NUTRITIVE EVALUATION OF TWO NATIVE NORTH TEXAS LEGUMES (*STROPHOSTYLES*) FOR GOATS

A Thesis

by

JAMIE LEE FOSTER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2004

Major Subject: Agronomy

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Approved as to style and content by:

James P. Muir (Co-Chair of Committee)	William C. Ellis (Co-Chair of Committee)
Mark McFarland (Member)	Mark Hussey (Head of Department)

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ABSTRACT

Nutritive Evaluation of Two Native North Texas

Legumes (*Strophostyles*) for Goats. (August 2004)

Jamie Lee Foster, B.S., Tarleton State University

Co-Chairs of Advisory Committee: Dr. J. P. Muir
Dr. W. C. Ellis

The objective of this study was to determine effects of supplementing coastal bermudagrass (*Cynodon dactylon*; CBG) hay with *Strophostyles helvula* (98 g kg^{-1} crude protein (CP), 476 g kg^{-1} neutral detergent fiber (NDF)), *S. leiosperma* (117 g kg^{-1} CP, 497 g kg^{-1} NDF), or cottonseed meal (506 g kg^{-1} CP, 352 g kg^{-1} NDF; CSM) upon intake of CBG hay (127 g kg^{-1} CP, 691 g kg^{-1} NDF) and apparent digestibility of dietary organic matter (OM), NDF, and true digestibility of CP. Six Boer-Spanish goats (46.22 ± 3.99 Kg) were fed CBG plus *S. helvula*, *S. leiosperma*, or CSM at 0.34 and 0.68% of BW in a 6•6 Latin square with 3•2 factorial arrangement of treatments. The CBG was fed *ad libitum*, and the legumes/CSM were fed in two equal daily feedings during a 7-d adjustment period and 7-d collection period in metabolism crates. Feces were collected every 24-h, and CBG, legumes/CSM, and fecal samples were analyzed for OM, NDF, and CP. There were no supplement type•amount interactions ($P > 0.05$). Supplement type did not affect OM digestibility ($P = 0.21$), but OM digestibility increased 6.4% ($P = 0.05$) at the 0.68% versus 0.34% level of supplementation with the legumes or CSM. Supplementation with CSM and *S. leiosperma* improved NDF digestibility 7% versus supplementation with *S. helvula* (*P* = 0.02); and as supplement amount increased NDF digestibility by 5.5% (*P* = 0.02). The diet supplemented with CSM had the greatest CP digestibility, and *S. helvula* CP was 6% less digestible than *S. leiosperma* (*P* = 0.02). As supplement amount increased, CP digestibility increased 7% (*P* = 0.01). Intake of DM, OM, and NDF of CBG was unaffected (*P* = 0.56) by supplementation with CSM, *S. helvula*, and *S. leiosperma,* but total diet NDF intake of diets supplemented with CSM and *S. helvula* was 10.5% less than diet supplemented with *S. leiosperma* (*P* = 0.01). Considering digestibility and intake, CSM and *S. leiosperma* were the best supplements fed in this experiment. *Strophostyles leiosperma* is recommended as use for diet supplementation for goats when CBG hay basal diet is fed.

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CHAPTER I

INTRODUCTION

The production of meat goats in Texas has increased in recent years. Texas is the number one state in the United States for goat production (TCE, 2001), with over 1.2 million head of meat goats in 2002 and 2003 (TASS, 2003). Texas goat producers are unable to meet the demand of national and international consumers, which is expected to rise as population increases (Muir, 2002c). Compared to other meat sources, goat is the most consumed meat in the world (Agriculture Alternatives, 2000). Exports in the United States are nearly twice that of imports based on total number of goats because more goat meat is consumed in other countries than in the United States (USDA, 2004). The growing ethnic population and the appearance of many small farm operations leads to the assumption that goat meat consumption within the United States will rise along with increasing exports (Agriculture Alternatives, 2000; Texas Farm Bureau, 2003).

In order to meet the demand for goat meat, producers must find ways to increase production. Currently, producers take goats to market directly from pasture which eliminates cost of grain for these producers (Texas Farm Bureau, 2003). In the United States, pastures are grass based, and in the southern United States, including north-central Texas, the primary cultivated grass utilized is bermudagrass (*Cynodon dactylon*) (Redmon, 2002).

This thesis follows the style and format of Small Ruminant Research.

Bermudagrass is a tropical grass which attains peak production during mid-summer, and is referred to as a warm-season forage (Sollenberger et al., 1989; Johnson et al., 2001; Arizmendi-Maldonado et al., 2003). Bermudagrass requires intensive management because production is dependent upon adequate fertilization and moisture. As applied nitrogen (N) increases, dry matter (DM) production increases, until peak production is achieved (Johnson et al., 2001). As rainfall or irrigation increases, production increases, and the proper amount of fertilizer must be applied in order to supply nutrients for plant metabolism so that the maximum production potential may be achieved with the amount of moisture provided (Prine and Burton, 1956; Stichler et al., 1998). In the cool growing season, bermudagrass may be over-seeded with ryegrass or small grain for year-round pasture production. Another option for year-round improved pasture systems is over-seeding with cool-season legumes such as clover alone or clover inter-seeded with cool-season grasses (Redmon, 2002). For the warm-season, there is currently no widely adapted legume species for improving pasture systems and thus goat productivity (Muir, 2002b).

Legumes generally have the greatest nutritive value, followed by cool-season annual grasses and cool-season perennial grasses, while warm-season annual and perennial grasses usually contain the lowest nutritive value (Ball et al., 2002). Grasses contain greater concentrations of structural carbohydrates, or neutral detergent fiber (NDF), which is an easily digestible fiber, than legumes; however, legumes generally contain a greater crude protein (CP) concentration than grasses (Van Soest, 1994). Although production of warm-season grasses peaks in mid-summer, animal production may decrease due to decreased forage quality (Sollenberger et al., 1989; Johnson et al., 2001). Because warm-season grass usually has the lowest nutritive value and its digestibility decreases in mid-summer, supplements must be offered if the nutritive requirement of the animal exceeds the amount provided by the pasture.

Animal nutrient requirement depends on size, age, and physiological state, such as pregnancy. Meat goats from 50 to 100 kg body weight (BW) require 2.38 to 4.01 Mcal of metabolizable energy (ME) for slight activity, which simulates grazing (NRC, 1981). Bermudagrass pasture and coastal bermudagrass (*Cynodon dactylon* (L.) Pers.) (CBG) hay only provide 2.21 Mcal kg^{-1} and 1.66 Mcal kg^{-1}, respectively (NRC, 1981). Intake is commonly estimated as 2.25% of BW (Van Soest, 1994); therefore, goats from 50 to 100 kg BW will consume from 1.1 to 2.25 kg DM day^{-1} of the pasture or hay. If the forage is not of the best quality as represented by the estimates given, the energy requirement for meat goats may not be met (NRC, 1981). The protein requirement of meat goats from 50 to 100 kg BW under slight activity conditions is up to 153 g of CP day^{-1}. The maximum CP of bermudagrass or CBG forages is 16.5 g kg^{-1} (NRC, 1981). Even with the highest quality forage at maximum intake, goat requirement for protein cannot be met without supplementation (NRC, 1981). Legumes, due to their greater CP concentration, are an ideal forage supplement for goats fed a basal diet of bermudagrass.

Legumes grow well in combination with grasses, and mixtures increase forage yield and CP concentration vis-à-vis solely grass pasture (Posler et al., 1993). Besides the nutritional improvement provided by mixed legume / grass pasture systems, there are several other advantages. Traditionally, production of forage crops is more economical than grain crops, and forage legumes may provide supplementation at lower cost than grains or commercial protein supplements (Jung and Allen, 1995). When annual legumes are grown in conjunction with perennial grassland, production is more environmentally friendly because soil is guarded from wind erosion, and requires less chemical herbicide application due to natural weed control (Jung and Allen, 1995; Grichar et al., 1996; Pengelly and Conway, 2000). Legumes may also serve as soil improvement crops by increasing the N and organic matter (OM) in the soil (Grichar et al., 1996; Pengelly and Conway, 2000; White and Wight, 1984). When forage legumes are grazed, most of the N stays in the pasture despite losses from animal urine evaporation and animal removal (Pengelly and Conway, 2000). This decreases commercial fertilizer needs, which furthers the economic benefits (Pengelly and Conway, 2000). Legumes also have the potential to provide browse for ruminant wildlife, seeds for birds, and cover for smaller wildlife species (Gee et al., 1994; Muir et al., 2004; Packard et al., 2004).

