PERFORMANCE OF FORAGE-FINISHED BEEF CATTLE GRAZING

RYEGRASS, RYE OR OATS, AND FORAGE QUALITY

MEASURED BY A HIGH-THROUGHPUT

PROCEDURE

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VITA

Adolfo Cândido Pereira, Jr, son of Adolfo Cândido Pereira (in memorian) and Anna Correa de Rezende Pereira, was born November 20, 1970 in Campo Grande, Mato Grosso do Sul State, Brazil and grew up on a ranch in the same State. He graduated from a high school technical college as an Agriculture Technician in December, 1988. He received his bachelor degree in Veterinary Medicine from Federal University of Mato Grosso do Sul, Brazil, in December, 1994. He also received a specialization degree in Rural Administration from Federal University of Lavras, Minas Gerais State, Brazil, in November, 1996. After working as animal nutritionist consultant for 4 years, he attended Univeridad de Baja Califonia- Mexicali, BC- Mexico where he obtained his Master of Sciences degree in June, 2001. Adolfo returned to Brazil and worked in the animal feeding industry. He married Maria Aparecida Oliveira, on April 03, 2004. He started his Ph.D. program in ruminant nutrition under Dr. Stephen Schmidt on January, 2006. Adolfo is a proud father of Arthur Rocha Pereira, his 3 years old boy.

DISSERTATION ABSTRACT

PERFORMANCE OF FORAGE-FINISHED BEEF CATTLE GRAZING RYEGRASS, RYE OR OATS, AND FORAGE QUALITY MEASURED BY A HIGH-THROUGHPUT PROCEDURE

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A 3-yr grazing trial was conducted with ryegrass (*Lolium perenne*), rye (*Secale cereale*) and oats (*Avena sativa*) as winter pasture for forage-finished beef. Replicate 1.42-ha paddocks were established and stocked with 3 Angus × Continental crossbred steers per paddock each year in a completely randomized design. Steers had free-choice access to salt-mineral mix and water. Forage mass (FM, kg DM/ha) and nutrient composition were determined. Put-and-take steers were used to maintain forage in the vegetative stage. Average daily gain differed ($P < 0.05$) among years, but there was no treatment effect or animal × yr interaction. Overall mean ADG was

1.32 ± 0.12 kg/d. In yr 1, seasonal-mean ADG (1.81 ± 0.05 kg/d) was higher ($P < 0.0001$) than in the other years, but ADG in yr 2 (1.05 ± 0.05 kg/d) and yr 3 (1.11 ± 0.05 kg/d) did not differ. There was no yr effect or yr × treatment interaction for forage concentration of NDF and ADF. Ryegrass had lower NDF (39.8% ± 1.1) and ADF (20.6 ± 0.6) than oats (46.0% ± 1.1 and 24.3 ± 0.6) and rye (46.2 % ± 1.1 and 24.4 ± 0.6). Total gain per area differed ($P < 0.05$) among years and forage type, but there were no yr × treatment interactions. Animals grazing oats had a greater ($P < 0.05$) gain per ha (504 ± 15.4 kg/ha) than those grazing rye (425 ± 15.4 kg/ha) or ryegrass (408 ± 15.4 kg/ha). In conclusion, cool-season annual pastures did not differ in terms of steer ADG, but oats was superior to the rye or ryegrass pastures in total gain per area. In experiment 2, a high-throughput procedure was developed for the sequential analysis of NDF and ADF allowing a high volume of samples to be analyzed in a relatively short period of time. The fiber bag ANKOM method served as the control for evaluation of the modified water bath method (WB). A completely randomized design with a replicated 2 × 3 × 2 factorial arrangement of treatments was used. There were no differences between the methods for either NDF (31.93% WB vs 31.33% ANKOM, $P = 0.29$) or ADF (15.54% WB vs 15.96% ANKOM, $P = 0.21$). The CV were low for NDF (100% of samples with CVs below 2.8%) and for ADF (83% of samples with CVs below 5% with the highest CV at 5.9%). The WB analysis method produced repeatable results comparable to the ANKOM method and can be used to process a large number of samples in the same amount of time that 12 duplicate samples are processed using the ANKOM method.

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I. INTRODUCTION

The preference for forage-finished beef by consumers in the U.S. is high due to its being perceived as more healthful and environmentally friendly than grain-finished beef (Razminowicz, et al., 2006). In order to achieve the goal of increasing production of finishing cattle on pasture, forage quality and availability must be high so that energy intake does not limit animal performance (Fontenot et al., 1985). Forage quality analysis is of major importance in ruminant nutrition, especially in a forage-finish system due to a use of fiber as source of energy.

The Southeastern United States has an environment that enables production of a variety of forages, even though most warm season grasses have a dormancy period of 5 or more months and generally do not support rapid gains desired for finishing cattle (Ball et al., 2002). This gap in the pasture system, is a major barrier to finishing cattle throughout the year (Matches and Burns, 1995). Small grains can be established as high quality pasture which will support fast gains and extend the grazing season.

Previous research has not resulted in a consensus when the palatability of forage-fed compared with grain-fed beef was compared. Some studies report more desirable flavor for forage-fed (Cross and Dinius, 1978; Kropf et al. 1975; Skelley et al. 1978; Schroeder et al. 1980; Kidwell, 2002); some report less desirable flavor (Wanderstock and Miller, 1948; Bowling et al., 1977; Brown et al., 1979), and others reported acceptable flavor for both (Oltjen et al., 1971; Huffman, 1974; Bidner et al., 1981). The flavors are known to vary with the type of grass being grazed and the length of time the grasses are grazed (Mandell et al., 1998).

The objective of the trial reported here was to examine trends in forage availability, forage quality and steer performance during the grazing/finishing phase.

In ruminant nutrition, fiber refers to the plant cell wall and is defined as part of the feedstuff not digested by mammalian enzymes (Moore and Hatfield 1994). Its concentration is nowadays more precisely determined by fiber analysis as NDF. The NDF method was developed by Van Soest and Wine (1967) and was intended to separate the feedstuff into two main fractions, a soluble fraction that is totally digested and an insoluble fraction that is incompletely and slowly digested in the rumen.

Since the original NDF method was developed (Van Soest and Wine 1967), there were several modifications (Robertson and Van Soest, 1981; Mascarenhas-Ferreira et al., 1983; Van Soest et al., 1991; Giger-Reverdin, 1995) before it received final approval as an official method in 2002 by the AOAC (Association of Official Analytical Chemists) (Mertens, 2002).

The NDF method is based on the ability of the detergent solution to solubilize cell matrix components, leaving just the fiber parts (cell wall) of the feed sample separated by filtration. Filtration problems became the major barrier in this procedure until the development of a procedure using filtration in filter bags (Komarek, 1993a,b; Komarek et al., 1994a,b) in a semi-automated fiber analyzer with a pressurized chamber from ANKOM company (Ankom Technology Corp., Fairport, NY).

However, the system still is limited by the number of samples per batch that can be analyzed and the price of the pressurized chamber itself. We developed a procedure for NDF and ADF analyses using the filter bags without the need of the special equipment (pressurized chamber) using a simple water bath.

The objective was to compare both procedures using different harvests of ryegrass, rye and oats forage samples. The hypothesis was that NDF and ADF values would not be significantly different between the water bath method and the ANKOM method.

II. LITERATURE REVIEW

Finishing cattle systems

Historical aspects. Historically, in the early 1800s beef cattle in the United States were slaughtered soon after weaning weighing about 200 to 240 kg (Wilford, 1951). At that time, the meat had good acceptance by the consumer. According to early publications the earliest mention of using corn for finishing cattle was in the late 1890s (Ball, 1998), but the feed industry started finishing cattle using some level of corn in the early 1950s (Butler et al., 1956), and the proportion of corn increased very fast, getting up to 100% before the 1960s (Perry et al., 1956). Since then, the level of concentrate used ranged from 40 to 60% in the total diet dry matter at lighter weights getting up to 100% of concentrate for finishing beef cattle (Zinn et al., 1970; Wise et al., 1968).

Researchers showed the advantages of finishing cattle using grain diets included increased ADG when compared with cattle finishing on grazing (Geurin et al. 1954) or compared with an all forage diet (Oltjen et al., 1971), having more intramuscular fat (Craig and Blumer, 1956) or superior carcass quality (Oltjen et al., 1971), and improved feed efficiency (Zinn et al., 1970). Because cattle were finished with diets having so many different concentrate levels, including feeding supplements on pastures (Oltjen et al., 1971), there was an increase in the type and quality of beef meat available. To help the consumer compare the different types of beef the USDA published the first beef grading system in 1926 (Matsushima, 1995). This system helped increase beef consumption in United States in years 1930 to 1953 (Corah, 2008; Figure 1). During the same period of time pork and beef were competing very closely to be the preferred meat in United States. In 1953, beef passed pork in per capita consumption (Corah, 2008) and has sustained this position since then. Beef consumption reached a peak in 1979 (Figure 1), when it began to decline. Competition with poultry consumption contributed to the decrease in beef consumption. Health concerns over fat and cholesterol, also contributed (Purcell, 1998). In 1997, the total per capita consumption of poultry (chicken and turkey) exceeded beef per capita consumption.

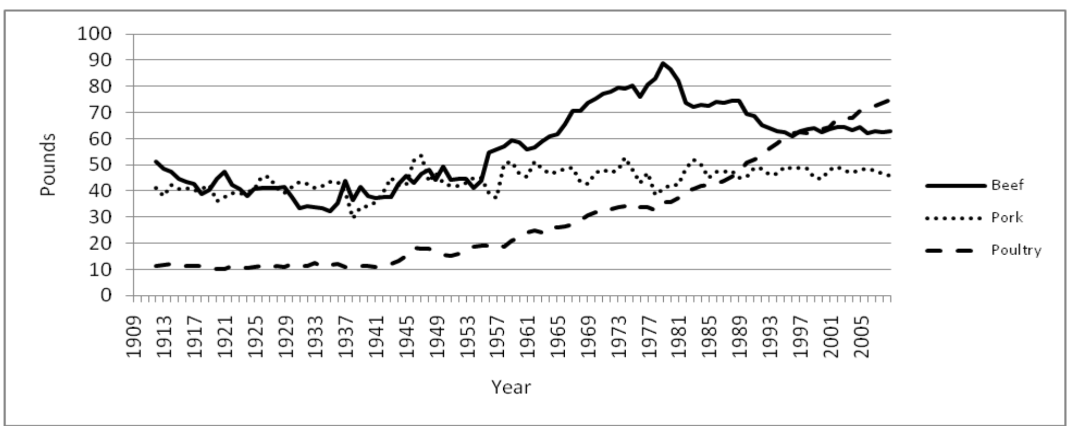

Figure 1: US per capita meat consumption: boneless equivalent (Adapted from USDA, 2008)

Growing phase.

Weaned calves normally are kept in a pasture system, but they also can be placed in a feedlot, for a growing phase before reaching a weight to start the finishing phase using a high-grain diet (Galyean and Goestch, 1993). Lewis et al. (1990b), in an experiment conducted to compare cattle performance in the feedlot immediately after weaning or after a growing phase on a pasture system showed that calves that were in the growing phase on pasture had 30% faster daily gain when in the feedlot but also 45% higher daily feed intake which resulted in 10% poorer feed efficiency and an increased annual beef production by 37 kg per animal. Other studies, using a pasture growing phase, also showed an increase in beef production per cow by 27 kg (Janovick et al., 2004) and 79 kg (Hersom, 1999). Even though cattle performances in the feedlot following pasture during growing phase were less efficient, they produced a high quality carcass and consequently were more profitable (Lewis et al., 1990a).

After the calves have been weaned there are different options used by the beef cattle industry in United Stated for a growing phase. However, the most commonly used are to graze cool-season forages or feed a forage–based grower diet.

Cool-season forages. Beef cattle production in United States is generally divided in three phases, cow-calf, stocker/backgrounding, and finishing systems. The objective of a stocker system is to support growth and development but not fattening in this stage. The reason for that is because it is normally cheaper to put on lean gain rather than fattening the animal and get the animal to 300 to 350 kg of live weight when the animal is ready to move to the finishing phase. There are different types of stocker programs available to the producer.

One option is to use small grains integrated as part of a crop-livestock system for stocker production. It can have some advantages as an improvement in nutrient recycling. Franzluebbers et al. (2001) showed that a greater accumulation of C with grazing was due to fecal excretion from animals rather than application elsewhere with hay harvest.

A problem with the integration of crop-livestock is the general concern with the potential to increase the soil compactation caused by the cattle grazing. Diaz-Zorita et al. (2002) concluded that grazing cattle in crop-pasture rotations compacted soil only under conventional tillage but not on no-tillage, suggesting that crop residues as small grains could be grazed without causing major compaction of soil if crops were established without tillage.

The easiest way to integrate crop and livestock is to use the crop residues after the grain has been harvested; small grain as oats or wheat could be used this way. Clark et al. (2004) showed that no-tillage systems were still possible on integrated crop and livestock system, where grazing reduced only 5 to 25% of the amount of residues in the soil. In the southeastern USA, many crops have been investigated to be used in integrated crop-livestock systems, and some small grains that can be used include wheat, rye, barley and oats (Sojka et al., 1984).

Using oats for stocking cattle, Horn et al. (1995) reported an ADG of 0.96 kg/d at a stocked rate of 1.2 head/ha for 84 to 115 days during three winters. In a recent review done by Redmon et al. (1995) where wheat was grown as a dual-purpose crop, they reported no effects of grazing on grain yield. During years of good precipitation, tall winter wheat cultivars grazed prior to jointing increased grain yield but not semidwarf cultivars which are more sensitive to grazing. They concluded that taller wheat cultivars could be used in dual-propose and be grazed by livestock while producing grain similar to that of semidwarf.

Hill et al. (2004) conducted a 3-year experiment using rye or ryegrass as cover crops during winter and compared grazed and ungrazed treatments. Using a stocking rate of 2.5 head (235kg ±12)/ha for 57 to 84 days, crop yields were not different with or without grazing, and cattle daily gains averaged 0.9 ± 0.1kg/head.

In Alabama, using oat and ryegrass as winter cover crops under grazing on cotton and peanut production, Siri- Prieto et al. (2005), Gamble et al. (2005) also showed an ADG above 1 kg/head/day with no negative effects on cotton yields.

Similarly in a preliminary data of Franzluebbers and Stuedemann (2004) in a two year experiment using two cropping systems (sorghum grain with rye as cover crop and wheat grain with pearl millet as cover crop) and two cover crop management (ungrazed and grazed by cattle), the result showed that cattle grazing in those systems had no negative effect on the subsequent grain crop production. Cover crop was grazed for 60-90 days and the average stocking rate was 4.45 head/ha depending on forage availability and cattle performance averaged 1.54 kg/head/day.

Another common use of small grain is interseeded into a warm season pasture to provide pasture year-around for stocker cattle (Coulibaly et al., 1996). Among the experiments conducted to evaluate the performance on the grazing program for small grains, there was large variation in ADG. Cleere et al. (2004) reported that steers grazing rye with ryegrass gained from 1.01 to 1.28 kg/d. Horn et al. (1995) used steers grazing wheat without supplementation; these gained from 0.80 to 0.97 kg/d over a 3 year period. Gadberry et al. (2004) reported ADG in heifers grazing wheat with ryegrass interseeded into bermudagrass averaged 0.74 kg/d. Beck et al. (2007) reported a range from 0.89 to 1.33 kg/d across rye, oats, and wheat pasture interseeded into bermudagrass.

The use of annual cool-season pastures as wheat in double purpose is possible without decreasing grain productivity and achieving 1kg of ADG if the grazing does not reach the apical meristems heights (Donnelly and McMurphy, 1983).

Forage-based grower diet. In the United States, beef calves normally are weaned at approximately 8 months of age, and they are managed to grow at around 0.5 to 1.0 kg/d on a forage-based diet. During this period there are several options available to the producer. A large number of different pasture species are available in the southeastern U. S. In northern Alabama, Mississippi, Georgia, and South Carolina, tall fescue is the predominant forage source. In the lower South other forages are available such as bermudagrass, bahiagrass and dallisgrass; although those pastures are mainly used by the cow herd (Hoveland, 1986).

Tall fescue provides forage during 8-10 months of the grazing season leaving a gap of 2 to 3 months when it is necessary to feed hay (Chamblee and Spooner, 1985). Also, warm season grasses such as bermudagrass or bahiagrass can be used during the summer, but they are dormant during the winter, requiring a long period of hay feeding unless they are over-seeded with cool-season annual grasses. In Southeast the main sources of forage for hay production are bermudagrass and tall fescue (Hoveland, 1992).

Another option for a forage-based growing program is the use of crop residue during the winter months. The use of wheat residue as an annual cool-season pasture can provide up to 1 kg of ADG (Donnelly and McMurphy, 1983).

The utilization of a feedlot system with a high roughage diet is another way to conduct a forage based growing program, however, due to the high fixed cost and the low gain provided by the high roughage diet this system usage is limited (Lake, 1987).

Finishing

In middle of 1960s the system of finishing cattle through feedlot by the beef cattle industry became very popular in USA. At the same time, per capita consumption of beef increased, and corn-based feedlot systems also start to grow in number and in size from 3,500 cattle feedlots in the 1940s (Matsuchima, 1995) to 100,000 in 1968 (Corah, 2008). Concurrently the beef cow population increased 75% from 1960 to 1975, going from 26.3 to 45.5 million head (Hodgson, 1977) due to a greater number of calves and yearlings going to feedlots at younger ages resulting in more pasture acreage available for cows.

Therefore, grain-fed beef was prevalent in supermarkets in the United States and consumers became used to the flavor profile, juiciness and tenderness grain-fed beef (Schupp et al., 1980). Demand for beef meat began to decrease after its peak in 1979 (Figure 1). According to Purcell (1998) the reason was a change in consumer preferences for low fat and low cholesterol foods, a desire for meat with more consistency, and as foods that were convenient and easy to prepare became more popular.

Feedlot using high-grain diet. Today, the feedlot system is the most traditional way to finish beef cattle in the United States (Taylor, 1984). Feedlots are feeding operations that feed cattle primarily a high concentrate diet to finish the animal prior to slaughter during, on average, 90 to 150 days, but the cattle can be fed to more than 200 days if calves go directly from weaning to the feedlot and receive a high concentrate diet.

There are several feeding programs that are available to the producer today. The choice of the feeding program depends on different factors such as the initial weight of the cattle, the desired finishing weight, age, sex, amount of feed available for the animals in the area, and the cost of the available feeds. The feeding program can be as simple as using a roughage source like corn silage mixed with some protein or mineral supplementation (Perry and Cecava, 1995).

A more complete feeding program for a feedlot system can include different levels of concentrate and roughage in the diet. Normally cattle start on a low level of concentrate in the diet which is increased as the cattle progress in the feeding period. The change in level of the concentrate and roughage in the diet can be from 2 to 4 times during the feeding period. The formulation of the diet is done utilizing least cost or highest gain programs depending on the needs and options of the producer. In the more complete feeding programs, the main goal is to optimize feed intake and maximize gain with the least cost possible. The feed bunk is managed in order to reduce feed waste and improve feed intake. Animals are fed 2 to 3 times a day aiming optimal DM digestibility, improving ADG and animal performance (Simpson and Farris, 1982).

Calves are normally fed initially with a high roughage diet to slow the weight gain in order for the animal to develop without fattening at a young age. Otherwise those animals may finish at lighter weights than desirable. Therefore, starting at lower levels of concentrate in the diet and increasing as the animal matures will permit fattening the animal to the desired level (Taylor, 1984).

