

2012

Forage systems for finishing steers in south Louisiana

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**FORAGE SYSTEMS
FOR FINISHING STEERS
IN SOUTH LOUISIANA**

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

Animal, Dairy & Poultry Sciences

by
Jose M. Rodriguez
B.S., Escuela Colombiana de Ingenieria, 2006
December 2012

ACKNOWLEDGEMENTS

I would like to thank my Lord and Savior Jesus Christ, for guiding me and leading every single one of my steps during this entire project. I would like to thank Him and give Him all the glory. I would also like to thank my best friend, the Holy Spirit, because without His help, encouragement, and support, I would have never made it to the end.

I would like to thank my mom, Olga de Rodriguez, for all her wisdom, support and prayers. I can say without a doubt that I am here today because of her. I would like to thank my brothers, Gustavo, Nicolas and Juan because of all that they have done for me throughout my life and during these years at LSU. I would like to thank them for the support they gave me and the patience that they had during this time, especially when I had to skip family reunions and celebrations because of work. I would like to thank them for their prayers, love and financial support. I would also like to thank my beautiful fiancée, Eva Hughes, for always being there to give me her love and support. I would also like to thank her for encouraging me to finish this chapter of my life and for all of her prayers.

I would like to thank my major professor Dr. Guillermo Scaglia for accepting me into his graduate program, and for his guidance and expertise throughout every single one of my trials. I appreciate his advice and assistance with every question I had. I would like to thank him for always making time for an educational discussion and for his willingness to assist me and motivate me with words of encouragement. I would also like to thank Dr. Glen Gentry and Dr. Kenneth McMillin for being in my committee and for their support and their patience. I would also like to thank Dr. McMillin for leading the harvesting of the steers, the carcass evaluation, the WB shear force and the cooking process of the samples.

Lastly, I would like to thank all the workers at Iberia Research Station for the hard work and dedication throughout this entire project.

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ABSTRACT

Research has found conflicting results on animal performance and carcass traits associated with the use of forage as the primary feed source for finishing cattle. Consumer interest in forage-fed products has grown and little research has been done comparing performance of forage-fed animals and beef finished on different forages. Spring weaned calves ($n=54$; 257 ± 2.5 kg; 3/8 Gelbvieh, 3/8 Red Angus, and 1/4 Brahman) were used in the evaluation of three forage systems (S1, S2, and S3) on a 100% forage diet in two consecutive years (June 2009 and 2010). Steers were divided into 9 groups based on initial body weight (d0) and randomly assigned to replicates within system (3 replicates per system). Pastures were rotationally stocked at 1.01 ha/steer. Steers in S1 grazed bermudagrass (45% of area) during summer, and ryegrass (35% of area) and ryegrass sod-seeded into bermudagrass paddocks (20% of area) in winter. Steers in S2 grazed bermudagrass (45% of area) during summer, dallisgrass/clover mix (20% of area) during fall and spring, and ryegrass/cereal rye/clover mix (35% of area) during winter. Those in S3 had access to bermudagrass (20% of area) and sorghum-sudan hybrid/forage soybean during summer (7.5% of area each), dallisgrass/clover mix (20% of area) during fall and spring, and ryegrass/cereal rye/clover mix (45% of area) during winter. Excess forage was cut for hay and fed within system when necessary. Average daily gain (ADG) for summer, winter and for the whole study were not different ($P > 0.05$) between systems. Animals in Y2 (0.5 kg/d) gained more ($P > 0.05$) than those in Y1 during summer (0.21 kg/d), but ADG in Y1 (1.5 kg/d) was greater ($P > 0.05$) than in Y2 (1.3 kg/d) during winter. No significant differences ($P > 0.05$, Table 3.12) were found in final weights, LM area, KPH, YG, lean color and marbling. Dressing percentage and hot carcass weight were greater ($P < 0.05$) for S3 than those for S1 and S2 was intermediate. Backfat and PYG was affected by YxS interaction ($P < 0.05$). Cooking loss and Warner-Bratzler shear force were greater ($P < 0.01$) for Y1 than for Y2.