Native warm-season legumes are adapted to local climate and soil, and retain greater quality even under stress conditions such as drought. However, they are currently not widely seeded in improved pasture or native grassland production systems (Call, 1985). The lack of adapted and persistent warm-season legumes, with greater nutrient concentrations than grass, needs to be addressed by evaluating warm-season legumes for their potential as forage. Native legumes in a grass pasture may improve pasture quality and, in turn, goat production during the summer months when drought decreases quantity and quality of warm-season grass.

If warm-season perennial grass, including bermudagrass, is inter-seeded with a warm-season legume, nutritional limitations can be mitigated and agronomic benefits can improve warm-season grass pasture systems. Smooth-seeded wild bean (*Strophostyles leiosperma*) and its close relative, trailing wild bean (*S. helvula*), are annual, warm-season legumes native to Texas that often colonize open, disturbed areas (Diggs et al., 1999; Muir et al., 2003). Both are common in the Cross Timbers region of north-central Texas and are persistent and productive when sod grasses are not dominant (Gee et al., 1994; Muir et al., 2003). Trailing wild bean has been documented as an important range plant throughout the United States and Canada while smooth-seeded wild bean, perhaps because it produces less dry matter, has been studied less despite reports of its existence as far north as Illinois (Diggs et al., 1999).

The objective of this study was to determine effects of two levels of *S. helvula, S. leiosperma*, or cottonseed meal (CSM) upon intake of CBG hay and apparent digestibility of dietary DM, OM, and NDF, and true digestibility of CP.

CHAPTER II

REVIEW OF LITERATURE

Nutritional Characteristics of Ruminants and Goats

Ruminant animals have evolved the ability to utilize vegetative plant material as their sole source of nutrition (Hofman, 1989). This utilization occurs via a symbiotic relationship with rumen microorganisms that ferment polysaccharides in vegetative plant material that cannot be easily digested and utilized by mammalian enzymes (Hungate, 1966). There are several types of ruminants: those that consume grasses are grazers, those that consume brush material are browsers, and those that consume both are intermediate feeders. Goats consume both grasses and brush material, and are therefore considered intermediate feeders, more specifically intermediate browsers (Pande et al., 2002; Lyons et al., 1998). Although concentrates, such as grain, are fed extensively to ruminant livestock, because of the digestive capacity of goats to utilize brushy materials, forages represent the most important and valuable feed resource for this ruminant (Jung and Allen, 1995).

Because goats are selective grazers / browsers, their feeding behavior allows them to select from available forage the plants and plant parts that have greater CP and NDF concentrations (Ahmed and Nour, 1997; Singh and Shankar, 2000; Pande et al., 2002). Selective feeding allows goats to maintain BW during the dry season (Ahmed and Nour, 1997), and is due to several adaptations including a narrow muzzle (Van Soest, 1994) and nimble-prehensile lips (Stevens, 1977; Dougherty and Collins, 1995).

In a study comparing eighteen legumes and eighteen grasses, goats selected legumes more often than grasses in the warm-season when legumes were most available (Singh and Shankar, 2000). In the cool-season, the legumes became less available and goats were forced to graze grasses more often (Singh and Shankar, 2000). Of the eighteen grasses offered, bermudagrass was the most preferred species, and contained the greatest NDF and CP concentrations of the grass species offered (Singh and Shankar, 2000). In a study comparing leguminous shrubs versus non-leguminous shrubs, goats browsed leguminous shrubs more often than non-leguminous species, although this was also seasonally variable and dependent upon availability of each shrub type (Pande et al., 2002). In an experiment in north-central Texas in which goats grazed a cool-season legume / grass pasture, average daily gain (ADG) increased compared to pure grass pasture, and selection for the more abundant and greater quality grass occurred until it matured and forage quality declined (Muir, 2002a). Warm-season research in north-central Texas confirms these findings; when warm-season pasture inter-seeded with grass and legume is grazed by goats, legume composition decreases over time, indicating a preference for legumes over mature grass (Goodwin et al., 2004). Also, when goats are fed hay they, select the parts of the hay containing greater nutrient concentration and select leaves from the hay containing CBG and peanut leaves and stems (Packard, 2004).

The maintenance requirement of ruminant animals is relative to BW and the formula for maintenance nutrient requirement is $BW^{0.75}$ (Van Soest, 1994). This formula suggests that the smaller the animal, the greater the diet quality necessary to maintain the animal because the smaller body size limits the amount of intake (Van

Soest, 1994). Goats are relatively small ruminants and in fact do have greater maintenance requirements than cattle (Ball et al., 2002). While bermudagrass can sustain cattle, goats need better nutrition than this warm-season grass can provide, especially at the end of the warm-season when quality of the grass decreases and before the goat breeding season begins and their nutritive requirement increases (Ball et al., 2002; Packard, 2004). Feed supplements must often be provided in the form of commercial concentrates or legumes (Ott et al., 2002; Ott et al., 2004).

Agronomic Attributes of Available Forages

Bermudagrass is a perennial grass that is productive during the warm-season, from May to October in the southern United States (Ball et al., 2002). Bermudagrass is drought tolerant although, as available moisture increases, DM production increases (Stichler, 1998). Production is therefore not maximized in north-central Texas due to limited rainfall, which averages 750 mm annually (TAES, 2002). Bermudagrass also is dependent on N fertilizer; and as fertilizer increases, DM production increases until a maximum production potential is reached, unless other soil nutrients are deficient (Prine and Burton, 1956). The amount of fertilizer necessary for maximum production varies with the amount of moisture from 267 kg of N ha^{-1} in a dry year to 534 kg of N ha^{-1} in a wet year, and, unless irrigation is applied, available moisture varies drastically from year to year (Prine and Burton, 1956).

For year-round pasture production, bermudagrass pasture may be over-seeded with cool-season legumes. Several cool-season legumes are adapted to the area and grow well in the southern United States, and evidence from previous research indicates that legume / grass mixtures have advantages compared to grass-only pasture (Ball et al., 2002; Redmon, 2002). Legumes have been proven to grow well in combination with grasses, and the mixture increases forage yield (Posler et al., 1993). Legumes are capable of developing root nodules through a symbiotic relationship with N-fixing bacteria (*Rhizobium*) which allows them to utilize atmospheric N. Legumes may be utilized as soil improvement crops to provide N to the soil over the long term and may double the CP concentration of grasses without using chemical fertilizer (Grichar et al., 1996; Pengelly and Conway, 2000; White and Wight, 1984). Inter-seeded legume / grass pasture can also improve the soil structure of a pasture by increasing the OM content of the soil (Pengelly and Conway, 2000).

Although the advantages of cool-season legumes are well documented (Van Soest, 1994; Ball et al., 2002), utilization of inter-seeded warm-season legumes is a less common management system in the southern United States because of the lack of adapted and persistent species (Call, 1985; Ball et al., 2002; Muir, 2002b). Very few species are commercially available, and those that are may not be palatable to the livestock species or are not productive mid to late summer when the benefits of legumes are needed in the pasture (Packard et al., 2004). In Australia, a surge of research in this area has uncovered a large number of legumes adapted to their production zones (Pengelly and Conway, 2000). While many of these legumes may show promise in the southern United States for the production of small ruminants, more research and development is necessary to continue enhancing production potential. In drier portions of the southern United States, research has focused on both introduced (Muir, 2002b) and native (Muir and Taylor, 2004) species. Preliminary agronomic research has been conducted on *S. helvula* and *S. leiosperma*, two legumes native in the United States and Canada, and indicates that both species have the potential for a high CP concentration (8-22%), and good reseeding rate relative to other native legumes. *Strophostyles helvula* also produces more forage quantity than comparable native or introduced legumes (1.8 kg forage plant^{-1} season^{-1}) (Muir et al., 2003; Muir et al., 2004; Packard et al., 2004). Due to the dynamic function of intake and digestibility, a feeding trial is necessary to determine the potential of *S. helvula* and *S. leiosperma* as warm-season forage for goats.

