EFFECT OF SUPPLEMENTAL ENERGY SOURCE ON THE PERFORMANCE OF LACTATING DAIRY COWS FED DIETS BASED ON SORGHUM AND RYEGRASS SILAGE

by

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(Under the Direction of John Bernard)

ABSTRACT

Two trials were conducted to evaluate the effect of supplemental energy source and forage combination on performance, ruminal fermentation, and apparent nutrient digestibility. In trial 1, 41 lactating Holstein cows were fed a standardized diet (2-wk) and then assigned randomly to one of six treatments (4-wk). Treatments were arranged as a 2 x 3 factorial with two combinations of sorghum and ryegrass silage (50:50 or 75:25) and supplemented with one of three energy sources: ground corn, hominy, or a blend of ground corn and hominy. Trial 2: Three ruminally cannulated Jersey cows were used (3 x 3 Latin square design) to determine the effects of supplement energy source with the 50:50 ryegrass and sorghum silage base. Results indicated that a higher proportion of forage should be provided by sorghum silage than ryegrass silage when fed together. Source of energy supplement did not alter animal performance although ruminal fermentation was altered.

INDEX WORDS: Ryegrass Silage, Sorghum Silage, Ground Corn, Hominy, Ruminal Fermentation

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DEDICATION

I dedicate this to my entire family, who has always given me their endless support and encouragement. I would especially like to thank my Dad for always being there with an encouraging word, helping hand to move furniture, and never giving up on getting me back to school. Thanks Dad!

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CHAPTER ONE

INTRODUCTION

Producers have long considered corn grain and silage to be staples for high producing dairy rations, but growing conditions and production costs are leading producers to explore alternative forages. The search for a crop that can provide the same energy value as corn and can grow in a wide range of climatic and environmental conditions has been difficult. A couple potential replacements for corn may be forage sorghum silage and annual ryegrass silage.

Interest in forage sorghum (*Sorghum bicolor*) is growing among dairy producers located in areas prone to the high summer temperatures and frequent drought conditions which make corn production risky (Sanderson et al., 1992; Oliver et al., 2004). Forage sorghum is drought and heat tolerant and typically harvested for silage in the early dough stage. The energy content of sorghum silage is 85-90% of corn silage. Researchers observed that during periods of drought or when grown on lower fertility soils, forage sorghums can be superior to corn (Undersander et al., 1990). Sorghum is usually planted May to June and is harvested July to September making it an excellent crop to follow winter annuals such as ryegrass (*Lolium multiflorum*) (Ball et al., 2002).

Another factor that must be considered is a supplemental energy source. Forage sorghum and annual ryegrass are both lower in energy content than corn and require energy supplementation for high producing cows. There are several potential energy supplements to be considered; ranging from processed corn grain such as steam rolled or ground corn to by-product feeds like hominy. Availability and price play a large role in supplement selection.

To date, the effects of feeding forage sorghum and annual ryegrass silage together at different ratios has not been adequately researched. The objective of this research project was to evaluate two forage sources (forage sorghum and annual ryegrass) at two ratios (50:50 and 75:25 respectively) in the diet. In addition, the effects of two different energy sources (ground corn and hominy) and a 50:50 combination of these energy sources on production and rumen digestibility in lactating dairy cow diets based on forage sorghum and annual ryegrass was examined.

CHAPTER TWO

LITERATURE REVIEWED

Perennial ryegrass:

Perennial ryegrass (*Lolium perenne L.*) is a cool season bunchgrass that originated in Europe, temperate Asia, and North Africa. Perennial ryegrass has been successfully imported to North and South America, New Zealand, and Australia. In the United States perennial ryegrass is best suited for the Pacific Northwest, Midwest, and Northeast because of their temperate climates (Ball et al., 2002). The ability to produce high quality forage in temperate climates has made perennial ryegrass an important forage in dairy operations in European countries and in select parts of the United States where it is well-adapted. Perennial ryegrass is best adapted to cool, moist climates where winter kill is not a problem and summer temperatures are moderate to mild. Perennial ryegrass also tolerates both acidic and alkaline soil types. A pH range of 5.1 to 8.4 can be tolerated, but best yields are observed when the soil pH is maintained between 5.5 and 7.5. Maximum growth occurs during the spring and fall months when temperatures are between 68-77°F. Perennial ryegrass is more sensitive to drought and temperature extremes than annual ryegrass and is less winter hardy than orchard grass or tall fescue. (Hannaway et al., 1999b) Ryegrass is primarily utilized by dairy producers for grazing operations or as a silage crop.

In areas where perennial grasses and legumes can both be produced, legumes are traditionally preferred because of the lower NDF concentrations. Research has shown a negative correlation between NDF content and DMI of ruminants (Mertens, 1994). However, perennial ryegrass has lower concentrations of NDF than other cool season perennial grasses (Hoffman et al., 1998). When perennial ryegrass is harvested in the vegetative stage, its NDF concentration is typically the lowest of all grasses (Weiss et al., 1999). Researchers have reported that vegetative perennial ryegrass typically has substantially lower concentrations of indigestible DM and NDF than alfalfa, but in situ studies showed DM and NDF digestion are lower than alfalfa (Hoffman et al., 1993: Broderick et al., 2002). Despite lower NDF concentrations and higher digestibility values for perennial ryegrass, the production response of high producing dairy cows has not always been positive. Hoffman et al. (1998) reported higher milk yield for cows fed diets based on alfalfa silage compared with perennial ryegrass silage. The researchers reported lower DMI, DM digestibility, and a slower rate of passage for the cows fed diets based on perennial ryegrass silage compared to the cows on alfalfa based diets.