Cattle that start in a feedlot around 300 to 350 kg are normally fed a higher concentrate level diet to be finished as quickly as possible because those animal have already grown to a level that allows them to deposit fat and be finished at the desired weight (Perry and Cecava, 1995).

Concentrate levels in the diet in feedlots can vary from 0 to 100%, but generally a diet ranges from 60 to 90% of concentrate. At least some roughage needs to be added to the diet in order to avoid metabolic diseases such as bloat and acidosis (Owens et al., 1998). Also, addition of minerals and vitamins is a common practice in commercial feedlots, accounting for a low percentage of the diet (Vasconcelos and Galyean, 2007).

Forage finishing

Consumer interest. Finishing cattle in a forage system in general has a limitation in performance due to a low energy intake which is overcome by any energy supplementation (Fontenot et al., 1985). The use of grain as a supplement in forage finishing systems had been done in the 1960s and 1970s as a method to decrease the time spend in the finishing phase in a forage system (Hoveland and Anthony, 1977) and to increase ADG (Allen et al., 1996; Berthiaume et al., 2006). But the result in terms of increasing ADG failed when high quality forages were used (Hoveland and Anthony, 1977) and also when feeding a high energy diet in a feedlot was compared to grain being fed in a forage-finished system (Coombs et al., 1990; Allen et al., 1996). In both studies cattle finished in a feedlot system were heavier than those finished in a grain supplemented forage system which also had more year to year variance depending on season. But in some years the result in terms of profitability is greater for forage system compared to feedlot system.

Finishing cattle in a forage system alone is possible and requires high quality pasture with a high level of pasture management to achieve a reasonable ADG in order to decrease the time needed to reach a slaughter weight and the USDA choice grade. It is also important to consider the weather variability which can affect the forage availability in drought years in addition some carcass characteristic as yellow fat, which is undesirable is some market place as in US, been reported to be greater in forage finished beef compared with concentrate finished beef (Crouse et al., 1984 and Duckett et al., 2007).

The grass-fed beef market has developed into a legitimate marketing option with incentives attractive enough to justify consideration. Generally, “certified grass-fed” cattle have received premiums ranging between 10 to 15% more per cwt for feeder cattle, depending upon location, quality and quantity (Prevatt et al., 2005).

The U.S. Department of Agriculture has put in place a set of national standards that food-labeled grass-fed cattle must meet. Grass-fed meat comes from animals that are fed from several categories of forage – Grass (annual and perennial), forbs (legumes), browse forage, or stockpiled forages, and post-harvest crop residue. In summary grass-fed beef should have at least 80% of the energy required for their lifetime maintenance and growth provide from a forage source. The only exception would include milk consumed prior to weaning (Federal Register, 2002).

On October 15, 2007, the USDA established a standard definition for "grass fed animal". It claims continuous access to pasture and prevents animals from being fed grain or grain-based products. The USDA published the definition: “Accordingly, the grass (forage) fed marketing claim will only apply to ruminant animals whose diet throughout their lifespan is derived solely from grass (forage), with the exception of milk consumed prior to weaning. AMS realizes that incidental supplementation may occur due to inadvertent exposure to non-forage feedstuffs or to ensure the animal's well being at all times during adverse environmental or physical conditions. If incidental supplementation occurs as described above, the producer must fully document (e.g., receipts, ingredients, and tear tags) the incidental supplementation that occurs including how much, how often, and what was supplemented. The producer must maintain sufficient records of the animal's diet for the lifespan of the animal to demonstrate compliance with the requirement that, throughout its lifespan, the ruminant animal's diet is derived solely from grass and forage, with the exceptions previously discussed". (Federal Register, 2002).

Forages that fit a forage finishing system. Very few cattle are finished in the southeastern United States (USDA, 2008) even though the climate and soil conditions are considered very good for year round forage production, and the opportunity exists for forage-finishing systems.

To be economical, finishing cattle in a forage system requires a high quality forage with good DM digestibility which would allow good intake and an acceptable ADG (Hodgson 1977).

In the southeastern US, tall fescue is well established and has been used as forage source for beef cattle production, but it is often infected with a fungus (Morgan-Jones and Gams, 1982), which decreases animal performance (Hoveland et al., 1980) Some research has shown that for each 10% increase in the percentage of infection there is a decrease of 45g in ADG (Crawford et al., 1989). Several techniques have been used to minimize this problem. The use of a legume with tall fescue has been reported to increase animal performance (Hoveland et al., 1981; Allen et al., 1996).

Allen et al. (1996) conducted a 7-yr experiment to study the previous forage species (tall fescue or orchard-grass with and without legume) on performance of cattle during the finishing phase on feedlot. They found no carryover effects of fescue on later performance in a feedlot which was in agreement with others (Tulley et al., 1992). Hancock et al. (1987) found no carryover effects when infection rates were between 17 and 77%, but in some cases (Allen et al., 1996) cattle still finished at a lighter BW after feedlot finishing, probably due to lack of compensatory gain in the feedlot finishing phase.

Another option would be the use of entophyte-free tall fescue which has been shown to provide an ADG close to 1 kg/d (Pederson et al., 1986). Pederson et al (1986) provide information that some high quality pastures, especially ryegrass, can be used in the southeast of U.S. to produce beef from forage finished system in different seasons of the year providing forage fed beef for local needs.

The main challenge for a good finishing program is to obtain good gain, because daily gain is correlated to good carcass quality (Bowling et al., 1978; Mott, 1976). The primary reason for having a good ADG is to increase the carcass quality grade (USDA, 1989).

The majority of warm season perennial forages have not been shown to be successful in a forage finishing beef cattle system due to the slow gains of animals on those forages. Coastal bermudagrass, for example, supports slow ADG because of its low nutritive quality (Bagley, 1984). Genetic improvement of bermudagrass pastures has provided some improvement in ADG; Tifton 78 has been reported to provide gains of 0.77 kg/d from April to October in southern Georgia (Hill and Utley, 1985). The most recent bermudagrass hybrid is Tifton 85, an F1 hybrid from a common bermudagrass line and Tifton 68 (Burton et al., 1993) that was selected for improved cold tolerance and improved digestibility. In a 3-yr trial that averaged 169 days of grazing (Hill et al., 1993), Tifton 85 produced 46% more gain per hectare than Tifton 78 (1,156 vs 789 kg) and 38% more grazing days per hectare (1,823 vs 1,319), but the ADG was not different (0.67 kg vs 0.65 kg). Early-weaned calves weighing 190 kg averaged gaining 0.42 kg/d with no supplementation and 0.65 kg/d when supplemented (14% CP and 70% TDN) at 15 g/kg BW (Vendramini et al., 2007). Tifton 85 has been shown to produce more gain per hectare than Tifton 78 due to its high dry matter yield and improved digestibility, but daily gains still are considered low for a forage-finishing program.

Another option would be the use of summer legumes such as alfalfa which supported daily gains of about 1 kg/d during the summer (Schmidt et al., 1985). Those authors conducted a trial from April to September and reported an ADG of 0.98 kg/d obtained from alfalfa pastures. This is important because it is the period when cool-season forages are not available for animals on forage finishing programs.

One of the best options for finishing beef cattle on pastures is the use of cool-season annual or perennial forages that would provide a good ADG for forage finished beef cattle on an all forage system (Hoveland, 1984). Small grains as rye or oats could be used in the southern U.S.; they have been shown to provide gains greater than 1 kg/d (Utley et al., 1975). Also a combination of those small grains with a perennial cool-season forage and legumes like rye, ryegrass and clover has been showed in Alabama to provide a long grazing season of more than 200 days with ADG of almost 1 kg/d (Hoveland and Anthony, 1977).

Bagley et al. (1988) reported a large number of winter and summer annual forages that can be used for beef cattle finishing systems, including rye, ryegrass, wheat and some clovers. Bransby et al. (1997) reported gains of 1.2 kg/d for steers grazing Marshall ryegrass during a 132 d grazing season.

Potential forage-finishing systems. Small grains are examples of cool-season forages utilized in forage-finished beef cattle systems. The immature grain has high starch content. Starch is readily available and soluble (Van Soest, 1994), but it also depends on the type of starch. Some research have reported that although at least 90% of starch in small grains is fermentable in the rumen, up to 40% of corn starch can escape rumen fermentation (Orskov, 1986). Starch can be broken down and absorbed in the small intestine via pancreatic amylase, but this ability is limited in ruminants. Very large quantities of starch in the small intestine will overcome this route, resulting in starch passing through the animal undigested. A complex matrix in the seed coat of small grains contributes to rumen escape fermentation. Some processing methods for grains such as steam flaking and grinding and high moisture fermentation ruptures the matrix, releasing starch and enhancing rumen fermentation of the starch (Owens et al., 1986; Orskov, 1986). This could be what is happening with an immature grain in graining situation.

Climatic and farm characteristics in southeastern of United States. The Southeastern United States is a warm, humid region defined based on mean annual air temperature ≥12ºC and mean annual precipitation ≥750 mm.

The weather plays a very important role in cropping and grazing cycles. The advantage of this climate condition for small grains is the possibility of having a long growing season that extends into winter with small grain crops.

The entire 11 states of the southeastern United States (AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, and VA) occupy approximately 20% of the land, 12% of the total farmland area, and has 26% of the total number of farms in the entire United States (USDA National Agricultural Statistics Service, 2004).

About 80% of the farms in the southeastern United States have cropland, 41 % have pasture and 53% of the farms have cattle (16% of the cattle in the USA). The most important small grain crop is wheat with average yield in 2002 of 4.1 ton/ha for wheat for grain or 4.9 ton/ha for harvested hay. The farms would normally have a diversity of agricultural enterprises (USDA National Agricultural Statistics Service, 2004).

Modifying the way pasture and crops are managed would have a large impact on overall production levels in this area. If just 10% of the cropland were converted to grazing pasture, there could be an increase of 367 thousand and 59 thousand beef cows in the Southern Coastal Plain and the Southern Piedmont, respectively, according to Stuedemann et al. (2003). The authors predicted that the loss in crop production could be regained due to higher productivity in the remaining area through rotation benefits, plus additional benefits in decreasing cost of crop production and increasing profit through animal sales.

Forage utilization by ruminants

Plant response to grazing by cattle. In a forage grazing system for beef cattle, it is important to understand some grazing principles in forage management, because forage is going to be the only source of energy to support growth. It also is important to understand some basic concepts of plant physiology to best utilize the available forage. The sources of energy in the plant important for animal growth are starch, sugars, protein and cell wall content. Plants do not get food for themselves for their maintenance and growth from the soil; they are dependent on photosynthesis to produce energy which plants convert from the sun using CO_2 from the atmosphere and minerals and water from soil to produce their own nutrients for maintenance and growth (Holechek et al., 2004).

In the grazing system, cattle remove leaves from the grass; therefore, the photosynthetic capacity of the plant is reduced due to the reduction in the amount of leaves exposed to the sun light. The photosynthesis rate is proportional to the leaf area exposed to the sun light. Therefore, defoliation affects forage production (Bedunah and Sosebee, 1995).

A certain amount of leaf area is necessary for optimal photosynthesis. Even though the grass reserves a considerable amount of nutrients in the roots, some plants need at least 50 to 70% of the leaves and stem left on the plant for optimum metabolism (Owens et al., 1998). Therefore, the most important effect that grazing has on the plant is the reduction in metabolic reserves (Launchbaugh, 1957). The importance of this reserve is illustrated by research showing that defoliation of plants during their dormancy period can reduce herbage mass production similar to the reduction occurring during the normal active growth period (Galt et al., 1999).

Other research has shown that some degree of grazing can increase plant productivity by removing the apical dormancy of the plant (McNaughton, 1979). This is called the grazing optimization theory that is supported by other authors (Owens and Wiegert, 1976). This theory states that plants with genetic resistance to grazing can benefit from it, and the production of the plant increases up to a certain level of grazing intensity before it starts to decrease due to heavy grazing intensity (Hilbert et al., 1981).

The consequence of grazing is dependent upon the amount of photosynthetic material removed. For example, if grazing removes only leaves, the defoliation effect on growth and the vigor of plant is minimum (Vallentine, 1990). However, if the grazing is so heavy that defoliation decreases a large proportion of the canopy, then plant photosynthesis rate and growth rate are reduced significantly, and regrowth of the plant is compromised (Briske and Richards, 1995). Briske and Richards (1995) also suggest that after grazing defoliation, the plant continues to grow due to translocation of energy from the stems, which results in an increase in photosynthesis rate.

Plants are more dependent on photosynthetic tissue than on root reserves of soluble carbohydrates. Richards and Caldwell (1985) reported that carbohydrate reserves in wheatgrass and bluebunch wheatgrass were equivalent to the energy produced by photosynthesis in 3 days. Other research, Deregibus et al. (1982) and Coyne et al. (1995) showed that different forage species use only small proportions of carbohydrate reserves for regrowth after clipping. This is the main reason why it is not recommended to overgraze any type of grass.

Grazing intensity, represented by stocking rate, affects the way plants are defoliated (Hart, 1978). When the stocking rate of a pasture increases, selectivity will decrease, and animals will be able to select less what they eat. Therefore, the defoliation of the grass increases, the sward morphology and composition of the plant is modified, affecting the regrowth of those plants (Matches et al., 1981).

Grazing behavior. Grazing behavior was heavily studied during 15 years after 1950s. It was observed that ruminants select a diet when grazing which was different from a hand clipped diet forage sample (Lofgreen et al, 1956; Edlefsen et al.1960). The selective grazing concept lead to the development of the esophageal cannula to be applied in those studies in order to typify the diet selected from pasture (Bath et al., 1956; Cook et al., 1958; Blaser, 1964). Those trials led to the development of new concepts in terms of cattle management to be based on pasture characteristic which is influenced by the forage vegetative stage throughout the year (Raleigh, 1970), the grazing pressure and the relationship between the ADG and gain per area (Bryant et al., 1970).

The diet selected is different among species, and there is integration of this diet to its fermentation and passage rate in the animal gastrointestinal tract (Huston, et al., 1986). The initial particle size reduction was reported to play an important role in forage digestion; ryegrass was easily disrupted compared with Coastal bermudagrass (Pond et al., 1984).

Forage quality and intake. Forage is made of cells that are very unique because it contains a very wide cell wall composed of polysaccharide rich in lignin complex and intracellular content. The intracellular content is considered almost completely digestible (Van Soest, 1994), and also the digestibility of this part does not change as forage grows and ages. On other hand, chemical structures in the forage cell wall (Nelson and Moser, 1994) changes as plant grows; the biggest change is the increase in fiber content as a percent of the entire forage.

In terms of chemical structure, there are several types of fiber in forage, and these influence the digestibility. The fiber faction that is considered essentially indigestible is lignin. Lignin increases rapidly as the plant matures and makes the digestibility of the whole plant decease, particularly when the plant reaches its reproductive stage. Not only does the amount of lignin influence the quality, but also its structure influences forage quality as well as the complex association of lignin and other cell walls constituents (Jung, 1989). In general, when fiber content increases the digestibility decreases and so does animal gain, but the only way to measure the true value of the forage is through animal performance (Van Soest, 1994).

The plant cell wall. The cell wall is formed of carbohydrate, which can be divided in many fractions: Cellulose, hemicelluloses and lignin. Those are measured chemically as NDF and give the forages the structure needed to grow straight. This strength that gives sustainability to the plant makes it very difficult to be digested. The digestion rates of NDF are very slow, around 3 to 12%/hr (Mertens, 1992).

The nonstructural carbohydrates (NSC), is another term for the cell contents. They are not part of the cell wall or structural portion of the plant, and so are more easily and rapidly digested than the cell wall. The NSC is composed of carbohydrates for storage or reserve such as starch, which is the principal carbohydrate storage form in plants specially in small grains, and fructosans, which are the main storage carbohydrates in grasses such as ryegrass (Moore and Hatfield, 1994).

A part of the cell wall that is an exception in terms of solubility are pectins. Pectins are usually soluble and quickly fermented in the rumen; therefore, they are considered soluble fiber and measured as part of NSC. Pectin is mostly dissolved by neutral detergent fiber (Van Soest, 1994); therefore, it is not measured in NDF. In grasses there are also beta glucans which are soluble in NDF. Therefore the NSC is defined as sugar, starches, pectins as glucans (Nocek and Russell, 1988).

Forage quality components. One way to understand forage quality is to identify the quality component in different parts of the plant. The leaves usually have the most digestible nutrients in a plant compared with the stems in all kinds of grazing plants like grasses, including C3 or C4 or legumes (Jung et al., 1993).

Animals lack the enzymes essential to digest the cell wall, but they have the enzymes to digest the cell contents (Van Soest, 1994). Microorganisms in the ruminant stomach are able to digest the cell wall and degrade the carbohydrates of it into simple sugar such as oligosaccharides, disaccharides or monosaccharides. The microorganisms use these simple sugars for growth and reproduction, forming bacterial mass releasing VFAs, which pass through the rumen cell wall and are used by the animal itself (McDonald, 1988).

***Pasture yield and forage mass determination*.** Forage quantity and quality reflects the performance of grazing animals. Forage production can be represented by the animal gain per unit of area. The number of animals per unit area can be kept constant, which doesn’t allow the investigator to determine the full potential of the forage, or the number of animals can be adjusted in order to maintain a certain level of forage mass production. This later is called put-and-take stocking method. In this method, some animals are kept on the treatment paddock during the entire grazing season; they are called test animals. Other animals are kept in an adjacent paddock grazing similar forage and are added or removed as needed in accordance to the forage production in the pasture (Burns, 2006).

Herbage mass determination is important in a grazing trial due to its high correlation to livestock production (Guerrero et al., 1984). Therefore, it is necessary to carefully monitor forage mass availability and quality when studying animal performance on grazing trials (Gonzales et al., 1990).

There are two main methods for measuring forage mass: the non-destructive methods and clipping methods. The non-destructive methods are represented by three types: measurement of plant height, disk metter, and capacitance meter. Plant height is the measurement of the canopy height using a meter stick, and its relation to production; it requires a special regression equation for each plant species to associate forage height with forage mass (Whitney, 1974). Disk meter is based on the measurement of the height of a weighted disk which is recorded after the disk is dropped from a determined height (Bransby et al., 1977). This also requires a regression equation to associate disk height to forage mass.

Clipping methods are based on harvesting the above ground material from a specific measured area and measure the amount of forage harvested. This procedure is repeated in the pasture to make the sample representative of the area being evaluated. The collected material is weighed, oven dried and weighed again to determine DM amount and DM percentage. This procedure can be performed by hand clipping or machine clipping (Wilm et al., 1944).

The advantage of the non-destructive methods is the possibility of collecting several number of samples in a short period of time. The disadvantage is that due to the forage variations caused by changes in climate, age, species, and other factors (Mitchell, 1982) as well as different sampling techniques and sward structure (Greathead et al., 1987), and changes in management or environment conditions, those methods require constant calibration to maintain its accuracy (Gonzales et al., 1990). The clipping methods provide greater accuracy with higher reliability. Therefore, clipping methods are recommended when the objective is to measure forage mass with accuracy.

Lab analysis. The measurement of forage quality in pastures is difficult because intake cannot be controlled or measured with precision. The efficiency of utilization of nutrients is even harder to determine. Therefore, laboratory tests and *in vivo* and *in vitro* digestibility trials are used with the intention of determining forage quality.

The oldest and most widely used laboratory procedure is the proximate analysis. The methods were developed by Henneberg and Stohmann in 1865 at the Weende Experimental Station in Germany and is sometimes called the Weende

System (Lloyd et al., 1978). Its main idea was to separate carbohydrates into the less digestible portion called crude fiber and the more digestible fraction called nitrogen free extract (NFE). The system also is used to determine water (moisture), ash, crude fat (ether extract), and crude protein. The NFE fraction is not determined directly but is determined by difference. The main purpose for the development of this system was to provide a tool to compare different products using the same set of laboratory procedures. To determine forage quality one needs to use laboratory results to predict animal performance. The proximate analysis system can be used to predict some factors related to performance, but it has deficiencies that prevent it from being a feasible tool (Galyean, 1997).