Nutritional Attributes of Available Forages

Grasses contain a greater concentration of digestible structural carbohydrates, or NDF, than legumes (Van Soest, 1994). This easily digested fiber fraction of warm-season forage grasses may meet the ME requirement of goats 50 to 100 kg BW under light activity situations. However, warm-season grass forages usually cannot meet the CP requirement of goats 50 to 100 kg BW under light activity situations. Several experiments have shown that the CP concentration of CBG increases with increasing N fertilization, and as CP concentration increases livestock performance generally increases (Ott et al., 2002). However, in an experiment grazing goats on CBG pasture that was split into either high or low fertilization rates, goats in both paddocks were supplemented. While ADG improved on high fertilization rate paddocks, goat ability to thrive on CBG pasture was influenced by supplementation (Ott et al., 2002). In a dry-lot experiment in which goats were fed a purchased complete feed ration, CBG hay, or peanut stover, goats fed the complete feed ration had 2.5 to 6 times greater ADG than goats fed either CBG hay or peanut stover (Packard, 2004). The carcass dressing percentage of goats fed complete feed ration and peanut stover was less than goats fed CBG hay, indicating that the CBG hay diet had the slowest rate of passage and greater amount of rumen fill at slaughter (Packard, 2004).

The nutritional deficit in warm-season grasses may become severe later in the growing season, when digestibility and CP concentration decrease as temperature increases (Johnson et al., 2001). Reduced forage quality may be attributed to an increase in the indigestible fraction of the bermudagrass due to increasing metabolic rate which the plant utilizes to avoid heat stress (Henderson and Robinson, 1982; Nelson and Volenec, 1995).

Supplements are often necessary for optimum goat production, and because protein is usually limiting in grass-based diets, protein supplementation will improve animal production (Ahmed and Nour, 1997; Ott et al., 2002). Relative to other herbaceous forages, legumes usually have greater CP concentration (both fermentable and bypass) and greater mineral concentration than grasses (Said and Tolera, 1993; Van Soest, 1994). Several experiments have shown that animal production is increased when legumes are introduced to pastures or rangelands, and when legume hays are fed. This response becomes particularly evident in mid-summer as pasture quality deteriorates and the protein provided in the legume hay diet can increase nanny milk yield and kid BW (Ahmed and Nour, 1997). Crop residues utilized for livestock production are usually limiting in CP, ME, minerals and vitamins (Said and Tolera, 1993). In an experiment in which poor quality byproducts were supplemented with high quality legumes, total DM intake increased 10-18% while the intake of the residues decreased, a phenomenon commonly called "supplementary effect" (Said and Tolera, 1993). Legumes with lower CP concentration and greater NDF concentrations however did not increase intake in a similar manner as the higher quality legumes (Said and Tolera, 1993).

Factors Determining Nutritive Potential of Individual Forages

The concentration and digestibility of NDF and CP as well as NDF intake contributes heavily to forage quality. There is a negative correlation between NDF concentration of a forage and intake, due to the need to hold the forage in the rumen for further mastication and fermentation by microorganisms (Jung and Allen, 1995). Fiber must become accessible before it can be fermented and pass from the rumen, thereby allowing space for further intake (Van Soest, 1994). Protein is degraded rapidly and excessively in the rumen, and may be the most limiting nutritional factor in higher-quality temperate forage legumes (Broderick, 1995).

Tropical legumes tend to contain greater tannin concentration than temperate legumes (Barahona et al., 1997). Tannins are secondary compounds that bind to protein and inhibit rapid microbial degradation of protein allowing it to pass into the ruminant's intestinal tract (Broderick and Albrecht, 1997). If microbial access is inhibited but intestinal digestion is not, protein utilization for the animal would be improved, bypassing the microbial waste of protein in the rumen (Broderick and Albrecht, 1997). If intestinal digestion is not improved, then N retention of the animal decreases and protein will limit growth (Fahey and Jung, 1989).

Because CP is limiting, greater amounts need to be provided through improved forages or supplementation. Legumes are a source of improved forage that provides greater CP concentration than grass-only pastures. In addition, legumes may have greater intake rates than grasses due to less rumination time and quicker rate of passage, because legumes tend to break into smaller particle size in the rumen (Wilson, 1994). As concentration of CP increases and concentrations of indigestible fractions, such as ADF and ADL, decrease, digestibility should increase (Russell et al., 1990; Van Soest, 1994). Increasing digestibility is largely due to stimulation of microbes in the rumen caused by an increase of substrate material. When substrate increases, microbes are able to utilize the substrate to digest more material in the rumen (Russell et al., 1990; Van Soest, 1994). As microbial digestion increases, degradation of plant material in the rumen occurs more rapidly (Van Soest, 1994). Particles in the rumen must be degraded to a critical size in order to pass through the ruticulo-omasal orifice and continue through the gastro-intestinal tract of the ruminant (Rodríguez et al., 2000). Reducing the time it takes for microbes to digest plant particles to this critical size, by increasing CP, concentration of the substrate and accessible digestible fiber, is crucial to further intake (Van Soest, 1994; Ellis et al., 2003). The capacity of the rumen to hold digesta is limited, and until it empties through the reduction of particle size the animal cannot intake more forage for digestion (Van Soest, 1994). As CP concentration increases, ADF and ADL concentrations increase, and digestion increases allowing space in the rumen for increasing intake. It has been suggested that this is a circular cycle, and that as intake increases, substrate increases, thus again improving digestion and passage of particles out of the rumen (Rodríguez et al., 2000).

CHAPTER III

MATERIALS AND METHODS

Experimental Design

The six diets consisted of 0.34 or 0.68% of goat BW of *S. helvula*, *S. leiosperma*, and CSM as supplement to a basal diet of CBG *ad libitum* with minerals. The experimental design was a 6 by 6 Latin square with six diets fed to each of six goats with a 3 by 2 factorial arrangement consisting of three types of supplement fed at two amounts. Boer-Spanish wether goats weighing 46.22 ± 3.99 kg and approximately one year old were each assigned to a 7-day adaptation phase followed by a 7-day data collection phase in metabolism crates for each diet. A temperature controlled indoor facility large enough for the metabolism crates was not available; instead a covered area with ventilation was used. Goats were fed the treatment diets from August to October of 2003. Data were used to compute mean nutritional responses of voluntary intake and digestibility for each diet and goat.

Feeding and Excreta Collection Practices

Strophostyles helvula and *S. leiosperma* seed were collected in the Cross Timbers region of Texas and from research plots at the Texas Agriculture Experiment Station in Stephenville, Texas, and was established in Windthorst fine sandy loam soil. Plants were harvested with an Almaco tractor at 5 cm from the ground, and dried in a forced air oven at 55°C for 72 hours. Coastal bermudagrass hay was harvested from fields at the Stephenville Texas Agriculture Experiment Station and stored in a fully enclosed barn, and solvent extracted CSM was purchased at a local feed store. Water and purchased mineral blocks containing 0.35% zinc, 0.2% iron, 0.2% manganese, 0.03% copper, 0.005% cobalt, and 0.007% iodine were available to the goats at all times.

Strophostyles helvula and *S. leiosperma* hay were chopped to reduce refusal with a mechanical mulcher to approximately 2.5 cm particle size. Intake was estimated as 2.25% of BW (Van Soest, 1994) and the amount of supplement (15 or 30% of intake) was calculated for each feeding period based on the weight taken the first day of the adjustment period, resulting in supplementation rates of 0.34 or 0.68% of BW. Legume and CSM supplements were fed in two equal feedings twice a day at 8:00 h and 17:00 h, with orts (refusals) collected one hour later. Mineral block was provided in the same slot that the supplement was fed, but removed in order to feed the supplement and immediately placed on offer again when the supplement was consumed by the goat. Coastal bermudagrass hay was feed *ad libitum* and orts were collected daily to determine total intake. Random forage samples were collected from each of CBG, CSM, *S. helvula,* and *S. leiosperma*, and all forage samples dried at 55°C in the same forced-air oven at the end of the feeding trial. Feces were collected from a plastic pan fastened under the elevated metabolism crate every 24 hours. The total excretion of feces was weighed, and a 10% aliquot taken and frozen until dried at 55°C. Forage, ort, and fecal samples were ground to pass a 1 mm screen of a sheer mill (Wiley, Arthur H. Thomas Co., Philadelphia, PA).