Annual Ryegrass:

Annual ryegrass (*Lolium multiflorum*) or Italian ryegrass (*Lolium perenne* L. ssp. *multiforum Lam.*) is a cool season bunchgrass that originated in southern Europe and is closely related to perennial ryegrass. Annual ryegrass is found around the world, including North and South America, Europe, New Zealand and Australia. This grass is best adapted to cool, moist conditions with the best growth observed between 68 and 77° F. Such characteristics make annual ryegrass a valuable winter annual crop with the best growth period being fall and early spring. While annual ryegrass is more heat tolerant than perennial ryegrass, high summer temperatures inhibit growth or lead to stand loss even with sufficient moisture present (Hannaway et al., 1999a). In the United States, annual ryegrass can be found in almost all areas of the country with the only major limitation being a high moisture requirement. Annual ryegrass can adapt and grow in a wide range of soil types. It can survive in wet, poorly drained soils and can tolerate a range of soil acidities from a pH 5.0 to 7.8 (Ball et al., 2002). In the United States the largest concentration of annual ryegrass production is found from Texas to the entire Atlantic coast with over 3 million acres in production. The most common use for annual ryegrass is winter pasture in the Southeast, but it is also harvested for silage in some areas. The high yields and high quality potential makes annual ryegrass a popular silage crop (Hannaway et al., 1999a).

The quality of annual ryegrass as with all forage crops, is related to the stage of maturity at harvest. It is recommended that annual ryegrass be harvested during the early boot stage for maximum quality and yield (Bernard, 2002). Annual ryegrass is known for its high digestibility and energy values. Bernard et al. (2002) reported that annual ryegrass is highly digestible and has more available energy than other winter annuals. Israeli researchers reported NDF digestibility of 49.6% and 64.1% for diets based on wheat silage and annual ryegrass silage respectively (Ben-Ghedalia et al., 1995). McCormick (1990) reported that annual ryegrass could support similar DMI and milk yield as corn silage. Bernard et al. (2002) reported that substituting ryegrass silage for corn silage in the ration resulted in improved milk yield and component yield from lactating dairy cows.

Forage Sorghum:

Sorghum originated in Northeastern Africa and is adapted throughout the mid to lower United States. Forage sorghum (*Sorghum bicolor*) is a coarse stemmed, erect growing annual with small seed heads. Forage sorghum is very drought and heat tolerant but is not adapted to highly acid soils. Sorghum also has some potential toxicity problems. Prussic acid or nitrate accumulation can occur under certain conditions and producers need to be aware of the risk and test for high nitrate levels before using the fed (Ball et al., 2002).

Interest in forage sorghum is growing among dairy producers located in areas prone to the high summer temperatures and the frequent drought conditions that make corn (*Zea mays* L.) production risky (Sanderson et al., 1992; Oliver et al., 2004). Sorghum has a later planting date than corn and is usually planted in May or June and harvested from July to September, making it an excellent crop to follow winter annuals such as ryegrass (Ball et al., 2002). These factors make sorghum well suited for parts of the United States with hot, dry climates or have delayed planting dates because of late winters or previous crops harvest dates. Sorghum is typically harvested for dairy rations at the soft dough stage of development and stored as silage. Typical nutrient content is 52-65% DM digestibility, 8-12% CP, 60-75% NDF, and 34-40% ADF. The energy content of forage sorghum silage is typically 85-90% of corn silage. Forage sorghum usually yields as much silage per acre as corn, but sorghum has less grain and higher fiber content than corn. Because of the high fiber and lower energy content of forage sorghum, an energy supplement is needed when feeding high production animals and it is recommended that sorghum silage not make up more then 50% of the diet (Undersander et al., 1990). Yet, during drought conditions or when grown on soils with lower fertility, forage sorghum can be superior in quality to corn (Undersander et al., 1990). Therefore, dairy producers in areas prone to these climatic and management conditions are beginning to consider forage-silage type sorghums as a viable alternative crop to corn.

Differences have been observed in DM digestibility between corn hybrids and conventional forage type sorghums. The digestibility values are usually greater for corn hybrids than for conventional forage sorghum hybrids. Lignin, the indigestible part of the plant cell wall, is ordinarily present at lower concentrations in the corn plant compared with normal sorghum silage hybrids. The higher lignin content of sorghum limits DMI because of slower passage rate and increased ruminoreticular fill. The end result is reduced milk yield by cows fed conventional forage sorghum based diets (Aydin et al., 1999).

Genetic research has been conducted to identify a solution to the high lignin content and improve digestibility of sorghums by reducing the amount of lignin or lignin cross linking within cell wall carbohydrates. Brown midrib (bmr) forage genotypes usually contain less lignin and may have altered lignin chemical composition (Bucholtz et al., 1980; Cherney et al., 1991; Oliver et al., 2004; Vogel and Jung, 2001). Current research suggests that genetic manipulation of the lignification process through changes in the bmr trait is the most productive approach to reducing lignin content and increasing digestibility of forage sorghums (Gerhardt et al., 1994).

Grant et al. (1995) reported higher NDF digestion for bmr sorghums versus conventional forage sorghums using in-situ and in-vitro testing procedures. Aydin et al. (1999) reported higher milk yield for Holsteins fed diets based on bmr forage sorghum compared with a conventional forage sorghum, but similar to that of cows fed diets based on corn silage. Oliver et al. (2004) compared diets based on conventional forage sorghum, bmr-6 forage sorghum, bmr-18 forage sorghum, or a corn hybrid to determine their effect on performance, ruminal fermentation, and total tract digestibility in lactating Holstein cows. These researchers reported that both bmr forage sorghums had lower lignin than the conventional sorghum or corn hybrid and reinforced the idea that some sorghum hybrids can support milk yield similar to corn silage based rations.

Nichols et al. (1998) reported that sorghum silage has an equal or greater nutritional value to tropical corn silage when both are fed at the same dietary NDF concentration (< 33% of the dietary dry matter). Their results also showed a linear decrease in DMI and milk yield as NDF concentrations in the diet increased. A more negative effect on DMI was observed with tropical corn silage as the NDF concentration increased than with sorghum silage. Cow performance was also negatively affected as NDF increased regardless of forage source.

Forage and Concentrate Combinations:

The use of different forage and concentrate combinations has long been of interest to researchers. The positive and negative effects of feeding different forage combinations and concentrates in lactating cow diets have been reported by several researchers, some results have been discussed in the forages section.

Bernard et al. (2002) investigated the possibility of replacing a portion or all of the corn silage in a lactating cow diet with ryegrass silage. Ryegrass silage replaced 0, 35, 65, and 100% of the corn silage in the diets. Although DMI was similar for all diets, yield of milk, fat, and protein increased as ryegrass replaced corn silage in the diet. The results indicate that replacing all or part of the corn silage with ryegrass silage could improve milk yields and components.