This system has the advantage of being a simple and relatively inexpensive way of having an idea of feed composition. But, because its ether extraction removes fats, waxes and other fat soluble materials, it may result in a fat content higher than it really is. Another concern is that Kjeldahl analysis assumes that all proteins contain 16% nitrogen, all nitrogen is in the protein form, and all the protein is digestible in the feed. Not every time those assumptions are true, and one may overestimate protein in a sample. The fiber method utilized is reliable for nonruminants, but because it doesn't distinguish between cellulose and hemicellulose (fermentable fraction) and lignin (nonfermentable fraction), it is of limited value for ruminants. Another weakness of the system is that the calculation of NFE will pull together the possible errors described above. Another deficiency of the technique is that it does not determine minerals and vitamins present in the sample (Gaillard, 1958).

Van Soest (1965) suggested a division of the dry matter of forages into two fractions, a digestible fraction made up of soluble cell contents, and an undigestible fraction that is insoluble and partially available made up of the cell wall constituents. In order to measure those two fractions Van Soest et al. (1991) developed sequential procedures that divides the forage in different components. Neutral Detergent Fiber (NDF) is the first fraction determined and represents as the name suggested the portion that is not soluble to neutral detergent solution. This fraction of the forage is broadly related to intake (Van Soest, 1965; Van Soest and Mertens, 1977).

NDF represents all the fiber of the sample, but the pectin substances in the cell wall are extracted; therefore, the method has a deficiency in determining cell wall constituents in legumes rich in pectin. If there is heat-damaged protein in the sample, the NDF method will partition it into the fiber portion. Those two disadvantages have to be taken into account if one wants to determine the cell wall as a biological structure, but shouldn't be a problem for ruminant nutrition, because the interest is in finding out the incompletely digested fiber (Jung, 1997).

Acid Detergent Fiber (ADF) is the next fraction and it represents the portion that is not soluble in an acid detergent solution. ADF is utilized to predict digestibility. ADF comprises cellulose, lignin and ash. As a disadvantage, ADF has been proven to under-estimate lignin, principally in grasses because a significant portion is solubilized (Jung, 1997).

Ruminal fiber digestion, forage quality, and intake. The cell wall digestion in the rumen has two important limitations that affect the rate of ruminal fiber digestion: the pH and physical chemical interactions among cell wall constituents. Ruminal pH is important in affecting fiber digestion through its influence on the cellulolytic bacteria activity, more specifically on growth rates of the bacteria responsible for the fiber digestion (Van Soest, 1994).

Each type of bacteria has an optimal pH range for growth, and for cellulolytic bacteria the optimal pH in the rumen is greater than pH 6.5 (Russell and Wilson, 1996). The pH in the rumen is so important that for each 0.1 unit decrease between pH of 6.5 to 6.0, the specific growth rate decreases 14%/hr. Even more important, when pH decreased below 6.0 the cellulolytic bacteria stop growing. According to research conducted by Russell and Wilson (1996) it probably is due to an inability of the cellulolytic bacteria to regulate the concentration of intracellular anion at a lower ruminal pH.

Another important limitation to the rate of fiber digestibility is the availability of the substrate to the cellulolytic bacteria in the rumen, which can affect the specific growth rate of those specialized bacteria. A substrate used by the cellulolitic bacteria is the cell wall, or more particularly the cellulose fibrils. Cell walls are made up of a matrix of fiber composed of hemicellulose, lignin, pectins and extensions, cemented together with the cellulose fibrils (Hatfield, 1993). The problem with it is the enormous barrier to the cellulolytic bacteria to access this matrix because of the physical/chemical connections of hemicellulose and lignin with cellulose (Hatfield, 1993).

There is strong evidence showing cellulose and xylan are directly linked by hydrogen bonding, and the linkage to lignin makes cellulose less available to cellulolytic and hemicellulolytic enzymes and thereby increases the resistance of forage cell walls to microbial attack and digestion, making it important that enzymes able to cleave xylan are available in the rumen (Iiyama et al. 1990; Lam et al. 1990). But cellulase and xylanase enzymes have been shown to be produced by the cellulolitic bacterium Fibrobaster succinognes in the rumen (McDermid et al., 1990). These enzymes cleave the majority of bonds found in cellulose and hemicellulose making the F. succinogenes one of the most important fibrolytic bacteria in the rumen (Cheng et al. 1991; Stewart and Flint, 1989).

Forage Intake. The first method to estimate dry matter intake (DMI) in pasture was developed by Garrigus (1935), and Hinman (1937) suggested the use of ADG as a measurement of pasture yield.

An estimation of a DMI is needed to determine the nutrients ingested by the animal which is considered the most important single factor that influences ADG (Mertens, 1994), but it is much more difficult to measure in a grazing system than in a feedlot system (Reeves et al., 1996). There are several techniques that can be used to estimate the DMI in a grazing animal. It can be estimated from animal gains or from the forage characteristics or indirectly measured through the use of internal or external markers (Lippke, 2002). Although any of those methods are only a way to estimate the intake and are not free of errors (Burns et al., 1994), it is possible to obtain a reasonable measurement of the amount of forage consumed in a grazing experiment (Lippke,. 2002).

Macoon et al. (2003) in an experiment conducted to compare three methods (Pulse-dose method, herbage disappearance method and animal performance method) concluded that the pasture sampling method was more closely related to the animal performance method than the pulse-dose method which varied more, but was not conclusively affirmed less acceptable than the other methods.

The decrease in DMI with increased forage maturity has been proposed to be a chemical effect mainly due to a decrease in nutrients and palatably and also a physical effect due to decreased breakdown and passage rate (Weston and Poppi, 1987).

Dry matter intake (DMI) is one of the most important factors in balancing diets in forage-fed animals because a good estimation of DMI is necessary to predict gain (Fox and Black, 1984) and to use in equations for predicting nutrient requirements (NRC, 2000). Several factors affect DMI which makes prediction of intake the weakest point in all models of diet formulation especially in grazing animal (NRC, 2000).

Factors Affecting DMI. Some factors affecting DMI have been studied more frequently (physiological factors such as initial weight in the feedlot; environmental effects such as temperature, mud and wind; and diet effects such as forage quality and quantity; and time effects for eating and ruminating) than others (like hormones and metabolites such as somatomedin, glucose, insulin or brain factors such as the hypothalamus and pituitary) because they are easily measured and can be included in prediction equations.

Forage factors. With a grazing system, factors related to the forage itself, for obvious reasons, is the most important because the quantity and quality of any forage can affect DMI (NRC, 2000). Forage availability has been shown to affect DMI. Rayburn (1986) in a review suggested that DMI was maximum at 2,250 kg of DM/ha or at a forage allowance of at 40g of organic matter/kg BW, but McCollum et al. (1992) working with a small grain reported a maximum DMI at 1,247 kg DM/ha or an allowance of 300g DM/kg BW.

The NRC (1987) suggested that DMI decreases to 60% of the maximum at 450kg of DM/ha or at a forage allowance of 20 g OM/kg BW. Rayburn (1986) also reported a reduction of ADG when forage utilization reached 40% or more, but the maximum gain/area was reached at 80%. In other words, animal performance decreases as the stocking rate increases up to 80% of relative forage utilization. This is due to selective grazing, since cattle eat a larger amount of growing forage compared with senescent forage (Minson, 1990).

Another forage factor reported to affect DMI is the protein content in the forage, especially if the protein content is below 6 to 8% of DM (NRC, 1987). In a trial using paired hay supplemented with soybean meal in calves (250kg) and steers (400kg), DMI increased as CP increased from 5 to 8% (Guthrie et al., 1984). Fox et al.

(1988), using corn silage in calves from 150 to 250 kg, reported that DMI increases as CP increased from 8 to 11%, reaching a plateau with no further increase up to 14%. Milford and Minson (1965) also reported an increase in DMI as CP increased from 2 to 8% in tropical grasses reaching a plateau between 8 and 14%. The NRC (1987) predicted a response in DMI when CP is below 6 to 8% in a diet.

Another forage factor reported to affect DMI is the cell wall content. Osbourn et al. (1974) using 56 types of forage fed to sheep found a relationship between organic matter intake and cell wall content. The organic matter intake decreased as the cell wall content increased. There was more variation in intake when forage cell wall content was less than 45%.

Several theories of DMI regulation have emerged. Three primary theories are accepted today: 1) the physical theory based on fill, 2) metabolic constraints, and 3) the integration of fill and metabolic constraints.

The physical theory is based on the observation that forage intake normally is less than the optimal amount of energy needed by the animal (NRC, 1987). This is due to rumen space, limited time for eating, and rumination. Because NDF ferments slowly and is retained in the rumen, it has a filling effect and has been found to be the best single chemical predictor of DMI (Van Soest, 1973). However, many other factors affect fill. These include rate of digestion at any digestion site (Gill et al., 1969), particle size (Welch, 1967), chewing frequency and rumination (Forbes, 1986). The latter is because ruminants are not likely to spend more than 9hr/d ruminating (Welch, 1982). Even the lower tract fill and fecal output can limit DMI (Demarquilly et al., 1965). The discovery of rumen receptors and the relationship of cell wall contents to intake support the theory of physical fill (Leek and Harding, 1975).

The metabolic constraints theory came from a version of nonruminant intake theory and is based upon a concept of satiety (Forbes, 1988). According to this theory, the animal is going to eat until the metabolic requirement (energy) is reached (Dinius and Baumgardt, 1970). The theory in ruminants is that the VFAs (volatile fatty acids) stimulate the secretion of CCK (cholesystokinin) from the hypothalamus causing the cessation of eating (Illius and Jessop, 1996).

The Integration of the two theories mainly says that the specific situation can promote one factor to become dominant, such as fill for pregnant animals and in animals fed lower quality forage, or metabolic when feeding a high concentrate diet (Forbes, 1986; Forbes, 2003).

Equations to predict intake are not accurate because the factors that regulate intake are not fully understood or can't be placed in an equation (Forbes, 2003). Most equations just use energy concentration to account to gastrointestinal fill (NRC, 1984; ARC, 1980), energy demand (Plegge et al., 1984) and other effects of nutrient absorption (NRC, 1996). Many equations use correction factors to account for other causes affecting intake such as environmental or management factors (Fox and Black 1984). All equations have some limitations; therefore, they need to be used as a general guide. For all-forage diets, the NRC (2000) has an equation and gives validation data which show the equation accounted for 47.5% of the DMI variation in steers and heifers with an overall prediction bias of -9.71%, and for cows the equation accounted for 43.57% of the variation with bias of -10.83%.

Summary

The feedlot system is the most traditional way to finish beef cattle in the United States (Taylor, 1984). The grass-fed beef market has developed into a legitimate marketing option with incentives attractive enough to justify consideration.

To be economical, finishing cattle in a forage system requires a high quality forage with good DM digestibility which would allow good intake and an acceptable ADG (Hodgson 1977). Small grains such as rye or oats could be used in the southeastern United States; they can provide an ADG greater than 1 kg/d (Utley et al., 1975).

This experiment is part of a larger research project in which the overall objective is to determine carcass and sensory traits of steers finished on ryegrass, rye, and oats. The objective of the trial reported here was to examine trends in forage availability, forage quality and steer performance during the grazing/finishing phase.

Neutral detergent fiber (NDF) is the first fraction determined in the Van Soest detergent procedure and represents, as the name suggests, the portion that is not soluble in neutral detergent solution. This fraction of the forage is broadly related to intake (Van Soest, 1965; Van Soest and Mertens, 1977). Acid detergent fiber (ADF) is the next fraction determined, and it represents the portion that is not soluble in an acid detergent solution. ADF is utilized to predict digestibility. Cellulose, lignin and ash comprise the ADF fraction.

The NDF method is based on the ability of the detergent solution to solubilize all components leaving just the fiber parts of the feed sample separated by filtration. Filtration problems became the major barrier in this procedure until the development of a procedure using filtration in filter bags (Komarek, 1993a,b, Komarek et al., 1994a,b) in a semi-automated fiber analyzer with a pressurized chamber from ANKOM company (Ankom Technology Corp., Fairport, NY). However, the system still is limited by the number of samples per batch that can be analyzed and the price of the pressurized chamber itself. We developed a procedure for NDF and ADF analyses using the filter bags without the need of the special equipment (pressurized chamber) using a simple water bath.

The objective was to compare both procedures using different harvests of ryegrass, rye and oats forage samples. The hypothesis was that NDF and ADF values would not be significantly different between the water bath method and the ANKOM method.

III. FORAGE QUALITY AND PERFORMANCE OF FORAGE-FINISHED BEEF CATTLE GRAZING RYEGRASS, RYE OR OATS

ABSTRACT: A 3-yr grazing trial was conducted with ryegrass (*Lolium perenne*), rye (*Secale cereale*) and oats (*Avena sativa*) as winter pasture for forage-finished beef. Replicate 1.42-ha paddocks (2 per forage) were established and stocked with 3 Angus × Continental crossbred steers per paddock each year in a completely randomized design. Initial BW, (mean ± SD) were 374 ± 5.5, 410 ± 7.0 and 400 ± 9.5 kg in yr 1,2 and 3, respectively. Steers had free-choice access to salt-mineral mix and water. Grazing was initiated on Jan 19 (84 d grazing, yr 1), Nov 27 (145 d grazing, yr 2) and Dec 18 (124 d grazing, yr 3) when average forage mass (FM) reached 1,000 kg/ha. Forage mass (kg DM/ha) and nutrient composition were determined by clipping 0.25-m^2 quadrats (8 per paddock) prior to the beginning of grazing and every 2 wk during the trial. Put-and-take steers were used to maintain forage in the vegetative stage. Grazing was terminated when steers reached 530 kg BW. Average daily gain differed ($P < 0.05$) among years, but there was no treatment effect or animal ×yr interaction. Overall ADG (mean ± SD) was 1.32 ± 0.12 kg/d. In yr 1, mean ADG (1.81 ± 0.05 kg/d) was higher ($P < 0.0001$) than in the other years, but ADG in yr 2 (1.05 ± 0.05 kg/d) and yr 3 (1.11 ± 0.05 kg/d) did not differ. There was a yr effect, but no yr ×

treatment interaction for forage concentrations of CP. In yr 3, forages had a lower percentage CP than in the other 2 years. Rye contained more CP (19.5 ± 0.6%) than ryegrass (16.1 ± 0.6%) and oats (17.0 ± 0.6%), but percentage CP did not differ between ryegrass and oats. There was no yr effect or yr × treatment interaction for concentration of NDF and ADF. Ryegrass had lower concentration of NDF (39.8% ± 1.1) and ADF (20.6 ± 0.6) than oats (46.0% ± 1.1 and 24.3 ± 0.6) and rye (46.2 % ± 1.1 and 24.4 ± 0.6). Total gain per area differed ($P < 0.05$) among years and forage type, but there were no yr × treatment interactions. In yr 2, there was greater ($P < 0.05$) gain per ha (556 ± 15.4 kg/ha) than in yr 1 (372 ± 15.4 kg/ha) and yr 3 (410 ± 15.4 kg/ha). Animals grazing oats had a greater ($P < 0.05$) gain per ha (504 ± 15.4 kg/ha) than those grazing rye (425 ± 15.4 kg/ha) or ryegrass (408 ± 15.4 kg/ha). In conclusion, cool-season annual pastures did not differ in production of steer ADG, but oats was superior to the rye or ryegrass pastures in total gain per area.
Key Words: Grazing, Pasture Finishing, Cool-season Forages

INTRODUCTION

Consumer interest in the benefits of forage-finished beef is high and has been perceived by some as more healthful and environmentally friendly than grain-finished beef (Razminowicz, et al., 2006). The preference for this type of product by a growing segment of the U.S. population warrants further development of forage systems that will produce forage-finished beef products. To achieve the goal of finishing cattle on pasture, forage quality and availability must be high so that energy intake does not limit animal performance (Fontenot et al., 1985).

The Southeastern United States has an environment that enables production of a variety of forages throughout the year (Ball et al., 2002). Most warm season grasses used in the Southeastern United States as part of beef cattle production systems, however, have a dormancy period of 5 or more months and generally do not support rapid gains desired for finishing cattle (Ball et al., 2002). This gap in the pasture system is a major barrier to finishing cattle throughout the year (Matches and Burns, 1995). Small grains can be established as high-quality pasture that can support rapid gains and extend the grazing season.

Previous research has not resulted in a consensus when the palatability of forage-fed compared to grain-fed beef was compared. Some studies report more desirable flavor for forage-fed (Cross and Dinius, 1978; Kropf et al. 1975; Skelley et al. 1978; Schroeder et al. 1980; Kidwell, 2002); some report less desirable flavor (Wanderstock and Miller, 1948; Bowling et al., 1977; Brown et al., 1979), and others reported acceptable flavor for both (Oltjen et al., 1971; Huffman, 1974; Bidner et al., 1981). The flavors are known to vary with the type of grass being grazed and the length of time the grasses are grazed (Mandell et al., 1998).

This experiment is part of a larger research project in which the overall objective is to determine carcass and sensory traits of steers finished on ryegrass, rye, and oats. The objective of the trial reported here was to determine forage availability, forage quality and steer performance during the grazing/finishing phase.

MATERIALS AND METHODS

All procedures and experimental protocols were approved by the Auburn University Institutional Animal Care and Use Committee.

A 3-yr grazing trial was conducted beginning in the winter/spring seasons of 2006 (yr 1), 2007 (yr 2) and 2008 (yr 3). Replicated 1.42-ha paddocks (2 per forage) containing ryegrass (*Lolium perenne*), rye (*Secale cereale*), and oats (*Avena sativa*) were established at the Wiregrass Research and Extension Center in Headland, AL (31.3° lat., 85.3° long., 105 m elev.) and stocked with three Angus × Continental crossbred steers (374 ± 5.5, 410 ± 7.0 and 400 ± 9.5 kg in yr 1,2 and 3, respectively) per paddock.

Prior to planting in all years, all paddocks were fertilized with 39 kg/ha of N plus 45 kg/ha each of P and K. Paddocks were seeded (150 kg/ha of oats or rye, or 30 kg/ha ryegrass) during the fall of all years (yr 1 on Nov 7, 2005, yr 2 on Oct 10, 2006 and yr 3 on Sept 27, 2007). Nitrogen and S were applied at rates of 78 and 11 kg/ha, respectively, at the beginning of the season, and again in mid February at rates of 56 and 11 kg/ha, respectively, in all years.

All steers had ad-libitum access to salt-mineral-mix and water and were weighed every 28 d. Grazing was initiated on Jan 19 (84 d grazing, year 1), Nov 27 (145 d grazing, year 2) and Dec 18 (124 d grazing, year 3) when average forage mass reached 1,000 kg/ha. Forage mass and nutrient composition were determined by clipping 0.25-m^2 quadrats (n=8 per paddock) prior to the beginning of grazing and every two weeks during the trial. Stocking rates were adjusted following quadrat clipping by using put-and-take steers to maintain forages in the vegetative stage. Harvested forage was weighed and oven dried at 50º C. Forage samples within paddocks were pooled for create composite samples for laboratory analysis from which a sub-sample was ground to pass a 1-mm screen in a Wiley mill. Samples were analyzed for dry matter (DM) and crude protein (CP); (AOAC, 1995), NDF, ADF, and acid detergent lignin (Van Soest et al., 1991). The experiment was ended when average BW of the steers reached 530 kg. Put-and-take steer were weighed every time they were added or removed from pastures. Gain per area was determined adding the weight gain of all the animals present in each pasture, including put-and-take steers.