CHAPTER I

INTRODUCTION

On a global scale, most beef is produced, with little exception, on pasture or rangeland. This maximizes the ruminant's ability to convert cellulose-based material into a highly nutritious human food (Nicol, 1987). Research suggests that forage-based diets can significantly improve the fatty acid composition and antioxidant content of beef. Despite the numerous forage-fed beef studies conducted, however, the vast majority of beef produced in the US today is grain-fed beef from feedlots within or close to the major grain-producing regions. Growing consumer interest in forage-fed beef has raised a number of questions with regard to the perceived differences in nutritional quality between forage-fed and grain-fed beef. Past research has found conflicting results associated with the use of forage as the primary feed source for finishing cattle. Finishing length period, average daily gain (ADG), dressing percentage, lean and fat color, quality and yield grade are examples of those issues. Winter annuals are often used to complement summer grazing by providing forage with a high nutritive value throughout winter months (Gunter et al., 2002). The cool, damp winters common in Louisiana and the southern United States make cool season annuals an option for winter grazing of high nutritive value forage (Feazel and Morris, 1992) opening a window for a forage finishing program.

CHAPTER II

LITERATURE REVIEW

SOUTHEASTERN FORAGES

Grassland agriculture is a farming system that emphasizes the importance of grasses and legumes in livestock and land management. When practiced properly, organic matter is renewed, soil erosion prevented, gully formation arrested, soil tilth improved and soil conservation becomes an opportunity instead of a problem (Hughes et al., 1962).

More than 40 species of forage crops (crops, annual or perennial, which are grown to be utilized by grazing or harvesting as a whole crop) are routinely grown in the south, although many can be successfully grown only in certain areas. These crops differ widely in their characteristics, potential uses and value. Climatic conditions largely determine the adaptation of forage species, but from the standpoint of plant survival and growth, the most critical aspects of climate are temperature and the distribution and amount of rainfall (Ball et al., 2007).

WARM SEASON GRASSES

Warm season grasses in the south of the US are mainly from tropical origin and grow during late spring, summer and early autumn. The productive season depends on the region in which they are grown, from as little as 3 months in the northern part of the US to 7 or 8 months in the Gulf Coastal area (Ball et al., 2007). Even though some of these grasses have the potential of very high forage yields, forage nutritive value of warm season grasses is generally lower than cool season grasses (Ball et al., 2007).

Weed competition is the major reason for the slow establishment of warm season grasses (Bryan and McMurphy, 1968). Lower weight gain of cattle during the summer with warm-season perennial grasses has been associated with lower organic matter digestibility (Duble et al., 1971; Pitman and Holt, 1982; Henderson and Robinson, 1982b).

Bermudagrass (*Cynodon dactylon*)

Bermudagrass is a sod forming perennial that spreads by stolons, rhizomes and/or seed. Stolons of bermudagrass readily root at the nodes. Lateral buds develop at the nodes to produce erect or ascending stems that reach 5 to 40 cm (rarely over 90 cm) in height (Ball et al., 2007).

Bermudagrass is adapted to tropical and subtropical climates. It grows best under extended periods of high temperatures, mild winters and moderate to high rainfall. However, it can survive in arid climates along waterways and in irrigated areas (Ball et al., 2007).

Bermudagrass can be productive in moderately drained and fertile soils (Burton and Hanna, 1985), but its forage nutritive value has been reported to decline in the middle to late grazing season (Utley et al., 1974, 1981; Pitman et al., 1984; Aiken and Brown, 1996). Reduced cattle weight gain during this period can be partially attributed to the adverse effect of high ambient temperature and humidity on dry matter intake. Additionally, high temperatures adversely affect forage nutritive value by increasing plant maturity and lignification (Henderson and Robinson, 1982a). Maturity will reduce the digestibility of bermudagrass, but the decline does not appear to be directly related to increases in neutral detergent fiber (Hill et al., 1993; Mandebvu et al., 1998, 1999).

With adequate moisture, bermudagrass responds to high rates of nitrogen fertilizer (110 to 450 kg N/ha). Several applications of nitrogen can be used more efficiently than a single large application (Lee et al., 2002).