Keys et al. (1984) fed different ratios of corn silage and grass-legume silage and observed the effects on milk production and cow health. Researchers reported feeding a 75:25 ratio of corn silage to grass-legume silage supported higher yields of milk, fat, and protein than the 50:50 treatment ratio. No differences were reported in days open, number of services, and calving interval among treatments. More cow death losses occured from “fat cow syndrome” at calving in the second and third lactation with the 75:25 rations.

Trimberger et al. (1972) also reported 60% cow losses during the third lactation compared to 20% losses in the second lactation when cows were fed diets based on corn silage and concentrate. These results were attributed to the high grain content of the corn silage (42-52% of total DM) coupled with high concentrate feeding, which may have provided excess amounts of easily digestible starch that was stored as adipose tissue. Energy source and concentration are important factors that must be taken into consideration when formulating a productive and balanced ration.

Energy Sources:

Sorghum silage and ryegrass silage both have lower energy and starch concentrations than corn silage. A minimum amount of starch is needed by the ruminal microorganism to optimize ruminal fermentation (Cameron et al., 1991). Typically, starch is provided by ground corn or other starchy cereal grains. However, many by-product feeds are commonly used because of availability and economics.

Hominy:

Hominy is a by-product of dry corn-milling during the production of pearl hominy, hominy grits, and table meal. Hominy consists of a finely ground mixture of bran, germ, and a portion of the starch from the corn kernel. Hominy can be higher in energy, protein, fat, and fiber than the original corn grain but, the increased value of corn oil is making it more profitable to extract more of the oil from hominy feed leading to a drier, powdery product with lower concentrations of fat and energy. The extraction process reduces the fat content and energy value of the hominy (Chase, 1992). Typically, hominy contains less starch but more fat than ground corn (Larson et al., 1993). It is possible that diets based on sorghum silage and ryegrass silage and supplemented with hominy may not result in optimal ruminal performance which in turn could limit milk yield.

Larson et al. (1993) reported that expeller-extracted hominy feed contained 87% of the energy of ground corn when included in finishing diets fed to beef cattle at up to 40% of DM, despite containing 20% less starch than ground corn. An interaction between hominy feed and ground corn was observed for NDF digestibility and as the level of ground corn in the diet increased, NDF digestibility decreased. Larson et al. (1993)

also reported that NDF digestibility tended to increase in diets containing hominy feed, indicating that corn fiber is more digestible than fiber from roughages (corn silage or alfalfa hay). These researchers concluded that hominy feed may be substituted for up to 40% of the corn in cattle finishing diets without compromising performance.

The reduced particle size of hominy feed and ground corn has also been shown to have an effect on digestion and passage rate. Goetsch et al. (1987) reported that ruminal passage rate tended to be faster for ground corn than for whole corn. Increased passage rate supports higher DMI which may shift the site of DM digestion from the rumen to the lower tract. Besides the potential increase in passage rate and shift in site of digestion, different proportions of nutrients in hominy versus ground corn may have contributed to the lower DM digestibility as the level of hominy in the diet increased. No interaction was observed between hominy and ground corn for starch intake or digestibility. The smaller particle size of ground corn and hominy is probably responsible for the increase in starch digestibility, but differences were small and probably not biologically important (Goetsch et al., 1987).

Ground Corn:

Yu et al. (1998) fed lactating Holstein cows diets containing fine or coarsely ground corn, steam-rolled corn, or steam-flaked corn and reported that differences in performance and feed efficiency were dependant on the processing method. Cows fed steam-flaked corn produced more milk than cows fed either coarsely ground corn or steam-rolled corn. Cows supplemented with finely ground corn had an intermediate milk yield. Finely ground corn improved feed efficiency because of lower DMI compared with the other supplements. These researchers did not observe any difference in concentration of milk protein, SNF, and lactose, but milk fat percentage was higher for cows fed diets containing coarsely ground or steam-flaked corn compared to finely ground corn diets. Starch digestibility in the total tract was lower for coarsely ground corn (87.4%) and steam-rolled (91.3%) than the other diets which averaged 96.3%. These results agree with previous reports comparing finely ground corn, coarsely ground corn, and whole corn in which milk yield increased whereas milk fat decreased as grain particle size decreased (Mitzner et al., 1994; Moe et al., 1977).

A summary by Theurer (1986) reported that total tract starch digestibility in beef cattle were approximately 98% for diets containing steam flaked corn, 91% for diets with various sizes of ground corn, 93% for diets with steam-rolled corn, and

90% for diets containing whole corn. Yu et al.(1998) reported that the digestibility of ADF and NDF were negatively related to starch digestibility with the highest values observed for diets with steam rolled corn followed by coarsely ground corn, steam-flaked corn, and finely ground corn.

Callison et al. (2001) examined the effects of particle size and processing on the site of digestibility of non-structural carbohydrates and NDF. Their results indicated that as particle size decreased, true ruminal digestibility of non-structural carbohydrates responded quadratically because of compensatory digestion post-ruminally, resulting in a smaller increase (91.3% to 98%) in total tract digestibility of non-structural carbohydrates with decreasing particle size. They concluded that corn should be finely ground for maximum organic matter digestibility or steam-rolled to densities less then 0.53 kg/L for maximum rumen starch digestibility, but fine grinding or steam-processing may have only a slight effect on total tract digestibility.

Rumen Fill:

Several factors affect diet digestibility and the potential energy available to support maintenance, growth, reproduction, and lactation. Rumen fill, type of feed, moisture levels, ruminal pH levels, and particle size are all part of the equation. Rumen capacity is the first determining factor in calculating potential DMI. Dry matter intake of ruminants can be limited by distension related to restricted flow of the digesta through the gastrointestinal tract. Intake effects are typically more pronounced when feeding mixed diets compared to single ingredient diets (Moe, 1981; Joanning et al., 1981). Research has shown that the rate of depression increases as the proportion of grain in the diet increases and is higher when a lower percentage of grain is fed with corn silage as the primary base. (Moe, 1981)

Dry matter intake varies inversely with fill capacity of forages, which is represented as fiber mass (Balch and Campling 1962; Allen, 1996). Van Soest (1965) reported that voluntary intake of forage by sheep was more highly related to NDF content than to any other chemical measure. Welch et al., (1967) reported a 30% decrease in voluntary intake of sheep fed a chopped alfalfa diet, when 150g of 7-cm long polypropylene fibers were inserted into the reticulorumen. Intake decreased 75% when the same amount of 30-cm polypropylene fibers was inserted into the reticulorumen. The decrease in intake occurred immediately after the insertion of either lengths of fiber. Although there was a gradual improvement over time with the breakdown of the polypropylene fibers and passage out of the reticulorumen, DMI never reached pre-test levels.

