		15	Goat	1.09	1.37	0.83	0.306	0.57	0.32			
			Sheep	0.84	1.44	0.72	0.341	0.82	0.17			
			Mean	0.97	1.41	0.78	0.315	0.69	0.22	1.10	1.00	0.187

Table 1, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
	2	3	Goat	1.34	1.32	1.40	0.120	0.73	0.74			
			Sheep	1.38	1.28	1.32	0.083	0.63	0.52			
			Mean	1.36	1.30	1.36	0.092	1.00	0.62	1.35	1.32	0.059
		5	Goat	1.36	0.93	1.03	0.223	0.33	0.38			
			Sheep	0.85	0.87	1.05	0.066	0.09	0.37			
			Mean	1.11	0.90	1.04	0.132	0.72	0.33	1.11	0.92	0.095
		7	Goat	1.19	1.17	1.07	0.057	0.21	0.55			
			Sheep	1.09	1.00	0.97	0.110	0.47	0.82			
			Mean	1.14	1.09	1.02	0.079	0.34	0.96	1.14b	1.02a	0.051
		9	Goat	0.81	0.85	0.87	0.089	0.69	0.96			
			Sheep	0.76	0.83	0.89	0.087	0.32	0.96			
			Mean	0.79	0.84	0.88	0.082	0.46	0.95	0.84	0.83	0.051
		11	Goat	0.71	0.65	0.71	0.053	1.00	0.37			
			Sheep	0.68	0.61	0.71	0.044	0.69	0.16			
			Mean	0.70	0.63	0.71	0.046	0.85	0.24	0.69	0.66	0.028
		13	Goat	0.69	0.50	0.63	0.060	0.47	0.07			
			Sheep	0.71	0.50	0.60	0.061	0.27	0.08			
			Mean	0.70	0.50	0.62	0.060	0.35	0.08	0.61	0.60	0.035
		15	Goat	0.53	0.58	0.56	0.066	0.74	0.70			
			Sheep	0.57	0.59	0.48	0.049	0.25	0.37			
			Mean	0.55	0.58	0.52	0.052	0.72	0.50	0.56	0.55	0.034

Table 1, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
NDF (% DM)[5]	1	3	Goat	67.8	63.5	66.9	3.71	0.86	0.44			
			Sheep	69.0	69.6	66.1	1.42	0.20	0.28			
			Mean	68.4	66.6	66.4	2.29	0.57	0.77	66.0	68.3	1.62
		5	Goat	59.6	55.2	53.7	10.01	0.69	0.92			
			Sheep	68.9	55.3	66.1	7.50	0.81	0.24			
			Mean	64.3	55.3	59.9	7.43	0.70	0.49	56.2	63.4	5.11
		7	Goat	48.6	51.8	42.8	11.79	0.74	0.69			
			Sheep	72.6	71.3	71.1	0.63	0.14	0.54			
			Mean	60.6	61.6	56.9	5.91	0.98	0.72	41.7a	71.7b	4.82
		9	Goat	51.4	44.3	46.3	13.29	0.80	0.79			
			Sheep	70.6	69.4	70.1	0.98	0.77	0.46			
			Mean	61.0	56.8	58.2	6.68	0.78	0.75	47.3a	70.0b	5.44
		11	Goat	39.0	47.0	44.9	12.55	0.75	0.76			
			Sheep	62.0	72.6	69.5	6.55	0.45	0.43			
			Mean	50.5	59.8	57.2	7.97	0.58	0.57	43.6a	68.0b	5.78
		13	Goat	46.8	35.8	64.8	10.97	0.29	0.19			
			Sheep	52.6	35.4	72.2	7.86	0.13	0.04			
			Mean	49.7	36.6	68.5	9.07	0.20	0.08	49.1	53.4	5.51
		15	Goat	64.4	53.2	72.8	9.35	0.55	0.23			
			Sheep	73.6	56.2	74.0	8.80	0.98	0.16			
			Mean	69.0	54.7	73.4	8.76	0.74	0.18	63.5	67.9	5.24
	2	3	Goat	67.2	67.2	59.7	3.03	0.13	0.36			
			Sheep	67.6	67.3	69.6	2.04	0.51	0.61			
			Mean	67.4	67.2	64.7	2.15	0.41	0.68	64.7	68.2	1.49

Table 1, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		5	Goat	60.9	70.7	69.5	6.62	0.40	0.52			
			Sheep	71.8	70.7	68.0	1.56	0.14	0.69			
			Mean	66.4	70.7	68.7	3.40	0.65	0.48	67.0	70.2	2.78
		7	Goat	64.3	67.2	65.5	2.73	0.76	0.53			
			Sheep	70.1	67.6	69.1	1.68	0.69	0.38			
			Mean	67.2	67.4	67.3	1.67	0.97	0.95	65.6	68.9	1.36
		9	Goat	69.4	73.6	69.5	1.97	0.98	0.14			
			Sheep	71.3	73.5	71.0	1.47	0.88	0.25			
			Mean	70.4	73.5	70.2	1.62	0.96	0.16	70.8	71.9	1.00
		11	Goat	68.5	72.3	66.1	3.33	0.63	0.27			
			Sheep	67.1	72.3	66.4	3.46	0.90	0.24			
			Mean	67.8	72.3	66.2	3.37	0.76	0.25	69.0	68.6	1.96
		13	Goat	66.9	73.8	72.8	5.66	0.50	0.59			
			Sheep	65.5	73.8	72.1	5.28	0.42	0.47			
			Mean	66.2	73.8	72.5	5.46	0.46	0.53	71.2	70.5	3.16
		15	Goat	75.9	77.3	78.5	1.43	0.24	0.97			
			Sheep	75.6	74.6	78.7	1.38	0.18	0.19			
			Mean	75.8	76.0	78.6	1.36	0.19	0.50	77.2	76.3	0.81
Ash (% DM)[6]	1	3	Goat	7.3	7.6	7.3	0.87	1.00	0.83			
			Sheep	7.8	7.9	8.5	0.33	0.20	0.49			
			Mean	7.6	7.7	7.9	0.59	0.71	0.98	7.4	8.1	0.38
		5	Goat	8.2	9.1	8.7	1.85	0.88	0.78			
			Sheep	7.0	9.4	8.2	1.13	0.50	0.25			
			Mean	7.6	9.3	8.4	1.28	0.68	0.47	8.7	8.2	0.88

Table 1, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		7	Goat	9.6	9.2	10.7	1.50	0.64	0.63			
			Sheep	6.8	6.9	7.5	0.43	0.25	0.70			
			Mean	8.2	8.0	9.1	0.78	0.44	0.57	9.8b	7.1a	0.64
		9	Goat	9.6	9.9	10.0	1.50	0.85	0.96			
			Sheep	7.0	7.2	8.0	0.39	0.12	0.55			
			Mean	8.3	8.6	9.0	0.78	0.54	0.93	9.9b	7.4a	0.63
		11	Goat	10.6	10.3	10.2	1.21	0.87	0.93			
			Sheep	8.1	8.1	7.7	0.60	0.68	0.86			
			Mean	9.3	9.2	9.0	0.69	0.74	1.00	10.4b	8.0a	0.55
		13	Goat	9.6	11.3	8.8	1.21	0.65	0.22			
			Sheep	8.6	10.9	8.7	0.94	0.95	0.10			
			Mean	9.1	11.1	8.7	1.04	0.82	0.14	9.9	9.4	0.62
		15	Goat	7.5	9.5	7.2	0.84	0.78	0.09			
			Sheep	6.4	9.7	7.1	0.73	0.52	0.02			
			Mean	7.0	9.6	7.2	0.77	0.88	0.04	8.1	7.8	0.45
	2	3	Goat	6.2	5.9	7.5	0.81	0.29	0.39			
			Sheep	5.6	6.1	6.0	0.36	0.42	0.57			
			Mean	5.9	6.0	6.8	0.49	0.25	0.61	6.5	5.9	0.36
		5	Goat	7.1	6.0	6.2	1.30	0.63	0.69			
			Sheep	5.7	6.6	6.5	0.41	0.21	0.37			
			Mean	6.4	6.3	6.3	0.70	0.95	0.93	6.4	6.3	0.56
		7	Goat	6.2	5.9	6.0	0.48	0.76	0.74			
			Sheep	5.8	6.1	6.5	0.26	0.10	0.87			
			Mean	6.0	6.0	6.3	0.29	0.56	0.73	6.0	6.2	0.22

Table 1, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		9	Goat	6.2	6.1	6.6	0.67	0.73	0.73			
			Sheep	6.8	6.6	6.6	0.68	0.89	0.94			
			Mean	6.5	6.3	6.6	0.67	0.93	0.83	6.3a	6.7b	0.39
		11	Goat	6.8	6.4	7.2	0.72	0.70	0.51			
			Sheep	6.4	6.7	7.3	0.52	0.26	0.81			
			Mean	6.6	6.5	7.2	0.61	0.47	0.62	6.8	6.8	0.36
		13	Goat	6.2	6.6	5.5	0.76	0.52	0.47			
			Sheep	6.6	6.6	5.9	0.69	0.49	0.68			
			Mean	6.4	6.6	5.7	0.71	0.50	0.56	6.1	6.3	0.42
		15	Goat	5.7	5.8	5.3	0.49	0.60	0.68			
			Sheep	6.3	7.0	5.6	0.43	0.32	0.10			
			Mean	6.0	6.4	5.5	0.39	0.38	0.22	5.6	6.3	0.27

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Week of the 16-week grazing period.

[4]N = significant effects of species ($P < 0.05$), year ($P < 0.05$), week ($P < 0.05$), treatment x week ($P < 0.05$), species x year ($P < 0.05$), year x week ($P < 0.05$), treatment x year x week ($P < 0.05$), treatment x year ($P < 0.09$), species x week ($P < 0.07$), and species x year x week ($P < 0.06$).

[5]NDF = significant effects (P < 0.05) of species, year, week, treatment x year, species x year, treatment x week, year x week, species x week, and species x year x week.

[6]Ash = significant effects of year (P < 0.05), week (P < 0.05), species x year (P < 0.05), species x year x week (P < 0.05), and species (P < 0.07).

Table 2
Means of time spent grazing, standing, ruminating, and idle of goats and sheep co-grazing mixed grass/forb pastures at different stocking rates based on visual observation during 13.5 h of daylight

				Treatment[1]				Effect[2]		Species		
Item	Year	Week[3]	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
Grazing (% daytime)[4]	1	3	Goat	58.0	52.5	60.5	2.96	0.57	0.09			
			Sheep	48.8	48.1	59.3	4.00	0.09	0.25			
			Mean	53.4	50.3	59.9	2.81	0.16	0.12	57.0	52.1	2.48
		9	Goat	49.4	52.5	54.3	3.16	0.29	0.88			
			Sheep	51.9	51.2	52.5	3.26	0.90	0.82			
			Mean	50.6	51.9	53.4	2.74	0.50	0.97	52.1	51.9	2.09
		13	Goat	64.2	69.8	71.6	2.80	0.09	0.60			
			Sheep	71.6	72.8	75.9	3.41	0.39	0.83			
			Mean	67.9	71.3	73.8	2.91	0.21	0.91	68.5	73.5	2.24
	2	3	Goat	52.5	68.5	70.4	5.00	0.03	0.27			
			Sheep	44.4	56.8	53.7	2.73	0.03	0.04			
			Mean	48.5	62.7	62.0	4.52	0.08	0.23	63.8a	51.6b	3.68
		9	Goat	45.7	53.7	50.6	3.75	0.37	0.25			
			Sheep	42.6	49.4	58.0	2.65	0.01	0.78			
			Mean	44.1	51.5	54.3	3.98	0.13	0.65	50.0	50.0	2.78
		13	Goat	49.4	54.9	65.4	3.44	0.01	0.57			
			Sheep	53.7	54.9	64.8	3.40	0.04	0.32			
			Mean	51.5	54.9	65.1	3.59	0.04	0.47	56.6	57.8	3.08
Standing (% daytime)[5]	1	3	Goat	62.3	60.5	65.4	3.25	0.52	0.41			
			Sheep	55.6	58.0	68.5	4.07	0.04	0.44			
			Mean	59.0	59.3	67.0	3.13	0.12	0.38	62.8	60.7	2.58

Table 2, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		9	Goat	53.7	63.0	69.1	3.80	0.02	0.75			
			Sheep	61.7	68.5	72.2	2.35	0.01	0.61			
			Mean	57.7	65.7	70.7	3.13	0.03	0.71	61.9	67.5	2.76
		13	Goat	71.0	75.3	79.0	3.11	0.09	0.94			
			Sheep	77.2	85.2	80.9	3.21	0.43	0.14			
			Mean	74.1	80.2	79.9	2.92	0.21	0.41	75.1	81.1	2.29
	2	3	Goat	67.3	73.5	78.4	4.98	0.14	0.92			
			Sheep	55.6	63.0	61.7	3.52	0.24	0.34			
			Mean	61.4	68.2	70.1	4.70	0.25	0.69	73.0b	60.1a	3.21
		9	Goat	51.2	62.3	63.0	3.78	0.05	0.28			
			Sheep	53.1	53.7	63.6	2.75	0.02	0.19			
			Mean	52.2	58.0	63.3	3.21	0.05	0.94	58.8	56.8	2.82
		13	Goat	62.3	71.0	67.3	3.95	0.40	0.23			
			Sheep	61.7	61.1	68.5	3.63	0.21	0.39			
			Mean	62.0	66.0	67.9	4.21	0.37	0.85	66.9	63.8	2.77
Ruminating (% daytime)[6]	1	3	Goat	16.0	23.5	18.5	3.96	0.67	0.23			
			Sheep	27.8	25.3	23.5	4.01	0.46	0.96			
			Mean	21.9	24.4	21.0	5.54	0.91	0.69	19.3a	25.5b	2.96
		9	Goat	27.2	19.6	25.3	3.85	0.74	0.19			
			Sheep	33.3	20.4	27.2	3.09	0.18	0.02			
			Mean	30.2	20.1	26.2	4.38	0.55	0.18	24.1	27.0	2.86
		13	Goat	17.3	15.4	8.0	2.10	0.01	0.30			
			Sheep	17.9	13.0	12.3	2.05	0.08	0.41			
			Mean	17.6	14.2	10.2	1.75	0.03	0.90	13.6	14.4	1.74