Put-and-take procedures. Animals were added or removed from paddocks according to the DM available in that particular paddock. Dry Matter availability was measured every two weeks. The amount of DM available on the week of measurement minus the amount of DM available on the prior week of measurement represented the amount of increase or decrease in DM. If the DM decreased it would indicate a necessity of removing animals, if DM increased it would indicate a need to increase animals. There is a limit where DM availability may limit intake (McCollum et al., 1992); in this procedure the limit set was 2000 kg of DM/ha. If the DM available approached 2000 kg DM/ha animals were maintained in the pasture; if available DM had decreased from the previous measurement, animals were removed according to the body weight of the animal, considering a DM intake of 3% of live BW. For example, an animal weighing 400 kg would consume 12 kg of DM/d, considering adjustments every two weeks, each animal would represent a 14 d x 12 kg/d which equals 168 kg DM. Therefore, an increase of about 168 kg/ha of DM above the 2000 triggers addition of one animal/ ha. On the other hand a decrease of about 168 kg of DM/ha results in removing one animal from the paddock. It is important to consider that not all available DM can be consumed, animals will trample some of the forage. With that in mind, adjustments for the 1.42-ha paddock were made on 1-ha basis with the remaining considered as trampling loss. An excel spreadsheet sample can be seen in appendix A.

Data were analyzed using the PROC GLM procedures of SAS and standard least-squares model fit (SAS Inst., Inc., Cary, NC, 2004). All data are reported as least squares means ± SE, and the significance level was preset at $P < 0.05$ for all analyses. The ADG and gain/area were regressed on forage parameters: Forage mass (kg DM/ha), forage availability (kg of DM $\cdot$100 kg $BW^{-1}\cdot d^{-1}$), DM, CP, NDF and ADF using the PROC REG procedure of SAS and stepwise model selection criteria (SAS Inst., Inc., Cary, NC, 2004). Parameter estimates, SE, variable P-values, model fit P-values, and Mallows C(p) are reported. The model fit was chosen according to Neter et al. (1985) using the Mallows C(p) values.

RESULTS AND DISCUSSION

There was a year effect but no year × treatment interaction for ADG, forage concentration of CP and steer gain/ha ($P < 0.05$). The overall mean for ADG was 1.32 ± 0.12 kg/d, and it differed ($P < 0.05$) among years (Table 1), with greater ADG ($P < 0.0001$) in yr 1 than the other two years.

Table 1. Effect of year on ADG, gain/area, forage concentration of CP and Forage mass (FM) for steers grazing ryegrass, rye and oats

Item	2006	2007	2008	SEM
Grazing Season, d	84	145	124	
Animal grazing days, d	322^{a}	707^{b}	494^{c}	19
Initial weight, kg	374 ± 5.5	410 ± 7.0	400 ± 9.5	
Final weight, kg	526	562	544	16
ADG, kg/d	1.81^{a}	1.05^{b}	1.11^{b}	0.05
Gain/ha, kg/ha	371.5^{b}	556.0^{a}	410.3^{b}	15.4
CP, %	18.0^{a}	18.8^{a}	15.9^{b}	0.6
Forage mass, kg DM/ha	2,124	1,607	1,711	95

[a,b,c]Means in the same row with different superscripts differ ($P < 0.05$).

The average initial weight of steers in yr 1 was less than in the other years. Generally, for feedlot finishing of cattle, ADG increases with increasing initial weight (IW) (Galyean et al., 1978; Zinn et al, 2008). The increased ADG observed in the present study for steers with lighter IW, which all had been born in the fall from the same herd of cows as steers used in yr 2 and yr 3, may be due to compensatory gain. In yr 1, the start date was later than in the other years due to a lack of rainfall at the beginning of the season. This resulted in the shortest grazing period (84 d). Which also coincided with the period of time when forage quality was the highest. In terms of gain/area, steers in yr 2 had a greater ($P < 0.05$) gain/ha than in yr 1 or yr 3. This is explained mainly by the longer grazing period in yr 2. Although the forages in yr 3 had a lower CP content than in the other years, all three years exceeded NRC requirement for finishing steers (NRC, 1996; NRC, 2000).

There was a treatment effect but no treatment × year interaction for forage concentration of NDF, ADF and CP, and total gain/ha ($P < 0.05$; Table 2). Rye contained more CP than ryegrass and oats, which were not different. Although the rye forage had a higher CP concentration than the other forages, all three forages exceeded NRC requirement for finishing steers (NRC, 1996).

Table 2. Effect of pasture type on forage concentration of NDF, ADF and CP and total gain/ha in steers grazing oats, rye or ryegrass

TRT	Oats	Rye	Ryegrass	SEM
ADG, kg/d	1.33	1.23	1.40	0.1
Gain/ha, kg/ha	504.4[a]	425.2[b]	408.2[b]	15
Animal grazing days, d	552[a]	524[a]	447[b]	19
Final weight, kg	547	530	555	15
Forage mass, kg DM/ha	2039	1815	1590	96
CP, %	17.1[b]	19.5[a]	16.1[b]	0.6
NDF, %	46.0[a]	46.2[a]	39.8[b]	1.1
ADF, %	24.3[a]	24.4[a]	20.6[b]	0.6

[a,b] Means in the same row with different superscripts differ ($P < 0.05$).

Ryegrass had lower concentration of NDF and ADF than oats and rye. Steers grazing the oats pasture had a greater ($P < 0.05$) gain/ha than those grazing rye or ryegrass (Table 2). The lower NDF and ADF concentration of ryegrass compared with rye and oats would indicate that ryegrass has superior quality for finishing cattle. However, this was not translated into higher ADG or gain/ha, probably due to lower DM production compared with the small-gain treatment (Figure 1).

These data agree with Siri-Prieto et al. (2003), who found no differences between oat and ryegrass forages in biomass production. They reported that oats produced more DM than ryegrass at grazing initiation, but by the end of grazing (70 d for the first yr and 84 d for second yr), these differences disappeared because oats have a shorter life cycle, and ryegrass starts producing more DM in late spring. However, the data are not in agreement with those of Bransby et al. (1999), who reported in a wide range of grazing experiments evaluating different winter annual pastures for stocker production that ryegrass was superior to small grains, for producing steer ADG.

Rainfall during the time steers were grazing in the first year was less than half of the 30-year average (Table 3). Even though daily gains were excellent, forage production was more adversely affected in the case of ryegrass compared with oats and rye (Fig. 1). In the second year, the rainfall was greater compared with the first year, resulting in a longer grazing period and a higher gain per area (Table 1), even though the ADG was less. In the third year the rainfall was very close to the 30 year average (Table 3), but did not result in a higher ADG, gain/area or grazing days (Table 1).

Table 3. Monthly average temperatures and precipitation at Headland, AL during the months of November through April for three consecutive grazing seasons and the 30-year average

Month	Average temperatures (°C)			Precipitation (mm)			
	2005/06	2006/07	2007/08	2005/06	2006/07	2007/08	30 Year Average
Nov	16	14	14	93	82	94	108
Dec	9	13	13	116	27	208	107
Jan	13	11	9	97	89	109	161
Feb	10	10	12	114	94	155	132
Mar	15	17	14	14	32	55	157
Apr	21	18	19	41	157	104	97
Average*	14	14	14	67	80	126	131

The variations in FM and ADG throughout the experiment in all years are given in Figure 1. In year 1, oats and rye FM increased faster than expected, resulting in pastures being under-stocked during the final portion of the trial. However, ryegrass growth was slower. In the second year, the oats and rye FM availability increased more than ryegrass during the first two-thirds of the experiment. During the last third, ryegrass FM availability increased faster than expected, showing its capacity to extend the grazing period under good weather conditions. During the third year, oats FM availability increased faster than expected, resulting in pastures being under-stocked during the initial portion of the trial and then followed about the same tread as year 2 just with higher FM availability, probably (Figure 1) due to a higher rainfall (Table 3).

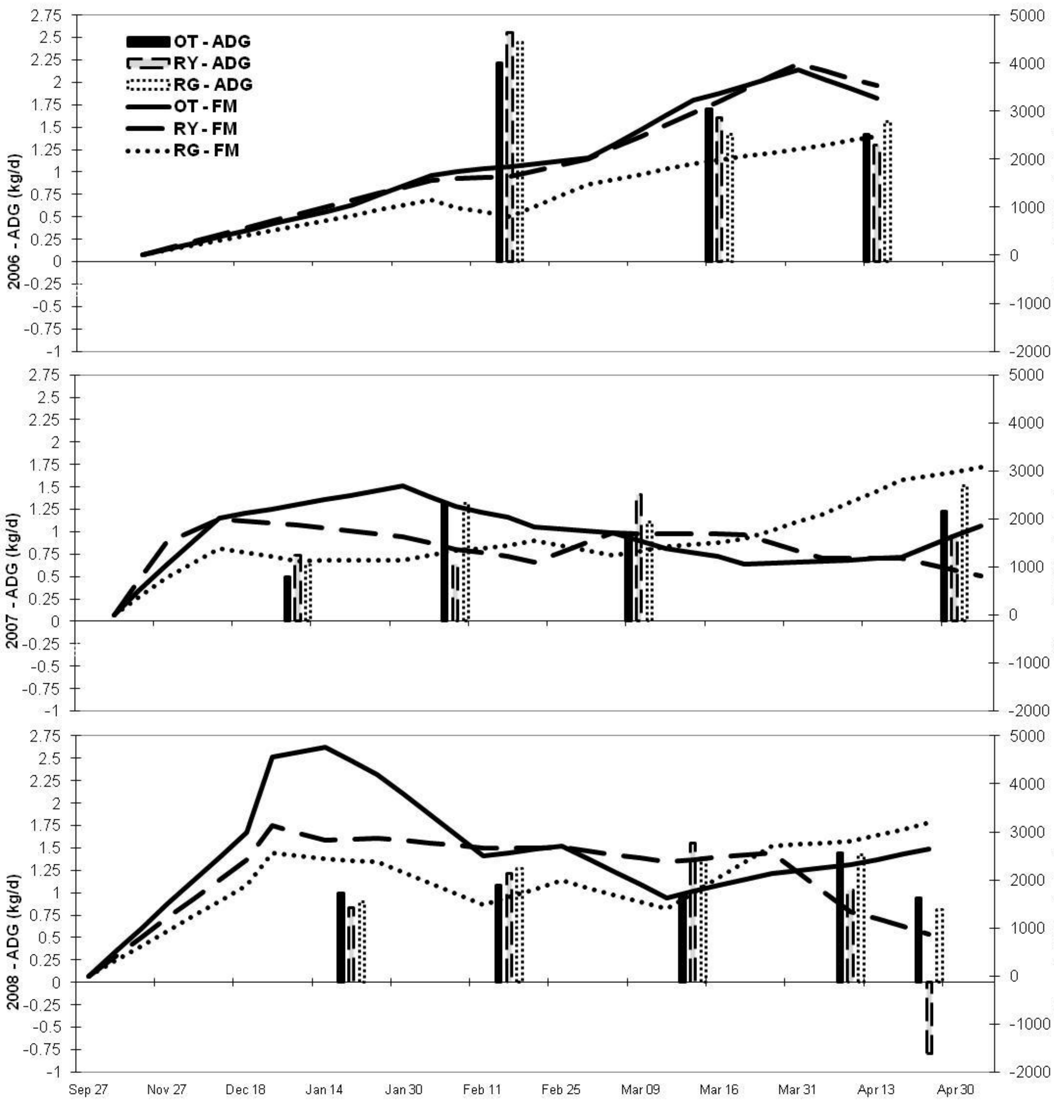

Figure 1. Steer ADG (kg/d) and FM (Forage mass in kg of DM/ha) for oats, rye and ryegrass (SEM for ADG=0.04; SEM for FM availability= 103)

In year 1 (2006) ryegrass FM probably limited intake and in turn limited steer performance from mid-February through mid-March, whereas decreasing forage quality in oats and rye may have limited intake and steer performance from mid-March through mid-April. In year 2 (2007) and year 3 (2008) forage mass probably did not limit intake with the exception of rye in April. Forage mass could explain the difference in gain/ha (Table 2) for steers grazing oats compared with those grazing the other pastures. The level at which forage mass started to limit intake was reported to be around 1,100 kg/ha for wheat forage (McCollum et al., 1992). Intake of cattle grazing various forages was indicated to be maximum at a FM of 2,250 kg/ha (NRC, 1996). In addition, Mott (1984) found animal performance was optimum when forage mass was 1,200 to 1,600 kg/ha.

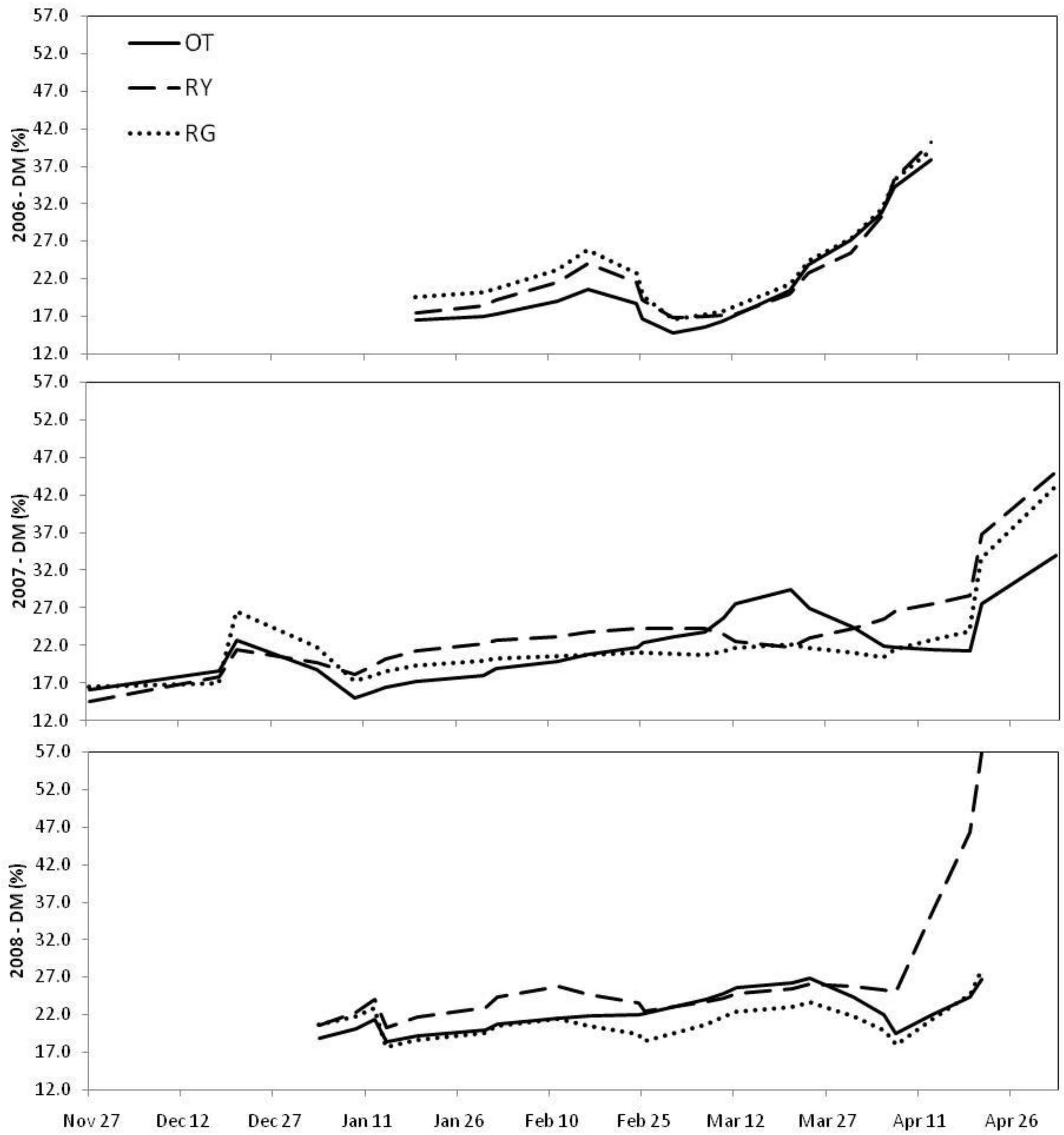

Figure 2. Change in percent DM for oats, rye and ryegrass over the grazing season

In general, the DM percentage of all forages increased as the grazing season progressed (Figure 2); rye had an abrupt increase in late March, 2008. Increase in DM may be due to stem elongation which resulted in a greater proportion of stem; it also may be responsible for an increase in the NDF concentration. Mader et al., 1983, reported a negative relationship between DM percentage and DMI and IVDMD in wheat. The acute decline in steer ADG during the last period for rye in 2008 may be explained by the sharp increase in DM percentage and associated decrease in forage digestibility.

Mallows' Cp was used in a stepwise regression analysis to determine if ADG and gain per area of steers grazing oats, ryegrass or rye could be predicted based on forage concentration of DM, CP and NDF, kg forage DM/ha and daily forage DM availability per 100 kg BW. The object was to find the simplest model that best predicted the dependent variable, ADG. Mallows Cp is a way to measure the error for each variable in the model, relative to the error with all variables included. It measures the bias and identifies the model with the least bias and also best explains the predicted value. If the Mallows Cp value is greater than the number of the independent variables in the model (including the constant), it is an indication that too few independent variables were included. On the other hand, if the Cp is less than the number of the independent variable in the model (also including the constant), it is an indication that too many independent variables were included (Neter et al., 1985). Therefore, ideally the best model would contain the fewest number of variables and a Cp value approximately equal to the number of variables including the constant. Because Cp is a random variable, it is important to consider its distribution when selecting the best model.

The linear regression equations between ADG and gain/ha with DMBW and chemical composition of forage are shown in Table 4. Among ADG and all measured forage parameters, significant relationships were found for ryegrass and rye. For ryegrass, no variable met the 0.15 significance level. Even though the oats treatment reached the criteria, the *P* value of the model was not significant (P> 0.05), and the R^2 was very low (Table 4). The model for rye shows a significant influence of forage concentration of DM, CP and NDF; the *P* value of the model is significant (P<0.01) and R^2 = 0.53.

Table 4: Stepwise regression analysis of a linear mixed effect model describing the influence of DM, CP, NDF, FM[1] and DMBW[2] on ADG of Oats, Ryegrass and Rye

Forage	Dependent Variable	Independent. Variable	Parameter	SE	Variable P-value	Model P-value	R^2 of the model	Mallows C (p)
OT[3]	ADG	Intercept	1.16	0.11	<.0001	0.0972	0.06	2.08
		DMBW[2]	0.01	0.01	0.0972			
RG[3]	ADG	No variable met the 0.1500 significance level for entry into the model						
RY[3]	ADG	Intercept	6.09	0.95	<.0001	<.0001	0.53	3.03
		DM	-0.05	0.01	0.0002			
		CP	-0.08	0.02	0.0021			
		NDF	-0.04	0.01	0.0011			
OT	Gain/ area	Intercept	84.69	16.45	<.0001	<.0001	0.5	1.71
		DMBW	-5.972	0.94	<.0001			
		FM	0.0382	0.01	<.0001			
RG	Gain/area	Intercept	97.006	12.23	<.0001	<.0001	0.42	2.46
		DMBW	-5.972	1.1	<.0001			
		FM	0.0219	0.01	0.0125			
RY	Gain/area	Intercept	312.61	63.03	<.0001	<.0001	0.61	5.47
		DMBW	-5.384	1.03	<.0001			

FM[1] = Forage mass in DM (kg/ha).
DMBW[2]: kg DM availability/100kg $BW \cdot d^{-1}$.
OT[3] = oats, RG = ryegrass, RY = rye.