Several studies have been conducted over the years to determine the effects of reticulorumen fill on DMI. A review of literature by Allen (1996a) does an excellent job of summarizing the various factors involved. Predicting voluntary DMI is vital to the assessment of forage quality and variation in DMI is responsible for more than 50% of the variation in digestible nutrient intake for ruminants. Allen (1996a) also concluded that distension from the restricted flow of digesta in the gastrointestinal tract is an important limitation on DMI, especially with low quality forages.

Allen (1996b) reported that ruminal pH is a more reliable way to determine fiber requirements in early lactation cows than dietary NDF concentrations. He recommended that diets should be balanced to maintain an adequate ruminal pH because as pH decreases there is a corresponding decrease in appetite, ruminal motility, microbial yield, and fiber digestion. Allen (1996b) concluded that low ruminal pH has direct, negative effects on energy intake and absorbed protein, both of which are primary limiting factors in high producing dairy cows. Allen (1996b) further stated that the fiber requirements for dairy rations should be determined by considering both the physical effectiveness of fiber and the production of fermentation acids.

Low quality forages require a greater intake to meet the animal's energy requirement, but low quality forages are typically digested more slowly. This leads to a reduced passage rate and increased fill, which reduces DMI and available energy for production or growth. The NDF concentration and particle size of the diet are not the only factors that effect digestibility. Moisture content of the forage can have a negative effect as well.

Moisture Content:

Research has shown that moisture content of feed can have an effect on intake and passage rate. High moisture levels in diets can be advantageous in preventing or reducing sorting by cows and may increase palatability by improving texture or masking undesirable flavors. Yet in the case of dairy cattle rations, high moisture diets have been shown to have a negative effect. Researchers have reported that high moisture levels can lead to reduced intake and performance in lactating cows. Observations also suggested that when given a choice, cattle will consume more DM from hay than haylage (Gordon et al., 1961; Roffler et al., 1967; Thomas et al., 1961).

Lahr et al. (1983) conducted two trials to investigate the impact of feed ingredient moisture levels on milk yield and DMI with lactating and dry dairy cows. Diets containing 78, 64, 52, and 40% DM were fed for the first 200 days of lactation. Dry hay was substituted for alfalfa silage to increase the DM content of the diet. As DM content increased in the diet during early lactation, there was a linear increase in DMI, but when corn silage was partially replaced with straw during the dry period there was no effect on DMI. No effect was observed on either milk yield or body weight gain among treatments. These researchers concluded that diets with less than 60-65% DM may reduce intake of lactating dairy cows.

In contrast, research reported by West (1994) showed no effect on DMI with diets containing wet brewer's grain with only 35.5% DM and approximately 50 versus 36.8% NDF for the control diet. West suggested that high moisture diets would not suppress DMI during hot weather because of already reduced intake during heat stress conditions. This research indicates that wet brewer's grain with added liquid brewer's yeast could increase milk yield despite high moisture and fiber content.

Moisture content has also been shown to have an impact on rumen passage rate. Pasha et al., (1994) reported that differences in the fiber digestibility of hay and high moisture forage are due to differences in rumen passage rates. Hooper and Welch (1985) reported that soaking hay in distilled water increased the functional specific gravity. Des Bordes and Welch

(1984) reported that particle specific gravity and size has a negative influence on particle passage rate.

Neel et al. (1995) suggested that adding water to dry-forage diets will increase the functional specific gravity of ruminal digesta. An increase in passage rate was not observed as specific gravity increased; therefore they concluded that passage rate is dependent on other factors besides specific gravity even when the particle size of the digesta leaving the rumen is similar.

Conclusion:

The need for a viable alternative to corn silage is a growing concern in the dairy industry, especially in arid parts of the country. High feed costs, drought conditions, and falling milk prices are causing dairy producers to consider alternative crops and energy supplements. Interest in forage sorghum has grown in areas of the country characterized by hot temperatures and low rainfalls. Forage sorghum offers a viable, high quality alternative to corn in areas where climate and growing conditions are not advantageous to corn production.

To date, there has been no research looking at the effects of combining forage sorghum and annual ryegrass silage on dairy production. The lack of research led to the decision to conduct this research project and evaluate two different combinations of annual ryegrass silage and forage sorghum silage with two different energy supplements and their effects on milk production and digestibility in lactating dairy cows.

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CHAPTER THREE

EFFECT OF SUPPLEMENTAL ENERGY SOURCE ON THE PERFORMANCE OF LACTATING DAIRY COWS FED DIETS BASED ON SORGHUM AND RYEGRASS SILAGE[1]

[1]Boyd J.A. and J. Bernard. To be submitted to *The Journal of Dairy Science.*

ABSTRACT:

Two concurrent trials were conducted to evaluate the effect of energy supplement source and forage combination on performance, ruminal fermentation, and apparent nutrient digestibility. In trial one, 41 lactating Holstein cows were fed a standardized diet for 2-wk and then assigned randomly to one of 6 treatments for the following 5 wk. Treatments were arranged as a 2 x 3 factorial and included two combinations of sorghum silage and ryegrass silage (50:50 or 75:25) and were supplemented with one of three energy sources ground corn, hominy, or a 50:50 blend of ground corn and hominy. No significant differences for DMI or milk yield were observed among the treatments. Milk protein percentage was higher for diets based on the 50:50 compared with 75:25 forage base when supplemented with a blend of ground corn and hominy. No differences were observed in concentrations of milk protein, lactose, or SNF. Yield of milk fat, energy-corrected-milk (ECM), and efficiency of milk production were also improved for cows fed diets based on 75:25 versus 50:50 forage combinations. In trial two, 3 ruminally cannulated Jersey cows were used in a 3 x 3 Latin square trial to compare the effects of each energy supplement using the 50:50 ryegrass and sorghum silage forage base. Ruminal pH and molar proportions of propionate were higher and molar proportions of butyrate were lower for cows supplemented with the blend compared with ground corn or hominy alone. No differences were observed in total VFA or molar proportions of acetate, isovalerate and valerate among supplements. Nutrient intake, total tract digestibility, ruminal pH, and proportions of VFA were similar among energy supplements. Results indicate that a higher proportion of forage in the ration should be provided by sorghum silage when fed in combination with ryegrass silage. Results also showed that the energy supplement source did not affect overall animal performance although ruminal fermentation was altered.