Analysis of Feed, Orts, and Feces

Dry Matter and Organic Matter

Dry matter concentration was obtained by drying samples (2.0 g) in an oven dryer at 100°C in a pre-weighed crucible for 4 hours, placing in a dessicator, allowing to reach room temperature, and weighing (A.O.A.C., 1990). Ash was determined by placing crucibles with samples in a muffle furnace at 540°C for 4 hours, allowing the muffle furnace to cool to avoid burns, placing crucibles in a dessicator, allowing to reach room temperature, and weighing (A.O.A.C., 1990).

Neutral Detergent Fiber

Neutral detergent fiber was determined by an extraction procedure developed by Goering and Van Soest (1970), in which neutral detergent solubles were extracted from forage and fecal samples and the residue contained within a Dacron analytical bag (5 by 5 cm; 53 μ pore size). Samples (1.0 g) were placed in the bag, heat-sealed and the duplicate samples placed in a basket. Eight baskets were stacked in a 2-L vessel, which was then filled with preheated (98-100°C) NDF solvent. Once stabilized to 98-100°C by the heating element, the baskets were mechanically agitated via reciprocating vertical cycles for 70 minutes. Bags were then rinsed four times for 5 minutes each with hot water (90-100°C), removed, and squeezed between napkins to remove water. Bags were then placed in a beaker, covered with acetone, and soaked for 10 minutes while agitating with a magnetic stir bar. After air-drying (dry to the touch), the bags were placed in a drying oven at 55°C for 24 hours, removed, placed in a dessicator, and weighed.

Acid Detergent Fiber and Acid Detergent Lignin

Analysis of acid detergent fiber (ADF) and acid detergent lignin (ADL) concentrations was completed on the CBG hay and supplement samples only and followed A.O.A.C. procedure (1990). Samples were weighed (1.0 g), placed in reflux beakers with 100 ml of ADF solution, and boiled for 1 h in the reflux unit. After the reflux period, sample residues were vacuum-filtered through Gooch fritted disc crucibles and rinsed with boiling distilled water and then with acetone. Then the crucible plus residue was oven-dried (105°C) overnight, placed in dessicator and allowed to cool, then weighed. After weights were taken, crucibles were placed in a pan, where 30 ml of 72% H2SO4 was poured into the crucible. Residues were stirred occasionally with glass rods and oxidized for 3 h. The crucibles were again vacuum-filtered and rinsed with boiling distilled water until acid was removed. Samples were oven-dried (105°C) overnight, cooled in a dessicator, and weighed to obtain ADL values.

Crude Protein

To determine N concentrations, samples were digested using a modified aluminum block digestion (Gallaher et al., 1975). Samples (0.5 g) were digested in 5 g of 33:1:1 K_2SO_4/$CuSO_4$/TiO_2 for 2 h at 400°C using 10 ml of 98.08% H_2SO_4. Nitrogen in the digestate liquid fraction was determined by semi-automated colorimetry (Hambleton, 1977), using a Technicon Autoanalyzer II (Technicon Industrial Systems, Tarryton, NY). Crude protein was estimated as 6.25 ● N (Van Soest, 1994).

Calculations

To determine the nutritional impact of the previous method the following calculations were used:

Dry Matter ($g\ kg^{-1}$) =

$$\frac{[(\text{pan weight (g)} + \text{sample weight, dried (g)}) - \text{empty pan weight (g)}]}{\text{sample weight, as is (g)}} \bullet 1000$$

Ash ($g\ kg^{-1}$) =

$$\frac{[(\text{pan weight (g)} + \text{sample weight, ashed (g)}) - \text{empty pan weight (g)}]}{\text{sample weight, as is (g)}} \bullet 1000$$

Organic Matter ($g\ kg^{-1}$) = DM ($g\ kg^{-1}$) – Ash ($g\ kg^{-1}$)

Neutral detergent fiber ($g\ kg^{-1}$) =

$$\frac{[(\text{bag weight (g)} + \text{sample weight, extracted (g)}) - \text{empty bag weight (g)}]}{\text{sample weight, as is (g)}} \bullet 1000$$

Acid detergent fiber ($g\ kg^{-1}$) =

$$\frac{[(\text{crucible weight (g)} + \text{sample weight, extracted (g)}) - \text{crucible weight (g)}]}{\text{sample weight, as is (g)}} \bullet 1000$$

Acid detergent lignin ($g\ kg^{-1}$) =

$$\frac{[(\text{crucible weight (g)} + \text{sample weight, extracted (g)}) - \text{crucible weight (g)}]}{\text{sample weight, as is (g)}} \bullet 1000$$

Crude Protein ($g\ kg^{-1}$) = (N% ● 6.25%) ● 10

Apparent Digestibility

Apparent digestibility of DM, OM, and NDF were determined through the following calculations:

Nutrient Intake ($g\ kg^{-1}$) = Intake (kg) ● Nutrient concentration ($g\ kg^{-1}$)
Nutrient Output ($g\ kg^{-1}$) = Feces (kg) ● Nutrient concentration ($g\ kg^{-1}$)

Apparent Digestibility ($g\ kg^{-1}$) =

$$\frac{[\text{Nutrient Intake } (g\ kg^{-1}) - \text{Nutrient Output} (g\ kg^{-1})]}{\text{Nutrient Intake } (g\ kg^{-1})}$$

True Digestibility

True digestibility of CP was determined through the following calculation, which assumes metabolic fecal CP (MFCP) as a constant 3% of fecal CP concentration (Van Soest, 1994):

$$\text{True Digestibility (g kg}^{-1}\text{)} = \frac{\text{[Nutrient Intake (g kg}^{-1}\text{)} - \text{Nutrient Output (g kg}^{-1}\text{)} - \text{3\% Metabolic Fecal CP (MFCP)]}}{\text{Nutrient Intake (g kg}^{-1}\text{)}}$$

Statistical Analysis Procedures

Calculations were computed using collected data, where outliers greater than two standard deviations from the mean of the 7-day collection period were removed. The general linear model (GLM) procedure of SAS based on the 6 by 6 Latin square with 3 by 2 (supplement type by supplement amount) factorial arrangement of treatments was utilized for statistical analysis (SAS Institute, 1991). The mathematical model $X_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \varepsilon_{ijk}$ where μ equals mean, α equals response variable, β equals goat, γ equals diet, ijk equal 1 to 36, and ε equals error, represents the latin square design in this experiment (Snedecor and Cochran, 1967). Least-squares means (LSM) was utilized for mean separation (SAS, 1991). Dependent variables measured were apparent digestibility of dietary DM, OM, and NDF, and true digestibility of CP, and DM, OM, and NDF intake of CBG and total diet.

CHAPTER IV

RESULTS

There were no interactions between supplement type and supplement amount (*P* > 0.05) for any of the response variables; therefore, means of main effects among supplement types and between supplement amounts are presented here. Because actual total intake differed from the estimated 2.25% of BW, the actual amount supplemented differed from 15 and 30% of intake and averaged 12.2 and 21.6% supplement in the total diet. There were no supplement refusals during this experiment. As expected, there were differences among the six goats (*P* < 0.05) for measured digestibilities, due to animal differences and feed preferences (Van Soest, 1994). Also, there were differences between the six periods of this trial (*P* < 0.05) for all of the measured variables which could be due to temperature changes.

Forage Analysis

Dry matter concentrations of the CBG hay and supplements were similar, and OM concentration demonstrated only slightly more variation (Table 1). The CBG hay (691 g kg^{-1}) contained 31% greater NDF concentration than *S. helvula* (476 g kg^{-1}) and 28% greater NDF concentration than *S. leiosperma* (497 g kg^{-1}). Cottonseed meal contained the least amount of ADF (171 g kg^{-1}), while ADF concentration of CBG hay (335 g kg^{-1}) was 3.3% greater than that of *S. leiosperma* (324 g kg^{-1}), and 17% greater than that of *S. helvula* (279 g kg^{-1}). Cottonseed meal (64 g kg^{-1}) contained the greatest amount of ADL, while CBG hay (40 g kg^{-1}) contained 15% less ADL than *S. helvula*

(47 g kg^{-1}) and 33% less ADL than *S. leiosperma* (60 g kg^{-1}). The CP concentration of CSM (506 g kg^{-1}) was 75% greater than CBG hay (127 g kg^{-1}), 81% greater than *S. helvula* (98 g kg^{-1}), and 77% greater than the CP concentration of *S. leiosperma* (117 g kg^{-1}) (Table 1). Coastal bermudagrass hay contained 23% greater CP concentration than *S. helvula* and 8% greater CP concentration than *S. leiosperma*. Representative forage samples containing both leaves and stem were collected for analysis from the daily feedings in this study.