Between gain/ha and all measured forage parameters, significant relationships were found for all forages. For gain/ha, the stepwise procedure was consistent in selecting DMBW for all forages. The best model selected by the stepwise procedure for rye has a significant ($P<0.0001$) influence just with the DMBW with a Cp higher than recommended but could explain 61% of the variation. While the best model selected for ryegrass and oats were influenced by the DMBW and FM with a Cp closer to the ideal value, but with a lower R^2. Those results indicated that DMBW and FM could be used to develop a model to predict the gain per area for small grains and ryegrass.

The DMBW availability/100 kg BW·d^{-1} for each forage during the 3 years is shown in Fig. 3. The forage DMBW during the 3 years ranged from 2.6 to 36.3 kg DM availability/100 kg BW·d^{-1} with an average of 10.4. Gain per area increased with decreasing DMBW for all forages. Even though the R^2 is not high, especially for rye, these values are consistent with values found by Lopes et al. (2008) who reported a higher gain/area by steers grazing ryegrass at 8.8 DM availability/100 kg BW·d^{-1} compared with 14.7, 29.0 and 48.9. Additionally , the data here are in agreement with Mott 1984, who suggested optimum animal performance for tropical forages at approximately 5 kg DM/100 kg BW.

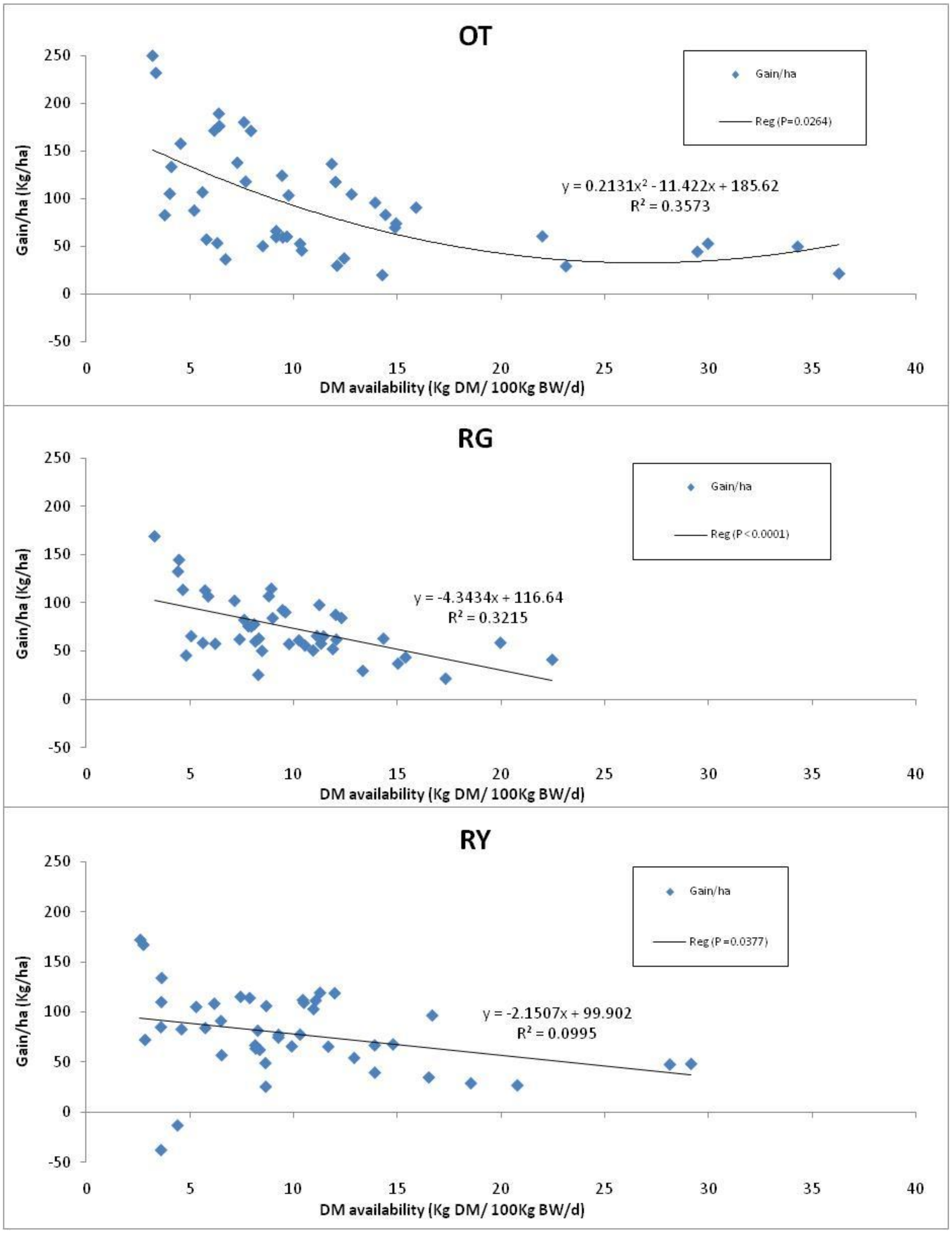

Figure 3: Relationship of gain/ha and forage availability (DM availability/100 kg BW·d^{-1}) for continuously stocked finishing beef cattle grazing oats, ryegrass or rye pastures.

SUMMARY AND CONCLUSIONS

In conclusion, steers grazing cool-season annual forages did not differ in ADG, but the oats pasture was superior in total gain/ha even though rye had greater CP content and ryegrass had less NDF and ADF. Cool-season annual pasture is highly dependent upon weather. However, it is possible to achieve ADG in finishing beef steers on ryegrass, oats or rye pastures that are acceptable and some years (2006), and similar to those observed in feedlots (2007). These forages also support good gain/area. Furthermore, these results demonstrate the potential for forage-fed beef in Alabama and the Southeastern United States.

LITERATURE CITED

AOAC. 1995. Official Methods of Analysis, 16th Ed. Association of Official Analytical Chemists, Washington, D.C.

Ball, D. M., C. S. Hoveland, and G. D. Lacefield. 2002. Southern Forages. Potash and Phosphate Inst. and the Foundation for Agronomic Res., Norcross, GA.

Bidner, T. D., A. R. Schupp, R. E. Montgomery, and J. C. Carpenter. 1981. Acceptability of beef finished on all-forage, forage-plus-grain or high energy diets. J. Anim. Sci. 53:1181.

Bowling, R. A., G. C. Smith, Z. L. Carpenter, T. R. Dutson and W. M. Oliver. 1977. Comparison of forage-finished and grain-finished beef carcasses. J. Anim. Sci. 45:209-215.

Bransby, D., B.E. Gamble, B. Gregory, M. Pegues, and R. Rawls. 1999. Feedlot gains on forages: Alabama’s stocker cattle can make significant gains on ryegrass pastures. Alabama Agricultural Experiment Station. Highlights of Agricultural Research Vol. 46, No. 2. Summer 1999.

Brown, H. J., S. L. Melton, M. J. Rieman and W. R. Backus. 1979. Effects of energy intake and feed source on chemical changes and flavor of ground beef during frozen storage. J. Anim. Sci. 48:338-347.

Cross, H. R. and D. A. Dinius. 1978. Carcass and palatability characteristics of beef steers finished on forage diets. J. Anim. Sci. 47:1265-1271.

Fontenot, J. P., V. G. Allen, and F. P. Horn. 1985. Forages and slaughter cattle. In: M. E. Heath, R. F. Barnes and D. S. Metcalfe (ed.). Forages: The Science of Grassland Agriculture. p 570. Iowa State University Press, Ames.

Galyean, M. L., D. G. Wagner and R. K. Johnson.1978. Studies on the feasibility of predicting feedlot performance from certain laboratory grain analyses. J Anim. Sci. 46:9-18.

Huffman, D. L. 1974. An evaluation of the tenderometer for measuring beef tenderness. J. Anim. Sci. 38:287–294

Kidwell, B. 2002. All grass, no grain. Progressive Farmer 117(11):18.

Kropf, D. H., D. M. Allen, and G. J. Thouvenelle. 1975. Grass-fed, short-fed and long-fed beef compared. Kansas Agric. Experiment Station, Report of Progress. 230:728.

Lopes, M. L. T., P. C. F. Carvalho, I. Anghinoni, D. T. Santos, F. Kuss, F. K. Freitas, J. P. C. Flores. 2008. Sistema de integração lavoura-pecuária: desempenho e qualidade da carcaça de novilhos superprecoces terminados em pastagem de aveia e azevém manejada sob diferentes alturas. Cienc. Rural. 38: 178-184. (In Portuguese)

Mader, T. L., G. W. Horn, W. A. Phillips and R. W. McNew. 1983. Low quality roughages for steers grazing wheat pasture. I. Effect on weight gains and bloat. J Anim. Sci. 56:1021-1028.

Mandell, I. B., J. G. Buchanan-Smith, and C. P. Campbell. 1998. Effects of forage vs grain feeding on carcass characteristics, fatty acid composition, and beef quality in Limousin-cross steers when time on feed is controlled. J. Anim. Sci. 76:2619–2630.

Matches, A.G., and J.C. Burns. 1995. Systems of grazing management. In R.F Barnes et al. (ed.) Forages. Vol. II. The science of grassland agriculture. 5th ed. Iowa State Univ. Press, Ames, IA. p. 179-192.

McCollum, F. T., M. D. Cravey, S. A. Gunter, J. M. Mieres, P. B. Beck, R. San Julian, and G. W. Horn. 1992. Forage mass affects wheat forage intake by stocker cattle. Okla. Agric. Exp. Sta. Anim. Sci. Res. Rep. p 312.

Mott, G. O. 1984. Relationship of available forage and animal performance in tropical grazing systems. Am. Forage Grassl. Counc. Proc. p 373.

Neter, J., W. Wasserman, and M. H. Kertner. 1985. Applied Linear Statistical Models. 2nd ed. Richard D Irwin Inc., Homewood, IL.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th ed. Nat. Acad. Press, Washington, DC.

NRC. 2000. Nutrient Requirements of Beef Cattle. updated 7th ed. National Academy Press, Washington, DC.

Oltjen, R. R., T. S. Rumsey and P. A. Putnam. 1971. All forage diets for finishing beef cattle. J. Anim. Sci. 32: 327.

Razminowicz, R.H., M. Kreuzer, M.R.L. Scheeder. 2006. Quality of retail beef from two grass-based production systems in comparison with conventional beef.Meat Science 73: 351–361.

SAS Institute. 2004. SAS/Stat 9.1 User's Guide. SAS Inst. Inc., Cary, NC.

Schroeder, J. W., D. A. Cramer, R. A. Bowling, and C. W. Cook. 1980. Palatability, shelf life and chemical differences between forage-and grain-finished beef. J. Anim. Sci. 50:852-859.

Siri-Prieto, G., D.W. Reeves, R.L. Raper, D. Bransby, and B.E. Gamble. 2003. Integrating winter annual grazing in a cotton-peanut rotation: Forage and tillage system selection. p. 104-115. In F.M. Rhoads (ed.) Proc. of Sod-Based Cropping Systems Conf., Quincy, FL. 20-21 Feb. 2003. North Florida Res. and Educ. Center, Quincy.

Skelley, G. C., R. L. Edward, F. B. Wardlaw, and A. K. Torrence. 1978. Selected high forage rations and their relationship to beef quality, fatty acids and amino acids. J. Anim. Sci. 47:1102-1108.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Wanderstock, J. J. and J. L. Miller. 1948. Quality and palatability of beef as affected by method of feeding and carcass grade. Food Res. 13:291.

Zinn, R. A., A. Barreras, F. N. Owens and A. Plascencia. 2008. Performance by feedlot steers and heifers: Daily gain, mature body weight, dry matter intake, and dietary energetic. J. Anim. Sci.86:2680-2689.

IV. A HIGH-THROUGHPUT PROCEDURE FOR MEASURING NEUTRAL DETERGENT FIBER AND ACID DETERGENT FIBER

ABSTRACT: A high-throughput-of procedure was developed for the sequential analysis of NDF and ADF that allows a large quantity of samples to be analyzed in a relatively short period of time. In the procedure, 60 forage samples (0.5 to 1.0 g) were weighed into individual pre-weighed and identified filter bags (F57, 25 µm, Ankom Technology Corp.) and then heat sealed. The samples were placed in a water bath with either NDF or ADF detergent solutions (10 L for 60 samples) and maintained at a constant temperature (99 ^{O}C) at 60 oscillations/min during 60 min. Filter bags were kept immersed with a metal basket. The fiber bag ANKOM method served as the control for evaluation of the modified water bath method (WB). The objective was to compare procedures using different harvests of ryegrass, rye and oats forage samples. A completely randomized design with a replicated 2 (analytical procedures) × 3 (forages) × 2 (harvests) factorial arrangement of treatments was used. The primary difference between the two procedures was the substitution of the pressurized chamber from the Ankom fiber analyzer by a stainless steel water bath. There was a harvest and forage effect ($P < 0.01$) forage concentration of NDF and ADF and also a harvest × forage interaction ($P < 0.05$ for NDF and $P < 0.01$ for ADF), but there were no differences between the methods for either NDF (31.93% WB vs. 31.33%

ANKOM, *P* = 0.29) or ADF (15.54% WB vs 15.96% ANKOM, *P* = 0.21). The coefficients of variation (CV) were low for NDF (100% of samples with CVs below 2.8%) and for ADF (83% of samples with CVs below 5% with the highest CV at 5.9%). The difference in the NDF value between methods and the mean was 0.3 percentage unit, which is 0.95% of the mean. For ADF, the value of the difference was 0.21 percentage unit, which is 1.3% of the mean. There was a strong relationship for both NDF (R^2 = 0.97) and ADF (R^2 = 0.89) between the methods. The WB analysis method produced repeatable results that were comparable to the ANKOM method and can be used to process a large number of samples (up to 60 replicate samples) in the same amount of time that 12 duplicate samples are processed using the ANKOM method.

KEYWORDS: Detergent system, NDF, ADF, Fiber analyses, forage

INTRODUCTION

Fiber analysis is a major analytical tool in ruminant nutrition because ruminants are one of the most specialized herbivores for utilizing fiber as source of energy (Van Soest, 1994). Even for finishing feedlot diets as revealed in a recent survey of beef cattle consulting nutritionists (Vasconselos and Galyean, 2007), fiber is commonly added (average 8.3 and 9.0% in DM for summer and winter, respectively). In ruminant nutrition, fiber refers to the plant cell wall and is defined as part of the feedstuff not digested by mammalian enzymes (Moore and Hatfield 1994). The proximate system of analysis, in which fiber is measured as crude fiber (CF), was one of the first methods developed and still is preferred by a majority of ruminant nutritionists (41.38% vs. 34.48% for NDF) (Vasconcelos and Galyean, 2007).

The CF method was developed to represent the indigestible fraction of the feed, but in reality it underestimates the cell wall and lignin content (Van Soest, 1994). The NDF method (Van Soest and Wine, 1967) was intended to separate the feedstuff into two main fractions, a soluble fraction that is totally digested and an insoluble fraction that is incompletely and more slowly digested in the rumen.

Since the original NDF method was developed (Van Soest and Wine 1967), there have been several modifications (Mertens, 2002, Giger-Reverdin, 1995, Van Soest et al., 1991, Mascarenhas-Ferreira et al., 1983, Robertson and Van Soest, 1981). It was developed originally for use with forages, but the presence of starch influences the values generated by this method. With the inclusion of heat stable amylase (Robertson and Van Soest, 1981) to reduce the starch contamination of fiber, the method also became widely used for starchy feeds. Later sodium sulphite was included in the procedure (Hintz et al., 1996) to reduce protein contamination in fiber measurement of high-protein feeds, plus several minor alterations to the procedure led to AOAC (Association of Official Analytical Chemists) approval of the NDF method in 2002 (Mascarenhas-Ferreira et al., 1983,Giger-Reverdin, 1995, Van Soest et al., 1991, Mertens, 2002).

The NDF method is based on the ability of the neutral detergent solution to solubilize nonstructural components, leaving just the fibrous parts of the feed sample separated by filtration. Filtration problems became the major barrier in this procedure until the development of a procedure using filtration in filter bags (Komarek, 1993a,b, Komarek et al., 1994a,b) in a semi-automated fiber analyser with a pressurized chamber from ANKOM company (Ankom Technology Corp., Fairport, NY). However, the system still is limited by the number of samples per batch that can be analyzed and the price of the pressurized chamber itself. We developed a procedure for NDF and ADF analyses using the filter bags without the need of the special equipment (pressurized chamber) using a simple water bath.

The objective was to compare both procedures using different harvests of ryegrass, rye and oats forage samples. The hypothesis was that NDF and ADF values would not be significantly different between the water bath method and the ANKOM method.

MATERIALS AND METHODS

Forage samples:

Sixty forage samples were harvested every other week during the winter of 2007, totaling 10 harvests from replicate 1.42 ha paddocks (2 per forage) containing ryegrass (*Lolium perenne*), rye (*Secale cereal*) and oats (*Avena sativa*) established at the Wiregrass Research and Extension Center in Headland, AL (31.3° lat., 85.3° long., 105 m elev.).

Fiber analysis:

Overview of procedures. The fiber analysis was conducted after all samples had been dried, finely ground to pass a 1-mm screen in a Wiley mill and all filter bags been weighed and identified in 6 general steps as follows:

Step 1: Sample bags. Weighed samples were placed in filter bags and heat sealed.

Step 2: Solution preparation. Neutral detergent (with sodium sulfite) or acid detergent solution was used in both procedures.

Step 3: Bag immersion. All bags were place in a chamber for ANKOM method or in a water bath for the WB method and immersed for extraction.

Step 4: Washing bags. Boiling water was used in the same amount per bag in both methods. Amylase enzyme was used in the NDF procedure in the first 60% of the water washes used to wash the bags. Pure boiling water was used for ADF.

Step 5: Drying bags. Excess water was removed, and all bags were immersed in acetone, dried, and placed in an oven until constant weight.

Step 6: Results. ADF or NDF content was calculated based on residual weight.

Details of procedures. All harvested forage was oven dried at 50^{o}C for 72 h and ground to pass through a 1 mm screen of a cutter mill (Thomas- Wiley, Laboratory Mill, Model 4, Arthur H. Thomas, Philadelphia, PA., U.S.A.) and stored in a sealed plastic bottle before analysis. Samples for NDF analysis were weighed (0.5 to1.0 g) into individual pre-weighed and labeled filter bags (F57, 25 µm, Ankom Technology Corp.) and then heat sealed (Impulse Sealer, Type: AIE-200, American International

Electric). Separate 1-g samples were weighed into aluminum pans and dried at 100°C to a constant weight for DM determination. Those procedures were the same for ANKOM and water bath method (WB) analysis.