Key words: ryegrass silage, sorghum silage, ground corn, hominy, ruminal fermentation

Abbreviation key: B = 50:50 blend of ground corn and hominy, ECM= energy corrected milk, GC = ground corn, HH = hominy, RS = ryegrass silage, SS = sorghum silage.

INTRODUCTION:

Interest in forage sorghum (*Sorghum bicolor*) is growing among dairy producers located in areas prone to the high summer temperatures and frequent drought conditions that make corn production risky (Sanderson et al., 1992; Oliver et al., 2004). Sorghum originated in Northeastern Africa and is adapted throughout the lower United States. Forage sorghum is drought and heat tolerant and is typically harvested for silage in the early dough stage for dairy rations. The energy content of sorghum silage (SS) is 85-90% of corn silage. During drought or when grown on lower fertility soils, forage sorghums are superior to corn (Undersander et al., 1990). Sorghum is usually planted May to June and is harvested July to September making it an excellent crop to follow winter annuals such as ryegrass (*Lolium multiflorum*) (Ball et al., 2002).

Annual ryegrass is a cool season grass that originated in Europe. It is highly digestible and has more energy than other winter annuals (Bernard et al., 2002). Researchers in Israel reported NDF digestibility of 49.6% and 64.1% for diets based on wheat silage and annual ryegrass silage (RS) respectively (Ben-Ghedalia et al., 1995). McCormick (1990) reported that annual ryegrass could support similar DMI and milk yield as corn silage. Bernard et al. (2002) reported that substituting RS for corn silage in the ration improved the yield of milk and components of lactating dairy cows.

Previous research demonstrated the positive effects of feeding forage combinations. Dhiman and Satter (1997) reported that cows fed a diet based on equal parts of corn silage and alfalfa silage optimized both milk yield and efficiency of production over cows fed either a corn silage or alfalfa silage based diet alone. Bernard et al. (2001) reported that feeding a blend of RS and corn silage supported higher milk yields than 100% RS and that steam flaked corn improved milk yield and the utilization of DM over ground corn as an energy source.

Sorghum silage and ryegrass silage both have lower energy and starch concentrations than corn silage. To optimize ruminal fermentation, a minimum amount of starch is needed by ruminal microorganisms (Cameron et al., 1991). Typically, starch is provided by ground corn (GC) or other starchy cereal grains. However, many by-product feeds are commonly used because of availability and economics. Hominy (HH) is a by-product of dry-milling corn and consists of a finely ground mixture of bran and germ. Typically, HH contains less starch but more fat then GC (Larson et al., 1993). It is possible that diets based on SS and RS and supplemented with HH may not give optimal ruminal performance which in turn could limit milk yield.

Data evaluating the effects of feeding combinations of RS and SS and the choice of energy supplements on performance of lactating dairy cows is limited. The objective of this research was to look at two different forage combinations of RS and SS and two energy supplements and their effects on cow performance and nutrient digestibility.

MATERIALS AND METHODS:

Forage Production:

Forage sorghum (Southland Silo Master D, Southern States Cooperative: Richmond, VA) was planted on July 31, 2003 in Tift sandy loam soil at a seeding rate of 29.6 kg per ha. The sorghum was harvested and chopped on November 10-11, 2003 in the early-mid dough stage and stored in 2.4m silo bags until use.

Annual ryegrass (Big Daddy, Southern States Cooperative: Richmond, VA) was planted on October 27, 2003 in Tift sandy loam soil with a seeding rate of approximately 34.6 kg per ha. The ryegrass was harvested April 12-13, 2004 at the vegetative-early bloom stage of maturity. The ryegrass was mown and allowed to wilt to approximately 30% DM before being chopped and stored in 2.4m silo bags. Both crops were fertilized with dairy wastewater to meet N requirements. Additional irrigation was provided as needed to supplement natural rainfall.

Trial One: Lactation Trial

Forty-one Holstein cows (157 ± 62 DIM, 37.0 ± 5.7 kg/d of milk, 4.06 ± 0.99% fat and 2.69 ± 0.49% protein) were used in a 7-wk trial using a randomized block design. Cows were trained to eat behind Calan doors (American Calan, Inc., Northwood, NH) before beginning the trial. The trial consisted of a 2-wk preliminary period followed by a 5-wk experimental period. Treatments were arranged as a 2 x 3 factorial to provide 2 forage combinations and 3 energy supplements. Experimental diets were based on SS and RS with a 50:50 and 75:25 ratio, and supplemented with one of three energy sources: GC, HH, or a 50:50 blend of GC:HH (B) (Table 1). All protocols for this study were approved by the University of Georgia Institute of Animal Care and Use Committee.

During the preliminary period, all cows were fed a basal diet based on corn silage and alfalfa hay. Rations were offered once daily behind Calan doors in amounts to provide for a 5% refusal. At the end of the preliminary period cows were assigned randomly to one the six experimental treatments. Feed was pushed up 3x times a day. The amount of experimental diet offered and refused was recorded and feeding rate adjustments were made daily.