Table 1. Chemical composition (g kg^{-1} dry matter (DM)) of forages and cottonseed meal

Feed	DM[a]	OM	NDF	ADF	ADL	CP
	g kg^{-1}					
Coastal bermudagrass hay	953	883	691	335	40	127
Strophostyles helvula	953	894	476	279	47	98
Strophostyles leiosperma	952	892	497	324	60	117
Cottonseed meal	948	879	352	171	64	506

[a] dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), crude protein (CP)

Organic matter diet composition was similar for all supplement types and amounts (Table 2). Diets containing *S. leiosperma* (652.9 g kg^{-1}) contained 0.7% greater NDF concentration than *S. helvula* (648.5 g kg^{-1}) and 3.4% greater NDF concentration than diets containing *S. leiosperma* (652.9 g kg^{-1}). As supplement amount increased from 0.34% of BW (655.5 g kg^{-1}) to 0.68% of BW (633.5 g kg^{-1}), NDF concentration of the diet decreased by 3.4%. Supplementation with *S. leiosperma* (333.3 g kg^{-1}) increased dietary ADF concentration by 2.2% over supplementation with *S. helvula* (326.1 g kg^{-1}), and 7.2% over supplementation with CSM (309.9 g kg^{-1}). As supplement amount increased from 0.34% of BW (319.7 g kg^{-1}) to 0.68% of BW (326.8 g kg^{-1}), ADF concentration decreased by 2.2%. Diet concentration of ADL was 4.6% greater when *S. leiosperma* (43.1 g kg^{-1}) was fed and 6% greater when CSM (43.7 g kg^{-1}) was fed versus feeding diets containing *S. helvula* (41.1 g kg^{-1}). As supplement amount increased from 0.34% of BW (41.8 g kg^{-1}) to 0.68% of BW (43.4 g kg^{-1}), ADL concentration decreased 3.7%. Crude protein concentration of diets fed CSM (185 g kg^{-1}) was 32% greater than that of diets fed *S. leiosperma* (125.5 g kg^{-1}) as supplement and 34% greater than that of diets fed *S. helvula* (122.4 g kg^{-1}) as supplement. As supplement amount increased from 0.34% of BW (139.2 g kg^{-1}) to 0.68% of BW (149.6 g kg^{-1}), CP concentration of the diet increased by 7%.

Table 2. Mean chemical composition (g kg^{-1} dry matter (DM)) of diets containing the three supplement types and two supplement amounts

	OM[a]	NDF	ADF	ADL	CP
	--------------------g kg^{-1}DM---------------------				
Supplement Type					
Strophostyles helvula	885.1	648.5	326.1	41.1	122.4
Strophostyles leiosperma	884.8	652.9	333.3	43.1	125.5
Cottonseed meal	882.8	631.0	309.9	43.7	185.0
Supplement Amount					
0.34% of body weight	883.9	655.5	326.8	41.8	139.2
0.68% of body weight	884.4	633.5	319.7	43.4	149.6

[a] dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), crude protein (CP)

Apparent Digestibility

There were slight differences in the digestibility of DM among diets containing the three supplement types (*P* = 0.07) and two supplement amounts (*P* = 0.08) (Table 3). Dry matter digestibility of CSM (646.5 ± 16.3g kg^{-1}) and *S. leiosperma* (639.9 ± 16.3 g kg^{-1}) tended to be different (*P* < 0.1) from the DM digestibility of *S. helvula* (595.1 ± 16.3 g kg^{-1}). At the greater supplementation level (644.2 ± 13.3 g kg^{-1}), DM digestibility tended to be 5.3% greater (*P* < 0.1) than DM digestibility of the low supplementation level (610.1 ± 13.3 g kg^{-1}). There were no differences in OM digestibility among diets containing either the legumes or CSM supplements (*P* = 0.21); however, there was a difference in OM digestibility between diets of the two supplement amounts (*P* = 0.05). Organic matter apparent digestibility means for 0.34 and 0.68% of BW supplementation levels were 602.6 and 643.8 ± 13.7 g kg^{-1}, respectively. As supplementation level increased, digestibility increased (*P* < 0.1) by 6.4% regardless of whether leguminous or non-leguminous supplement was fed. Both supplement type (*P* = 0.02) and level (*P* = 0.02) affected NDF digestibility. Cottonseed meal and *S. leiosperma* (647.9 and 646 ± 12.4 g kg^{-1}), respectively, differed (*P* < 0.01) from *S. helvula* (601.7 ± 12.4 g kg^{-1}) (Table 3). Diet NDF digestibility at the 0.68% of BW supplementation level (649.7 ± 10.1 g kg^{-1}) was 5.5% greater (*P* < 0.01) than at the 0.34% of BW supplementation level (614 ± 10.1 g kg^{-1}).

Table 3. Dry matter (DM), organic matter (OM), and neutral detergent fiber (NDF) apparent digestibility, and crude protein (CP) true digestibility of diets containing the three supplement types and two supplement amounts

	DM[a]		OM		NDF		CP	
	--------g digestibility kg^{-1} forage----------------							
Supplement Type								
Strophostyles helvula	595.1	b[b]	598.2	a	601.7	b	658.1	c
Strophostyles leiosperma	639.9	a	632.5	a	646	a	689.1	b
Cottonseed meal	656.5	a	638.8	a	647.9	a	719.9	a
Supplement Amount								
0.34% of body weight	610.1	b	602.8	b	614	b	663.9	b
0.68% of body weight	644.2	a	643.8	a	649.7	a	714.2	a

[a] dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), crude protein (CP)

[b]values in the same column followed by different letters differ ($P \leq 0.1$) according to least-squares means (LSM) multiple range test.

Crude Protein True Digestibility

True digestibility was used for CP digestibility because metabolic fecal losses are factored into apparent digestibility, and this may decrease the estimated digestibility (Van Soest, 1994). Crude protein digestibility differed for all three supplement types ($P = 0.02$) and between supplement amounts ($P = 0.01$). The diet supplemented with CSM (719.9 ± 14.4 g kg^{-1}) had the greatest CP digestibility ($P < 0.1$), and *S. helvula* (648.1 ± 14.4 g kg^{-1}) was 6% less digestible ($P < 0.1$) than *S. leiosperma* (689.2 ± 14.4 g kg^{-1}) (Figure 4). Crude protein digestibility for the 0.68% of BW supplementation level (714.2 ± 11.8 g kg^{-1}) was 7% greater than the 0.34% of BW supplementation amount (663.9 ± 11.8 g kg^{-1}).

Intake

Coastal bermudagrass intake DM, OM, and NDF were undifferentiated among supplement types (P = 0.56) and between supplement amounts (P = 0.24) (Table 4). Because of the nature of the subtraction of OM and NDF from DM, the P-values for all three measured variables were equal.

Table 4. Dry matter (DM), organic matter (OM), and neutral detergent fiber (NDF) concentration of the coastal bermudagrass hay intake as affected by three supplement types and two supplement amounts

	DM[a]		OM		NDF	
	g kg^{-1} kg (body weight) BW^{-1}					
Supplement Type						
Strophostyles helvula	25.7	a[b]	22.7	a	12.2	a
Strophostyles leiosperma	26.8	a	23.7	a	12.8	a
Cottonseed meal	26.8	a	23.7	a	12.7	a
Supplement Amount						
0.34% of body weight	27	a	30.3	a	23.9	a
0.68% of body weight	25.9	a	32.3	a	22.9	a

[a] dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), body weight (BW)

[b] values in the same column followed by different letters differ ($P \leq 0.1$) according to least-squares means (LSM) multiple range test.

Dry matter intake of the total diet was not different among the supplement types (P = 0.55), but differed between supplement amounts (P = 0.04) (Table 5). Similarly, OM intake of the total diet did not differ among supplement types (P = 0.57); however, differences between supplement amounts were apparent (P = 0.04). Differences in total diet intake of DM and OM caused by supplement amount can be explained by the nature of the experiment, since more supplement was fed to goats receiving 0.68% of BW supplement than in the 0.34% of BW supplement and CBG intake did not change; therefore, the greater the amount of supplement fed in this experiment the greater the intake of DM and OM in the total diet.