Bermudagrass is grown extensively throughout the southeast of the US for use as pasture and as harvested forage and different varieties (seeded and hybrids) are used. ‘Coastal’ bermudagrass is normally the standard to which other bermudagrass varieties such as ‘Tifton85’, ‘Alicia’ and ‘Jiggs’ are compared. ‘Tifton 85’ bermudagrass has greater nutritive value and greater yield compared to ‘Coastal’ bermudagrass (Burton et al., 1993). ‘Tifton 85’ bermudagrass has greater dry matter and fiber digestibility than ‘Coastal’, resulting in greater gains and utilization by cattle (Hill et al., 1993; Mandebvu et al., 1999; Hill et al., 2001a). Additional research has indicated greater digestibility of

‘Tifton 85’ hay compared with ‘Coastal’ hay at differing maturity dates (Hill et al., 2001a). ‘Tifton 85’ has lower concentrations of ether-linked ferulic acid than ‘Coastal’, with decreased ether bonding in lignin in ‘Tifton 85’, which results in greater ruminal microbial digestion of this forage (Mandebvu et al., 1999; Hill et al., 2001ab). Harvesting bermudagrass hays at 4 to 6 wk is recommended. Increasing maturity of hays leads to a decline in digestibility of CP, ADF and NDF (Hill et al., 1997b, 2001b, Mandebvu et al., 1998a, 1999a).

Corriher et al. (2007) compared cow-calf performance before weaning on ‘Tifton 85’ vs. ‘Coastal’ pastures. ‘Tifton 85’ produced substantially greater DM yields, digestibility, and ADG in beef steers, beef calves, and cows compared with ‘Coastal’ bermudagrass. Under continuous stocking, ‘Tifton 85’ pastures had greater nutritive value and were stocked with more cattle than ‘Coastal’ pastures (4.39 and 3.73 cows/ha, respectively). Milk protein tended to increase for cows grazing ‘Tifton 85’ compared with ‘Coastal’ pastures, contributing to increased calf gains.

‘Alicia’ bermudagrass is a variety released by Cecil Greer Grass Farms of Edna, TX. ‘Alicia’ is a selection from a strain collected in South Africa. It spreads rapidly during establishment and can be established from hay-type cuttings or from sprigs. Compared to Coastal, it produces fewer rhizomes, is less winter hardy, less drought tolerant and has less disease tolerance, according to ratings at the LSU AgCenter’s Hill Farm Research Station at Homer, LA (Twidwell, 2010). ‘Alicia’ bermudagrass is susceptible to rust, a foliage disease that destroys leaf tissue and reduces yields and quality (Lee et al., 2002).

‘Jiggs’ bermudagrass establishes easiest of all varieties and quicker than ‘Coastal’ on heavy textured soils. It is adapted to various soil types even on heavy, wet soils and it can be planted with long hay cuttings. Compared to ‘Coastal’ or ‘Tifton 85’, it does not have as many rhizomes, yields less in a drought, and has less cold tolerance (Twidwell, 2010).

A number of studies have shown similar average values of CP, ADF and NDF for the grazing season of bermudagrass. In a two-year study comparing pasture performance and steer performance

grazing three bermudagrass cultivars ('Tifton 78', 'Tifton 58' and 'Coastal'), Hill et al., (1997) reported average values ranging from 14.9 to 17.5% for CP, from 33.1 to 32.4% for ADF and from 72.5 to 71.0 for NDF for the bermudagrass grazing season (168 and 126 d for year 1 and year 2, respectively). They also stated that ADG were unaffected ($P > 0.1$) by bermudagrass cultivar with values ranging from 0.65 to 0.74 kg.

Twidwell (2010) stated that ADG for steers grazing bermudagrass ranged from 0.63 to 0.82 kg after concluding a 4-year study evaluating steer performance on 4 different cultivars ('Brazos', 'Grazer', 'Coastal' and 'Tifton 44') in Louisiana. Steers grazing 'Grazer' gained more ($P < 0.05$) than those grazing the other three cultivars. In the same publication, Twidwell (2010) stated that in studies made at the Hill Farm, LSU AgCenter research station in Homer, LA, values of CP and NDF for 'Russell', 'Coastal', and 'Tifton 85' bermudagrass were found to be 11.6, 12.3 and 12.5 for CP and 70, 69 and 70 for NDF, respectively.

Dallisgrass (*Paspalum dilatatum*)

Dallisgrass is a warm-season perennial grass indigenous to South America, primarily Uruguay, Argentina and southern Brazil (Pizarro, 2000). Dallisgrass grows best on deep, moist, fertile, alluvial and basaltic clay soil and sandy soil, and its ideal rainfall range is from 900 to 1,250 mm/yr. It has little tolerance to salinity, is very tolerant to poor drainage and, because of its deep root system, is drought-tolerant following establishment (Evers and Burson, 2004). Dallisgrass is high in palatability and nutritive value prior to maturation, and it has an open-type sod that allows its grazing season to be extended by interseeding perennial legumes and/or cool season annuals. Furthermore, dallisgrass tolerates frequent defoliation and maintains its nutritive value longer into the growing season than many others commonly utilized warm-season C4 grasses (Davies and Forde, 1991). Dallisgrass is one of the best warm-season grasses in terms of nutritive value, with CP concentration ranging from 4.4 to 23.2 % (Committee on Animal Nutrition and Feed Composition, 1971), NDF concentration ranging from approximately 59 to 68%, and IVDMD typically between 40 to 63% (Acosta et al., 1996).