Table 1: Experimental diets composed of sorghum silage (SS) and annual ryegrass silage (RS). (Expressed on a % dry matter basis)

	50:50 SS:RS			75:25 SS:RS		
Item	B	GC	HH	B	GC	HH
SS	21.39	21.39	21.39	28.93	28.93	28.93
RS	21.39	21.39	21.39	9.64	9.64	9.64
Whole cottonseed	11.54	11.54	11.54	11.54	11.54	11.54
GC	12.05	23.21	0.00	13.80	26.45	0.00
HH	12.05	0.00	25.18	13.80	0.00	28.84
Brewers' grain	10.0	10.0	10.0	10.0	10.0	10.0
Soybean meal	5.36	6.25	4.29	5.80	6.96	4.57
Urea	0.09	0.09	0.09	0.36	0.36	0.36
Base Premix[2]	7.23	7.23	7.23	7.23	7.23	7.23

[1]GC = ground corn, HH = hominy, B = 50:50 mix GC & HH

[2]Base premix was the same for all treatment groups: (%DM)= 29.16 % Calcium salt of palm fatty acids; 32.95% ProLak (Church and Dwight; Providence, NJ); 11.67% limestone; 4.37% MgO; 1.46% Dynamate (Mosaic Products and Services, Minneapolis, Minnesota); 4.08% salt; 8.75% Na bicarbonate; 2.92% DCAD Minus (Church and Dwight Inc.); 3.79% yeast; 0.66% trace mineral premix; 0.01% vitamin premix.

Cows were milked 2x a day at 0400 and 1500 and yield was recorded at each milking (Alfa Laval Agri., Inc., Kansas City, MO). Milk samples were collected from two consecutive milkings each week and shipped to Dairy Farmers of America (Knoxville, TN) for analysis of milk fat, protein, lactose, urea nitrogen, and somatic cell concentrations.

Samples of ingredients and diets were collected three days each week. The DM content was determined by drying in a forced-air oven at 55°C for 48 h. Samples were composited by week and ground to pass through a 6-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA). A 100g sub-sample was retained for determining *in vitro* digestibility and the remaining sample ground to pass through a 1-mm screen before analyses of DM, CP, ash (AOAC, 1990), ADF, and NDF (Van Soest et al., 1991).

A second sample of each forage and energy source was collected 3 times each week, compiled by week, and frozen. Samples were shipped to Cumberland Valley Analytical Services, Inc. (Maugansville, MD) for analyses of nutrient content and fermentation metabolites. (Table 2)

Body weights were recorded on two consecutive days at the end of the preliminary period and at the end of the experimental period. To reduce variation, the cows were weighed immediately after the evening milking and before having access to feed or water.

Table 2: Average chemical composition of diet ingredients for ground corn (GC), hominy (HH), annual ryegrass silage (RS), and sorghum silage (SS). (Mean ± SD)

	HH	GC	RS	SS
DM	88.1 ± 0.71	86.5 ± 0.72	29.4 ± 2.52	30.1 ± 4.53
		% DM		
CP	10.70 ± 0.19	9.11 ± 0.56	16.0 ± 0.21	7.92 ± 0.32
S. Protein[1]	2.79 ± 0.14	1.98 ± 0.28	9.36 ± 0.52	2.46 ± 0.18
ADF	5.69 ± 2.12	4.84 ± 1.51	30.96 ± 0.74	35.18 ± 0.98
NDF	16.21 ± 6.37	12.79 ± 2.04	41.60 ± 0.82	51.90 ± 0.92
IVDMD	NA	NA	66.7 ± 1.8	45.7 ± 1.2
Ash	2.15 ± 0.09	2.19 ± 0.62	16.46 ± 2.05	4.74 ± 0.87
Starch	58.50 ± 7.06	61.13 ± 3.47	1.50 ± 0.10	20.12 ± 2.48
NFC[2]	67.94 ± 6.36	73.63 ± 3.09	24.64 ± 2.84	34.12 ± 1.57
Ca	0.06 ± 0.01	0.22 ± 0.16	0.59 ± 0.02	0.23 ± 0.02
P	0.44 ± 0.02	0.31 ± 0.01	0.50 ± 0.01	0.21 ± 0.01
Mg	0.18 ± 0.01	0.15 ± 0.02	0.27 ± 0.004	0.22 ± 0.01
K	0.56 ± 0.01	0.46 ± 0.06	5.17 ± 0.18	1.02 ± 0.037
Na	0.03 ± 0.01	0.06 ± 0.04	0.19 ± 0.02	0.01 ± 0.003
pH	NA	NA	4.48 ± 0.46	4.00 ± 0.32
Lactic Acid	NA	NA	10.18 ± 3.52	3.24 ± 1.44
Acetic Acid	NA	NA	2.02 ± 0.44	1.97 ± 0.49
Propionic Acid	NA	NA	0.21 ± 0.07	0.54 ± 0.38
Total VFA	NA	NA	12.33 ± 3.74	5.82 ± 1.30

[1]soluble protein
[2]NFC = non-fibrous carbohydrate= (100-(CP+ NDF+ Fat + Ash)

Data was subjected to covariate analysis of variance using the preliminary data as a covariate. Dry matter and production data was analyzed as a randomized block with repeated measures using PROC MIXED procedures of SAS (1989). Cow within treatment was included as a random effect and week was a repeated effect. The model included forage, energy supplement, week, and interactions.

Trial Two: Rumen Fermentation Trial

Concurrent with trial one, 3 ruminally cannulated lactating Jersey cows were used in a Latin square design trial to determine the effect of energy supplement on ruminal fermentation and nutrient digestibility. Experimental diets were the same as in trial one and were based the 50:50 blend of SS and RS. Treatments were GC, HH, or B. Each period consisted of a 2-wk ration adjustment period followed by a 1-wk collection period (Table 1).

Prior to beginning the trial, cows were trained to eat behind Calan doors (American Calan, Inc., Northwood, NH). Cows were fed once daily at 110% of expected daily intake. Feed was pushed up 3 times each day. The amount of feed offered and refused was recorded daily and adjustments were made as needed.

Cows were milked twice daily and weights recorded at each milking. During the collection week, milk samples were collected from each cow at 2 consecutive milkings and shipped to the Dairy Farmers of America lab (Knoxville, TN) for analysis of fat, protein, lactose, urea nitrogen, and somatic cell concentrations.

Samples of experimental diets, ingredients, and orts were collected daily during the collection period. The DM content was determined by drying in a forced air oven at 55°C for 48 h and composited by cow within each period. Samples were ground to pass through a 1-mm screen using a Wiley mill and analyzed for DM, ash, CP, NDF, ADF, and lignin as described previously.