Table 5. Dry matter (DM), organic matter (OM), and neutral detergent fiber (NDF) concentrations of the total diet as affected by three supplement types and two supplement amounts

	g kg^{-1} kg (body weight) BW^{-1}					
Supplement Type						
Strophostyles helvula	30.6	a[b]	27.1	a	14.6	b
Strophostyles leiosperma	31.7	a	28.1	a	16.1	a
Cottonseed meal	31.6	a	27.9	a	14.4	b
Supplement Amount						
0.34% of body weight	30.3	b	26.8	b	14.5	b
0.68% of body weight	32.3	a	28.6	a	15.6	a

[a] dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), body weight (BW)

[b] values in the same column followed by different letters differ ($P \leq 0.1$) according to (least-squares means) LSM multiple range test.

Total diet NDF intake differed among both supplement types ($P = 0.01$) and between supplement amounts ($P = 0.02$). Total intake means for CSM and *S. helvula* were both approximately 14 ± 0.39 g d^{-1} kg BW^{-1} and were 10.5% less than *S. leiosperma* (16.1 ± 0.38 g d^{-1} kg BW^{-1}). When supplement was fed at 0.68% of BW, total intake was 15.6 ± 0.32 g d^{-1} BW^{-1} but decreased by 7% when only 0.34% of BW supplement was fed (14.5 ± 0.32 g $d^{-1}BW^{-1}$). This increase is explained by the increase in the amount of supplement when fed at 0.68% of BW, while the amount of CBG remained unchanged in the diet.

CHAPTER V

DISCUSSION

There were digestibility differences among the six goats, resulting from differences in metabolism and feed preference found among individual animals (Van Soest, 1994). These differences are difficult to eliminate from biological experiments (Van Soest, 1994). Period differences could be due to temperature changes during the time which the experiment was completed. The temperature averaged 83.5°C in August, 72.2°C in September, and 65.6°C in October 2003 (TAES, 2004). Temperature is an environmental factor which affects intake and metabolism; when under heat stress, animals consume less and when under cold stress animals utilize more of their intake for maintenance in order to maintain homeostatic body temperature (Van Soest, 1994; Dougherty and Collins, 1995).

Forage Analysis

The greater amount of NDF concentration in the CBG hay versus both legumes is consistent with previous research that indicates grasses generally contain greater concentrations of NDF than legumes (Van Soest, 1994). The greater amount of ADL in the legumes versus the CBG hay is consistent with previous research that indicates that legumes often contain more ADL, because of the different type of plant structure of legumes which has more developed stem tissue than grasses (Collins and Fritz, 1995). Acid detergent lignin is a cell wall fiber that passes through the rumen mainly undigested (Dougherty and Collins, 1995) because of the strong covalent bonds in the lignin that hold the polysaccharides together (Van Soest, 1994).

The greater amount of CP concentration of the CSM was expected because CSM is sold as an agro-industrial byproduct specifically as a protein supplement. The greater CP concentration in the CBG hay versus the legumes could be due to the management of the CBG pasture before harvest and during hay production, as well as characteristics of the two legume hays. Both legume species may vary from 80 g kg^{-1} CP in mature plant material to 220 g kg^{-1} CP in re-growth following defoliation (Muir et al., 2004). In addition, when legumes are harvested as hay, leaf shattering occurs, which can significantly lower the quality of the legume hay because the stem which is left contains more indigestible nutrients (Said and Tolera, 1993).

Digestibility

As the amount of supplement provided increased, the digestibility increased, and the increase in digestibility occurred regardless of supplementation with leguminous or non-leguminous supplement. This indicates that the legumes utilized in this experiment may not contain levels of condensed tannins or secondary toxins in levels high enough or were not fed in amounts large enough to affect digestibility. Research by Lascano and Palacios (1993) suggested that the quality of the legume used as supplement and the proportion of the diet at which it is fed when it does contain tannins or secondary toxins both affect diet digestibility when supplementing with legumes. Although the legumes supplemented in this experiment contained greater amounts of ADF than CSM, this did not affect digestibility.

Increased CP in the diet stimulates primary rumen microbes, which utilize fiber as a substrate, and the subsequent increase in the numbers of microbes enhances rate of digestion in the rumen (Van Soest, 1994). As the amount of supplement increased, CP increased and therefore digestibility increased. Because CSM contained more than four times the CP concentration of the legumes, improved digestibility was expected. Visually, *S. helvula* has a more stemy structure which usually indicates more ADF and ADL because stems contain more lignin (Nelson and Moser, 1994), but forage analysis in this case showed that *S. leiosperma* contained greater ADF and ADL concentrations. The 5% greater CP digestibility of *S. leiosperma* versus *S. helvula* is unusual because of the greater ADF and ADL concentration of the *S. leiosperma*. Any CP contained within the lignified structure would also pass through the animal without digestion, considered ruminal undegraded protein (RUP) (Dougherty and Collins, 1995). In this case, however, *S. leiosperma* was more digestible possible evidence of tannins or secondary toxins in the *S. helvula* (Barahona et al., 1997). The increase of CP digestibility at increasing supplementation was surprising because the CP concentration of the CBG exceded the amount in the legumes, and supplementing with legumes did not increase CP concentration of the diet. However, the amount of digestible CP did increase indicating that legume CP was more digestible (Wilson, 1994).

Intake

A common phenomenon in ruminant nutrition is the increase of basal diet as supplementary CP increases, known as the “supplementary effect” (Van Soest, 1994). A supplementary effect was expected but not evident in this experiment; the intake of CBG hay did not increase with increased supplementation amount and/or type. There are several possible reasons for the lack of increased intake for the legume supplemented diet, including the high quality of CBG and relatively lower quality of the legumes. When poor quality hays are supplemented with legumes, hay intake increases linearly as the amount of legume supplement increases (Said and Tolera, 1993). However, supplementation with legumes of lower CP and higher NDF concentrations does not demonstrate the same supplementary effect and may decrease hay and total intake (Said and Tolera, 1993). In a study comparing *Chloris gayana* (CP 61.9 g kg^{-1} DM; NDF 829 g kg^{-1} DM) hay diet supplemented with maize or one of three legumes, goats on the control diet consumed more hay than those supplemented with legumes (Mupangwa et al., 2000). The diets which were supplemented with legumes did not differ in hay intake but total diet intake did increase (Mupangwa et al., 2000). In the present experiment, there was no pure CBG hay diet with which to compare to the diets supplemented with CSM and legumes.

The only intake difference found in this experiment was the difference in total diet NDF concentration intake between CSM and *S. helvula*, versus *S. leiosperma*. This difference may be caused by the greater concentration of NDF in *S. leiosperma* and of the diet containing *S. leiosperma*. When NDF concentration increases, intake of the same mass would increase the NDF concentration of the total diet. Because *S. leiosperma* had a greater NDF concentration, intake of this supplement, although the same DM mass as the other two supplements, increased the NDF concentration of the total diet.

CHAPTER VI

CONCLUSIONS

Considering digestibility of CP and NDF, the best supplements fed in this experiment were CSM and *S. leiosperma*. The 0.68% of BW, which was actually 22.1% of intake, supplementation level tended ($P < 0.5$) to improve digestibility of all factors considered, and was found to be the better level of supplementation of the two in this experiment. Intake of CBG did not change among supplement types or supplement amounts, and as supplementation increased from 0.34 to 0.68% of BW, a greater proportion of the legume in the diet substituted the hay. Digestibility increased as supplementation increased indicating that the quality of the supplements surpassed that of CBG in this experiment. Because *S. leiosperma* has comparable NDF and CP digestibility to CSM, this native legume could be a resource to improve the poor quality of pasture grasses in mid-summer.

Pasture studies may produce different results from those of this study, primarily because protein concentrations of legume hays in this study were likely low relative to live plants as a result of leaf shattering and late harvest of mature plants. Because of the selective grazing / browsing ability of goats, they can select the younger legume plants and / or leaves from the whole standing plants (Nelson and Moser, 1994; Ahmed and Nour, 1997; Singh and Shankar, 2000; Pande et al., 2002). Plant leaves typically contain greater CP concentration and lower ADF and ADL concentrations than stem tissue (Nelson and Moser, 1994; Van Soest, 1994). Younger legumes also tend to contain greater CP concentration because of a greater leaf:stem ratio (Nelson and Moser, 1994). In a pasture situation, goats would likely select a greater proportion of legumes than grasses than was fed in this experiment (Singh and Shankar, 2000; Muir, 2002a, Pande et al., 2002; Goodwin et al., 2004). Greater selection of the leaves of young legumes should increase CP concentration of the diet (Ahmed and Nour, 1997; Singh and Shankar, 2000).