Dallisgrass is a close relative of bahiagrass (*Paspalum notatum*) but is generally not as persistent because it has shorter rhizomes and requires high fertility soils with greater water-holding capacity than those needed by bahiagrass. Dallisgrass produces forage from April through September (Ball et al., 2007), and the nutritive value is generally greater than both bahiagrass and bermudagrass. Dallisgrass is propagated from seed in March or April (Ball et al., 2007). It initiates spring growth earlier than most warm-season perennial grasses and generally persists later into the fall (Venuto et al., 2003). The species can survive under heavy grazing and has excellent forage nutritive value when properly managed (Holt, 1956).

Several factors limit forage production of dallisgrass. Establishment can be difficult because of poor seed quality and slow germination (Holt, 1956). Germination of commercially available seed is often less than 50%, and seed production is limited by low seed set and ergot (*Claviceps paspali*) infection (Mayland and Cheeke, 1995). Ergot infection produces dallisgrass poisoning in cattle; also known as ‘dallisgrass staggers’. It occurs several days after cattle ingest a significant amount of dallisgrass seed-heads infected with the fungus. The seed heads typically are infected with the fungus in the fall, as the seed-heads age. Usually not all the herd is affected, and it appears that it occurs when some animals develop a preference for the tips of the seed-head (Poore, 2000).

Dallisgrass is commonly utilized as pasture, but in some cases it is also harvested for hay. However, because it doesn’t grow as tall as other subtropical perennial grasses, it does not produce as high yields, and therefore it is used for hay mainly in locations where taller-growing grasses do not grow well (Evers and Burson, 2004). Venuto et al. (2003) evaluated five different accessions of dallisgrass in Louisiana and Texas for yield, persistence and nutritive value. On poorly drained clay soils, stand persistence and yield of ‘Uruguayan’ dallisgrass was superior compared to ‘Common’ dallisgrass. Across the five accessions and on average, CP concentrations were 9.8 and 11%, NDF concentrations were 70.7 and 69.5%, and IVDMD were 71.2 and 63.8% in Texas and Louisiana,

respectively. No differences in nutritive value between 'Uruguayan' and 'Common' dallisgrass were reported (Venuto et al., 2003).

Dallisgrass grows well in mixtures with other forage species. Because of its open-type sod, it allows inter-seeding with ryegrass (*Lolium multiflorum* Lam.) and legumes such as clover (*Trifolium* spp.), which provides opportunity for utilization in year-round grazing systems (Evers and Burson, 2004).

Gunter et al. (2005) compared the performance of steer calves managed on dallisgrass and under different stocking rates and N fertilization rates. The ADG and BW gain per steer were greatest at a stocking rate of 3.7 steers/ha and 336 kg/ha of N. Body weight gain per hectare peaked at 701 kg when cattle were stocked at 8.9 steers/ha and the pasture was fertilized with 336 kg/ha of N.

Sorghum-sudan (*Sorghum bicolor* x *S. bicolor* var. *sudanense*)

Sorghum-sudangrass hybrid grasses are summer annuals. As crosses between forage-type sorghums and sudangrass, they have some variability in growth characteristics. In general, they can grow from 1.5–3.7 m tall and have long, slender leaves and stalks, which can grow woody as they mature (Ball et al., 2007). The hybrids are crosses between forage-type sorghums and sudangrass. Compared with corn, they have less leaf area, more secondary roots and a waxier leaf surface, traits that help them withstand drought (Sarrantonio, 1994). Like corn, they require good fertility and usually supplemental lime on highly acid soils (Ball et al., 2007). Compared with sudangrass, these hybrids are taller, coarser and more productive.