During the last 4d of each collection week, fecal samples were collected twice daily at 12h intervals with the collection time advancing 3h each day so that samples were collected at 0100, 0400, 0700, 1000, 1300, 1600, 1900, and 2200h. Samples were composited by cow within each period and dried in a forced air oven for 48h at 55°C. Samples were ground to pass through a 1-mm screen using a Wiley mill and analyzed for DM, CP, ADF, NDF, and lignin. Diet, ort, and fecal samples were analyzed for indigestible ADF as an internal digestibility marker as described by Cochran et al. (1986).

On the last day of each experimental period, ruminal fluid samples were collected at 0, 2, 4, 6, and 8h post feeding. Approximately 50 ml of ruminal fluid was collected and strained through three layers of cheesecloth before freezing for later analysis of pH. A 10 ml sub-sample was strained through three layers of cheesecloth and immediately mixed with 2 ml of metaphosphoric acid (25% w/v). The sample was then centrifuged at 10,000 x g for 10 min, supernatant collected, and frozen for later analyses of VFA (Erwin et al., 1961) using a Hewlett Packard 5890A gas chromatograph (Hewlett-Packard Company, Avondale, PA).

Nutrient intake and digestibility data were analyzed as a Latin square using PROC GLM procedures of SAS (1989). The model included the cow, period, and energy supplement. PROC MIXED procedures of SAS (1989) were used to analyze the ruminal fermentation data in order to account for time.

RESULTS AND DISCUSSION:

The chemical composition of the experimental ingredients is presented in Table 2 and diets in Table 3. The DM content of the RS and SS were similar. Both silages had lower DM concentrations then are normally desired, but are similar to values observed in the field. Poor drying conditions in the spring frequently result in a lower DM for RS. Lower DM values

Table 3: Composition of diets based on sorghum silage (SS) and ryegrass silage (RS) and supplemented with ground corn (GC), hominy (HH), or a 50:50 mix of ground corn and hominy (B).

	50:50 SS:RS			75:25 SS:RS		
Item	GC	HH	B	GC	HH	B
DM%	56.9	56.6	57.1	56.7	56.1	56.9
			----% DM----			
CP	17.3	16.3	16.4	17.1	16.4	16.7
RDP[1]	10.7	10.7	10.7	10.7	10.7	10.7
RUP[1]	5.7	5.7	5.7	5.8	5.8	5.8
NDF	34.7	35.6	35.2	33.9	35.5	34.7
ADF	21.4	21.3	21.4	22.2	21.0	21.4
NeL,(Mcal/kg)[1]	1.61	1.61	1.61	1.61	1.61	1.61

[1] Values calculated using the NRC(2001).

are also seen in SS when the grain becomes too mature. The RS had higher concentrations of CP, soluble protein, and lower concentrations of NDF, ADF, and starch compared with SS. The IVDMD was higher for RS (66.7%) compared with SS (45.7%) (Table 2). This suggests a higher quality value for the RS, but the SS had a higher concentration of starch then the RS. This difference in starch availability led to the higher production levels observed in the cows on the 75:25 based rations. Joanning et al. (1981) observed that lower starch availability leads to a reduction in the amount of energy available for synthesis of microbial protein in the reticulo-rumen. This would result in a drop in CP digestibility and production potential.

Concentrations of DM, CP, ash, and starch were similar for GC and HH. The HH had a slightly higher concentration of NDF than GC. Greater variation in fiber and starch contents were observed for HH than GC based on the standard deviation. The GC and HH were both obtained from a single feed manufacturer on two occasions during the trial. The higher variation observed for HH is consistent with the results reported by De Peters et al. (2001). Although HH typically contains less starch and more fiber then GC, that was not the case in the current trial.

Dry matter intake and performance for trial one is presented in Table 4. An interaction of forage and energy supplement ($P < 0.004$) was observed for milk protein percentage. The 50:50 diet supplemented with B yielded higher milk protein compared with the 75:25 diet supplemented with B. Yield of milk fat ($P < 0.05$) and ECM ($P < 0.03$) were higher and milk yield tended to be higher ($P < 0.10$) for cows fed diets based on the 75:25 compared with the 50:50 SS:RS. Because DMI was similar dairy efficiency was higher ($P < 0.02$) with the 75:25 SS:RS (Table 4). No differences were observed for milk component concentrations. Supplemental energy source did not affect ($P < 0.10$) intake performance.

These results are similar to those reported by Keys et al. (1984) in which milk yield was optimized when diets containing a 75:25 ratio of corn silage to grass-legume silage were fed. Although the diets were formulated to provide similar amounts of energy, the sorghum silage was higher (20.12% ± 2.48) in starch content, in comparison to the ryegrass silage (1.50% ± 0.10). Therefore the 75:25 SS:RS diet had more available starch, which probably led to improved ruminal fermentation and increased production. Work reported by Bernard et al. (2002) stated that lower starch availability would effectively reduce the amount of energy available for synthesis of microbial protein in the reticulo-rumen, lowering CP digestibility and production potential. Energy supplements did not differ greatly in starch content, which may account for the lack of any production response.

Nutrient intake and apparent digestibility of diets using the ruminally cannulated cows in trial 2 was similar among energy supplements (Table 5). The digestibility coefficients are consistent with previous values reported (Bernard et al., 2002). These cows were in late lactation and averaged 14 kg/d of milk containing 4.7% fat, 3.6% protein, and 4.1% lactose.

Table 4: Performance of lactating Holstein cows fed diets based on sorghum silage (SS) and ryegrass silage (RS) and supplemented with ground corn (GC), hominy (HH) or 50:50 mix of ground corn and hominy (B).