The 7% greater NDF digestibility of diets supplemented with CSM and *S. leiosperma* could be caused by the greater CP concentration and / or digestibility in these supplements as compared to the *S. helvula*. In this experiment a 0% of BW supplementation diet was not fed. Had this treatment been included in the experiment, it would have allowed comparison of pure CBG hay diet to CBG plus legume diet. This comparison is a determining factor to the decision of utilizing these legumes as forage for goats. A study which allows comparison of wild-bean supplemented diet to CBG either as hay or pasture is recommended before determining whether *S. helvula* or *S. leiosperma* may become a warm-season legume available for commercial sale.

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APPENDIX A

ALPHABETICAL LIST OF ABBREVIATIONS

Abbreviation	Full Reference
ADF	acid detergent fiber
ADG	average daily gain
ADL	acid detergent lignin
BW	body weight
CBG	coastal bermudagrass
CP	crude protein
CSM	cottonseed meal
DM	dry matter
GLM	general linear model
LSM	least-squares means
ME	metabolizable energy
MFCP	metabolic fecal crude protein
N	nitrogen
NDF	neutral detergent fiber
OM	organic matter
RUP	ruminal undegraded protein

APPENDIX B

STATISTICAL ANALYSIS

Digestibility Analysis of Variance

The GLM Procedure

Class Level Information

Class	Levels	Values
goat	6	1 2 3 4 5 6
trt	6	A B C D E F
supp	3	CSM Helo Leo
amt	2	H L
period	6	I II III IV V VI

Number of observations 36

The GLM Procedure

Dependent Variable: Dry Matter Apparent Digestibility

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	139893.0698	9326.2047	2.93	0.0132
Error	20	63682.4053	3184.1203		
Corrected Total	35	203575.4751			

R-Square	Coeff Var	Root MSE	DMDig Mean
0.687180	8.997375	56.42801	627.1608

Source	DF	Type III SS	Mean Square	F Value	Pr > F
period	5	54757.34378	10951.46876	3.44	0.0210
goat	5	54293.29110	10858.65822	3.41	0.0217
supp	2	18779.90543	9389.95272	2.95	0.0754
amt	1	10452.10158	10452.10158	3.28	0.0851
supp*amt	2	1610.42792	805.21396	0.25	0.7790

Dependent Variable: Organic Matter Apparent Digestibility

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	150544.9017	10036.3268	2.96	0.0125
Error	20	67802.4828	3390.1241		
Corrected Total	35	218347.3845			

R-Square	Coeff Var	Root MSE	OMDig Mean
0.689474	9.343235	58.22477	623.1757

Source	DF	Type III SS	Mean Square	F Value	Pr > F
period	5	70645.61344	14129.12269	4.17	0.0093
goat	5	51491.61852	10298.32370	3.04	0.0336
supp	2	11453.61846	5726.80923	1.69	0.2100
amt	1	15268.27643	15268.27643	4.50	0.0465
supp*amt	2	1685.77489	842.88745	0.25	0.7822

Dependent Variable: Neutral Detergent Fiber Apparent Digestibility

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	102463.5401	6830.9027	3.72	0.0035
Error	20	36678.8627	1833.9431		
Corrected Total	35	139142.4028			

R-Square	Coeff Var	Root MSE	NDFDig Mean
0.736393	6.777325	42.82456	631.8801

Source	DF	Type III SS	Mean Square	F Value	Pr > F
period	5	32208.98278	6441.79656	3.51	0.0193
goat	5	39968.81448	7993.76290	4.36	0.0076
supp	2	16419.25957	8209.62979	4.48	0.0247
amt	1	11450.85232	11450.85232	6.24	0.0213
supp*amt	2	2415.63100	1207.81550	0.66	0.5284

Dependent Variable: Crude Protein True Digestibility

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	150066.4959	10004.4331	4.01	0.0022
Error	20	49904.7226	2495.2361		
Corrected Total	35	199971.2186			

R-Square	Coeff Var	Root MSE	CPDig Mean
0.750440	7.249285	49.95234	689.0657

Source	DF	Type III SS	Mean Square	F Value	Pr > F
period	5	58806.92074	11761.38415	4.71	0.0053
goat	5	42872.02882	8574.40576	3.44	0.0211
supp	2	22995.65093	11497.82546	4.61	0.0226
amt	1	22668.44379	22668.44379	9.08	0.0069
supp*amt	2	2723.45164	1361.72582	0.55	0.5878

Intake Analysis of Variance

Dependent Variable: Dry Matter CBG Hay Intake

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	428.9789547	28.5985970	3.56	0.0045
Error	20	160.6245612	8.0312281		
Corrected Total	35	589.6035159			

R-Square	Coeff Var	Root MSE	DMCBGHayIn Mean
0.727572	10.70469	2.833942	26.47385

Source	DF	Type III SS	Mean Square	F Value	Pr > F
period	5	338.1357111	67.6271422	8.42	0.0002
goat	5	67.8092333	13.5618467	1.69	0.1833
supp	2	9.6099560	4.8049780	0.60	0.5593
amt	1	11.7018579	11.7018579	1.46	0.2415
supp*amt	2	1.7221964	0.8610982	0.11	0.8988

Dependent Variable: Dry Matter Total Diet Intake

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	453.7627792	30.2508519	3.76	0.0033
Error	20	160.8991549	8.0449577		
Corrected Total	35	614.6619341			

R-Square	Coeff Var	Root MSE	DMTotalIn Mean
0.738231	9.060093	2.836363	31.30612

Source	DF	Type III SS	Mean Square	F Value	Pr > F
period	5	337.6007251	67.5201450	8.39	0.0002
goat	5	66.2849394	13.2569879	1.65	0.1933
supp	2	9.9076328	4.9538164	0.62	0.5502
amt	1	38.3212523	38.3212523	4.76	0.0412
supp*amt	2	1.6482297	0.8241149	0.10	0.9031

Dependent Variable: Organic Matter CBG Hay Intake

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	334.7751430	22.3183429	3.56	0.0045
Error	20	125.3513950	6.2675698		
Corrected Total	35	460.1265380			

R-Square	Coeff Var	Root MSE	OMCBGHayIn Mean
0.727572	10.70469	2.503511	23.38706

Source	DF	Type III SS	Mean Square	F Value	Pr > F
period	5	263.8810827	52.7762165	8.42	0.0002
goat	5	52.9183204	10.5836641	1.69	0.1833
supp	2	7.4996089	3.7498045	0.60	0.5593
amt	1	9.1321290	9.1321290	1.46	0.2415
supp*amt	2	1.3440019	0.6720010	0.11	0.8988

Dependent Variable: Organic Matter Total Diet Intake

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	354.0734268	23.6048951	3.76	0.0033
Error	20	125.5647687	6.2782384		
Corrected Total	35	479.6381955			

R-Square	Coeff Var	Root MSE	OMTotalIn Mean
0.738209	9.051958	2.505641	27.68066

Source	DF	Type III SS	Mean Square	F Value	Pr > F
period	5	263.4469201	52.6893840	8.39	0.0002
goat	5	51.7258708	10.3451742	1.65	0.1934
supp	2	7.2713724	3.6356862	0.58	0.5695
amt	1	30.4458031	30.4458031	4.85	0.0396
supp*amt	2	1.1834605	0.5917302	0.09	0.9105

Dependent Variable: Neutral Detergent Fiber CBG Hay Intake

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	97.0627509	6.4708501	3.56	0.0045
Error	20	36.3436518	1.8171826		
Corrected Total	35	133.4064027			

R-Square	Coeff Var	Root MSE	NDFCBGHayIn Mean
0.727572	10.70469	1.348029	12.59289

Source	DF	Type III SS	Mean Square	F Value	Pr > F
period	5	76.50814087	15.30162817	8.42	0.0002
goat	5	15.34282898	3.06856580	1.69	0.1833
supp	2	2.17439282	1.08719641	0.60	0.5593
amt	1	2.64771617	2.64771617	1.46	0.2415
supp*amt	2	0.38967207	0.19483604	0.11	0.8988