Table 2, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
	2	3	Goat	9.3	7.4	9.3	1.95	1.00	0.46			
			Sheep	20.4	26.5	29.0	3.89	0.14	0.71			
			Mean	14.8	17.0	19.1	4.60	0.54	1.00	8.6a	25.3b	2.23
		9	Goat	25.3	22.8	28.4	4.70	0.65	0.50			
			Sheep	40.1	34.0	34.0	2.16	0.07	0.27			
			Mean	32.7	28.4	31.2	4.08	0.80	0.51	25.5a	36.0b	2.66
		13	Goat	11.7	9.3	12.3	2.96	0.87	0.46			
			Sheep	21.0	23.5	21.6	2.57	0.87	0.51			
			Mean	16.4	16.4	17.0	3.27	0.90	0.95	11.1a	22.0b	1.72
Idle (% daytime)[7]	1	3	Goat	28.4	24.1	18.5	5.16	0.20	0.93			
			Sheep	22.8	24.1	15.4	3.69	0.18	0.30			
			Mean	25.6	24.1	17.0	4.90	0.26	0.66	23.7	20.8	3.21
		9	Goat	23.5	27.2	20.4	3.87	0.59	0.29			
			Sheep	14.8	28.4	18.5	3.56	0.48	0.02			
			Mean	19.1	27.8	19.4	3.90	0.96	0.13	23.7	20.6	3.03
		13	Goat	15.4	11.1	16.7	3.46	0.81	0.27			
			Sheep	7.4	10.5	8.0	2.58	0.87	0.40			
			Mean	11.4	10.8	12.3	3.28	0.85	0.80	14.4	8.6	2.10
	2	3	Goat	38.3	24.1	20.4	4.62	0.02	0.37			
			Sheep	35.8	16.7	16.0	4.82	0.02	0.14			
			Mean	37.0	20.4	18.2	4.83	0.04	0.27	27.6	22.8	4.44
		9	Goat	29.0	22.8	20.4	4.00	0.15	0.72			
			Sheep	17.3	16.0	8.0	2.33	0.02	0.26			
			Mean	23.1	19.4	14.2	4.08	0.18	0.89	24.1b	13.8a	2.66

Table 2, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		13	Goat	35.2	31.5	18.5	3.24	0.01	0.27			
			Sheep	22.8	17.2	9.9	2.05	0.01	0.72			
			Mean	29.0	24.4	14.2	3.37	0.03	0.53	28.4b	16.7a	2.75

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Week of the 16-week grazing period.

[4]Grazing = significant effects of treatment ($P < 0.05$), year ($P < 0.05$), week ($P < 0.05$), year x treatment ($P < 0.05$), species x week ($P < 0.05$), year x week ($P < 0.05$), and treatment x year x week ($P < 0.06$).

[5]Standing = significant effects ($P < 0.05$) of treatment, year, week, year x species, species x week, and year x week.

[6]Ruminating = significant effects of species ($P < 0.05$), week ($P < 0.05$), treatment x week ($P < 0.05$), year x species ($P < 0.05$), year x week ($P < 0.05$), and species x week ($P < 0.06$).

[7]Idle = significant effects ($P < 0.05$) of treatment, species, year, week, treatment x year, treatment x week, year x species, and year x week.

Table 3
Means of grazing behavior of goats and sheep co-grazing mixed grass/forb pastures at different stocking rates measured by IGER grazing behavior monitoring system units over a 24-h period

			Treatment[1]				Effect[2]		Species		
Item	Year	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
Number of steps (x 1000)[3]	1	Goat	2.32	2.93	2.80	0.141	0.06	0.08			
		Sheep	2.56	2.68	2.78	0.101	0.22	0.92			
		Mean	2.42	2.80	2.86	0.119	0.08	0.36	2.68	2.70	0.074
	2	Goat	2.06	2.58	2.61	0.076	0.01	0.04			
		Sheep	2.19	2.67	2.98	0.209	0.04	0.76			
		Mean	2.13	2.63	2.79	0.116	0.01	0.30	2.42	2.61	0.091
Lying (h)[4]	1	Goat	11.60	10.21	8.39	0.725	0.03	0.82			
		Sheep	9.70	8.62	8.68	0.608	0.33	0.51			
		Mean	10.65	9.42	8.53	0.520	0.07	0.81	10.07	9.00	0.423
	2	Goat	10.78	10.70	9.07	0.302	0.01	0.09			
		Sheep	11.80	11.31	9.62	0.436	0.02	0.31			
		Mean	11.29	11.00	9.35	0.296	0.01	0.11	10.19a	10.91b	0.217
Ruminating (h)[5]	1	Goat	8.41	8.30	7.83	0.247	0.15	0.59			
		Sheep	7.99	8.12	5.98	0.861	0.20	0.36			
		Mean	8.20	8.21	6.90	0.358	0.09	0.24	8.18	7.36	0.291
	2	Goat	7.38	7.06	6.63	0.147	0.02	0.76			
		Sheep	7.89	7.18	6.69	0.382	0.07	0.83			
		Mean	7.69	7.12	6.66	0.205	0.02	0.93	7.02	7.25	0.167
Eating (h)[6]	1	Goat	7.04	8.21	9.12	0.235	0.01	0.69			
		Sheep	7.94	8.79	11.96	1.831	0.22	0.65			
		Mean	7.49	8.50	10.54	0.699	0.06	0.59	8.12	9.56	0.568

Table 3, Continued

			Treatment[1]				Effect[2]		Species		
Item	Year	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
	2	Goat	7.03	7.72	8.49	0.171	0.01	0.86			
		Sheep	7.51	8.75	9.03	0.203	0.01	0.11			
		Mean	7.27	8.23	8.76	0.161	0.01	0.31	7.74a	8.43b	0.109
Idle (h)[7]	1	Goat	8.54	7.50	7.05	0.355	0.03	0.52			
		Sheep	8.07	7.09	6.07	1.124	0.30	1.00			
		Mean	8.30	7.29	6.56	0.477	0.09	0.83	7.70	7.08	0.388
	2	Goat	9.26	9.22	8.88	0.202	0.24	0.57			
		Sheep	8.60	8.07	8.29	0.353	0.56	0.43			
		Mean	8.93	8.65	8.58	0.204	0.28	0.68	9.12b	8.32a	0.166

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Number of steps = significant effects of treatment ($P < 0.05$) and year ($P < 0.07$).

[4]Time spent lying (h) = significant effects ($P < 0.05$) of treatment, year, and species x year.

[5]Time spent ruminating (h) = significant effects ($P < 0.05$) of treatment, year, and species x year.

[6]Time spent eating (h) = significant effects of treatment ($P < 0.05$), species ($P < 0.05$), and year ($P < 0.07$).

[7]Time spent idle (h) = significant effects of species ($P < 0.05$), year ($P < 0.05$), and treatment ($P < 0.06$).

Table 4
Means of heart rate and energy expenditure of goats and sheep co-grazing mixed grass/forb pastures at different stocking rates

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
Ratio of EE to heart rate[4]	1		Goat	5.7	5.6	6.2	0.23	0.25	0.23			
			Sheep	5.9	6.0	5.8	0.19	0.72	0.52			
			Mean	5.8	5.8	6.0	0.15	0.49	0.58	5.8	5.9	0.12
	2		Goat	5.8	6.0	5.7	0.23	0.76	0.50			
			Sheep	6.0	6.0	6.3	0.12	0.14	0.48			
			Mean	5.9	6.0	6.0	0.15	0.69	0.82	5.8	6.1	0.11
Heart rate (beats/min)[5]	1	3	Goat	102	105	118	4.0	0.03	0.36			
			Sheep	101	105	113	1.8	0.01	0.47			
			Mean	101	105	116	2.2	0.01	0.27	108	106	2.7
		9	Goat	83	89	96	4.2	0.07	0.88			
			Sheep	78	91	92	4.3	0.08	0.31			
			Mean	82	90	94	4.0	0.08	0.73	90	88	2.8
		13	Goat	90	89	96	3.4	0.37	0.48			
			Sheep	82	87	90	2.4	0.05	0.83			
			Mean	86	88	92	2.9	0.19	0.80	91a	86b	1.8
	2	3	Goat	99	96	103	4.5	0.56	0.44			
			Sheep	101	112	111	3.5	0.12	0.20			
			Mean	100	104	107	3.5	0.23	0.86	99a	108b	2.5
		9	Goat	78	78	95	2.5	0.01	0.04			
			Sheep	95	96	106	4.4	0.12	0.49			
			Mean	86	87	101	4.2	0.06	0.27	84a	99b	3.0
		13	Goat	81	75	91	2.9	0.06	0.02			
			Sheep	91	89	93	1.5	0.32	0.18			
			Mean	86	82	92	2.6	0.15	0.08	83a	91b	2.1

Table 4, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
EE (kJ/kg $BW^{0.75}$)[6]	1	3	Goat	580	584	725	16.6	0.01	0.02			
			Sheep	595	635	657	32.2	0.26	0.83			
			Mean	586	609	691	19.4	0.01	0.26	630	632	21.8
		9	Goat	477	491	593	30.2	0.04	0.28			
			Sheep	470	549	536	30.1	0.20	0.26			
			Mean	473	519	565	26.0	0.06	0.98	520	521	21.7
		13	Goat	514	496	563	17.9	0.12	0.11			
			Sheep	482	522	525	21.1	0.20	0.51			
			Mean	498	509	530	21.1	0.33	0.86	515	510	13.1
	2	3	Goat	572	574	587	18.0	0.59	0.81			
			Sheep	606	676	694	20.5	0.03	0.34			
			Mean	589	625	640	23.1	0.17	0.73	577a	659b	13.6
		9	Goat	454	466	544	19.1	0.02	0.21			
			Sheep	566	579	667	33.3	0.08	0.40			
			Mean	510	523	605	31.1	0.08	0.40	488a	604b	20.2
		13	Goat	472	449	523	16.3	0.07	0.06			
			Sheep	542	536	583	9.1	0.02	0.06			
			Mean	507	492	553	18.4	0.13	0.15	481a	554b	11.4

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Week of the 16-week grazing period.

[4]Ratio of EE (energy expenditure) to heart rate determined at the beginning of the experiment.

[5]Heart rate = significant effects of treatment ($P < 0.05$), species ($P < 0.05$), week ($P < 0.05$), year x species ($P < 0.05$), year x week ($P < 0.06$), and treatment x species ($P < 0.10$).

[6]EE = energy expenditure; significant effects of treatment ($P < 0.05$), species ($P < 0.05$), week ($P < 0.05$), year x species ($P < 0.05$), year x week ($P < 0.05$), year x treatment x species ($P < 0.05$), and year x treatment x sampling ($P < 0.06$).

Table 5
Means of body weight and tissue gain of goats co-grazing mixed grass/forb pastures with sheep at different stocking rates during year 1

	Treatment[1]				Effect[2]	
Item	4	6	8	SE	L	Q
Initial						
Shrunk BW (kg)	17.7	18.0	17.9	0.67	0.81	0.80
Water concentration (%)	65.5	66.1	65.4	0.64	0.95	0.48
Fat concentration (%)	13.8	13.2	13.9	0.69	0.93	0.53
Protein concentration (%)	17.7	17.8	17.7	0.12	0.95	0.48
Ash concentration (%)	2.9	3.0	2.9	0.04	0.95	0.48
Total mass (kg)	17.6	18.0	17.9	0.67	0.80	0.78
Final						
Shrunk BW (kg)	22.1	21.8	21.9	0.52	0.76	0.80
Water concentration (%)	60.0	62.0	62.5	0.86	0.11	0.51
Fat concentration (%)	19.8	17.8	17.3	0.90	0.12	0.52
Protein concentration (%)	16.6	17.0	17.1	0.17	0.10	0.50
Ash concentration (%)	2.7	2.8	2.8	0.04	0.11	0.51
Total mass (kg)	21.9	21.7	21.8	0.50	0.88	0.84
Daily gain						
Shrunk BW (g)	44.3	34.2	35.4	7.94	0.49	0.61
Water (g)	17.3	15.3	17.4	3.7	0.98	0.68
Fat (g)	19.0	12.7	11.6	3.39	0.23	0.59
Protein (g)	5.5	4.7	5.1	1.09	0.83	0.65
Ash (g)	0.78	0.69	0.78	0.17	0.99	0.68
Energy (kJ)	873	609	575	153.0	0.27	0.58

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

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CHAPTER V

PERFORMANCE BY GOATS AND SHEEP CONSUMING A 65% CONCENTRATE DIET SUBSEQUENT TO CO-GRAZING OF GRASS/FORB PASTURES AT DIFFERENT STOCKING RATES

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Abstract

A study was conducted to determine effects of co-grazing of mixed grass/forb pastures at three stocking rates (SR) on subsequent performance of goats and sheep consuming a 65% concentrate diet. Experimental periods, in 2002 and 2003, were 15 weeks in length, following 16 weeks of grazing. Sheep (Khatadin) and goats (≥ 75% Boer) were 4 to 5 months of age when grazing began. Stocking rates were four (4), six (6), and eight (8) animals per 0.4-ha pasture, with equal numbers of sheep and goats and three pastures per SR. Two goats and two sheep from each pasture were used in this subsequent confinement period, with initial BW of 23 ± 2.7 and 25 ± 3.6 kg, respectively. Average daily gain (ADG) by all animals during grazing tended to decrease linearly ($P < 0.10$) with increasing SR (61, 51, and 47 g for 4, 6, and 8, respectively). In the period after grazing, DMI was affected ($P < 0.05$) by year x SR (year 1: 958, 955, and 1011g/day; year 2: 1109, 904, and 931 g/day for 4, 6, and 8, respectively (SE = 49.6)) and species x year ($P< 0.06$) interactions (year 1: 1105 and 844; year 2: 1164 and 799 g/day for sheep and goats, respectively (SE = 40.5)). ADG tended ($P < 0.08$) to be affected by the four-way interaction of SR, species, year, and 3-week period. Differences in ADG in the 3-week periods among SR were inconsistent and of small magnitude. Overall ADG (183, 153, and 159 g for 4, 6, and 8, respectively (SE = 8.3)) and gain efficiency (ADG:DMI) were not influenced by SR ($P > 0.10$). Sheep had higher overall ADG than goats (193 vs 137 g; SE = 8.1). Energy expenditure (EE) measured in weeks 3 and 9 via heart rate tended to increase linearly ($P < 0.07$) with increasing SR (562, 592, and 628 kJ/kg $BW^{0.75}$ for 4, 6, and 8, respectively; SE = 15.9). Body composition at the beginning and end of the experiment, based on shrunk BW and urea space, was not impacted by SR. Daily accretion rates of fat (85.1 vs 61.0 g (SE = 8.14) and energy (3756 vs 2819 kJ (SE = 340.2)) were greater for sheep than for goats, although daily gain of protein was similar (17.7 and 18.2 g for sheep and goats, respectively (SE = 1.53)). In conclusion, ADG by neither sheep nor goats consuming a 65% concentrate diet compensated for the effect of SR on ADG in a previous grazing period, which may involve effect of prior SR on subsequent EE.