	50:50 SS:RS			75:25 SS:RS				P <		
Item	B	GC	HH	B	GC	HH	SE	Forage	Grain	Forage x Grain
DMI, kg/d	22.8	23.9	24.4	22.9	23.5	23.3	0.77	0.47	0.39	0.71
Milk, kg/d	32.2	32.8	33.3	34.7	34.2	33.1	0.86	0.10	0.93	0.36
Fat, %	3.87	3.82	3.78	3.93	4.22	4.11	0.22	0.15	0.85	0.71
Protein, %	3.05	2.83	2.80	2.80	2.84	2.90	0.05	0.26	0.16	0.004
Lactose, %	4.87	4.58	4.67	4.75	4.72	4.79	0.09	0.54	0.26	0.34
SNF, %	8.69	8.18	8.29	8.37	8.31	8.55	0.15	0.85	0.22	0.17
Fat, kg/d	1.25	1.24	1.28	1.36	1.49	1.33	0.09	0.05	0.74	0.48
Protein, kg/d	0.98	1.0	0.94	0.96	0.98	0.97	.065	0.32	0.70	0.45
Lactose, kg/d	1.5	1.4	1.7	1.6	1.7	1.6	0.09	0.29	0.71	0.37
SNF, kg/d	2.7	2.6	2.9	2.8	2.9	2.8	0.15	0.33	0.66	0.40
ECM, kg/d[1]	33.5	32.9	33.7	35.6	37.4	34.3	1.27	0.03	0.68	0.31

	50:50 SS:RS			75:25 SS:RS				*P* <		
Item	B	GC	HH	B	GC	HH	SE	Forage	Grain	Forage x Grain
Dairy efficiency[2]	1.46	1.37	1.40	1.57	1.58	1.49	0.03	0.02	0.59	0.65
Initial BW, kg	616.5	624.1	640.1	584.1	622.0	658.5	29.0	0.82	0.26	0.68
BW gain, kg	0.00	1.45	16.07	-1.27	3.56	-7.76	11.1	0.40	0.91	0.46

[1]Energy corrected milk = (.3246 x kg milk) + (12.86 x kg fat) + (7.04 x kg protein).

[2]Unit of milk per unit of DMI.

No interaction between the energy supplements and sampling time was observed ($P < 0.10$). The least square means for ruminal fermentation parameters are presented in Table 5. Ruminal pH ($P < 0.06$) and molar proportions of propionate ($P < 0.02$) were higher when cows were supplemented with B compared with GC or HH. Also molar proportions of butyrate ($P < 0.002$) decreased when supplemented with B compared with GC and HH. No differences were observed among the treatments for total VFA, acetate, isovalerate and valerate (Table 6).

CONCLUSIONS:

Results indicate that feeding a higher percentage of sorghum silage in the diet when used in combination with ryegrass silage supported an increase in milk yield and energy efficiency in lactating dairy cows. This is in contradiction to work done by Undersander (1990) that recommends that sorghum silage not constitute more than 50% of the forage in dairy rations. The increase yield of milk and fat with for the 75:25 diets may be credited to the higher starch concentrations in the sorghum silage vs. ryegrass silage.

Trial 2 showed an effect on ruminal fermentation by the energy source B, but no effect on performance was observed. The data demonstrates that the different energy supplements, when used with a 50:50 forage base do not have an effect on overall cow performance. Producers can therefore use economics and product availability as the deciding factor in energy supplement selection. Additional research is needed to completely evaluate the effect on ruminal fermentation by the energy supplements when fed in combination with 75:25 forage base.

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Table 5: Nutrient intake and apparent digestibility of lactating Jersey cows fed diets containing a 50:50 ratio of ryegrass silage and sorghum silage supplemented with ground corn (GC), hominy (HH), or a 50:50 mix of ground corn and hominy (B).

	GC	HH	B	SE[1]
Intake, kg/d				
DM	12.8	14.0	14.4	0.52
CP	2.3	2.5	2.5	0.12
ADF	2.6	2.9	3.1	0.18
NDF	5.1	5.5	5.8	0.25
----------------Apparent digestibility %----------------				
DM	55.9	56.3	53.1	4.3
CP	57.7	60.9	55.8	3.6
ADF	26.1	30.3	28.7	3.6
NDF	41.5	40.6	38.2	3.0

[1]No significant differences were detected among treatments ($P > 0.10$).

Table 6: Comparison of ruminal pH and VFA concentrations in lactating Jersey cattle fed a 50:50 ratio of ryegrass silage and sorghum silage, supplemented with ground corn (GC), hominy (HH), and 50:50 mix ground corn and hominy (B).

	GC	HH	B	SE	P<
pH	6.45^{a}	6.36^{b}	6.69^{a}	0.10	0.06
T.VFA (mmol)	89.09	86.87	85.92	1.19	0.17
---------------------------------%---------------------------					
Acetate	64.12	63.39	63.78	0.38	0.41
Propionate	23.62^{b}	23.36^{b}	24.42^{a}	0.20	0.02
Butyrate	9.95^{b}	10.26^{a}	9.21^{b}	0.19	0.002
Isovalerate	1.38	1.71	1.50	0.15	0.30
Valerate	0.93	1.28	1.09	0.12	0.15
A:P	2.71	2.71	2.61	0.04	0.15

[1]No interaction observed between collection time and treatment ($P < 0.10$)

[a] [b] = means in the same row with unlike superscripts differ ($P < 0.05$)

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CHAPTER FOUR

CONCLUSIONS

Corn silage is the most common ingredient in high production dairy rations, but it is not always possible to produce high quality corn silage. Areas like the Southeast that are prone to high temperatures and drought conditions need an alternative forage crop. Forage sorghum is a viable alternative to corn in those climate conditions because of it has a higher drought and heat tolerance. Forage sorghum can produce a high energy crop similar to corn, in areas where quality corn production is not feasible because of climate and growing conditions.

Forage sorghum and annual ryegrass are both good forage crops to consider, but an energy supplement is needed in rations containing these forages to match high quality corn silage in energy value. Ground corn and hominy are both good choices. It has been observed that both offer similar production results alone and in a blend when used in sorghum and ryegrass diets leaving the producer with a choice to make. Producers can look at availability and cost when considering ground corn or hominy for their rations.

The use of a combination of 75% forage sorghum and 25% ryegrass silage had a positive effect on milk yield and efficiency when supplemented with ground corn, hominy, or a blend of the two. This provides producers something to consider when planning their forage crops in areas where corn production is risky. Forage sorghum combined with annual ryegrass silage may be a viable solution to the problem by offering a high energy forage that is more suitable for areas with high temperatures and low rainfall then corn.