For the ANKOM method for NDF and ADF measurement, the ANKOM Fiber Analyzer (Model No: ANKOM 200, Ankom Technology, Fairport, NY) was used. Two liters of neutral detergent (# FND20, ANKOM Co.) or acid detergent (# FAD20CB, ANKOM Co.) solution was poured into the extraction chamber with 24 filter bags containing sample from the first 2 harvests of the 3 forage types from 2 paddocks per forage (12 samples), each replicated, totaling 24 bags. For NDF, 20 g of sodium sulphite was mixed with ND solution for 5 min before it was added to the fiber analyzer. After inserting the plastic trays with the 24 samples, the chamber lid was sealed, the heat turned on to be heated to 100° C and sample incubated for 60 min total time. After 60 min, detergent was removed and the chamber was filled with 2L of distilled water (100ºC) to wash the filter bags for 5min with the chamber lid left open and the heater turned off. This procedure was repeated 5 times for both NDF and ADF analyses (10 L of water/24 bags= 416 ml/bag), but for NDF the first 3 times, 4ml of ANKOM heat stable bacterial Alpha-Amylase (activity = 17,400 Liquefon Units / ml - ANLOM technology FAA) was added. After the last water wash, all filter bags were taken off the plastic trays and placed between two absorbent papers, gently pressed to remove excess water. All filter bags were then placed in a 500=ml glass jar, covered with acetone, the air was taken out using an Erlenmeyer flask as a “plunger,” and soaked for 5 min. Under an air flow hood system, all bags were placed between two absorbent papers, gently pressed to remove excess acetone, and let air dry under the hood. All bags were then dried in an laboratory oven at 100^{o}C until a constant weight. For both methods duplicate samples were analyzed (i.e., two replications), and analysis was considered to be precise if the difference between the sample and the mean were less than 5%.

For the WB method all 60 duplicate samples (120 bags) were used but just the same 2 harvests (12 duplicated samples = 24 bags) were used for comparing with the ANKOM. The same detergent solutions were used in WB for NDF and ADF analysis with the same amount per sample (2 L/24 samples) and the same type and amount per sample of heat stable bacterial alpha-amylase (4ml/24 sample for 3 times). Therefore, 10 L of either NDF (with 100 g of sodium sulphite) or ADF solution were placed in an inox (stainless steel) Shaker bath, 50 liter capacity (Model 50 Precision Scientific, Chicago, IL), heated to 99^{o} C, and all filter bags (F57, 25 µm, Ankom Technology Corp.) were placed in the bath. The solution was maintained at a constant temperature (99^{o}C) with 60 oscillations/min. All filter bags were kept immersed in the NDF or ADF solution using a metal basket. After a 60-min extraction period the NDF or ADF solution was drained from the Shaker bath and all filter bags were placed in a plastic bucket (20 L).

For NDF analysis, the bucket was filled with 4 L of distilled water (100ºC) with 7.5 ml of ANKOM heat stable bacterial alpha-amylase (activity = 17,400 Liquefon Units/ ml - ANLOM technology FAA) to wash the filter bags by hand mixing with a glass rod for 5 min. The bucket contents then were drained through a metallic basket where the filter bags were recovered and placed back in the bucket. This was repeated 8 times followed by 4 times without the alpha-amylase enzyme. The last time the bucket was filled with 6 L of distilled water (100ºC) to total 50 L of water used for 120 bags (416 ml/bag).

For ADF analyses these procedures were exactly the same but the alpha-amylase enzyme was not used. After the last water wash for both NDF and ADF analyses, all other steps were the same as already described for the ANKOM method.

The NDF and ADF concentrations were calculated as follows:

NDF or ADF (% of DM) = $100 (W3 – (W_1 \times C_1)) / W_2$.

Where:

W_1 = Bag tare weight

W_2 = Sample weight, expressed on a dry matter basis

W_3 = final bag and fiber weight

C_1 = Blank bag correction (final oven-dried weight / original blank bag weight)

Statistical analysis:

Data were analyzed using the GLM procedure of SAS (release 9.1; SAS Institute Inc., Cary, NC) in a linear model procedure for a completely randomized design with a replicated 2 (analytical procedures) × 3 (forage) × 2 (harvests) factorial arrangement of treatments. The significance level was preset at $P < 0.05$ for all analyses.

RESULTS AND DISCUSSION

There was a harvest and forage effect (*P* < 0.01) for forage concentration of NDF and ADF, and also a harvest × forage interaction (*P* < 0.05 for NDF and *P* < 0.01 for ADF).

Table 1. Least squares means of concentration of NDF and ADF in all sample grouped by harvest

Harvest	NDF	SE	*P*	ADF	SE	*P*
First	29.91[a]	0.38	< 0.001	15.06[a]	0.22	< 0.001
Second	33.35[b]			16.44[b]		

[a,b,c]Means in the same column with different superscripts differ (*P* < 0.01)

The lower NDF and ADF content of the first harvest would indicate that cell wall concentration increased in the 2 weeks between harvests (Table 1).

Table 2. Least squares means of concentration of NDF and ADF in all samples grouped by Forage type

Forage	NDF	SE	*P*	ADF	SE	*P*
Oats	32.19[b]			16.11[b]		
Ryegrass	29.71[a]	0.47	< 0.0001	14.18[a]	0.27	< 0.0001
Rye	32.99[b]			16.95[c]		

[a,b,c]Means in the same column with different superscripts differ (*P* < 0.01)

The lower NDF and ADF concentration of the ryegrass indicates higher quality of this grass in relation to the others in this experiment (Table 2).

Table 3. Least squares means of concentration of NDF and ADF in all samples grouped by Treatment

TRT	NDF	SE	*P*	ADF	SE	*P*
WB	31.93	0.38	0.29	15.54	0.22	0.21
ANKOM	31.33			15.96		

The results of NDF and ADF analyses of all samples conducted by the WB and ANKOM methods are shown in table 3. There were no differences between the two methods for both NDF (P = 0.29) and ADF (P = 0.22). The difference in the mean NDF value between methods and the overall mean was 0.3 percentage unit, which is just 0.95% of the mean. For ADF the value of the difference was 0.21, which is 1.3% of the mean. The small differences between ANKOM and WB for NDF and ADF are consistent with the results of Vogel et al., (1999), who reported that ADF and NDF means for ANKOM and conventional methods (Van Soest et al., 1991) differed by 1.5 % for ADF and 2.5% for ADF with no significant differences between methods for bromegrass and sorghum forage.

Table 4: Mean, SD and coefficients of variation (CV) for NDF and ADF values by forage sample pooled across both methods of analysis

Harvest		First			Second	
Sample type[1]		NDF	ADF		NDF	ADF
RG Plot 1	Mean	30.91	15.22		30.02	13.76
	SD	0.62	0.74		0.35	0.14
	CV	2.01	4.88		1.17	1
RG Plot 2	Mean	27.22	13.52		30.69	14.25
	SD	0.62	0.8		0.56	0.72
	CV	2.27	5.91		1.82	5.09
RY Plot 1	Mean	30.66	15.14		36.62	19.23
	SD	0.36	0.41		0.64	0.45
	CV	1.18	2.74		1.74	2.34
RY Plot 2	Mean	30.5	15.6		34.18	17.85
	SD	0.19	0.54		0.33	0.53
	CV	0.62	3.46		0.96	2.99
OT Plot 1	Mean	30.45	15.61		34.44	17.07
	SD	0.82	0.27		0.32	0.19
	CV	2.68	1.72		0.92	1.12
OT Plot 2	Mean	29.76	15.26		34.13	16.51
	SD	0.82	0.29		0.62	0.38
	CV	2.75	1.93		1.81	2.33

[1]RG = Ryegrass, RY = Rye, OT = Oats.

The coefficients of variation (CV) were low for NDF (100% of samples with CVs below 2.8%) and for ADF (83% of samples with CVs below 5% with the highest CV at 5.9%). The CV reported here is lower than the results of Jung (1991), who compared the Ankom method with a conventional fiber analysis (Van Soest and

Robertson, 1980). He reported 83% of the hay samples with a CV below 5% for NDF. Other researchers also reported a CV for NDF from 1.14 to 5.68 % and ADF from 0.68 to 7.02 (Holechek and Vavra, 1982; Berchielli et al., 2001) in a comparison between two methods already in use.

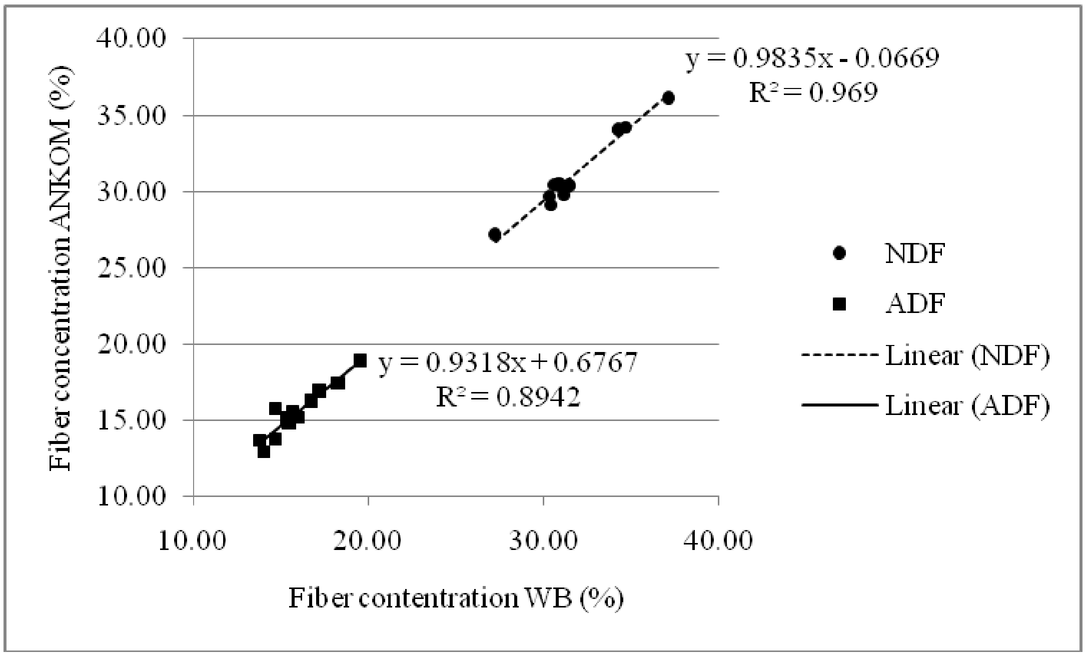

Figure 1. Comparing ANKOM and WB mean forage ADF and NDF concentrations compared across all forage samples.

Figure 1 shows the relationship between NDF and ADF for both methods of analysis. There proved to be a high relationship between the method for both NDF (R^2 = 0.97) and ADF (R^2 = 0.89). Both NDF and ADF had a correlation coefficient (P < 0.0001) between WB and ANKOM results. The slope of the equation for the mean results were 0.9835x and 0.8942x respectively, suggesting that there were a very strong (P < 0.0001) relationship between both methods. Koivisto (2003) also reported a correlation coefficient ($P > 0.001$) between methods for NDF and ADF with a slope of the equation for the means of 0.8257 and 0.9454 respectively.

SUMMARY AND CONCLUSION

The results show that the WB method is comparable to the ANKOM method. From a practical point of view, the method could be used for the analysis of a large number of samples in a relatively short period of time using a stainless steel shaker bath.

LITERATURE CITED

Berchielli, T. T.; Sader, A. P. O.; Tonani F. L.; Paziani S. F.; Andrade P. 2001. Avaliação da Determinação da Fibra em Detergente Neutro e da Fibra em Detergente Ácido pelo Sistema ANKOM. Rev. bras. zootec., 30(5):1572-1578, 2001

Giger-Reverdin, S. 1995. Review of the main methods of cell wall determination: Interest and limits for ruminants. Anim. Feed Sci. Tech. 55:295–334.

Hintz, R.W., Mertens, D.R., Albrecht, K.A., 1996. Effects of sodium sulfite on recovery and composition of detergent fiber and lignin. J. AOAC Int. 79, 16–22.

Holechek, J. L. and M. Vavra. 1982. Comparison of micro- and macro-digestion methods for fiber analysis. J. Range Manage. 35:799.

Jung, H.G. Comparison of the Ankom filter bag method with conventional fiber analysis of forages. 1991. St. Paul, USDA-ARS, University of Minnesota.

Koivisto, Jason M. 2003. FibreBags vs. FibreCaps for acid and neutral detergent fibre analysis. Reproduction Nutrition Development 43 5 (2003) 431-436.

Komarek, A. R. 1993a. A filter bag procedure for improving efficiency of fiber analysis. J. Dairy Sci. 76(suppl.1):250.

Komarek, A. R. 1993b. An improved filtering technique for the analysis of neutral detergent fiber and acid detergent fiber utilizing the filter bag technique. ANKOM Co., Publ. 101. Fairport, NY.

Komarek, A. R., J. B. Robertson, and P. J. Van Soest. 1994a. A comparison of methods for determining ADF using the filter bag technique versus conventional filtration. J. Dairy Sci. 77(suppl.1):114.

Komarek, A. R., J. B. Robertson, and P. J. Van Soest. 1994b. Comparison of the filter bag technique to conventional filtration in the Van Soest Analysis of 21 feeds. Page 78 in Proc. Natl. Conf. Forage Quality, Evaluation, and Utilization, Lincoln, NE.

Mascarenhas-Ferreia, A., Kerstens, J., Gast, C.H., 1983. The study of several modifications of the neutral detergent fibre procedure. Animal Feed Sci. Technol. 9: 19-28.

Mertens, D. R. 2002. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: Collaborative study. J. AOAC Int. 85:1217–1240.

Moore, K. J. and Hatfield, R. D. 1994. Carbohydrates and forage quality. In: Forage Quality, Evaluation, and Utilization (Fahey, G. C., Jr., Collins, M. C., Mertens, D. R. & Moser, L. E., eds.), pp. 229–280. ASA-CSSA-SSSA, Madison, WI.

Robertson, J.B., Van Soest, P.J., 1981. The detergent system of analysis and its application to human foods. In: James, W.P.T., Theander, O. (Eds.). The Analysis of Dietary Fibre in Foods. Marcel Dekker, New York.

SAS Institute. 2004. SAS/Stat 9.1 User’s Guide. SAS Inst. Inc., Cary, NC.

Van Soest, P. J., and J. B. Robertson. 1980. Systems of analysis for evaluating fibrous feeds. In: W. J. Pigden, C. C. Balch, and M. Graham (Ed.) Standardization of Analytical Methodology for Feeds. pp 49–60. Publication No. IDRC-134e. Int. Dev. Res. Center, Ottawa, Canada.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Van Soest, P.J., 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca, NY/London, 476 pp.

Van Soest, P.J., Wine, R.H., 1967. The use of detergents in analysis of fibrous feeds: IV. Determination of plant cell wall constituents. J. AOAC 50, 50–55.

Vasconcelos, J. T., and M. L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim. Sci. 85:2772.

Vogel, K. P., J. F. Pedersen, S. D. Materson, and J. J. Toy. 1999. Evaluation of a filter bag system for NDF, ADF, and IVDMD forage analysis. Crop Sci. 39:276–279.

V. CONCLUSIONS

The results of the grazing study shows that steers grazing cool-season annual forages tested did not differ in ADG, but the oats pasture was superior in total gain per ha even though rye had greater CP content and ryegrass had less NDF and ADF. Cool-season annual pasture is highly dependent upon weather. However, it is possible to achieve ADG in finishing beef steers on ryegrass, oats or rye pastures that are acceptable and some years (2006), and similar to those observed in feedlots (2007). These forages also support good gain/area. Furthermore, these results demonstrate the potential for forage-fed beef in Alabama and the Southeastern United States.

The results of the experiment 2 show that the use of WB method is repeatable and comparable to the ANKOM method. It is a less expensive option for NDF and ADF analysis because it does not need the very expensive chamber ANKOM Fiber Analyzer; only a common stainless steel shaker bath is needed. From a practical point of view, the method could be used for inexpensive analyses of a large number of samples.

BIBLIOGRAPHY

Allen, V. G., J. P. Fontenot, R. F. Kelly, and D. R. Notter. 1996. Forage systems for beef production from conception to slaughter: III. Finishing systems. J. Anim. Sci. 74:625–638.

AOAC. 1995. Official Methods of Analysis, 16th Ed. Association of Official Analytical Chemists, Washington, D.C.

ARC. 1980. Agricultural Research Council. The Nutrient Requirements of Ruminant Livestock. Technical Review. Farnham Royal, U. K.: Commonwealth Agricultural Bureaux.

Bagley, C. P. 1984. Slaughter beef from warm season pasture. Proc. Amer. Forage and Grassl. Council. Houston, TX. pp 9--17.

Bagley, C. P., G. M. Hill, J. W. Knox, D. F. Coombs, W. M. Oliver, A. F. Loyacano, W. E. Wyatt, D. C. Huffman, K. W. McMillin, and T .D. Binder. 1988. Using forages to produce stocker and finished beef year-round. La Agric. Exp. Sta. Bull. 17-19.

Ball, C. E. 1998. Pages 1–296 in Building the Beef Industry. Saratoga Publishing Group, Saratoga Springs, NY.

Ball, D. M., C. S. Hoveland, and G. D. Lacefield. 2002. Southern Forages. Potash and Phosphate Inst. and the Foundation for Agronomic Res., Norcross, GA.

Bath, D. L., W. C. Weir, and D. T. Torell. 1956. The use of the esophageal fistula for the determination of consumption and digestibility of pasture forage by sheep. J. Anim. Sci. 15:1166–1171.

Beck, P. A., C. B. Stewart, J. M. Phillips, K. B. Watkins and S. A. Gunter. 2007. Effect of species of cool-season annual grass interseeded into Bermudagrass performance of growing calves. J Anim Sci. 85:536-544.

Bedunah, D. J. and R. E. Sosebee. 1995. Wildland plants: Physiology, ecology, and developmental morphology. Society for Range Management, Denver, CO.

Berchielli, T. T.; Sader, A. P. O.; Tonani F. L.; Paziani S. F.; Andrade P. 2001. Avaliação da Determinação da Fibra em Detergente Neutro e da Fibra em Detergente Ácido pelo Sistema ANKOM. Rev. bras. zootec., 30(5):1572-1578, 2001

Berthiaume, R., I. Mandell, L. Faucitano, and C. Lafrenière. 2006. Comparison of alternative beef production systems based on forage finishing or grain-forage diets with or without growth promotants: 1. Feedlot performance, carcass quality, and production costs. J Anim Sci. 84: 2168-2177.

Bidner, T. D., A. R. Schupp, R. E. Montgomery, and J. C. Carpenter. 1981. Acceptability of beef finished on all-forage, forage-plus-grain or high energy diets. J. Anim. Sci. 53:1181.

Blaser, R. E. 1964. Symposium on forage utilization: Effects of fertility levels and stage of maturity on forage nutritive value. J. Anim. Sci. 23:246–253.

Bowling, R. A., G. C. Smith, Z. L. Carpenter, T. R. Dutson and W. M. Oliver. 1977. Comparison of forage-finished and grain-finished beef carcasses. J. Anim. Sci. 45:209-215.

Bowling, R. A., J. K. Riggs, G. C. Smith, Z. L. Carpenter, R. L. Reddish, and O. D. Butler. 1978. Production, carcass and palatability characteristics of steers produced by different management systems. J. Anim. Sci. 46:333.

Bransby, D. I., A. G. Matches, and G. F. Krause. 1977. Disc meter for rapid estimation of herbage yield in grazing trials. Agron. J. 69:393-396.

Bransby, D. I., M. Pegues, and R. Rawls. 1997. Marshall ryegrass dramatically superior under grazing. Highlights of Agric. Res. (Alabama Agric. Exp. Stn.) 44 (No. 2):12-14.

Bransby, D.I., B.E. Gamble, B. Gregory, M. Pegues, and R. Rawls. 1999. Feedlot gains on forages: Alabama’s stocker cattle can make significant gains on ryegrass pastures. Alabama Agricultural Experiment Station. Highlights of Agricultural Research Vol. 46, No. 2. Summer 1999.

Briske, D. D. and J. H. Richards. 1995. Plant responses to defoliation: A physiological, morphological and demographic evaluation, pp. 635-710. In: Physiological ecology and developmental morphology, D. J. Bedunah and R. E. Sosebee (eds.), Society for Range Management, Denver, CO.