Key Words: Goats, Stocking rate, Performance

Introduction

In livestock production systems, feed accounts for most of the cost of production. Free-ranging production, however, minimizes feed cost. But performance of grazing ruminants often is less than their genetic potential because of insufficient and seasonal oscillations in nutrient supply (Owens et al., 1993). Subsequent feeding of diets rich in concentrate feedstuffs may, therefore, be an important aspect of management for animals to reach marketable size and condition, for greater economic returns compared with marketing immediately after grazing. Upon realimentation with high quality diets, ruminants can compensate for an earlier period of low nutritional plane through increased feed intake and(or) enhanced efficiency of feed utilization (Hornick et al., 1998a, 2000).

Expression of compensatory growth is influenced by factors such as the severity and duration of the limited nutritional plane, age, level of realimentation, and characteristics of diets consumed during and after nutrient restriction (Thornton et al., 1979; Ryan, 1990; Drouillard et al., 1991; Poppi and McLennan, 1995; Barash et al., 1998; Drouillard and Kuhl, 1999; Tolla et al., 2003; Joemat et al., 2004). In addition, there appears to be differences among genotypes within species of cattle, sheep, and goats in the ability to undergo compensatory growth (Folman et al., 1974; Goetsch, 1999; Joemat et al., 2004). Although, for goats consuming a 75% concentrate diet subsequent to 50% concentrate, compensatory growth of Alpine, Angora, Boer, and Spanish wethers goats was similar (Urge et al., 2004).

Compensatory growth is an important component of extensive livestock production systems where the quantity and quality of available forage are limited during parts of the year, with yearly variations as well. One of the key management decisions that impacts forage available for grazing is stocking rate (SR). High SR decrease forage mass and nutritive value (Senft, 1989; Wilson and MacLeod, 1991; Davies and Southey, 2001), with the consequence of low growth rate and body weight loss (Sahlu et al., 1989; Aiken et al., 1991; Seman et al., 1991; Huston et al., 1993). A review by Drouillard and Kuhl (1999), however, indicated that finishing performance by beef cattle has been inconsistently affected by SR during previous grazing, with effects ranging from neutral to positive. Relatedly, Albin (1969) and Stock et al. (1983) suggested that the accuracy of determining body weight at the end of grazing, such as influenced by digesta fill, may play a role in this variability. In this regard, Rodel et al. (1981) noted little difference in the efficiency of use of concentrate by steers that previously grazed a star grass (*Cynodon aethiopicus*) pasture at four SR, although steers lightest at the end of grazing showed a tendency to convert concentrate more efficiently into carcass mass during finishing. Likewise, Hornick et al. (1998b) failed to note differences in the finishing performance of Belgian Blue bulls that had grazed *Lolium perenne* and *Trifolium repens* pasture with six vs. eight animals per hectare, although in a similar experiment Dufrasne et al. (1995) noted greater live weight gain during finishing by bulls that had previously grazed at a high than low SR.

Though compensatory growth in sheep and goats has been documented, there have been less studies of compensatory growth by small ruminants than cattle. Furthermore, effects of SR as the factor influencing capacity for compensatory growth by small ruminants has not been investigated. Therefore, objectives of this experiment were to determine effects of co-grazing of grass/forb pastures at different SR on subsequent performance of sheep and goats consuming a 65% concentrate diet.

Materials and Methods

Animals and treatments

This experiment was conducted at the E (Kika) de la Garza American Institute for Goat Research of Langston University, Langston, Oklahoma, and was approved by the Langston University Animal Care Committee. There were two consecutive years (2002 and 2003) of experimentation, with each year consisting 15 weeks (September to January). The experimental periods followed 16 weeks of grazing (May to September). 27 goat (≥ 75% Boer) and 27 sheep (Khatadin) wethers were used in each year. Sheep and goats averaged 21 ± 4.8 and 21 ± 3.7 kg initial body weight (BW), respectively, and were 4 to 5 months of age when grazing began. Both sets of animals were purchased from commercial sources. Most sheep were from the same source in the two years. Goats were, however, from two different sources but were both located near Sonora, Texas. Upon arrival, wethers were quarantined for 3 weeks, vaccinated with Covexin 8 (Schering-Plough, Kinilworth, NJ), and treated for internal parasites (Ivomec® orally; Merck Ag Vet Division, Rahway, NJ). Fecal egg counts by the modified McMaster method (Stafford et al., 1994) were made with samples from two goats and two sheep per pasture every 28 days during the grazing period to ascertain need for re-treatment. These same animals were used for this experiment.

There were nine 0.4-ha (1 acre) pastures used for grazing. Pastures were randomly assigned to three SR. SR were four (4; low), six (6; moderate), and eight (8; high) animals per pasture, with equal numbers of sheep and goats. Pastures were divided into four paddocks, which were sequentially grazed in 2-week periods for an 8-week grazing cycle (2 weeks of grazing and 6 weeks of regrowth). Pastures contained a complex mixture of grasses, predominantly bermudagrass (*Cynodon dactylon*) with a lesser amount of johnsongrass (*Sorghum halepense*), and various forbs, primarily ragweed (*Ambrosia artemisiifolia*) but also including others such as *Lespedeza cuneata* and nightshade (*Solanum spp.*). Animals were allocated to nine groups for similar mean BW and variation in BW within group and species in accordance with SR, and groups were randomly assigned to the pastures. Pastures were subjected to the same SR in both years. Water and trace mineralized salt were freely available, and a shelter was situated in each pasture as well. Two sheep and two goats from each pasture were randomly selected before grazing began for use in this subsequent confinement experimental phase. Goats and sheep averaged 23 ± 2.7 and 25 ± 3.6 kg initial BW, respectively, when the confinement phase began. Wethers were treated for internal parasites as noted earlier when moved to the confinement facility. Animals were randomly assigned to pens consisting of 6 x 6 m enclosed area adjacent to a 6 x 9 m area outside. Pens were fitted with Calan gates (American Calan, Northwood, NH) and an automatic waterer.

A 65% concentrate diet was offered for ad libitum intake (110% of consumption on the preceding few days) once daily at 0800 h. Diets were formulated to contain 2.628 Mcal/kg ME (11.0 MJ/kg), 14.4% CP, 9.4% ruminally degraded CP, 0.8% calcium, and 0.4% phosphorous (Table 1). There was 1 week allowed before measurements for adaptation to experimental conditions. During this time there were gradual increases in the amount of the mixed diet offered, along with a stepwise decline in the level of grass hay fed. Also, training for use of Calan gates was provided during this period.

Measurements and laboratory analysis

Each morning feed refusals were weighed and discarded before feeding. Wethers were weighed at the beginning of the confinement phase and every 3 weeks thereafter. Intake of dry matter (DM), nitrogen (N), and NDF, average daily gain (ADG), and gain efficiency (ADG:DM intake) were determined in five 3-week periods.

The diet was sampled weekly and stored frozen. During week 8, daily grab samples of feed refusals were collected to form one composite sample per animal, with refrigeration between days. Partial DM concentration of feed and feed refusals was determined by drying in a forced-air oven at 55°C for 48 h. Thereafter, samples were ground to pass a 1-mm screen before anlysis for DM (100°C), ash, Kjeldahl N (AOAC, 1990), and NDF (filter bag technique; Ankom Technology Corp., Fairport, NY). Feedstuff samples were also analyzed for in vitro true DM digestibility (IVDMD; filter bag technique; Ankom Technology Corp.) with NDF as the end-point measure. Ruminal fluid for IVDMD was collected from three mature Boer crossbred goats grazing native grass pasture and supplemented with a moderate amount of concentrate.

Blood was sampled via jugular venipuncture into two heparinized tubes on weigh days. Samples were placed in ice until harvesting of plasma by centrifugation, with storage at –20 °C until analysis. One sample was assayed for glucose and urea N calorimetrically using a Technicon AutoAnalyzer II system (Technicon Instruments, Tarrytown, NY) and the other was for leptin. Plasma concentration of leptin was determined by radioimmunoassay (Delavaud et al., 2000) in a single run using purified recombinant ovine leptin for standards (Gertler et al., 1988), with an intraassay CV of 5%.

Energy expenditure (EE) and body composition were determined with one-half of the animals used (i.e., one animal of each species in each pasture), which had been randomly selected before grazing began. Before grazing, heat production or EE was determined over a 24-h period based on O_2 consumption and production of CO_2 and CH_4 (Brouwer, 1965) with a headbox respiration calorimetry system (Sable Systems, Henderson, NV), while simultaneously measuring heart rate (HR) with a Polar S610 monitor (Polar, Woodbury, NY). Coarsely ground alfalfa hay was consumed ad libitum during this period. The average ratio of EE:HR over the 24-h period for each animal was then used to predict EE from HR while grazing, and in weeks 3 and 9 of the confinement phase. Body composition was determined at the beginning and end of the experiment based on urea space and shrunk BW. Procedures for sheep were similar to those of Galloway et al. (1996) and Goetsch (1999) and for goats were those Wuliji et al. (2003a,b).

Statistical analyses

Animal responses to SR treatments were analyzed using mixed model procedures of SAS, assuming a compound symmetry covariance structure (Littell et al., 1996). Year was considered a fixed effect, because effects of SR in the first year of grazing could impact results in the second year. Also, as mentioned later, these pastures were not grazed in the year preceding this experiment. Because growing animals were used, the same animals could not be employed each year. However, there was effort expended to ensure that animals used in the two grazing seasons were similar in genotype, age, and body weight.

The model for intake of DM, OM, NDF, and N, BW, ADG, gain efficiency, HR, EE, and plasma concentrations of glucose, urea N, and leptin consisted of SR, species, year, 3-week period or week of sampling, and their interactions. Random effects were animal group within SR and species within group x SR, and the repeated measure was year x 3-week period or week of sampling. The model for body composition and tissue gain consisted of SR, species, year, and their interactions. Random effects were animal group within SR and species within group x SR, and the repeated measure was year. Analyses were conducted separately for species in each sampling time or period within year when there was a significant ($P < 0.10$) three-way interaction or the following two-way interactions: 1) SR x year and SR x week, or 2) year x week. Since in most instances interactions justified analysis by species, week, and year, in some other cases when these interactions were not significant data were analyzed similarly. Orthogonal contrasts were performed for linear and quadratic effects of SR.

Results and Discussion

Diet composition

The analyzed dietary CP concentration (14.1%, DM basis; Table 2) was similar to that formulated for. Also, the diet averaged 29.1% NDF, 20.7% ADF, 7.5% ash, and 85.3% IVDMD. The total digestible nutrient (TDN) concentration based on the ingredient composition of the diet and feedstuff TDN values of NRC (1996) was 72.7%. Wheat hay used for adaptation was 8.5% CP, 63.4% NDF, 40.4% ADF, 7.0% ash, and 73.0% IVDMD.

Feed intake

DM intake (DMI; Table 3) increased ($P < 0.05$) as the feeding period advanced (625, 915, 1036, 1135, and 1179 g/day for week 1-3, 4-6, 7-9, 10-12, and 13-15, respectively (SE = 36.8)), corresponding to increasing BW and the associated higher nutrient demand for maintenance. There were interactions in DMI between SR and year ($P < 0.05$) (year 1: 958, 955, and 1011 g/day; year 2: 1109, 904, and 931 g/day for low, moderate, and high SR, respectively (SE = 49.6)) and species and year ($P < 0.06$) (year 1: 1105 and 844 g/day; year 2: 1164 and 799 g/day for sheep and goats, respectively (SE = 40.5)). OM intake (OMI) was also affected ($P < 0.05$) by 3-week period (580, 845, 949, 1051, and 1091 g/day for weeks 1-3, 4-6, 7-9, 10-12, and 13-15, respectively (SE = 33.9)), and there were SR x year (year 1: 886, 884, and 935 g/day; year 2: 1022, 834, and 857 g/day for low, moderate, and high SR, respectively (SE = 45.8)) and species x year interactions ($P < 0.06$) (year 1: 1017 and 786 g/day; year 2: 1069 and 740 g/day for sheep and goats, respectively (SE = 37.4)).

There were year x SR interactions ($P < 0.05$) in intake of NDF (year 1: 335, 345, and 349 g/day; year 2: 340, 274, and 282 g/day (SE = 17.2)) and N (year 1: 26, 26, and 28 g/day; year 2: 25, 20, and 21 g/day for low, moderate, and high SR, respectively SE = 1.34)) (Table 3). There was also an interaction in NDF intake ($P < 0.05$) between year and 3-week period (year 1: 200, 389, 443, 328, and 355 g/day; year 2: 176, 270, 349, 379, and 317 g/day for week 1-3, 4-6, 7-9, 10-12, and 13-15, respectively (SE = 16.3)). Intake of N differed among 3-week periods ($P < 0.05$), generally increasing as time advanced (15, 21, 26, 30, and 30 g/day for weeks 1-3, 4-6, 7-9, 10-12, and 13-15, respectively (SE = 1.0)). As was the case for DM and OM, average NDF and N intakes were greater (P <

0.05) for sheep compared with goats. For the analysis by species, year, and week, there was a quadratic effect of SR ($P < 0.05$) on NDF intake by goats in week 4-6 of year 1 ($P < 0.05$) and a linear effect for sheep in week 1-3 of year 2 ($P < 0.09$). N intake by goats was affected by SR quadratically in week 4-6 of year 1 ($P < 0.05$), linearly in weeks 1-3 ($P < 0.07$) and 4-6 of year 2 ($P < 0.03$), and quadratically in week 10-12 of year 2 ($P < 0.05$).