Sorghum-sudangrass produce ample biomass, usually about 4,400 to 5,600 kg DM/ha. Up to 20,100 kg DM/ha has been measured with multiple cuttings on fertile soils with adequate moisture. Sorghum-sudangrass is generally used for pasture, hay and silage. Nitrate accumulation or prussic acid can cause toxicity under some circumstances (after a drought and/or canopy height lower than 50 to 60 cm) (Ball et al., 2007). In general, sorghum-sudangrass requires high stocking rates and preferably is rotationally grazed to utilize rapid growth and maintain high nutritive value (Ball et al., 2007).

The brown mid-rib ('BMR') trait is commercially available in forage sorghum and in sorghum-sudangrass hybrids. The BMR mutant contains substantially less lignin and greater fiber digestibility (Cherney, 1990; Fritz et al., 1990; Cherney et al., 1991; Aydin et al., 1999). The seed do not perform well in cold soils and soil temperature must be over 9.5 °C for rapid emergence and growth. Under proper growing conditions, 'BMR' sorghum-sudangrass will out-compete weeds and not need herbicide. Research have shown that with sufficient N and depending on weather conditions, harvesting 'BMR' sorghum-sudangrass at a height of 91 to 121 cm will yield energy levels similar to corn silage, CP levels of 15 to 20%, and yields ranging from 20,175 to 40,350 kg DM/ha (35% DM) (Kilcer et al., 2007). 'BMR SxS' must be grazed or green chopped when the plants reach a minimum of 61 cm in height to avoid prussic acid poisoning.

COOL SEASON GRASSES

Cool-season forages provide winter and spring grazing that reduce the need for stored forages (Ball et al., 2002), have a greater nutritive value that results in better animal performance than warm-season grasses (Ellis and Lippke, 1976), and provide spring weed control (Evers, 1983). Cool perennial grasses are the main pasture and hay species in the south of the US during the cool season. They provide forage with high nutritive value when warm season grasses are dormant (Ball et al., 2007).

Ryegrass (*Lolium multiflorum*)

There are two species of ryegrass that are grown in the US: perennial (*L. perenne* L.) and annual (*L. multiflorum*). Annual ryegrass is widely grown in the southern US and has become an important component in winter forage-livestock systems (Ball et al., 2007).

Annual ryegrass is a bunch-type grass that tillers profusely. The plant appears shiny, dark green and grows to a height of 60 to 90 cm. It has a deeply fibrous root system, erect culms, glabrous leaves and a spike-type inflorescence (Ball et al., 2007).

The peak season of forage production for ryegrass is later than that of oats (*Avena sativa*) or rye (*Secale cereale*). Seasonal production in areas receiving adequate rainfall, generally along the Gulf

Coast, occurs from November to May (Ball et al., 2007). When planted late, overseeded into perennial grass pastures, or in areas of low rainfall, production will generally be delayed until February, but may continue through May. In general, the warmer the location where the ryegrass is planted, the shorter the growing season is.

Annual ryegrass has faster seedling establishment and greater seedling vigor than perennial ryegrass (Miller, 1984). This species tolerates extended wet periods (Hofstetter, 1988). Short periods of flooding will not damage a stand, but long periods will do damage (McLeod, 1982). The pH range is 5 to 8, with the optimum between 6 and 7 (Riewe and Mondart, 1985). Annual ryegrass is shade intolerant (Riewe and Mondart, 1985). Like most grasses, annual ryegrass has a fibrous root system, which can be extensive. It can be grazed in spring or fall, hayed, used as cover crop, plowed as green manure, or used as nurse crop for fall-seeded legumes (McLeod, 1982; Miller, 1984; Hofstetter, 1988). When sown in mixtures with small grains, ryegrass extends the spring grazing season (Miller, 1984).

Ryegrass can be grazed when plants reach an approximate height of 15 to 20 cm. Animals can graze the forage as low as 5 to 10 cm, which allows sufficient leaf area remaining for regrowth. Annual ryegrass is considered to be one of the highest nutritive value winter forages utilized in the southeastern area of the US. Dry matter digestibility is generally greater than 65% and CP content exceeds the requirements for most classes of livestock animal gains (Blount et al., 2009).

Beef and dairy cattle producers in the southeastern region of the US rely primarily on annual ryegrass to meet their pasture needs for winter and spring (Redfearn, 2002). The use of ryegrass for forage and hay is increasing because of its low seed cost, seed availability, and wide adaptation to the southern environment.