Brown, H. J., S. L. Melton, M. J. Rieman and W. R. Backus. 1979. Effects of energy intake and feed source on chemical changes and flavor of ground beef during frozen storage. J. Anim. Sci. 48:338-347.

Bryant, H. T., R. E. Blaser, R. C. Hammes Jr., and J. P. Fontenot. 1970. Symposium on pasture methods for maximum production in beef cattle: Effect of grazing management on animal and area output. J. Anim. Sci. 30:153–158.

Burns, J. C. 2006. Grazing research in the humid East: A historical perspective. Crop Sci. 46:118–130

Burns, J. C., K. R. Pond, and D. S. Fisher. 1994. Measurement of forage intake. Page 494 in Forage quality, evaluation, and utilization. G. C. Fahey, M. Collins, D. R. Mertens, and L. E. Moser, ed. ASA, CSSA, SSSA, Madison, WI.

Burton, G. W., R. N. Gates, and G.M. Hill. 1993.Registration of ‘Tifton 85’bermudasgrass. Crop Sci.33:644.

Butler, O. D., B. L. Warwick, and T. C. Cartwright. 1956. Slaughter and carcass characteristics of short fed yearling, Hereford, and Brahman × Hereford steers. J. Anim. Sci. 15:93–96.

Chamblee, D. S. and A. E. Spooner. 1985. Hay and pasture seedings for the humid South. P. 359-370. In M. E. Health et al. (ed.) Forages, the science of grassland agriculture. Iowa State Univ. Press, Ames.

Cheng, K.J., Forsberg, C.W., Minato, H. and Costerton, J.W. 1991. Microbial ecology and physiology of feed degradation within the rumen. In: Physiological Aspects of Digestion and Metabolism in Ruminants: Proceedings of the Seventh International Symposium on Ruminant Physiology. Ed T. Tsuda., T. Sasaki. And R. Kawashima. Academic Press. San Diego. 595-624.

Clark, J.T., J.R. Russell, D.L. Karlen, P.L. Singleton, W.D. Busby, and B.C. Peterson. 2004. Soil surface property and soybean yield response to corn stover grazing. Agron. J. 96:1364–1371.

Cleere, J. J., F. M. Rouquette, Jr., and G. M. Clary. 2004. Impact of stocking rate and stocking strategy on gain per animal and gain per hectare of steers grazing rotational or continuous stocked rye-ryegrass pasture. J. Anim. Sci. 87(Suppl. 1):292. (Abstr.).

Cook, C. W., J. L. Thorne, J. T. Blake, and J. Edlefsen. 1958. Use of an esophageal-fistula cannula for collecting forage samples by grazing sheep. J. Anim. Sci. 17:189–193.

Coombs, D. F., C. P. Bagley, G. M. Hill, J. W. Knox, A. F. Loyacano, W. M. Oliver, W. E. Wyatt, D. C. Huffman, K. W. McMillin, T. D. Bidner, and A. M. Saxton. 1990. Year-round production of beef using maximum levels of forages. II. Finishing phase. Appl. Agric. Res. 5:315.

Corah, L. R. 2008. ASAS Centennial Paper: Development of a corn-based beef industry. J. Anim Sci. 86: 3635-3639

Coulibaly, N., D. J. Bernardo, and G. W. Horn. 1996. Energy supplementation strategies for wheat pasture stocker cattle under uncertain forage availability. J. Agric. Appl. Econ. 28:172–179.

Coyne, P. I., M. J. Trlica, and C. E. Owensby. 1995. Carbon and nitrogen dynamics in range plants, pp. 59-167. In: Physiological ecology and developmental morphology, D. J. Bedunah and R. E. Sosebee (eds.), Society for Range Management, Denver, CO.

Craig, H. B., and T. W. Blumer. 1956. Measurements of intramuscular fat, myoglobin and hemoglobin content of beef ribeye muscle from animals fed several combinations of grass and grain. J. Anim. Sci. 15(Suppl.):1273 (Abstr.)

Crawford, R. J., Jr., J. R. Forwood, R. L. Belyea, and G. B. Garner. 1989. Relationship between level of endophyte infection and. J. Prod. Agric. 2:147.

Cross, H. R. and D. A. Dinius. 1978. Carcass and palatability characteristics of beef steers finished on forage diets. J. Anim. Sci. 47:1265-1271.

Crouse, J. D., H. R. Cross, and S. C. Seideman. 1984. Effects of a grass or grain diet on the quality of three beef muscles. J. Anim. Sci. 58:619–625.

Demarquilly, C., J. M. Boissau and G. Cuylle. 1965. Factors affecting the voluntary intake of green forage by sheep. Proc. 9th Int. Grass. Cong., p 877.

Deregibus, V. A., M. J. Trlica, and D. A. Jameson. 1982. Organic reserves in herbage plants: Their relationship to grassland management, pp. 315-344. In: M. Rechcigl, Jr. (ed.), Handbook of Agricultural Productivity. Vol. 1, Plant Productivity, CRD Press, Boca Raton, FL.

Diaz-Zorita, M., G.A. Duarte, and J.H. Grove. 2002. A review of no-till systems and soil management for sustainable crop production in the subhumid and semiarid Pampas of Argentina. Soil Tillage Res. 65:1–18.

Dinius, D.A., and B.R. Baumgardt. 1970. Regulation of food intake in ruminants. 6. Influence of caloric density of pelleted rations. J. Dairy Sci. 53:311-316.

Donnelly, K. J. and W. E. McMurphy. 1983. Cultural practices for maximizing forage production in wheat. p. 3-22. In G. W. Horn (ed.) National Wheat Pasture Symp. Proc. Oklahoma Agric. Exp. Stn. MP-115.

Duckett, S. K. ,J. P. S. Neel, R. N. Sonon Jr., J. P. Fontenot, W. M. Clapham, and G. Scaglia. 2007. Effects of winter stocker growth rate and finishing system on: II.

Ninth–tenth–eleventh-rib composition, muscle color, and palatability. J. Anim. Sci. 85:2691–2698

Edlefsen, J. L., C. W. Cook, and J. T. Blake. 1960. Nutrient content of the diet as determined by hand plucked and esophageal fistula samples. J. Anim. Sci. 19:560–567.

Federal Register. 2002. United States standards for livestock and meat marketing claims 67(250):79554.

Fontenot, J. P., V. G. Allen, and F. P. Horn. 1985. Forages and slaughter cattle. In: M. E. Heath, R. F. Barnes and D. S. Metcalfe (ed.). Forages: The Science of Grassland Agriculture. p 570. Iowa State University Press, Ames.

Forbes, 2003. The multifactorial nature of food intake control. J Anim Sci 2003. 81:E139-144.

Forbes, J. M. 1986. Review of theories of food intake control. Pages 15–34 in The Voluntary Food Intake of Farm Animals. P. C. Garnsworthy, ed. Butterworths, London, UK.

Forbes, J. M. 1988. Metabolic aspects of the regulation of voluntary food intake and appetite. Nutr. Res. Rev. 1:145.

Forbes, J. M. 1996. Integration of Regulatory Signals Controlling Forage Intake in Ruminants. J. Anim. Sci. 74:3029–3035.

Fox, D. G. and J. R. Black. 1984. A system for predicting body composition and performance of growing cattle. J. Anim. Sci. 58:725.

Fox, D. G., C. J, Sniffen, and J. D. O'Connor. 1988. Adjusting nutrient requirements of beef cattle for animal and environmental variations. J. Anim. Sci. 66:1475-1495.

Franzluebbers, A.J., and J.A. Stuedemann. 2004. Crop management and animal production in yearly rotation under inversion and no tillage. p. 231–238. In D. Jordan and D. Caldwell (ed.) Proc. 26th South. Conserv. Tillage Conf., Tech. Bull. 321, Raleigh, NC. 8–9 June 2004. North Carolina Agric. Res. Serv.

Franzluebbers, A.J., J.A. Stuedemann, and S.R. Wilkinson. 2001. Bermudagrass management in the Southern Piedmont USA: I. Soil and surface residue carbon and sulfur. Soil Sci. Soc. Am. J. 65:834–841.

Gadberry, M. S., P. A. Beck, and S. A. Gunter. 2004. Forage intake and performance by beef heifers grazing cool-season pasture supplemented with de-oiled rice bran or corn. Prof. Anim. Sci. 20:394–400.

Gaillard, B. D. E. 1958. A detailed summative analysis of the crude fiber and nitrogen-free extractives fractions of roughages. I. Proposed scheme of analysis. J. Sci. Food. Agric. 9: 170.

Galt, D., G. Mendez, J. Holechek, and J. Joseph. 1999. Heavy winter grazing reduces forage production: An observation. Rangelands. 21(4): 18-21.

Galyean, M. L. 1997. Laboratory Procedures in Animal Nutrition Research. Texas Tech Univ., Lubbock. http://apps.depts.ttu.edu/afs/home/mgalyean/ Accessed Feb. 20, 2009.

Galyean, M. L., and A. L. Goetsch. 1993. Utilization of forage fiber by ruminants. Pages 33–37 in Forage Cell Wall Structure and Digestibility. H. G. Jung, D. R. Buxton, R. D. Hatfield, and J. Ralph, ed. ASA-CSSA-SSSA, Madison, WI.

Galyean, M. L., D. G. Wagner and R. K. Johnson.1978. Studies on the feasibility of predicting feedlot performance from certain laboratory grain analyses. J Anim. Sci. 46:9-18.

Gamble, B.E., G. Siri-Prieto, D.W. Reeves, and R.L. Raper. 2005. Forage and tillage systems for integrating winter-grazed stocker cattle in peanut production. p. 162–164. In W.. Busscher et al. (ed.) Proc. South. Conserv. Tillage Conf., Florence, SC. 27–29 June 2005. Clemson Univ.

Garrigus, W. P. 1935. The forage consumption of grazing steers. Am. Soc. Anim. Prod.:66–69.

Geurin, H. B., J. C. Thompson, H. L. Wilcke, and R. M. Bethke. 1954. Cob portion of ground ear corn as sole roughage for fattening cattle. J. Anim. Sci. 13(Suppl.):984 (Abstr.).

Giger-Reverdin, S. 1995. Review of the main methods of cell wall determination: Interest and limits for ruminants. Anim. Feed Sci. Tech. 55:295–334.

Gill, D. R., F. N. Owens, J. J. Martin, D. E. Williams, R. A. Zinn, and R. J. Hillier. 1981. Roughage levels in feedlot rations. Okla. Agric. Exp. Stn. MP 108:141-146. Okla. State Univ., Stillwater.

Gill, S.S., H.R. Conrad, and J.W Hibbs. 1969. Relative rate of in vitro cellulose disappearance as a possible estimator of digestible dry matter intake. J. Dairy Sci. 52:1687-1690.

Gonzalez, M. A., M. A. Hussey, and B.E. Conrad. 1990. Plant Height, Disk, and Capacitance Meters Used to Estimate Bermudagrass Herbage Mass. Agron. J. 82:861-864.

Greathead, K. D., J. Wallace, and J. N. Boultwood. 1987. The nature of the relationship of electronic capacitance meter readings to pastures on offer in short swards. Grass Forage Sci. 42:161-167.

Guerrero, J. N., B. E. Conrad, E. C. Holt, and H. Wu. 1984. Prediction of animal performance on Bermudagrass pasture from available forage. Agron. J. 76:577–580.

Guthrie, M. J., D. G. Wagner and D. S. Buchanan. 1984. Effect of level of protein supplementation on intake and utilization of medium quality prairie hay by heifers, p 156. Oklahoma Agric. Exp. Sta. MP-116, Stillwater.

Hancock, D. L., J. E. Williams, H. B. Hedrick, E. E. Beaver, D. K. Larrick, M. R. Ellersieck, G. B. Garner, R. E. Morrow, J. A. Paterson, and J. R. Gerrish. 1987. Performance, body composition and carcass characteristics of finishing steers as influenced by previous forage systems. J. Anim. Sci. 65:1381.

Hart, R. H. 1978. Stocking rate theory and its application to grazing and rangelands. P. 550-553. In D. N. Hyder (ed.) Proc. 1st Int. Rangel. Congr. Dever. 14-18 Aug. Soc. Range Managem. Denver, CO.

Hatfield, R. D. 1993. Cell wall polysaccharide interactions and degradability. In:Forage Cell Wall Structure and Digestibility. Am. Soc. Agron., Crop Sci. Soc. Am., and Soil Sci. Soc. Am., Madison, WI. Page 285.

Hersom, M. J. 1999. Evaluation of year-round forage management systems for beef cattle. M.S. Thesis. Iowa State Univ., Ames.

Hilbert ,D. W., D. M. Swift, J. K. Detling, and M. I. Dyer. 1981. Relative growth rates and the grazing optimization hypothesis. Oecologia. 51:14-18.

Hill, G. M. and P. R. Utley. 1985. Tifton 78, a promising new bermuda-grass for Georgia cattlemen. Georgia Cattleman. 13(4):26.

Hill, G. M., R. N. Gates, and G. W. Burton. 1993. Forage quality and grazing steer performance from Tifton 85 and Tifton 78 bermudagrass pastures. J. Anim. Sci. 71:3219–3225.

Hill, G.M., R.K. Hubbard, R.C. Lacy, and C. Blalock. 2004. Integration of winter grazing and irrigated cotton production. p. 40–45. In 2003 Georgia Cotton Research and Extension Reports. UGA/CPES Res.-Ext. Publ. 6. Univ. of Georgia CAES and USDAARS, Athens.

Hinman, R. B. 1937. Live weight gains as a measure of pasture yields. Am. Soc. Anim. Prod. 1937:83–84.

Hintz, R.W., Mertens, D.R., Albrecht, K.A., 1996. Effects of sodium sulfite on recovery and composition of detergent fiber and lignin. J. AOAC Int. 79, 16–22.

Hodgson, H. J. 1977. Gaps in Knowledge and Technology for Finishing Cattle on Forages. J Anim Sci. 44: 896-900.

Holechek, J. L. and M. Vavra. 1982. Comparison of micro- and macro-digestion methods for fiber analysis. J. Range Manage. 35:799.

Holechek, J. L., R. D. Pieper, and C. H. Herbel. 2004. Range management: principles and practices. 5th ed. Upper Saddle River, NJ, USA: Prentice-Hall Book Co. 607 p.

Horn, G. W., M. D. Cravey, F. T. McCollum, C. A. Strasia, E. G. Krenzer, Jr., and P. L. Claypool. 1995. Influence of high-starch vs. high-fiber energy supplements on performance of stocker cattle grazing wheat pasture and subsequent feedlot performance. J. Anim. Sci. 73:45–54.

Hoveland, C. S. 1984. Slaughter beef from cool season pastures. Proc. Amer. Forage and Grassl. Council. Houston, TX. pp 18--24.

Hoveland, C. S. 1986. Beef-Forage Systems for the Southeastern United States. J. Anim. Sci. 63:978-985.

Hoveland, C. S., and W. B. Anthony. 1977. Existing and potential systems of finishing cattle on forages or limited grain rations in the Piedmont region of the South. In: J. A. Stuedemann (Ed.). Forage-Fed Beef: Production and Marketing Alternatives in the South. p 377. So. Coop. Series Bull. 220.

Hoveland, C. S., R. L. Haaland, C. C. King, Jr., W. B. Anthony, E. M. Clark, J. A. McGuire, L. A. Smith, H. W. Grimes, and J. L. Holliman. 1980. Association of Epichloe typhina fungus and steer performance on tall fescue pasture. Agron. J. 72:1064.

Hoveland, C. S., R. R. Harris, E. E. Thomas, E. M. Clark, J. A. McGuire, J. T. Eason, and M. E. Ruf. 1981. Tall fescue with ladino clover or birdsfoot trefoil as pasture for steers in northern Alabama. Ala. Agric. Exp. Sta. Bull. 530.

Hoveland, C.S. 1992. Grazing systems for humid regions. J. Prod. Agr. 5:23–27.

Huffman, D. L. 1974. An evaluation of the tenderometer for measuring beef tenderness. J. Anim. Sci. 38:287–294

Huston, J. E., B. S. Rector, W. C. Ellis, and M. L. Allen. 1986. Dynamics of digestion in cattle, sheep, goats and deer. J. Anim. Sci. 62:208–215.

Iiyama, K., Lam, T.B.T. and Stone, B.A. 1990. Phenolic acid bridges between polysaccharides and lignin in wheat internodes. Phytochemistry 29: 733-737.

Illius, A. W., and N. S. Jessop. 1996. Metabolic constraints on voluntary intake in ruminants. J. Anim. Sci. 74:3052.

Janovick, N. A., J. R. Russell, D. R. Strohbehn, D. G. Morrical. 2004. Productivity and hay requirements of beef cattle in a Midwestern year-round grazing system. J. Anim. Sci. 82: 2503-2515.

Jung, H. G. 1989. Forage lignins and their effects on fiber digestibility. Agron. J. 81:33.

Jung, H. G., D. R. Mertens, and A. J. Payne. 1993. Correlation of acid detergent and Klason lignin in forages with in vitro and in vivo dry matter and neutral detergent fiber digestibility. J. Dairy Sci. 76(Suppl. 1):248 (Abstr.).

Jung, H. J. 1997. Analysis of forage fiber and cell walls in ruminant nutrition. J. Nutr. 127:810S–813S.

Jung, H.G. 1991. Comparison of the Ankom filter bag method with conventional fiber analysis of forages. St. Paul, USDA-ARS, University of Minnesota.

Kidwell, B. 2002. All grass, no grain. Progressive Farmer 117(11):18.

Koivisto, Jason M. 2003. FibreBags vs. FibreCaps for acid and neutral detergent fibre analysis. Reproduction Nutrition Development 43 5 (2003) 431-436.

Komarek, A. R. 1993a. A filter bag procedure for improving efficiency of fiber analysis. J. Dairy Sci. 76(suppl.1):250.

Komarek, A. R. 1993b. An improved filtering technique for the analysis of neutral detergent fiber and acid detergent fiber utilizing the filter bag technique. ANKOM Co., Publ. 101. Fairport, NY.

Komarek, A. R., J. B. Robertson, and P. J. Van Soest. 1994a. A comparison of methods for determining ADF using the filter bag technique versus conventional filtration. J. Dairy Sci. 77(suppl.1):114.

Komarek, A. R., J. B. Robertson, and P. J. Van Soest. 1994b. Comparison of the filter bag technique to conventional filtration in the Van Soest Analysis of 21 feeds. Page 78 in Proc. Natl. Conf. Forage Quality, Evaluation, and Utilization, Lincoln, NE.

Kropf, D. H., D. M. Allen, and G. J. Thouvenelle. 1975. Grass-fed, short-fed and long-fed beef compared. Kansas Agric. Experiment Station, Report of Progress. 230:728.

Lake, R. P. 1987. Limit feeding high energy rations to growing cattle. p. 303-315. In F. N. Owens (ed.) Proc.: Feed intake by beef cattle. Oklahoma Agric. Exp. Stn. MP-121.

Lam, T.B.T., Iiyama, K. and Stone, B.A. 1990. Distribution of free and combined phenolic acids in wheat internodes. Phytochemistry 29: 429-433.

Launchbaugh, J. L. 1957. The effect of stocking rate on cattle gains and on native shortgrass vegetation in west-central Kansas. Kans. Agric. Exp. Stn. Bull. 394.

Leek, B. F., and R. H. Harding. 1975. Sensory nervous receptors in the ruminant stomach and the reflex control of reticulo-ruminal motility. In: I. W. McDonald and A.C.I. Warner (Ed.) Digestion and Metabolism in the Ruminant. pp 60-76. University of New England, Armidale, Australia.