Factors responsible for the SR x year interaction in DMI are unclear. ADG in the previous grazing phase was not similarly impacted by a SR x year interaction, but there was a tendency ($P < 0.10$) for ADG to linearly decrease as SR increased (61, 51, and 47 g/day for low, moderate, and high SR, respectively). Hence, as compensatory growth is often partially attributable to greater than expected feed intake based on BW, a linear increase in DMI during the confinement phase as previous SR increased might have been expected for both years. There are some studies with cattle in which increasing SR has not influenced subsequent intake of a concentrate-based diet (Dufranse et al., 1995; Hornick et al., 1998b), in accordance with findings of the present experiment in year 1. Increased intake as a percentage of mean BW during realimentation due to high prior SR has been noted as well (Hersom et al., 2004a). However, findings of Hersom et al. (2003) are similar to those of year 2. In the experiment of Hersom et al. (2003), beef steers were fed a high concentrate after being subjected to different SR on winter wheat pasture that yielded ADG of 0.68 (high SR) and 1.31 kg/day (low SR). Overall DMI in the 64-day finishing period was 16% lower for high vs low SR steers (i.e., 6.32 vs 7.49 kg/day). But, the authors did not note that DMI by steers of both treatments was less than expected under typical feedlot conditions.

Performance

Year x SR (year 1: 32.3, 32.0, and 32.6 kg; year 2: 34.8, 30.1, and 30.8 kg for low, moderate, and high SR, respectively (SE = 1.05)) and species x week (sheep: 25.2, 28.5, 33.2, 37.3, 41.5, and 44.9 kg; goat: 22.5, 23.9, 27.3, 30.2, 33.6, and 36.8 kg for week 0, 3, 6, 9, 12, and 15 respectively (SE = 1.12)) interactions ($P < 0.05$) in BW were noted (Table 4). Greater initial BW for sheep than for goats in both year 1 ($P < 0.08$) and 2 ($P < 0.05$) relates to higher ADG while grazing (69 vs. 36 g; Chapter III). BW of both sheep and goats increased as the experiment advanced; however, there was a smaller increase in goat BW in the first 3 weeks (1.4 kg) compared with other 3-week periods (2.9 to 3.4 kg) and with sheep in all periods (3.3 to 4.7 kg), which may have been largely responsible for the period x SR interaction. There were no effects of SR with the analysis by species, year, and week.

BW was similar between sheep and goats at the beginning of the grazing period (21 and 21 kg for sheep and goats, respectively; Chapter III). As noted above, the low nutritional plane during the grazing phase resulted in only a 2.7 kg BW difference at the start of this confinement phase. Conversely, the 65% concentrate diet consumed ad libitum facilitated a considerable increase in the BW difference between sheep and goats, with a magnitude of change twice that during grazing (i.e., 5.4 vs. 2.7 kg). This may reflect greater genetic potential of the sheep for growth compared with the goats used, with a potential degree of expression greater with high vs. low diet quality and nutrient intake, as well as possible differences in mature size.

There was a tendency for a four-way interaction ($P < 0.08$) in ADG involving SR, species, year, and 3-week period (Table 4). There was also a trend ($P < 0.08$) for an interaction between SR and year (year 1: 172, 160, and 177 g; year 2: 193, 147, and 142 g for low, moderate, and high SR, respectively (SE = 13.4)), and year and 3-week period interacted ($P < 0.05$) as well (year 1: 80, 241, 159, 213, and 155 g; year 2: 147, 145, 180, 158, and 173 g for week 1-3, 4-6, 7-9, 10-12, and 13-15, respectively (SE = 16.5)). Differences among SR x year means are in accordance with those in DMI. Averaged over year and period, ADG was greater for sheep vs goats (194 vs. 137 g; SE = 8.1). For the analysis by species, year, and 3-week period, SR had a quadratic effect on ADG by sheep in year 1 during weeks 1-3 ($P < 0.09$) and 10-12 ($P < 0.05$) and by goats during week 10-12 of year 2 ($P < 0.07$). Sheep had greater ADG ($P < 0.05$) than goats in weeks 4-6 and 10-12 of year 1 and week 1-3 of year 2; ADG in all other 3-week periods was numerically greater for sheep.

Gain efficiency was affected by a four-way interaction of SR, species, year, and 3-week period ($P < 0.05$; Table 4). There was also a year x 3-week period interaction ($P < 0.05$) (year 1: 86, 262, 152, 198, and 134 g/kg; year 2: 212, 117, 180, 137, and 144 g/kg for week 1-3, 4-6, 7-9, 10-12, and 13-15, respectively (SE = 23.4)). The analysis by species, year, and 3-week period revealed no effects of SR other than quadratic change ($P < 0.05$) for goats in week 10-12 of year 1. Similarly, Hersom et al. (2004a) noted that grazing of wheat pasture by beef steers at two SR to achieve high and low rates of gain did not influence gain efficiency or ADG when fed a high concentrate diet. In the present experiment, goats had greater gain efficiency ($P < 0.05$) than sheep in week 10-12 of year 2, but values were similar between species at other times.

An obvious factor contributing to higher ADG in this confinement phase than while grazing is the high digestibility of the 65% concentrate diet consumed ad libitum.

However, this difference could also be partially explained by low ADG during grazing that created potential for compensatory growth. In this regard, based on grazing phase ADG, an increase in ADG during the confinement phase with increasing previous SR could be anticipated. Perhaps the magnitude of the effect of SR on grazing ADG was inadequate to influence the degree of compensatory growth potential. But, it is possible that the fairly long grazing period of 16 weeks with relatively low ADG could have resulted in an irreversible limitation of future growth (i.e., stunting) given the fairly young age of the animals when grazing. If this occurred, then because of the tendency for grazing ADG to decrease with increasing SR, a similar effect of SR on later ADG in the confinement phase might be a likely consequence, which, in fact, was observed in year 2.

Heart rate and energy expenditure

The ratio of EE:HR measured for each animal before grazing was addressed in Chapter IV. In this experimental period while consuming the 65% concentrate diet, HR tended to be affected by a year x species x week of measurement interaction ($P < 0.09$; Table 5). Overall, HR increased ($P < 0.05$) with increasing SR (96, 100, and 105 beats/min for low, moderate, and high SR, respectively (SE = 1.4)). The analysis by species, year, and week revealed a linear increase in HR of sheep with increasing SR in week 3 of year 1 and in both weeks of year 2 ($P < 0.05$). The same was true for goats in week 9 of year 2 ($P < 0.05$), and a similar numerical effect ($P < 0.11$) occurred in week 3 as well. HR was greater ($P < 0.05$) for sheep than for goats in year 2, but was greater for goats in week 3 of year 1.

EE (Table 5) was affected by year x species ($P < 0.05$) (year 1: 574 and 574 kJ/kg $BW^{0.75}$; year 2: 658 and 569 kJ/kg $BW^{0.75}$ for sheep and goats, respectively (SE = 16.2)) and species x week of measurement interactions ($P < 0.09$) (sheep: 584 and 648 kJ/kg $BW^{0.75}$; goats: 564 and 580 kJ/kg $BW^{0.75}$ for weeks 3 and 9, respectively (SE = 16.2)). Also, EE tended to increase linearly ($P < 0.07$) with increasing SR (562, 592, and 628 kJ/kg $BW^{0.75}$ for low, moderate, and high SR, respectively (SE = 15.9)). The analysis by species, year, and week of sampling resulted in linear effects of SR for sheep in weeks 3 and 9 of year 2. Sheep had greater EE than goats in year 2 ($P < 0.05$), but values in year 1 were not different. Similarly, Hersom et al. (2004a) reported greater total heat production during a feedlot phase by steers that grazed wheat pasture at 2.45 steers/ha compared with ones grazed at 1.1 steers/ha.

Based on EE, it appears that there was a carryover effect of SR on subsequent EE in confinement, the nature of which is unclear. It is possible that increases in grazing time and number of steps with increasing SR during grazing influenced later activity in confinement. A more plausible consideration is a difference in EE by the metabolically active gastrointestinal tract and liver. Increased grazing time with increasing SR implies that splanchnic tissue EE increased during grazing (Osuji, 1974). For example, oxygen consumption and tissue protein synthetic capacity and fractional synthesis rate in duodenal tissues during a feedlot, high concentrate diet phase were greater for beef steers that had previously grazed wheat pasture at 2.45 animals/ha compared with 1.1 (Hersom et al., 2004b). However, the length of time in the confinement phase of the present experiment during which splanchnic tissue EE might have been influenced by prior SR is unknown. Hersom et al. (2003) measured blood flow and splanchnic tissue oxygen consumption at days 0, 14, 28, 42, and 64 of a high-grain finishing period, and noted overall higher hepatic blood flow and total splanchnic tissue oxygen consumption in beef steers that had previously grazed winter wheat grass at high vs. low SR. Goetsch and Aiken (1999) suggested that effects of diet composition and level of intake in a growing confinement period on later performance in a 6-week period of ad libitum intake of a concentrate-based diet were primarily attributable to differences in splanchnic tissue EE, although there was no direct measurement of splanchnic metabolism. Freetly et al. (1995) found that 21 and 29 days were required for liver and portal-drained viscera oxygen consumption in wethers fed at 70% of the maintenance requirement to return to maintenance levels, although a high quality pelleted diet was fed throughout.

Other factors could have influenced EE during confinement in addition to or rather than those mentioned above. For example, low temperature in this fall/winter period could have elevated EE (NRC, 1981; Ekpe and Christopherson, 2000); however, there seems no reason available to expect the impact of this factor to vary with prior SR. Data in Table 6 do not suggest that effect of SR on the composition of tissue being accreted influenced EE. Moreover, feed intake data do not imply that the higher amount of EE during and shortly after meals compared with other times was involved in the effect of SR on EE.

Regardless of the underlying physiological condition responsible for increasing EE in the confinement phase as prior grazing SR increased, these findings suggest that limited growth due to high SR may affect subsequent performance differently than restricted feed intake during confinement. According to relationships between efficiency of energy utilization and feed intake proposed by Tolkamp and Ketelaars (1992, 1994), if the effect of SR on EE while grazing continued for a portion of the subsequent period, then a stimulatory effect of previous high SR on confinement phase feed intake would not be expected. Rather, no change in DMI or a negative effect would be most likely, which is in agreement with findings of this experiment.

Body composition

Initial water, fat, protein, and ash concentrations (Table 6) were affected ($P < 0.05$) by species (water: 66.9 and 62.6% (SE = 0.75); fat: 12.9 and 17.4% (SE = 0.86); protein: 18.2 and 17.1% (SE = 0.18); ash: 4.3 and 2.8% for sheep and goats, respectively (SE = 0.05)) and year (water: 63.7 and 65.9% ($P < 0.08$; SE = 0.76); fat: 16.6 and 13.7% (SE = 0.86); protein: 17.4 and 17.9% ($P < 0.07$; SE = 0.18); ash: 3.5 and 3.6% for year 1 and year 2, respectively ($P < 0.07$; SE = 0.18)). Year and species interacted ($P < 0.05$) in final concentrations of water (year 1: 55.1 and 58.2%; year 2: 54.0 and 52.0% (SE = 1.11)), fat (year 1: 26.3 and 23.8%; year 2: 27.7 and 30.8% (SE = 1.40)), protein (year 1: 15.0 and 16.2%; year 2: 14.7 and 14.9% (SE = 0.29)), and ash (year 1: 3.5 and 2.6%; year 2: 3.4 and 2.3% for sheep and goats, respectively (SE = 0.06)). Overall, SR did not influence ($P > 0.10$) initial or final concentrations of water, fat, protein, or ash. But, with analysis by species and year, for sheep in year 1 there were linear increases in initial water, protein, and ash concentrations and a linear decrease in fat concentration as SR increased ($P < 0.05$). Similarly, Hersom et al. (2004a) reported greater empty body fat and lower empty body fat-free organic matter concentrations in beef steers at the end of grazing at a SR of 1.1 steers/ha compared with 2.45. They also reported no difference in empty body chemical composition at the end of the subsequent feedlot phase, in line with our observations.

Initial and final shrunk BW (Table 6) were greater ($P < 0.05$) for sheep vs. goats (initial BW: 26.4 and 23.0 kg (SE = 0.56); final BW: 45.1 and 37.8 kg (SE = 1.72)) and in year 2 than 1 (initial BW: 23.6 and 25.8 kg (SE = 0.57); final BW: 39.5 and 43.4 kg (SE = 1.72)). Shrunk BW gain was greater for sheep than for goats in year 1 ($P < 0.05$) and 2 ($P < 0.08$). Effects of SR on initial and final shrunk BW and shrunk BW gain were not significant ($P > 0.10$), but with the analysis by species and year for sheep in year 1 there was a linear decrease in initial shrunk BW as SR increased ($P < 0.05$).

Initial water, protein, and ash mass (Table 6) were affected by interactions of SR, year, and species ($P < 0.05$). There were linear decreases with increasing SR in initial water, protein, and ash mass ($P < 0.05$) of sheep in year 1 and goats in year 2. Sheep had greater ($P < 0.05$) initial water, protein, and ash mass in both years compared with goats. Final water, protein, and ash mass were affected only by species, with values greater ($P < 0.05$) for sheep than for goats (water: 24.5 and 20.7 kg (SE = 0.64); protein: 6.6 and 5.8 kg (SE = 0.19); ash: 1.54 and 0.93 kg (SE = 0.040)). SR did not affect final water, protein, or ash mass except for a quadratic effect with sheep in year 1 ($P < 0.05$). Daily accretion of water ($P < 0.05$), protein ($P < 0.07$), and ash ($P < 0.05$) were greater in year 1 vs 2 (water: 68.7 and 56.8 g (SE = 5.41); protein: 19.1 and 16.8 g (SE = 1.53); ash: 3.76 and 3.11 g (SE = 0.293)). Daily ash gain was greater ($P < 0.05$) for sheep compared with goats (4.15 and 2.72 g (SE = 0.294)). SR had little effect on daily gain values, although gains of water, protein, and ash by sheep did tend to linearly increase ($P < 0.08$) with increasing SR in year 1. Initial fat mass was not affected by SR, year, species, or their interactions ($P > 0.10$). Final fat mass and daily gain of fat were also not influenced by SR, but were affected by species (fat mass ($P < 0.06$): 12.3 and 10.5 kg (SE = 0.97); fat gain (P < 0.05): 4.2 and 2.7 g/day for sheep and goats, respectively (SE = 0.29)) and year (fat mass (P < 0.05): 10.0 and 12.8 kg (SE = 0.97); fat gain (P < 0.05): 3.8 and 3.1 g/day for year 1 and 2, respectively (SE = 0.29)).