Dependent Variable: Neutral Detergent Fiber Total Intake

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	123.6992234	8.2466149	4.53	0.0010
Error	20	36.4056359	1.8202818		
Corrected Total	35	160.1048593			

R-Square	Coeff Var	Root MSE	NDFTotalIn Mean
0.772614	8.957504	1.349178	15.06199

Source	DF	Type III SS	Mean Square	F Value	Pr > F
period	5	76.50296125	15.30059225	8.41	0.0002
goat	5	14.96294920	2.99258984	1.64	0.1943
supp	2	19.71385957	9.85692979	5.42	0.0132
amt	1	10.74058072	10.74058072	5.90	0.0247
supp*amt	2	1.77887262	0.88943631	0.49	0.6206

Least-Squares Means Supplement Type

Dependent Variable: Dry Matter Apparent Digestibility

supp	DMDig LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
CSM	646.535852	16.289363	<.0001	1
Helo	595.091306	16.289363	<.0001	2
Leo	639.855169	16.289363	<.0001	3

Least Squares Means for effect supp
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: DMDig

i/j	1	2	3
1		0.0371	0.7748
2	0.0371		0.0662
3	0.7748	0.0662	

Dependent Variable: Organic Matter Apparent Digestibility

supp	OMDig LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
CSM	638.815312	16.808044	<.0001	1
Helo	598.215711	16.808044	<.0001	2
Leo	632.496092	16.808044	<.0001	3

Least Squares Means for effect supp
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: OMDig

i/j	1	2	3
1		0.1031	0.7931
2	0.1031		0.1647
3	0.7931	0.1647	

Dependent Variable: Neutral Detergent Fiber Apparent Digestibility

supp	NDFDig LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
CSM	647.929673	12.362386	<.0001	1
Helo	601.698012	12.362386	<.0001	2
Leo	646.012489	12.362386	<.0001	3

Least Squares Means for effect supp
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: NDFDig

i/j	1	2	3
1		0.0156	0.9138
2	0.0156		0.0197
3	0.9138	0.0197	

Dependent Variable: Crude Protein True Digestibility

supp	CPDig LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
CSM	719.984364	14.419998	<.0001	1
Helo	658.076420	14.419998	<.0001	2
Leo	689.136446	14.419998	<.0001	3

Least Squares Means for effect supp
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: CPDig

i/j	1	2	3
1		0.0065	0.1460
2	0.0065		0.1434
3	0.1460	0.1434	

Dependent Variable: Dry Matter CBG Hay Intake

supp	DMCBGHayIn LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
CSM	26.7935366	0.8180886	<.0001	1
Helo	25.7449990	0.8180886	<.0001	2
Leo	26.8830031	0.8180886	<.0001	3

Least Squares Means for effect supp
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: DMCBGHayIn

i/j	1	2	3
1		0.3756	0.9391
2	0.3756		0.3371
3	0.9391	0.3371	

Dependent Variable: Dry Matter Total Diet Intake

supp	DMTotalIn LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
CSM	31.6006553	0.8187876	<.0001	1
Helo	30.5691420	0.8187876	<.0001	2
Leo	31.7485546	0.8187876	<.0001	3

Least Squares Means for effect supp
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: DMTotalIn

i/j	1	2	3
1		0.3836	0.8996
2	0.3836		0.3206
3	0.8996	0.3206	

Dependent Variable: Organic Matter CBG Hay Intake

supp	OMCBGHayIn LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
CSM	23.6694764	0.7227015	<.0001	1
Helo	22.7431956	0.7227015	<.0001	2
Leo	23.7485113	0.7227015	<.0001	3

Least Squares Means for effect supp
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: OMCBGHayIn

i/j	1	2	3
1		0.3756	0.9391
2	0.3756		0.3371
3	0.9391	0.3371	

Dependent Variable: Organic Matter Total Diet Intake

supp	OMTotalIn LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
CSM	27.8965002	0.7233163	<.0001	1
Helo	27.0550147	0.7233163	<.0001	2
Leo	28.0904509	0.7233163	<.0001	3

Least Squares Means for effect supp
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: OMTotalIn

i/j	1	2	3
1		0.4204	0.8515
2	0.4204		0.3235
3	0.8515	0.3235	

Dependent Variable: Neutral Detergent Fiber CBG Hay Intake

supp	NDFCBGHayIn LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
CSM	12.7449562	0.3891425	<.0001	1
Helo	12.2461954	0.3891425	<.0001	2
Leo	12.7875130	0.3891425	<.0001	3

Least Squares Means for effect supp
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: NDFCBGHayIn

i/j	1	2	3
1		0.3756	0.9391
2	0.3756		0.3371
3	0.9391	0.3371	

Dependent Variable: Neutral Detergent Fiber Total Diet Intake

supp	NDFTotalIn LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
CSM	14.4401835	0.3894742	<.0001	1
Helo	14.6438976	0.3894742	<.0001	2
Leo	16.1018828	0.3894742	<.0001	3

Least Squares Means for effect supp
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: NDFTotalIn

i/j	1	2	3
1		0.7154	0.0068
2	0.7154		0.0155
3	0.0068	0.0155	

Least-Squares Means Supplement Amount

Dependent Variable: Dry Matter Apparent Digestibility

amt	DMDig LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1=LSMean2 Pr > |t|
H	644.200029	13.300209	<.0001	0.0851
L	610.121522	13.300209	<.0001	

Dependent Variable: Organic Matter Apparent Digestibility

amt	OMDig LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1=LSMean2 Pr > |t|
H	643.769849	13.723711	<.0001	0.0465
L	602.581560	13.723711	<.0001	

Dependent Variable: Neutral Detergent Fiber Apparent Digestibility

amt	NDFDig LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1=LSMean2 Pr > |t|
H	649.714834	10.093846	<.0001	0.0213
L	614.045282	10.093846	<.0001	

Dependent Variable: Crude Protein True Digestibility

amt	CPDig LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1=LSMean2 Pr > |t|
H	714.159149	11.773879	<.0001	0.0069
L	663.972338	11.773879	<.0001	

Dependent Variable: Dry Matter CBG Hay Intake

amt	DMCBGHayIn LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1=LSMean2 Pr > |t|
H	25.9037133	0.6679666	<.0001	0.2415
L	27.0439792	0.6679666	<.0001	

Dependent Variable: Dry Matter Total Diet Intake

amt	DMTotalIn LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1= LSMean2 Pr > |t|
H	32.3378533	0.6685373	<.0001	0.0412
L	30.2743813	0.6685373	<.0001	

Dependent Variable: Organic Matter CBG Hay Intake

amt	OMCBGHayIn LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1= LSMean2 Pr > |t|
H	22.8834043	0.5900833	<.0001	0.2415
L	23.8907180	0.5900833	<.0001	

Dependent Variable: Organic Matter Total Diet Intake

amt	OMTotalIn LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1= LSMean2 Pr > |t|
H	28.6002839	0.5905853	<.0001	0.0396
L	26.7610267	0.5905853	<.0001	

Dependent Variable: Neutral Detergent Fiber CBG Hay Intake

amt	NDFCBGHayIn LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1= LSMean2 Pr > |t|
H	12.3216914	0.3177335	<.0001	0.2415
L	12.8640849	0.3177335	<.0001	

Dependent Variable: Neutral Detergent Fiber Total Diet Intake

amt	NDFTotalIn LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1= LSMean2 Pr > |t|
H	15.6082017	0.3180043	<.0001	0.0247
L	14.5157742	0.3180043	<.0001	

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PUBLICATIONS

Foster, J.L., Muir, J.P., Ellis, W.C., Sawyer, J., 2004. Effects of source and level of two legumes or cotton seed meal on intake and digestibility of coastal bermudagrass (*Cynodon dactylon*) hay diet by goats. Abstr. ASAS/ASDA/ASPA/ Joint Meeting, St. Louis, MO.

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PROFESSIONAL AFFILIATIONS

Sigma Alpha National Women's Professional Agriculture Organization, National Board Vice President, 2003 to 2005

Alpha Zeta, National Agriculture Honor Society

Alpha Chi, National General Honor Society

Phi Kappa Phi, National Honor Society