Lewis, J. M., T. J. Klopfenstein, and R. A. Stock. 1990a. Effects of rate of gain during winter on subsequent grazing and finishing performance. J. Anim. Sci. 68:2525–2529.

Lewis, J. M., T. J. Klopfenstein, R. A. Stock, M. K. Nielsen, 1990b. Evaluation of intensive vs. extensive systems of beef production and the effect of level of beef cow milk production on postweaning performance. J. Anim. Sci. 68: 2517-2524

Lippke, H. 2002. Estimation of forage intake by ruminants on pasture. Crop Sci. 42:869–872.

Lloyd, L. E., B. E. McDonald, and E. W. Crampton. 1978. Fundamentals of Nutrition (2nd Ed.). W. H. Freeman and Company, San Francisco, CA.

Lofgreen, G. P., J. H. Meyer, and M. L. Peterson. 1956. Nutrient consumption and utilization from alfalfa pasture, soilage, and hay. J. Anim. Sci. 15:1158–1165.

Lopes, M. L. T., P. C. F. Carvalho, I. Anghinoni, D. T. Santos, F. Kuss, F. K. Freitas, J. P. C. Flores. 2008. Sistema de integração lavoura-pecuária: desempenho e qualidade da carcaça de novilhos superprecoces terminados em pastagem de aveia e azevém manejada sob diferentes alturas. Cienc. Rural. 38: 178-184. (In Portuguese)

Macoon, B., L. E. Sollenberger, J. E. Moore, C. R. Staples, J. H. Fike, and K. M. Portier. 2003. Comparison of three techniques for estimating the forage intake of lactating dairy cows on pasture. J. Anim. Sci. 81:2357–2366.

Mader, T. L., G. W. Horn, W. A. Phillips and R. W. McNew. 1983. Low quality roughages for steers grazing wheat pasture. I. Effect on weight gains and bloat. J Anim. Sci. 56:1021-1028.

Mandell, I. B., J. G. Buchanan-Smith, and C. P. Campbell. 1998. Effects of forage vs grain feeding on carcass characteristics, fatty acid composition, and beef quality in Limousin-cross steers when time on feed is controlled. J. Anim. Sci. 76:2619–2630.

Mascarenhas-Ferreia, A., Kerstens, J., Gast, C.H., 1983. The study of several modifications of the neutral detergent fibre procedure. Animal Feed Sci. Technol. 9: 19-28.

Matches, A. G., F. A. Martz, D. A. Sleper, and M. T. Krysowaty. 1981. Selecting levels of herbage allowance to compare forages for animal performance. p. 331-339. In J. L. Wheeler and R. D. Mochrie (ed.) Forage evaluation: Concepts and techniques. CSIRO, Melbourne.

Matches, A.G., and J.C. Burns. 1995. Systems of grazing management. In R.F Barnes et al. (ed.) Forages. Vol. II. The science of grassland agriculture. 5th ed. Iowa State Univ. Press, Ames, IA. p. 179-192.

Matsushima, J. 1995. A journey back – A history of cattle feeding in Colorado and the United States. Calf News Publishing, Garden City, KS.

McCollum, F. T., M. D. Cravey, S. A. Gunter, J. M. Mieres, P. B. Beck, R. San Julian, and G. W. Horn. 1992. Forage mass affects wheat forage intake by stocker cattle. Okla. Agric. Exp. Sta. Anim. Sci. Res. Rep. p 312.

McDermid K. G., C. R. MacKenzie, and C. W. Forsberg. 1990. Esterase activities of Fibrobacter succinogenes subxp. succinogenes S85. Appl. Environ. Microbiol. 56: 127.

McDonald, P. 1988. Animal Nutrition (Forth Edition). Longman Scientific & Technical.

McNaughton, S. J. 1979. Grazing as an optimization process: Grass-ungulate relationship in the Serengeti. Am. Nat. 113: 691-703.

Mertens, D. R. 1992. Nonstructural and structural carbohydrates. Pages 219–235 in Large Dairy Herd Management. H. H. Van Horn and C. J. Wilcox, ed. Am. Dairy Sci. Assoc., Champaign, IL.

Mertens, D. R. 1994. Regulation of forage intake. Pages 450–493 in Forage Quality, Evaluation, and Utilization. G. C. Fahey Jr., ed. ASA-CSSA-SSSA, Madison, WI.

Mertens, D. R. 2002. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: Collaborative study. J. AOAC Int. 85:1217–1240.

Milford, R. and D. J. Minson. 1965. Intake of tropical pasture species. Proc. Int. Grassld. Congr. 9:815.

Minson, D. J. 1990. Forage in ruminant nutrition. San Diego: Academic.

Mitchell, P. 1982. Value of a rising plate meter for estimating herbage mass of grazed perennial ryegrass-white clover swards. Grass Forage Sci. 37:81-87.

Moore, K. J. and Hatfield, R. D. 1994. Carbohydrates and forage quality. In: Forage Quality, Evaluation, and Utilization (Fahey, G. C., Jr., Collins, M. C., Mertens, D. R. & Moser, L. E., eds.), pp. 229–280. ASA-CSSA-SSSA, Madison, WI.

Morgan-Jones, G., and W. Gams. 1982. Notes on Hyphomycetes. XLI. Mycotaxon 15:311.

Mott, G. O. 1976. Pasture + concentrate: Not easy, but worth it. Crops and Soils 29:15.

Mott, G. O. 1984. Relationship of available forage and animal performance in tropical grazing systems. Am. Forage Grassl. Counc. Proc. p 373.

Nelson, C. J., and L. E. Moser. 1994. Plant factors affecting forage intake. Page 115 in Forage Quality Evaluation and Utilization. G. C. Fahey Jr., ed. Am. Soc. Agron./Crop Sci. Soc. Am./Soil Sci. Soc. Am.

Neter, J., W. Wasserman, and M. H. Kertner. 1985. Applied Linear Statistical Models. 2nd ed. Richard D Irwin Inc., Homewood, IL.

Nocek, J. E., and J. B. Russell. 1988. Protein and energy as an integrated system. Relationship of ruminal protein and carbohydrate availability to microbial synthesis and milk production. J. Dairy Sci. 71:2070.

NRC. 1984. Nutrient Requirements of Beef Cattle. 6th rev. ed. Natl. Acad. Press, Washington, DC.

NRC. 1987. Predicting Feed Intake of Food Producing Animals. National Academy Press, Washington, DC.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th ed. Nat. Acad. Press, Washington, DC.

NRC. 2000. Nutrient Requirements of Beef Cattle. updated 7th ed. National Academy Press, Washington, DC.

Oltjen, R. R., T. S. Rumsey and P. A. Putnam. 1971. All forage diets for finishing beef cattle. J. Anim. Sci. 32: 327.

Orskov, E. R. 1986. Starch digestion and utilization in ruminants. J. Anim. Sci. 63:1624.

Osbourn, D. F., R. A. Terry, G. E. Outen and S. B. Cammell. 1974. The significance of a determination of cell walls as the rational basis for the nutritive evaluation of forages. Proc. XII Int. Grassland Congr. II1:374.

Owens, D. F. and R. G. Wiegert. 1976. Do consumers maximize plant fitness? Oikos. 27:488-492.

Owens, F. N., R. A. Zinn, and Y.K. Kim. 1986. Limits to starch digestion in the ruminant small intestine. J. Anim. Sci. 63:1634–1648.

Owens, O. S., D. D. Chiras, and J. Reganold. 1998. Natural resource conservation. 7th ed. Prentice Hall, Upper Saddle River, NJ.

Pederson, J. F., J. A. McGuire, S. P. Schmidt, C. C. King, Jr., C. S. Hoveland, and L. A. Smith. 1986. Steer performance as affected by tall fescue cultivar and level of Acremonium coenophialum infection. N. Z. J. Exp. Agric. 14:307-312.

Perry, T. W. and M. J. Cecava. 1995. Beef cattle feeding and nutrition. 2nd ed. Academic Press, San Diego.

Perry, T. W., M. T. Mohler, and W. M. Beeson. 1956. Self-fed free choice vs. self-feeding a complete mixture for fattening steers. J. Anim. Sci. 15(Suppl.):1241. (Abstr.).

Plegge, S. D., R. D. Goodrich, S. A. Hanson, and M. A. Kirick. 1984. Predicting dry matter intake of feedlot cattle. P.56 in Proceedings of the Minnesota Nutrition Conference.

Pond, K. R., W. C. Ellis, and D. E. Akin. 1984. Ingestive mastication and fragmentation of forages. J. Anim. Sci. 58:1567–1574.

Prevatt, Walt, Deacue Fields, Chris Kerth, and Ed Whatley. 2005. Merchandising A New Beef Product. Timely Information Report, DAERS 05-11. Auburn University.

Purcell, W. D. 1998. A primer on beef demand. Research Bull. Research Institute on Livestock Pricing and Agricultural and Applied Economics. Virginia Tech, Blacksburg, VA.

Raleigh, R. J. 1970. Symposium on pasture methods for maximum production in beef cattle: Manipulation of both livestock and forage management to give optimum production. J. Anim. Sci. 30:108–114.

Rayburn, E. B. 1986. Quantitative aspects of pasture management. Seneca Trail RC&D Technical Manual. Franklinville N.Y.: Seneca Trail RC&D.

Razminowicz, R.H., M. Kreuzer, M.R.L. Scheeder. 2006. Quality of retail beef from two grass-based production systems in comparison with conventional beef.Meat Science 73: 351–361.

Redmon, L. A., F. T. McCollum, III, G. W. Horn, M. D. Cravey, S. A. Gunter, P. A. Beck, J. M. Mieres, and R. San Julian. 1995. Forage intake by beef steers grazing winter wheat with varied herbage allowances. J. Range Manage. 48:198–201.

Reeves, M., W. J. Fulkerson, R. C. Kellaway, and H. Dove. 1996. A comparison of three techniques to determine the herbage intake of dairy cows grazing kikuyu (Pennisetum clandestinum) pasture. Aust. J. Exp. Agric. 36:23–30.

Richards, J. H. and M. M. Caldwell. 1985. Soluble carbohydrates, concurrent photosynthesis and efficiency in regrowth following defoliation: A field study with Agropyron species. J. Appl. Ecol. 22: 907-920.

Robertson, J.B., and Van Soest, P.J., 1981. The detergent system of analysis and its application to human foods. In: James, W.P.T., Theander, O. (Eds.). The Analysis of Dietary Fibre in Foods. Marcel Dekker, New York.

Russell, J. B., and D. B. Wilson. 1996. Why are ruminal cellulolytic bacteria unable to digest cellulose at low pH? J. Dairy sci. 79:1503.

SAS Institute. 2004. SAS/Stat 9.1 User's Guide. SAS Inst. Inc., Cary, NC.

Schmidt, S. P., C. S. Hoveland, E. D. Donnelly and R. A. Moore. 1985. Beef steer performance on alfalfa and sericea lespedeza pastures. Proc. South. Pasture and Forage Crop. Imp. Conf. 41:21.

Schroeder, J. W., D. A. Cramer, R. A. Bowling, and C. W. Cook. 1980. Palatability, shelf life and chemical differences between forage-and grain-finished beef. J. Anim. Sci. 50:852-859.

Schupp, A. R., Bidner, T. D., and Clark, N. C. 1980. Consumer acceptance of beef produced under alternative feeding systems. Southern Journal Agricultural Economics (December). 31-35.

Simpson, F. R. and V. Farris. 1982. The world's beef business. The Iowa State University Press. Ames IA.

Siri-Prieto, G., D.W. Reeves, R.L. Raper, and B.E. Gamble. 2005. Forage and tillage systems for integrating winter-grazed stocker cattle in cotton production. p. 160–161. In W. Busscher et al. (ed.) Proc. South. Conserv. Tillage Conf., Florence, SC. 27–29 June 2005. Clemson Univ.

Siri-Prieto, G., D.W. Reeves, R.L. Raper, D. Bransby, and B.E. Gamble. 2003. Integrating winter annual grazing in a cotton-peanut rotation: Forage and tillage system selection. p. 104-115. In F.M. Rhoads (ed.) Proc. of Sod-Based Cropping Systems Conf., Quincy, FL. 20-21 Feb. 2003. North Florida Res. and Educ. Center, Quincy.

Skelley, G. C., R. L. Edward, F. B. Wardlaw, and A. K. Torrence. 1978. Selected high forage rations and their relationship to beef quality, fatty acids and amino acids. J. Anim. Sci. 47:1102-1108.

Sojka, R.E., G.W. Langdale, and D.L. Karlen. 1984. Vegetative techniques for reducing water erosion of cropland in the southeastern United States. Adv. Agron. 37:155–181.

Stewart, C. S., and H. J. Flint. 1989. Bacteroides (*Fibrobacter*) *succinogenes*, a cellulolytic anaerobic bacterium from the gastrointestinal tract. Appl. Microbiol. 30:433.

Stuedemann, J.A., A.J. Franzluebbers, D.H. Seman, and D.W. Reeves. 2003. Potential outcomes of integrating cattle and cropping systems in southeastern Major Land Resource Areas. p. 81–103. In F.M. Rhoads (ed.) Proc. Sod-Based Cropping Syst. Conf., Quincy, FL. 20–21 Feb. 2003. Inst. Food and Agric. Sci., Univ. of Florida.

Taylor, R. E. 1984. Beef production and the beef industry: A beef producer's perspective. Burgers Pub. Co. Minneapolis, MN

Tulley, J., J. P. Fontenot, and V. G. Allen. 1992. Feedlot performance of steers that grazed endophyte-free and endophyteinfected fescue. Anim. Sci. Res. Rept. No. 10. Va. Agric. Exp. Station Rept. p. 109.

USDA. 1989. United States Department of Agriculture. Official U.S. Standards for Grades of Carcass Beef. AMS, USDA, Washington, DC.

USDA. 2004. Agricultural Statistics. U.S. Government Printing Office. Washington, DC.

USDA. 2008. Agricultural Statistics. U.S. Government Printing Office. Washington, DC.

Utley, P. R., R. E. Hellwig and W. C. McCormick. 1975. Finishing beef cattle for slaughter on all forage diets. J. Anita. Sci. 40:1034.

Vallentine, J. F. 1990. Grazing management. Academic Press, San Diego.

Van Soest, P. J. 1965. Symposium on factors influencing the voluntary intake of herbage by ruminants: Voluntary intake in relation to chemical composition and digestibility. J. h i m . Sci. 24: 834.

Van Soest, P. J. 1973. The uniformity and nutritive availability of cellulose. Fed Proc. 32: 1804-1808.

Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca, NY.

Van Soest, P. J. and D. R. Mertens. 1977. Analytical parameters as guides to forage quality. P. 50-52. Proc. Internat'l. Meet. on Anim. Prod. From Temperate Grassland, Dublin, Ireland.

Van Soest, P. J. and R. H. Wine. 1967. The use of detergents in analysis of fibrous feeds: IV. Determination of plant cell wall constituents. J. AOAC 50, 50–55.

Van Soest, P. J., and J. B. Robertson. 1980. Systems of analysis for evaluating fibrous feeds. In: W. J. Pigden, C. C. Balch, and M. Graham (Ed.) Standardization of Analytical Methodology for Feeds. pp 49–60. Publication No. IDRC-134e. Int. Dev. Res. Center, Ottawa, Canada.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Vasconcelos, J. T., and M. L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim. Sci. 85:2772.

Vendramini, J.M.B., L.E. Sollenberger, J.C.B. Dubeux, Jr., S.M. Interrante, R.L. Stewart, Jr., and J.D. Arthington. 2007. Concentrate supplementation effects on forage characteristics and performance of early weaned calves grazing Tifton 85 bermudagrass pastures. Agron. J. 99:399–404.

Vogel, K. P., J. F. Pedersen, S. D. Materson, and J. J. Toy. 1999. Evaluation of a filter bag system for NDF, ADF, and IVDMD forage analysis. Crop Sci. 39:276–279.

Wanderstock, J. J. and J. L. Miller. 1948. Quality and palatability of beef as affected by method of feeding and carcass grade. Food Res. 13:291.

Welch, J. G. 1967. Appetite control in sheep by indigestible fibers. J. Anim. Sci. 26: 849.

Welch, J. G. 1982. Rumination, particle size and passage from the rumen. J. Anim. Sci. 54:885–894.

Weston, R H. and D. P. Poppi. 1987. Comparative aspects of food intake. In: J. B. Hacker and J. H. Temouth (Ed.) The Nubition of Herbivores. pp. 133-162. Academic Press, New York.

Whitney, A. S. 1974. Measurements of foliage height and its relationship to yield of two tropical forages. Agron. J. 66:334-336.

Wilford, E. J. 1951. Some carcass characteristics of calves produced by Kentucky cow-and-calf plan. J. Anim. Sci. 10(Suppl.):1034 (Abstr.).

Wilm, H. G., D. F. Costello, and G. E. Klipple. 1944. Estimating forage yield by the double sampling method. Agron. J. 36:194-203.

Wise, M. B., R. W. Harvey, B. R. Haskins and E. R. Barrick. 1968. Finishing Beef Cattle on All-Concentrate Rations. J. Anim. Sci. 27:1449-1461.

Zinn, D. W., R. M. Durham, and H. B. Hedrick. 1970. Feedlot and carcass characteristics of steers and heifers as influenced by days on feed. J. Anim. Sci. 31:302–306.

Zinn, R. A., A. Barreras, F. N. Owens and A. Plascencia. 2008. Performance by feedlot steers and heifers: Daily gain, mature body weight, dry matter intake, and dietary energetic. J. Anim. Sci.86:2680-2689.

APPENDICES

APPENDIX A.

Put-and-take calculations – Table and explanations:

A	B	C	D	E	F	G	H	I	J	K	L	M
PLOT	10-Mar	DM (%)	24-Mar	DM (%)	Diff	7-Apr	DM (%)	Diff	DM Limit	DM Excess	Calculation	Acctual Change
Formulas:					= D - B			= G - D		= G - J	= K/(14 * 12)	
Rye-1	2,010	21	1,725	21	-285	1,598	18	-127	2000	-402	-2.4	-3
Ryegrass-2	1,425	19	1,675	19	250	2,183	24	508	2000	183	1.1	2
Oats-3	1,246	19	1,395	19	149	1,939	25	544	2000	-61	-0.4	0
Ryegrass-4	1,071	20	1,875	20	804	2,469	25	594	2000	469	2.8	2
Rye-5	1,685	24	1,695	24	10	1,527	18	-168	2000	-473	-2.8	-2
Oats-6	1,278	22	1,490	22	212	1,945	28	455	2000	-55	-0.3	0

7-Apr	Actual	Action	After
Rye-1	6	-3	**3**
Ryegrass-2	4	2	**6**
Oats-3	3	0	**3**
Ryegrass-4	4	2	**6**
Rye-5	5	-2	**3**
Oats-6	3	0	**3**
Total	25		**24**

Column A represents the different paddocks.
Column B is the DM available on March 10 sample collection.
Column C represents the DM concentration (%) for each forage.
Column D represents the DM available on March 24.
Column E the DM concentration (%) from column D sample day.
Column F represents the difference between column D and B.
Column G represents the forage DM available on April 7.
Column H represents the DM concentration (%) on G sample day.
Column I represents the difference between G and D.
Column J is the amount of DM set as the limit (2000 kg DM/ha).
Column K represents the difference between the last sample date (column G) and the DM limit (column J).
Column L is the calculation of animals (column K divided by 168 (12 kg/d × 14 d = 168 kg DM).
The calculation results in non-integer numbers, therefore the actual change in animals needs to be made manually (column M), and the adjustment of this number is based on the calculation and an evaluation of the pattern the forage increase or decrease in the previous three sample dates (columns G, D, and B).