Daily energy retention (Table 6) was affected by species and year (P < 0.05), with values greater for sheep compared with goats (3749 and 2820 kJ (SE = 340.2)) and in year 2 vs 1 (2728 and 3841 kJ (SE = 339.7)). For the analysis by species and year, daily energy gain was greater for sheep vs goats in year 1 (P < 0.05), with a numerical difference in year 2 (P > 0.10). Overall, SR had very little effect on body composition and tissue gain and differences between species relate primarily to greater ADG and shrunk BW gain by sheep vs goats.

Plasma constituents

Glucose concentration in plasma (Table 7) collected every 3 weeks was affected by three-way interactions of SR, species, and week (P < 0.06) and of year, species, and week (P < 0.05). Year and SR also interacted (P < 0.05) in glucose concentration (year 1: 58.1, 59.5, and 62.6 mg/dl; year 2: 74.0, 73.0, and 70.6 mg/dl for low, moderate, and high SR, respectively (SE = 1.30)). The analysis by species, year, and week resulted in a linear effect of SR for sheep in initial values of year 1 and in week 6 of year 2, and a quadratic effect occurred in week 12 of year 2. For goats, there were linear effects of SR in weeks 3, 6, and 12 of year 1 and a quadratic effect in initial values of year 2. Differences between species (P < 0.05) were noted in weeks 3 and 15 of year 1 and weeks 3, 6, and 9 of year 2, with greater values for sheep compared with goats. These species differences may have been a consequence of higher DMI relative to BW by sheep

(Herselman et al., 1999), with an expected greater level of ruminal production of propionate.

Year and week interacted ($P < 0.05$) in plasma urea N concentration (Table 7) (year 1: 13.8, 15.7, 15.9, 18.0, 17.6, and 13.9 mg/dl; year 2: 15.1, 17.0, 14.7, 16.9, 19.2, and 19.0 mg/dl for 0, 3, 6, 9, 12, and 15 weeks, respectively (SE = 0.85)). Particularly in year 2 urea N concentration increased as the feeding period advanced, apart from a decrease towards the end of the first year. The increase in urea N with advancing week probably was because of limited ADG during the grazing phase, which was at least partially attributable to low CP concentration in ingested forage. Hence, efficient N utilization early in this confinement phase was expected. Urea N concentration was also affected ($P < 0.06$) by species (17.0 and 15.8 mg/dl for sheep and goats, respectively (SE = 0.35)). The analysis by species, year, and week revealed a quadratic effect of SR ($P < 0.05$) for sheep in week 3 of year 1. For goats there was a linear increase in plasma urea N with increasing SR in week 9 of year 1 and week 6 of year 2 ($P < 0.09$), and quadratic changes occurred in weeks 3 ($P < 0.05$) and 9 ($P < 0.07$) of year 2.

There were SR x year ($P < 0.05$) (year 1: 7.7, 8.8, and 10.3 ng/ml; year 2: 9.4, 8.5, and 8.4 ng/ml (SE = 0.86)) and species x week of sampling (sheep: 0.8, 5.7, 12.3, 13.4, 17.9, and 20.9 ng/ml; goats: 1.2, 2.6, 5.4, 6.5, 6.9, and 10.2 ng/ml for 0, 3, 6, 9, 12, and 15 week of sampling, respectively (SE = 1.11)) interactions in plasma leptin concentration (Table 7). With the exception of the first two times of sampling in year 1 and the initial time in year 2, leptin concentration was higher for sheep compared with goats ($P < 0.05$). Leptin concentration increased as the feeding period advanced, but the magnitude of change was greater for sheep than for goats. Similarly Hersom et al.

(2004c) noted an increasing leptin blood concentration in steers as time consuming a high concentrate diet subsequent to grazing of wheat pasture at two SR advanced. Such increases in leptin with advancing time may relate to increasing energy intake, as has been shown in sheep (Blache et al., 2000; Delavaud et al., 2000) and cattle (Delavaud et al., 2002). The increasing body fat concentration would also seem involved (Chilliard et al., 2001; Delavaud et al., 2000), although it would not appear that greater change with time for sheep vs. goats was due to a difference in whole body fat concentration. There were positive correlations between BW and leptin concentration (r = 0.82 and 0.73 for sheep and goats, respectively), which may reflect the association between BW and fatness. However, again, greater leptin concentration for sheep vs. goats is not in accordance with initial and final fat concentrations, which were either similar between species or greater for goats. SR had no effect on the concentration of leptin, except for a quadratic effect in weeks 0 and 3 of year 1 and a linear effect in week 6 of year 2 for goats. In contrast, Hersom et al. (2004c) found a higher leptin level at the end of the grazing period and during the feedlot phase in steers grazed at low SR compared with a higher SR.

Summary and Conclusions

In summary, intake of a 65% concentrate diet in a 15-week confinement period subsequent to 16 weeks of co-grazing of sheep and goats at low, moderate, or high SR, with a trend for grazing ADG to decrease as SR increased, did not increase with increasing SR. In fact, DMI and ADG were similar among SR in year 1 and lower for moderate and high SR vs. low SR in year 2. Relatedly, EE tended to increase linearly with increasing prior SR, indicating a carryover effect that presumably influenced ADG and possibly impacted DMI as well. In conclusion, SR during grazing influenced subsequent performance of sheep and goats consuming a concentrate-based diet. Effects of SR on ADG during grazing by small ruminants may not necessarily be compensated for later with a high quality diet and, in fact, negative effects of high SR during grazing may in some cases continue.

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Table 1
Ingredient composition of the diet consumed by goats and sheep after co-grazing mixed grass/forb pastures at three stocking rates

Ingredient	DM (%)
Coarsely ground alfalfa hay	35.00
Ground corn	55.50
Soybean Meal	3.50
Molasses	3.00
Dicalcium phosphate	0.72
Limestone	0.28
Vitamin premix[1]	0.50
Trace mineralized salt[2]	0.50
Ammonium chloride	0.50
Sodium sulfate	0.50

[1]Contained 2200 IU Vitamin A, 1200 IU Vitamin D_3, and 2.2 IU Vitamin E per gram.

[2]Contained 95-98.5% NaCl and at least 0.24% Mn, 0.24% Fe, 0.05% Mg, 0.032% Cu, 0.011% Co, 0.007% I, and 0.005% Zn.

Table 2
Composition of feedstuffs consumed by goats and sheep after co-grazing grass/forb pastures at three stocking rates

Year	Week	Feedstuff	DM[a]	Ash[b]	NDF[b]	ADF[b]	N[b]	IVDMD[c]
1	0	Wheat hay	84.0	6.6	62.2	40.4	1.30	67.7
	1	Concentrate diet	85.2	6.8	26.2	16.7	2.35	89.8
	2	Concentrate diet	85.3	6.8	29.6	19.8	2.38	86.8
	3	Concentrate diet	85.6	7.2	27.9	19.6	2.46	86.3
	4	Concentrate diet	85.4	6.4	31.8	21.9	2.11	84.3
	5	Concentrate diet	83.3	7.0	39.6	28.2	2.26	78.7
	6	Concentrate diet	82.9	7.4	33.8	23.3	2.33	83.6
	7	Concentrate diet	82.3	8.8	35.0	27.7	2.50	78.7
	8	Concentrate diet	83.3	8.0	36.3	26.7	2.49	80.3
	9	Concentrate diet	82.0	7.0	38.4	27.6	2.21	77.1
	10	Concentrate diet	84.0	9.2	32.3	23.2	2.79	84.6
	11	Concentrate diet	85.5	6.2	27.0	19.4	2.51	87.4
	12	Concentrate diet	83.2	6.9	29.0	20.5	2.41	86.0
	13	Concentrate diet	82.8	6.7	29.2	22.8	2.62	85.9
	14	Concentrate diet	83.8	6.0	30.0	23.5	2.43	86.1
	15	Concentrate diet	85.0	7.1	28.5	21.4	2.65	86.5
2	0	Wheat hay	82.3	7.3	64.6	40.5	1.41	78.3
	1	Concentrate diet	83.2	7.5	25.9	18.8	2.16	87.6
	2	Concentrate diet	86.4	7.0	25.4	18.8	2.01	88.4
	3	Concentrate diet	86.4	7.3	24.6	16.8	1.94	88.0
	4	Concentrate diet	86.6	7.1	26.7	20.8	1.84	86.8
	5	Concentrate diet	86.8	9.0	26.7	17.3	2.10	87.9
	6	Concentrate diet	86.8	8.3	28.5	19.9	2.14	85.6
	7	Concentrate diet	86.5	6.0	29.4	21.2	2.13	84.5
	8	Concentrate diet	87.4	8.4	28.7	19.3	2.12	87.6
	9	Concentrate diet	86.7	9.9	27.5	20.8	2.22	86.8
	10	Concentrate diet	86.6	6.1	27.9	19.3	2.00	88.0
	11	Concentrate diet	86.0	8.5	27.1	18.5	2.29	88.3
	12	Concentrate diet	84.5	8.0	27.6	18.0	2.11	88.9
	13	Concentrate diet	85.5	10.5	23.7	17.5	2.17	89.0
	14	Concentrate diet	86.5	7.6	25.3	17.2	2.03	89.7
	15	Concentrate diet	86.5	6.9	22.4	14.6	2.00	88.5

[a]%.

[b]% DM.

[c]In vitro DM digestion, %; filter bag technique with NDF as the end-point measure.

Table 3
Means of intake of DM, OM, NDF, and N by goats and sheep during a concentrate-based diet feeding phase after co-grazing grass/forb pastures at three stocking rates

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
DM intake (g/day)[4]	1	1-3	Goat	514	616	612	64.2	0.30	0.52			
			Sheep	727	613	762	90.4	0.78	0.29			
			Mean	621	615	687	56.8	0.43	0.60	580	712	43.3
		4-6	Goat	741	949	764	68.7	0.82	0.04			
			Sheep	1159	960	1258	128.5	0.57	0.17			
			Mean	950	953	1011	102.0	0.68	0.84	818a	1146b	59.4
		7-9	Goat	812	1000	863	84.3	0.68	0.14			
			Sheep	1236	1013	1230	137.9	0.98	0.25			
			Mean	1024	1005	1047	112.2	0.89	0.84	892a	1178b	71.5
		10-12	Goat	862	981	961	81.4	0.41	0.50			
			Sheep	1313	1254	1255	135.1	0.76	0.87			
			Mean	1087	1090	1108	114.7	0.90	0.97	935a	1276b	65.5
		13-15	Goat	953	1017	1015	93.8	0.65	0.78			
			Sheep	1259	1287	1388	153.7	0.54	0.86			
			Mean	1106	1125	1201	106.4	0.55	0.85	995a	1314b	67.3
	2	1-3	Goat	454	477	417	79.7	0.76	0.67			
			Sheep	917	786	640	100.4	0.08	0.96			
			Mean	685	631	535	86.9	0.28	0.85	451a	781b	53.4
		4-6	Goat	728	681	644	112.4	0.62	0.97			
			Sheep	1301	932	889	123.1	0.04	0.30			
			Mean	1015	806	775	106.6	0.17	0.53	686a	1041b	72.4

Table 3, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		7-9	Goat	963	821	773	105.7	0.24	0.72			
			Sheep	1454	1081	1216	154.3	0.30	0.20			
			Mean	1209	951	1014	113.3	0.28	0.29	857a	1251b	78.6
		10-12	Goat	1083	960	936	72.4	0.19	0.59			
			Sheep	1521	1143	1381	118.6	0.42	0.06			
			Mean	1302	1052	1175	97.2	0.40	0.17	997a	1348b	63.4
		13-15	Goat	1107	973	989	83.9	0.35	0.48			
			Sheep	1564	1190	1443	138.0	0.55	0.09			
			Mean	1335	1082	1232	106.2	0.53	0.17	1026a	1399b	70.2
OM intake (g/day)[5]	1	1-3	Goat	478	572	568	58.6	0.30	0.51			
			Sheep	671	567	702	83.0	0.78	0.30			
			Mean	574	570	635	51.9	0.43	0.62	539	657	39.7
		4-6	Goat	693	886	715	63.4	0.82	0.04			
			Sheep	1073	886	1160	118.4	0.59	0.17			
			Mean	883	886	937	92.5	0.69	0.84	765a	1059b	54.7
		7-9	Goat	746	924	793	78.3	0.68	0.13			
			Sheep	1125	918	1118	125.9	0.97	0.25			
			Mean	935	922	955	101.4	0.89	0.87	821a	1071b	65.9
		10-12	Goat	802	916	893	75.7	0.42	0.47			
			Sheep	1210	1151	1155	124.6	0.75	0.85			
			Mean	1006	1010	1024	104.4	0.91	0.98	870a	1174b	60.8
		13-15	Goat	894	956	952	87.7	0.65	0.77			
			Sheep	1174	1195	1290	142.9	0.55	0.85			
			Mean	1034	1052	1121	100.9	0.56	0.85	934a	1222b	62.6