Many cultivars of annual ryegrass are currently marketed. Where winter temperatures are milder, ‘Gulf’ annual ryegrass is the preferred cultivar because of lower seed cost. Conversely, in areas where winter temperatures are below freezing for several consecutive weeks, cultivars with demonstrated cold tolerance such as ‘Marshall’ are preferred (Redfearn, 2002). There have been several studies

conducted to determine animal performance on annual ryegrass. Finishing steers on annual ryegrass had ADG of 1.04 kg from December to May (Roberts et al., 2009). Hafley (1996) reported steer ADG grazing annual ryegrass pastures were greater in continuous compared to rotational grazing (1.32 and 0.92, respectively), but there were no differences among cultivars ('Marshall' and 'Surrey'). Beck et al. (2007) evaluated the effect of species of cool-season annual grass on the growth of stocker cattle over a period of three years in Arkansas. He reported ADG values of 0.53 kg from December to March, and 1.22 kg from March to May for animals grazing annual ryegrass. Also in Arkansas, Coffey et al. (2002) reported ADG values of 1.0 kg for stocker steers grazing "Marshall" annual ryegrass from December to April in a three-year study.

Annual ryegrass is a high-quality forage that requires increased labor, equipment, seed and input in comparison to perennial forages (Allen et al., 2000). While forage nutritive value is greater in the early spring months, it declines as plant matures. In a study of six annual ryegrass cultivars, Redfearn et al. (2002) reported that CP concentration differed significantly among harvest with general decrease from 260 to 120 g CP/kg as the growing season progressed. Declines in crude protein occurred from April through the end of the growing season. Roberts et al. (2009) reported values of CP starting at 20% in January, peaking at 27% in March and decreasing linearly to 10% in May. In the same study, ADF and NDF concentrations increased linearly throughout the grazing season from 16 and 34% in January to 33 and 62% in May, respectively.

It is suggested that the use of late-maturing cultivars such as 'Marshall' and 'Rio' would allow producers to extend the production of greater nutritive value forage into late-spring (Redfearn et al., 2002). Forage mass of annual ryegrass has been reported in studies comparing various cultivars, stocking rates, and grazing method (Redfearn et al., 2002; Syfrett, 2003; Hafley, 1996). Redfearn et al. (2002) reported that 40% of the total forage production from the annual ryegrass cultivars occurred as early-season (December-February) growth with the remaining 60% occurring in late-season (March-May) growth. Approximately 30% of the total production occurred during April alone.

SMALL CEREALS

Rye (*Secale cereale*)

Cereal rye is an erect annual grass with green-blue, flat blades and an extensive fibrous root system. It resembles wheat, but usually is taller (90 to 152 cm) and tillers less (Munz, 1973). Compared to other cereal grains, cereal rye grows faster in fall and winter and produces more dry matter per unit area as a winter cover crop. Optimum soil pH is 5.0 to 7.0, but it tolerates pH range of 4.5 to 8.0 (Sattell et al., 1998).

It is the most winter hardy of all small cereal grains enduring all but the most severe climates (Miller, 1984; Stoskopf, 1985). Cereal rye is one of the best crops where fertility is low and winter temperatures are extreme (McLeod, 1982). It grows best with ample moisture, but excessive moisture during the fall and winter suppresses vegetative growth (Sattell et al., 1998). The wide range of adaptation for cereal rye is due to its great winter hardiness and tolerance of marginal soils, for example, it can be grown in soils too acidic for wheat (Stoskopf, 1985). Evans and Scoles (1976) indicated that the extensive root system of cereal rye enables it to be the most drought-tolerant cereal crop and its maturation date can change based on moisture availability.

Cereal rye can serve as grain, hay, pasture, cover crop, and green manure (McLeod, 1982). It produces large amounts of organic matter (McLeod, 1982). Biomass yields are not always great; in a three-year field trial in Georgia, cereal rye biomass averaged only 4,030 kg/ha (Hargrove, 1986). Cereal rye grain and straw have relatively low nutritive value as livestock feed (Bushuk, 1976). In a three-year study in Arkansas comparing steer performance, Coffey et al. (2002) found greater body weight gains for steers grazing ryegrass alone than those grazing ryegrass and cereal rye mixed (113.5 and 106.3 kg for the grazing season).

WARM SEASON LEGUMES

Warm-season legumes are important in some grazing and hay production systems in the Southeastern region of the US. They include a wide range of plant types that are adapted to hot, humid

conditions. They also provide high nutritive value forage and fix nitrogen over an extended period of the year (Ball et al., 2007)

Soybean (*Glycine max*)

Soybean is a rapid-growing annual with branching habit, stems being mostly primary tissue. Leaves are alternate, pinately trifoliate with pulvini, stipels and stipules. The plants are tap-rooted, up to 2 m in depth, with numerous lateral roots. Seeds are normally yellow with either a dull or a shiny seed coat and a hilum color ranging from yellow to black, with black being most common.