Table 3, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
	2	1-3	Goat	426	445	390	73.3	0.74	0.68			
			Sheep	848	728	593	91.7	0.07	0.95			
			Mean	637	587	498	79.4	0.27	0.85	422a	723b	49.0
		4-6	Goat	671	632	595	103.1	0.62	1.00			
			Sheep	1190	855	813	112.0	0.04	0.31			
			Mean	931	744	711	96.5	0.17	0.54	634a	953b	66.0
		7-9	Goat	886	758	713	97.9	0.24	0.74			
			Sheep	1333	990	1112	141.3	0.29	0.20			
			Mean	1110	874	930	103.1	0.27	0.29	790a	1145b	72.2
		10-12	Goat	1008	894	870	67.0	0.18	0.59			
			Sheep	1407	1057	1272	110.1	0.40	0.06			
			Mean	1208	976	1086	86.6	0.38	0.17	928a	1246b	58.8
		13-15	Goat	1018	898	910	76.0	0.34	0.49			
			Sheep	1430	1087	1318	125.6	0.54	0.09			
			Mean	1224	992	1128	95.7	0.51	0.13	944a	1278b	64.0
NDF intake (g/day)[6]	1	1-3	Goat	159	196	186	22.2	0.41	0.41			
			Sheep	231	193	242	29.7	0.78	0.29			
			Mean	195	195	214	19.2	0.50	0.71	180	225	24.5
		4-6	Goat	301	383	297	29.5	0.92	0.04			
			Sheep	461	398	505	51.4	0.53	0.24			
			Mean	381	389	401	41.6	0.75	0.97	327a	462b	24.0
		7-9	Goat	360	437	366	39.1	0.92	0.15			
			Sheep	526	457	520	52.0	0.94	0.36			
			Mean	443	445	443	45.1	1.00	0.97	388a	506b	28.2

Table 3, Continued

Item	Year	Week[3]	Species	Treatment[1]				Effect[2]		Species		
				4	6	8	SE	L	Q	Goat	Sheep	SE
		10-12	Goat	253	297	279	28.5	0.53	0.38			
			Sheep	388	396	363	39.3	0.65	0.70			
			Mean	320	337	321	35.1	0.99	0.73	276a	381b	20.2
		13-15	Goat	293	320	305	32.8	0.81	0.61			
			Sheep	382	414	424	48.8	0.53	0.87			
			Mean	337	358	364	33.7	0.59	0.88	306a	405b	22.1
	2	1-3	Goat	130	136	113	22.9	0.62	0.61			
			Sheep	266	224	188	30.5	0.09	0.95			
			Mean	198	180	152	25.9	0.27	0.89	127a	226b	15.8
		4-6	Goat	229	212	197	36.9	0.56	1.00			
			Sheep	409	289	288	40.3	0.05	0.25			
			Mean	319	251	245	35.3	0.19	0.50	213a	329b	24.1
		7-9	Goat	322	276	250	39.0	0.23	0.84			
			Sheep	483	354	410	53.9	0.36	0.18			
			Mean	403	315	337	39.3	0.29	0.30	285a	416b	27.8
		10-12	Goat	355	314	295	27.6	0.16	0.76			
			Sheep	495	364	453	41.8	0.49	0.05			
			Mean	425	339	380	33.7	0.39	0.18	323a	438b	23.0
		13-15	Goat	290	257	244	26.2	0.25	0.76			
			Sheep	417	309	389	43.4	0.65	0.10			
			Mean	354	283	322	32.5	0.52	0.22	265a	372b	22.1
N intake (g/day)[7]	1	1-3	Goat	13	16	16	1.8	0.32	0.55			
			Sheep	20	16	21	2.6	0.75	0.25			
			Mean	17	16	18	1.6	0.44	0.54	15a	19b	1.2

Table 3, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		4-6	Goat	17	22	18	1.9	0.73	0.04			
			Sheep	29	24	32	3.4	0.47	0.16			
			Mean	23	23	25	3.0	0.62	0.82	19a	29b	1.6
		7-9	Goat	21	25	23	2.3	0.61	0.25			
			Sheep	34	28	35	4.1	0.94	0.24			
			Mean	27	26	29	3.4	0.83	0.67	23a	33b	2.0
		10-12	Goat	24	27	27	2.4	0.37	0.73			
			Sheep	39	37	38	4.1	0.84	0.85			
			Mean	31	31	32	3.7	0.86	0.83	26a	38b	2.0
		13-15	Goat	28	29	30	2.7	0.62	0.96			
			Sheep	38	39	42	4.3	0.49	0.84			
			Mean	33	33	36	3.5	0.54	0.75	29a	40b	2.0
	2	1-3	Goat	9	10	9	1.8	0.71	0.59			
			Sheep	21	18	14	2.4	0.07	0.99			
			Mean	15	14	12	2.1	0.28	0.84	9a	18b	1.2
		4-6	Goat	15	14	13	2.4	0.50	0.88			
			Sheep	29	20	20	2.8	0.03	0.26			
			Mean	22	17	16	2.6	0.17	0.48	14a	23b	1.6
		7-9	Goat	22	19	17	2.3	0.14	0.68			
			Sheep	35	26	29	3.7	0.28	0.21			
			Mean	29	22	24	2.9	0.26	0.31	19a	30b	1.9
		10-12	Goat	25	22	21	1.5	0.11	0.57			
			Sheep	36	27	33	2.8	0.45	0.05			
			Mean	31	25	28	2.5	0.43	0.20	23a	32b	1.5

Table 3, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		13-15	Goat	24	20	21	1.9	0.26	0.44			
			Sheep	36	27	32	3.3	0.50	0.11			
			Mean	30	24	27	2.7	0.49	0.22	22a	32b	1.7

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Week of the 16-week grazing period

[4]DM intake = significant effects of species, week, treatment x year ($P < 0.05$), and species x year ($P < 0.06$).

[5]OM intake = significant effects of species, week, treatment x year ($P < 0.05$), and species x year ($P < 0.06$).

[6]NDF intake = significant effects ($P < 0.05$) of species, year, week, treatment x year, and year x week.

[7]N intake = significant effects ($P < 0.05$) of species, year, week, and treatment x year.

Table 4
Means of body weight, average daily gain and gain efficiency of goats and sheep during concentrate-based diet feeding phase after co-grazing grass/forb pastures at three stocking rates

				Treatment[1]				Effect[2]		Species		
Item	Year	Week[3]	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
Body weight (kg)[4]	1	0	Goat	21.9	24.2	22.5	1.10	0.72	0.17			
			Sheep	25.2	25.1	24.9	1.81	0.92	0.98			
			Mean	23.5	24.5	23.7	1.27	0.93	0.62	22.9	25.1	0.84
		3	Goat	22.3	25.9	23.5	1.67	0.65	0.17			
			Sheep	28.8	25.1	28.4	2.75	0.92	0.35			
			Mean	25.6	25.5	25.9	1.66	0.88	0.94	23.9	27.9	1.24
		6	Goat	26.5	30.1	27.8	1.50	0.56	0.14			
			Sheep	34.6	31.6	33.7	2.55	0.81	0.46			
			Mean	30.5	30.7	30.8	1.77	0.94	0.99	28.2a	33.5b	1.14
		9	Goat	29.0	33.1	30.7	1.75	0.50	0.16			
			Sheep	38.8	34.8	38.0	3.37	0.85	0.39			
			Mean	33.9	33.8	34.3	2.18	0.89	0.91	30.9a	37.5b	1.35
		12	Goat	33.2	35.6	34.8	2.04	0.59	0.53			
			Sheep	43.7	41.5	42.5	3.14	0.79	0.71			
			Mean	38.4	38.0	38.6	2.49	0.95	0.87	34.5a	42.7b	1.40
		15	Goat	36.8	38.3	37.9	2.07	0.71	0.71			
			Sheep	46.5	44.7	46.6	3.42	0.99	0.69			
			Mean	41.6	40.9	42.2	2.65	0.88	0.77	37.7a	46.1b	1.49
	2	0	Goat	23.3	21.7	21.6	1.17	0.35	0.59			
			Sheep	26.1	23.4	26.3	1.42	0.94	0.13			
			Mean	24.7	22.5	24.2	1.01	0.74	0.17	22.2a	25.3b	0.76

Table 4, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		3	Goat	25.5	23.6	23.1	1.62	0.32	0.71			
			Sheep	32.1	28.1	28.5	1.94	0.22	0.37			
			Mean	28.8	25.8	26.0	1.48	0.25	0.41	24.1a	29.5b	1.04
		6	Goat	28.4	25.7	25.2	2.30	0.36	0.69			
			Sheep	37.0	30.2	32.7	2.56	0.26	0.17			
			Mean	32.7	27.9	29.3	1.98	0.28	0.26	26.5a	33.3b	1.46
		9	Goat	31.6	28.9	28.1	2.30	0.31	0.74			
			Sheep	42.1	34.6	36.6	3.11	0.24	0.24			
			Mean	36.8	31.7	32.7	2.30	0.26	0.33	29.6a	37.7b	1.64
		12	Goat	35.3	32.0	30.9	2.42	0.23	0.73			
			Sheep	46.1	37.5	39.9	3.37	0.22	0.21			
			Mean	40.7	34.7	35.8	2.40	0.21	0.28	32.8a	41.1b	1.76
		15	Goat	39.2	34.6	34.5	2.46	0.22	0.45			
			Sheep	50.8	41.2	43.2	3.95	0.20	0.26			
			Mean	45.0	37.9	39.2	2.65	0.18	0.24	36.2a	45.1b	1.99
ADG (g/day)[5]	1	1-3	Goat	20	81	45	39.9	0.66	0.34			
			Sheep	171	-4	164	70.6	0.94	0.09			
			Mean	96	47	105	41.7	0.88	0.36	49	125	32.7
		4-6	Goat	200	202	208	35.6	0.88	0.98			
			Sheep	275	310	254	41.5	0.71	0.43			
			Mean	238	245	231	31.1	0.88	0.80	203a	275b	21.0
		7-9	Goat	117	141	138	23.6	0.54	0.64			
			Sheep	200	155	202	36.8	0.97	0.36			
			Mean	158	147	170	25.2	0.75	0.61	132	190	17.2

Table 4, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		10-12	Goat	199	119	193	28.5	0.88	0.05			
			Sheep	234	319	217	24.1	0.61	0.02			
			Mean	217	196	205	34.2	0.82	0.75	170a	249b	21.2
		13-15	Goat	170	130	149	35.5	0.68	0.51			
			Sheep	135	152	194	39.9	0.29	0.83			
			Mean	153	139	171	25.8	0.62	0.51	150	161	20.8
	2	1-3	Goat	108	90	70	39.1	0.52	0.98			
			Sheep	282	225	105	44.9	0.02	0.58			
			Mean	195	158	89	36.2	0.09	0.74	91a	204b	26.5
		4-6	Goat	136	100	101	45.7	0.62	0.75			
			Sheep	234	103	199	70.0	0.73	0.21			
			Mean	185	102	155	42.1	0.64	0.24	113	179	33.9
		7-9	Goat	152	155	139	20.0	0.67	0.71			
			Sheep	242	206	184	44.1	0.38	0.91			
			Mean	197	181	164	25.8	0.41	1.00	149	211	19.5
		10-12	Goat	178	148	130	16.8	0.07	0.79			
			Sheep	193	138	158	23.0	0.31	0.21			
			Mean	185	143	145	14.0	0.10	0.25	154	163	12.1
		13-15	Goat	186	121	174	37.9	0.84	0.22			
			Sheep	223	179	157	35.2	0.21	0.81			
			Mean	204	150	165	26.3	0.34	0.33	159	187	21.2
Gain efficiency (g/kg)[6]	1	1-3	Goat	16	85	57	71.9	0.71	0.60			
			Sheep	171	-32	217	89.4	0.72	0.12			
			Mean	94	26	137	56.8	0.61	0.28	53	119	46.5

Table 4, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		4-6	Goat	265	214	276	33.7	0.82	0.23			
			Sheep	259	349	208	50.0	0.48	0.14			
			Mean	262	282	242	29.5	0.66	0.47	252	272	24.1
		7-9	Goat	144	147	158	27.3	0.74	0.92			
			Sheep	152	147	161	27.8	0.80	0.79			
			Mean	148	147	159	18.1	0.67	0.79	150	154	14.8
		10-12	Goat	229	116	200	20.6	0.36	0.01			
			Sheep	195	272	172	37.6	0.67	0.14			
			Mean	212	189	186	24.0	0.47	0.75	182	210	16.9
		13-15	Goat	179	123	145	26.2	0.41	0.27			
			Sheep	101	113	141	30.4	0.35	0.85			
			Mean	140	118	143	18.7	0.89	0.37	149	118	15.3
	2	1-3	Goat	232	160	143	82.4	0.49	0.80			
			Sheep	312	288	137	81.9	0.19	0.55			
			Mean	272	224	139	57.0	0.16	0.80	178	246	46.6
		4-6	Goat	159	115	85	82.5	0.56	0.95			
			Sheep	176	-71	238	135.7	0.76	0.15			
			Mean	168	22	162	80.7	0.97	0.20	120	114	65.9
		7-9	Goat	168	201	205	37.4	0.53	0.76			
			Sheep	170	222	114	47.2	0.44	0.22			
			Mean	169	212	159	30.7	0.83	0.25	191	169	24.8
		10-12	Goat	167	152	143	17.9	0.38	0.89			
			Sheep	126	126	110	15.1	0.50	0.71			
			Mean	147	139	126	13.1	0.32	0.89	154b	121a	9.7

Table 4, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		13-15	Goat	165	118	180	36.9	0.78	0.27			
			Sheep	139	157	103	21.5	0.29	0.22			
			Mean	152	138	141	27.5	0.80	0.81	154	133	18.9
Gain efficiency[7]	1		Goat	183	146	173	15.8	0.67	0.16			
			Sheep	180	182	177	9.7	0.84	0.82			
			Mean	182	164	175	9.7	0.64	0.31	168	180	7.9
	2		Goat	174	152	166	12.0	0.68	0.28			
			Sheep	173	162	135	15.2	0.13	0.68			
			Mean	173	157	151	9.3	0.15	0.70	164	157	7.6

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Week of the 16-week grazing period.

[4]Body weight = significant effects ($P < 0.05$) of species, week, treatment x year, and species x week.

[5]ADG = average daily gain; significant effects of species, week, year x week ($P < 0.05$), treatment x year ($P < 0.08$), and treatment x species x year x week ($P < 0.08$).

[6]Gain efficiency = g ADG/kg DM intake; significant effects ($P < 0.05$) of year x week, and treatment x year x species x week.

[7]Averaged over week.

Table 5
Means of heart rate and energy expenditure of goats and sheep during a concentrate-based diet feeding phase after co-grazing grass/forb pastures at three stocking rates

				Treatment[1]				Effect[2]		Species		
Item	Year	Week[3]	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
Heart rate (beats/min)[4]	1	3	Goat	100	95	99	4.1	0.87	0.41			
			Sheep	81	91	93	3.4	0.05	0.45			
			Mean	91	93	96	3.6	0.32	0.90	98b	88a	2.3
		9	Goat	100	101	99	4.5	0.85	0.74			
			Sheep	101	105	111	10.4	0.49	0.91			
			Mean	101	103	105	5.1	0.55	0.99	100	106	3.9
	2	3	Goat	92	97	99	2.6	0.11	0.60			
			Sheep	99	102	116	3.2	0.01	0.22			
			Mean	95	100	108	3.0	0.04	0.66	96a	106b	2.5
		9	Goat	92	100	104	3.3	0.05	0.73			
			Sheep	104	112	114	3.4	0.08	0.51			
			Mean	98	106	109	3.3	0.06	0.60	99a	110b	2.4
EE (kJ/kg $BW^{0.75}$)[5]	1	3	Goat	559	529	611	27.4	0.23	0.15			
			Sheep	481	546	541	22.2	0.11	0.24			
			Mean	520	538	576	21.0	0.11	0.70	566	523	16.9
		9	Goat	573	564	610	40.4	0.54	0.60			
			Sheep	596	636	652	76.1	0.60	0.91			
			Mean	584	593	631	38.1	0.41	0.77	582	627	29.8
	2	3	Goat	536	582	566	24.2	0.42	0.33			
			Sheep	590	614	729	28.3	0.02	0.24			
			Mean	563	598	648	28.1	0.08	0.84	561a	644b	20.7

Table 5, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		9	Goat	541	596	596	33.2	0.29	0.53			
			Sheep	620	674	718	27.9	0.05	0.88			
			Mean	581	635	657	28.9	0.12	0.66	577a	671b	19.4

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Week of the 16-week grazing period

[4]Heart rate = significant effects of treatment, year, week, year x species, species x week ($P < 0.05$), species ($P < 0.08$), and year x species x week ($P < 0.09$).

[5]EE = energy expenditure; significant effects of year, week, year x species ($P < 0.05$), treatment ($P < 0.07$), species ($P < 0.06$), and species x week ($P < 0.09$).

Table 6
Means of body weight and tissue concentration and gain of goats and sheep during a concentrate-based diet feeding phase after co-grazing grass/forb pastures at three stocking rates

Item	Year	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
Initial concentration											
Water (% BW)[3]	1	Goat	60.0	62.0	62.5	0.86	0.11	0.51			
		Sheep	63.2	64.9	69.3	1.45	0.03	0.51			
		Mean	61.6	63.2	66.6	1.30	0.04	0.59	61.4	66.1	0.94
	2	Goat	66.1	62.0	62.8	1.82	0.25	0.32			
		Sheep	65.3	71.0	67.9	3.20	0.65	0.31			
		Mean	65.8	66.5	64.1	2.08	0.61	0.55	63.7	68.6	1.38
Fat (% BW)[4]	1	Goat	19.8	17.8	17.3	0.90	0.12	0.52			
		Sheep	18.0	15.9	10.7	1.82	0.03	0.56			
		Mean	18.9	17.0	13.4	1.29	0.03	0.60	18.4	14.6	1.11
	2	Goat	14.3	18.1	17.1	1.98	0.35	0.37			
		Sheep	14.7	7.4	10.6	3.66	0.54	0.29			
		Mean	14.4	12.8	15.5	2.41	0.78	0.47	16.5	10.4	1.55
Protein (% BW)[5]	1	Goat	16.6	17.0	17.1	0.17	0.11	0.51			
		Sheep	17.2	17.6	18.8	0.40	0.03	0.51			
		Mean	16.9	17.2	18.1	0.32	0.03	0.54	16.9a	17.9b	0.25
	2	Goat	17.8	17.0	17.2	0.35	0.26	0.32			
		Sheep	17.7	19.3	18.5	0.87	0.65	0.31			
		Mean	17.8	18.1	17.5	0.51	0.73	0.42	17.3a	18.6b	0.33
Ash (% BW)[6]	1	Goat	2.7	2.8	2.8	0.04	0.11	0.52			
		Sheep	4.0	4.1	4.4	0.09	0.03	0.51			
		Mean	3.4	3.3	3.8	0.34	0.42	0.59	2.8a	4.2b	0.06

Table 6, Continued

Item	Year	Species	Treatment[1]			SE	Effect[2]		Species		
			4	6	8	SE	L	Q	Goat	Sheep	SE
	2	Goat	3.0	2.8	2.8	0.08	0.25	0.32			
		Sheep	4.2	4.5	4.3	0.20	0.65	0.31			
		Mean	3.4	3.6	3.2	0.37	0.68	0.48	2.9a	4.4b	0.08
Final concentration											
Water (% BW)[7]	1	Goat	60.8	57.1	57.0	1.82	0.21	0.44			
		Sheep	54.0	54.6	55.6	1.74	0.51	0.95			
		Mean	57.4	56.2	56.1	1.62	0.60	0.78	58.5b	54.8a	0.99
	2	Goat	50.9	51.3	53.9	1.44	0.22	0.57			
		Sheep	51.8	55.2	53.3	3.76	0.82	0.58			
		Mean	51.5	53.3	53.8	1.90	0.47	0.79	51.8	54.2	1.19
Fat (% BW)[8]	1	Goat	21.0	25.3	25.1	2.13	0.24	0.42			
		Sheep	27.9	26.7	25.6	2.28	0.49	0.98			
		Mean	24.4	25.7	25.5	1.91	0.72	0.77	23.6	26.7	1.21
	2	Goat	32.1	31.8	28.5	1.95	0.26	0.55			
		Sheep	30.4	26.2	28.5	4.66	0.82	0.58			
		Mean	31.2	29.0	28.5	2.45	0.50	0.79	31.1b	27.3a	1.51
Protein (% BW)[9]	1	Goat	16.7	16.0	16.0	0.37	0.22	0.44			
		Sheep	14.7	14.8	15.1	0.47	0.51	0.95			
		Mean	15.7	15.5	15.4	0.45	0.70	0.93	16.3b	14.9a	0.23
	2	Goat	14.6	14.7	15.3	0.32	0.22	0.58			
		Sheep	14.1	15.0	14.5	1.02	0.82	0.58			
		Mean	14.5	14.9	15.1	0.52	0.49	0.93	14.8	14.7	0.31

Table 6, Continued

Item	Year	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
Ash (% BW)[10]	1	Goat	2.7	2.6	2.6	0.08	0.21	0.44			
		Sheep	3.4	3.5	3.5	0.11	0.51	0.95			
		Mean	3.1	2.9	3.1	0.21	0.84	0.52	2.6a	3.5b	0.05
	2	Goat	2.3	2.3	2.4	0.06	0.21	0.57			
		Sheep	3.3	3.5	3.4	0.24	0.82	0.58			
		Mean	2.7	2.9	2.7	0.30	0.92	0.61	2.3a	3.4b	0.07
Initial mass											
Shrunk BW (kg)[11]	1	Goat	22.1	21.8	21.9	0.52	0.76	0.80			
		Sheep	26.9	26.0	23.0	0.64	0.01	0.27			
		Mean	24.5	23.5	22.5	0.98	0.20	0.99	21.9a	25.2b	0.55
	2	Goat	25.2	23.8	22.9	1.31	0.25	0.90			
		Sheep	28.0	25.6	29.1	2.76	0.82	0.41			
		Mean	26.3	24.7	24.4	1.44	0.41	0.74	24.0	26.9	0.97
Water mass (kg)[12]	1	Goat	13.3	13.5	13.7	0.22	0.30	0.83			
		Sheep	17.0	16.9	15.9	0.14	0.01	0.07			
		Mean	15.1	14.9	15.0	0.77	0.92	0.85	13.5a	16.6b	0.17
	2	Goat	16.6	14.7	14.4	0.47	0.02	0.25			
		Sheep	18.2	18.1	19.8	1.13	0.46	0.51			
		Mean	17.2	16.4	15.7	0.94	0.32	0.95	15.2a	18.4b	0.48
Fat mass (kg)	1	Goat	4.4	3.9	3.8	0.28	0.21	0.58			
		Sheep	4.9	4.1	2.5	0.53	0.02	0.55			
		Mean	4.6	4.0	3.0	0.33	0.02	0.71	4.0	3.8	0.35

Table 6, Continued

Item	Year	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
	2	Goat	3.7	4.4	3.9	0.70	0.83	0.56			
		Sheep	4.2	2.0	3.1	1.19	0.62	0.32			
		Mean	3.9	3.2	3.7	0.65	0.88	0.47	4.0	2.9	0.49
Protein mass (kg)[13]	1	Goat	3.7	3.7	3.7	0.06	0.52	0.96			
		Sheep	4.6	4.6	4.3	0.04	0.01	0.07			
		Mean	4.1	4.1	4.1	0.20	0.85	0.51	3.7a	4.5b	0.05
	2	Goat	4.5	4.0	3.9	0.15	0.05	0.44			
		Sheep	4.9	4.9	5.4	0.31	0.46	0.51			
		Mean	4.7	4.5	4.3	0.26	0.37	1.00	4.1a	5.0b	0.13
Ash mass (kg)[14]	1	Goat	0.60	0.61	0.61	0.009	0.30	0.83			
		Sheep	1.08	1.07	1.01	0.009	0.01	0.07			
		Mean	0.84	0.79	0.85	0.108	0.93	0.72	0.60a	1.05b	0.009
	2	Goat	0.74	0.66	0.64	0.021	0.02	0.25			
		Sheep	1.16	1.15	1.26	0.072	0.46	0.51			
		Mean	0.91	0.90	0.80	0.122	0.56	0.74	0.68a	1.17b	0.025
Final mass											
Shrunk BW (kg)[15]	1	Goat	33.6	36.8	35.5	2.56	0.64	0.50			
		Sheep	43.9	46.4	43.1	1.69	0.75	0.25			
		Mean	38.7	40.6	40.1	2.58	0.73	0.72	35.4a	43.9b	1.15
	2	Goat	40.7	41.4	37.2	2.86	0.44	0.50			
		Sheep	46.7	45.6	45.9	7.56	0.84	0.86			
		Mean	43.0	43.5	39.8	4.25	0.64	0.69	40.1a	45.9b	2.22

Table 6, Continued

Item	Year	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
Water mass (kg)[16]	1	Goat	20.4	20.9	20.2	1.16	0.92	0.67			
		Sheep	23.6	25.3	24.0	0.41	0.50	0.04			
		Mean	22.0	22.7	22.5	1.04	0.76	0.73	20.7a	23.9b	0.48
	2	Goat	20.6	21.2	20.0	0.94	0.70	0.47			
		Sheep	25.2	24.7	24.5	2.86	0.89	0.97			
		Mean	22.4	23.0	21.5	1.58	0.73	0.60	20.7a	24.7b	0.80
Fat mass (kg)[17]	1	Goat	7.1	9.4	9.0	1.30	0.38	0.41			
		Sheep	12.4	12.4	11.1	1.45	0.52	0.76			
		Mean	9.7	10.6	10.2	1.24	0.80	0.71	8.4a	11.8b	0.73
	2	Goat	13.2	13.3	10.6	1.68	0.34	0.53			
		Sheep	14.8	12.4	13.1	4.10	0.82	0.77			
		Mean	13.3	12.8	11.3	2.23	0.58	0.85	12.6	12.9	1.25
Protein mass (kg)[18]	1	Goat	5.6	5.9	5.7	0.34	0.94	0.61			
		Sheep	6.4	6.9	6.5	0.11	0.50	0.04			
		Mean	6.0	6.3	6.2	0.26	0.68	0.61	5.8a	6.5b	0.14
	2	Goat	5.9	6.1	5.7	0.30	0.61	0.47			
		Sheep	6.9	6.7	6.7	0.78	0.89	0.97			
		Mean	6.2	6.4	6.0	0.43	0.74	0.59	5.9a	6.7b	0.23
Ash mass (kg)[19]	1	Goat	0.91	0.94	0.91	0.052	0.92	0.67			
		Sheep	1.50	1.61	1.52	0.027	0.50	0.04			
		Mean	1.21	1.21	1.28	0.150	0.75	0.87	0.93a	1.52b	0.024
	2	Goat	0.92	0.95	0.90	0.042	0.70	0.47			
		Sheep	1.60	1.57	1.57	0.182	0.89	0.97			
		Mean	1.20	1.26	1.12	0.183	0.80	0.64	0.93a	1.57b	0.048

Table 6, Continued

Item	Year	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
Daily gain											
Shrunk BW (g)[20]	1	Goat	109.3	142.6	129.8	25.57	0.61	0.49			
		Sheep	161.2	193.4	191.5	18.87	0.28	0.43			
		Mean	135.3	157.3	169.7	23.33	0.34	0.88	129.6a	176.8b	11.97
	2	Goat	147.3	167.3	136.7	19.92	0.74	0.34			
		Sheep	197.1	190.2	160.0	48.57	0.67	0.85			
		Mean	160.0	178.7	144.2	28.07	0.71	0.45	152.1	181.0	14.85
Water (g)[21]	1	Goat	67.8	70.5	62.2	14.30	0.76	0.71			
		Sheep	62.4	80.3	76.6	4.71	0.08	0.15			
		Mean	65.1	69.7	73.3	9.26	0.56	0.97	69.1	69.6	5.04
	2	Goat	38.2	61.5	54.1	8.05	0.24	0.17			
		Sheep	66.8	63.5	44.9	19.69	0.54	0.75			
		Mean	46.1	62.5	52.5	12.05	0.74	0.40	50.9	59.2	6.91
Fat (g)[22]	1	Goat	25.9	52.6	49.2	12.75	0.27	0.37			
		Sheep	71.6	78.3	81.5	16.49	0.67	0.94			
		Mean	48.7	62.4	68.8	13.11	0.32	0.84	42.0a	76.4b	7.67
	2	Goat	90.7	84.7	63.7	10.79	0.16	0.59			
		Sheep	101.0	98.8	95.1	31.80	0.92	0.99			
		Mean	92.4	91.8	72.8	15.83	0.45	0.65	81.7	96.9	9.40
Protein (g)[23]	1	Goat	18.5	20.5	18.3	3.37	0.97	0.63			
		Sheep	17.0	21.8	20.8	1.28	0.08	0.15			
		Mean	17.8	19.8	20.4	2.46	0.49	0.82	19.7	18.9	1.43

Table 6, Continued

Item	Year	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
	2	Goat	13.8	19.4	16.8	2.37	0.44	0.21			
		Sheep	18.2	17.3	12.2	5.35	0.54	0.75			
		Mean	14.6	18.3	15.8	3.22	0.82	0.46	16.6	16.0	1.84
Ash (g)[24]	1	Goat	3.0	3.2	2.8	0.52	0.76	0.71			
		Sheep	4.0	5.1	4.9	0.30	0.08	0.15			
		Mean	3.5	3.9	4.0	0.48	0.46	0.79	3.1a	4.5b	0.26
	2	Goat	1.7	2.8	2.4	0.36	0.24	0.17			
		Sheep	4.2	4.0	2.9	1.25	0.54	0.75			
		Mean	2.7	3.4	2.6	0.70	0.94	0.39	2.3a	3.8b	0.39
Energy (kJ)[25]	1	Goat	1446	2543	2538	566.0	0.33	0.39			
		Sheep	3237	3584	3688	656.7	0.61	0.88			
		Mean	2327	2917	3172	549.1	0.32	0.82	2117a	3350b	438.2
	2	Goat	3885	3781	2893	672.6	0.22	0.52			
		Sheep	4392	4283	4024	1293.1	0.88	0.97			
		Mean	3956	4032	3216	700.8	0.51	0.62	3520	4162	476.9

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Initial water concentration = significant effects of species ($P < 0.05$) and year ($P < 0.08$).

[4]Initial fat concentration = significant effects ($P < 0.05$) of species and year.

[5]Initial protein concentration = significant effects of species ($P < 0.05$) and year ($P < 0.07$).

[6]Initial ash concentration = significant effects of species ($P < 0.05$) and year ($P < 0.07$).

[7]Final water concentration = significant effects ($P < 0.05$) of year and year x species.

[8]Final fat concentration = significant effects ($P < 0.05$) of year, and year x species.

[9]Final protein concentration = significant effects ($P < 0.05$) of year, species, and year x species.

[10]Final ash concentration = significant effects of year, species ($P < 0.05$), and year x species ($P < 0.07$).

[11]Initial shrunk BW = significant effects ($P < 0.05$) of species and year.

[12]Initial water mass = significant effects ($P < 0.05$) of species, year, and treatment x species x year.

[13]Initial protein mass = significant effects ($P < 0.05$) of species, year, and treatment x species x year.

[14]Initial ash mass = significant effects ($P < 0.05$) of species, year, and treatment x species x year.

[15]Final shrunk BW = significant effects ($P < 0.05$) of species and year.

[16]Final water mass = significant effect ($P < 0.05$) of species.

[17]Final fat mass = significant effects of year ($P < 0.05$), and species ($P < 0.06$).

[18]Final protein mass = significant effect ($P < 0.05$) of species.

[19]Final ash mass = significant effect ($P < 0.05$) of species.

[20]Shrunk BW gain = significant effect ($P < 0.05$) of species.

[21]Water gain = significant effect ($P < 0.05$) of year.

[22]Fat gain = significant effects ($P < 0.05$) of species and year.

[23]Protein gain = significant effect ($P < 0.07$) of year.

[24]Ash gain = significant effects ($P < 0.07$) of species and year

[25]Energy gain = significant effects ($P < 0.05$) of species and year.

Table 7
Means of glucose, urea N and leptin concentrations in plasma of goats and sheep during a concentrate-based diet feeding phase

				Treatment[1]				Effect[2]		Species		
Item	Year	Week[3]	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
Glucose (mg/dl)[4]	1	0	Goat	52.2	55.9	51.3	2.35	0.78	0.18			
			Sheep	53.2	60.8	59.2	1.88	0.04	0.09			
			Mean	52.7	57.8	55.2	1.71	0.33	0.13	53.1	57.4	1.37
		3	Goat	48.0	46.7	60.2	3.45	0.03	0.11			
			Sheep	57.7	56.8	68.3	4.56	0.11	0.32			
			Mean	52.8	50.8	64.2	3.33	0.05	0.12	51.6a	61.7b	2.94
		6	Goat	58.7	64.7	69.5	4.02	0.08	0.92			
			Sheep	67.2	66.0	63.3	3.40	0.40	0.87			
			Mean	63.0	65.1	66.4	3.83	0.55	0.94	64.3	65.4	2.61
		9	Goat	67.5	63.9	77.5	7.08	0.34	0.34			
			Sheep	65.4	61.4	61.3	4.14	0.47	0.73			
			Mean	66.4	62.9	69.4	4.31	0.64	0.40	69.6	62.9	3.41
		12	Goat	54.6	56.1	65.6	3.63	0.05	0.38			
			Sheep	60.4	68.5	59.9	3.88	0.93	0.13			
			Mean	57.5	61.0	62.8	2.86	0.23	0.81	58.8	62.2	2.31
		15	Goat	52.3	55.4	60.6	3.95	0.16	0.82			
			Sheep	60.4	57.6	54.9	2.74	0.17	1.00			
			Mean	56.4	56.3	58.0	2.57	0.66	0.79	56.1	57.8	2.01
	2	0	Goat	60.6	65.3	52.4	2.92	0.08	0.03			
			Sheep	67.9	65.1	64.3	3.71	0.52	0.84			
			Mean	64.2	65.2	58.9	2.57	0.20	0.29	59.7	65.8	2.11

Table 7, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		3	Goat	65.9	63.7	56.6	5.07	0.23	0.70			
			Sheep	78.2	76.8	73.1	3.91	0.37	0.82			
			Mean	72.1	70.2	64.8	4.41	0.30	0.76	62.0a	76.0b	2.88
		6	Goat	62.9	60.3	69.3	4.69	0.36	0.33			
			Sheep	90.6	78.3	73.1	3.87	0.01	0.47			
			Mean	76.7	69.3	70.3	5.57	0.45	0.56	63.4a	80.7b	3.44
		9	Goat	75.5	70.1	75.8	4.66	0.97	0.35			
			Sheep	86.2	84.4	83.2	3.62	0.58	0.96			
			Mean	80.8	77.3	79.7	3.76	0.84	0.54	73.5a	84.6b	2.50
		12	Goat	67.2	73.6	71.1	4.36	0.55	0.41			
			Sheep	76.6	80.1	71.6	2.32	0.16	0.06			
			Mean	71.9	76.9	71.4	2.52	0.90	0.14	70.6	76.1	2.01
		15	Goat	73.0	79.9	78.0	4.48	0.45	0.43			
			Sheep	83.3	78.4	78.6	2.91	0.28	0.49			
			Mean	78.1	79.1	78.1	3.31	0.99	0.81	76.6	80.1	2.21
Urea N (mg/dl)[5]	1	0	Goat	15.4	13.8	14.4	1.89	0.73	0.65			
			Sheep	14.0	11.7	13.4	1.55	0.78	0.33			
			Mean	14.7	13.3	13.9	1.62	0.75	0.62	14.6	13.3	1.06
		3	Goat	15.5	15.7	15.6	1.47	0.97	0.95			
			Sheep	13.1	18.0	16.4	1.37	0.09	0.09			
			Mean	14.3	16.6	16.0	1.00	0.26	0.29	15.6	15.5	0.84
		6	Goat	12.6	17.1	12.1	2.54	0.90	0.16			
			Sheep	19.2	17.9	16.3	3.09	0.50	0.97			
			Mean	15.9	17.4	14.2	2.00	0.57	0.39	13.9	17.8	1.57

Table 7, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		9	Goat	15.8	18.5	20.8	1.81	0.07	0.93			
			Sheep	19.3	15.4	18.5	2.51	0.82	0.32			
			Mean	17.5	17.3	19.7	1.53	0.35	0.53	18.4	18.0	1.26
		12	Goat	13.9	16.0	15.6	2.60	0.64	0.71			
			Sheep	22.2	19.1	19.2	1.64	0.19	0.49			
			Mean	18.0	17.2	17.4	1.88	0.82	0.85	15.1a	20.3b	1.24
		15	Goat	12.2	13.3	14.3	1.69	0.41	1.00			
			Sheep	12.8	14.7	16.3	1.63	0.14	0.93			
			Mean	12.5	13.8	15.2	1.14	0.14	1.00	13.3	14.5	0.95
	2	0	Goat	14.1	16.3	14.4	1.34	0.89	0.24			
			Sheep	14.6	14.9	16.0	1.30	0.46	0.82			
			Mean	14.4	15.6	15.3	0.90	0.51	0.51	15.0	15.2	0.74
		3	Goat	18.2	14.5	19.9	1.49	0.44	0.03			
			Sheep	15.0	17.3	17.1	2.05	0.49	0.63			
			Mean	16.6	15.9	18.4	1.36	0.39	0.36	17.4	16.5	1.09
		6	Goat	10.8	13.1	17.0	2.29	0.08	0.77			
			Sheep	16.4	15.4	15.5	1.64	0.70	0.78			
			Mean	13.6	14.2	16.2	1.49	0.27	0.73	13.4	15.7	1.17
		9	Goat	16.5	12.2	18.7	2.25	0.51	0.07			
			Sheep	16.7	17.9	19.2	2.10	0.42	0.98			
			Mean	16.6	15.0	19.0	1.71	0.37	0.24	15.7	17.9	1.41
		12	Goat	18.8	18.1	19.0	1.36	0.93	0.64			
			Sheep	20.0	18.2	21.3	1.58	0.57	0.24			
			Mean	19.4	18.2	20.2	1.02	0.58	0.24	18.6	19.8	0.83

Table 7, Continued

Item	Year	Week[3]	Species	Treatment[1] 4	6	8	SE	Effect[2] L	Q	Species Goat	Sheep	SE
		15	Goat	15.8	19.4	20.1	3.42	0.41	0.74			
			Sheep	20.5	18.4	20.0	3.00	0.93	0.63			
			Mean	18.1	18.9	20.0	2.19	0.57	0.95	18.3	19.6	1.77
Leptin (ng/ml)[6]	1	0	Goat	1.6	2.7	1.4	0.45	0.74	0.07			
			Sheep	1.3	1.4	1.5	0.23	0.60	0.87			
			Mean	1.5	2.1	1.4	0.26	0.96	0.14	1.8	1.4	0.22
		3	Goat	3.0	4.7	2.7	0.69	0.80	0.06			
			Sheep	5.5	2.9	5.4	1.48	0.98	0.22			
			Mean	4.2	3.9	4.1	0.85	0.90	0.85	3.4	4.8	0.65
		6	Goat	5.1	8.7	7.1	1.71	0.43	0.24			
			Sheep	11.2	12.7	15.5	3.49	0.37	0.90			
			Mean	8.1	10.3	11.3	2.09	0.32	0.83	6.9a	13.2b	1.52
		9	Goat	4.6	7.9	8.1	1.82	0.20	0.50			
			Sheep	13.4	11.0	16.8	3.06	0.43	0.32			
			Mean	9.0	9.2	12.1	2.03	0.32	0.61	6.9a	13.9b	1.39
		12	Goat	5.0	8.3	8.3	1.98	0.25	0.50			
			Sheep	14.3	20.3	23.6	3.98	0.11	0.80			
			Mean	9.6	13.1	15.9	3.25	0.21	0.94	7.2a	19.2b	1.82
		15	Goat	9.3	7.6	10.3	1.93	0.74	0.38			
			Sheep	18.1	20.8	22.6	3.61	0.37	0.93			
			Mean	13.7	12.9	16.4	3.02	0.54	0.60	9.1a	20.4b	1.57
	2	0	Goat	0.7	0.5	0.8	0.19	0.88	0.31			
			Sheep	0.4	0.5	0.6	0.20	0.51	0.93			
			Mean	0.6	0.5	0.7	0.15	0.63	0.50	0.7	0.5	0.11

Table 7, Continued

				Treatment[1]				Effect[2]		Species		
Item	Year	Week[3]	Species	4	6	8	SE	L	Q	Goat	Sheep	SE
		3	Goat	2.5	1.6	1.7	0.43	0.22	0.37			
			Sheep	7.5	9.0	4.4	1.94	0.27	0.21			
			Mean	5.0	5.3	3.1	1.55	0.42	0.53	1.8a	7.0b	0.93
		6	Goat	5.0	3.4	3.1	0.56	0.04	0.35			
			Sheep	14.2	11.5	11.5	2.95	0.54	0.72			
			Mean	9.6	7.4	7.6	2.37	0.58	0.72	3.9a	12.4b	1.21
		9	Goat	5.9	6.0	6.5	1.17	0.72	0.87			
			Sheep	13.2	15.6	13.2	3.44	1.00	0.59			
			Mean	9.6	10.8	10.1	2.42	0.88	0.77	6.1a	14.0b	1.44
		12	Goat	6.2	5.8	7.5	1.48	0.56	0.56			
			Sheep	19.6	17.2	16.6	2.86	0.47	0.81			
			Mean	12.9	11.5	12.3	2.82	0.90	0.76	6.4a	17.8b	1.28
		15	Goat	11.9	10.2	11.8	2.59	0.98	0.60			
			Sheep	25.6	20.5	22.1	5.04	0.64	0.61			
			Mean	18.7	15.3	17.4	3.50	0.80	0.55	11.3a	22.7b	2.24

[1]4 = two goats and two sheep per 0.4-ha grass/forb pasture; 6 = three goats and three sheep per 0.4-ha grass/forb pasture; 8 = four goats and four sheep per 0.4-ha grass/forb pasture.

[2]L and Q = observed significance levels for linear and quadratic effects of stocking rate, respectively.

[3]Week of the 16-week grazing period

[4]Glucose = significant effects ($P < 0.05$) of species, year, week, treatment x year, species x year, species x week, year x week, treatment x species x week, and year x species x week.

[5]Urea N = significant effects of year ($P < 0.05$), week ($P < 0.05$), year x week ($P < 0.05$), and species ($P < 0.06$).

[6]Leptin = significant effects ($P < 0.05$) of species, week, treatment x year, and species x week.

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