Soybeans were originated in Asia and were first introduced to Europe and North America as a forage crop (Caldwell, 1973). It is now only used as a forage crop if there is a need for extra forage or if the soybean crop had been damaged too severely for use as a grain crop (Johnston and Bowman, 2000).

Soybean tolerates drought when it is grown for forage, but it is intolerant of soil acidity and low fertility (Ball et al., 2007). Most cultivars can be used for forage, including those intended for oil production, if emergency forage is required. However, the USDA Agricultural Research Service has developed three new cultivars: ‘Derry’, ‘Donegal’, and ‘Tyrone’ (Devine et al., 1998a, b). These cultivars have been specifically bred for forage production, yielding up to 66% higher than adapted grain cultivars (Devine et al., 1998a).

Soybeans are suitable for ensiling, which is the main use for pure-sown forage stands. In North America, intercropping maize (corn) and soybeans has been found to improve total forage yield and forage nutritive value marginally (Putman et al., 1985). There was an increase of 11 to 51% in the CP concentration for maize-soybean intercrops relative to pure sowings of maize (Putman et al., 1986). *In vitro* dry matter digestibility of whole plant soybeans remains relatively constant at approximately 60% DM digestibility across various reproductive growth stages (Munoz et al., 1983). In contrast to other forage crops, the forage nutritive value of whole plant soybeans does not decrease rapidly with

advancing maturity because the seed is much higher in protein and energy (Coffey et al., 1995). The digestibility of DM, energy, CP, ADF, and NDF was similar to maize silage (Murphy et al., 1984).

There appears to be no anti-quality factors from using soybeans for forage production. However, soybean forage harvested at R7 maturity stage should be limited to a maximum of 50% of the diet. High concentrations of ether extract might affect forage intake and fiber digestion (Brown, 1999; Hintz et al., 1992).

Sheaffer et al. (2001) stated that forage and grain soybean had similar forage yields averaging 8,800 kg/ha (Sheaffer et al., 2001). Altinok et al. (2004), however, found an average of 7,343 kg DM/ha yield with six grain-type soybean cultivars at R6 stage. The results suggested that forage soybean would have superior DM yields to the grain types if harvested at a similar maturity stage (Devine and Hatley, 1998ab; Sheaffer et al., 2001) and Acikgoz et al. (2007) demonstrated that soybeans managed for forage can yield an average of 9,300 to 11,300 kg DM/ha at R4 and R6 stages, respectively averaging 13.3% CP.

COOL SEASON LEGUMES

With high costs of nitrogen fertilizer, many producers in the South are considering grass-legume mixtures for grazing, rather than grass alone. Legumes not only can fix nitrogen but also are highly digestible and high in crude protein. Legumes, if properly inoculated, can supply from 55 to 225 kg N/ha per year, depending upon the type of legume and density of stand (Ball et al., 2007). Cool season legumes make most of their growth in late winter-early spring and in autumn when temperatures and rainfall are generally favorable (Ball et al., 2007). Cool-season legumes are high in nutritive value and result in improved animal performance, including growth, milk production, conception rate, weaning weight, and weaning percentages (Stanley et al., 2010).

Berseem clover (*Trifolium alexandrium*)

Berseem clover is an erect-growing, non-reseeding annual legume with oblong, slightly hairy leaflets lacking a watermark (Ball et al., 2007). Miller et al. (1989) stated that berseem clover may

reach a height of 45 cm. Berseem clover does not withstand extreme heat or cold and is the least winter hardy of the cultivated clovers (McLeod, 1982), but it can germinate when the soil surface is moderately dry, and can emerge from a greater depth than white clover (Duke, 1981). Berseem clover grows in most of the U.S. and does especially well along the Gulf coast and in the Yuma, Rio Grande, and Imperial valleys of the Southwest (McLeod, 1982). Berseem clover can tolerate more soil moisture than either alfalfa (*Medicago sativa*) or white sweetclover (*Melilotus alba*) and is similar to alfalfa in drought tolerance (Knight, 1985). Soils with pH ranging from 4.9 to 7.8 appear to be suitable for berseem clover (Duke, 1981) and it has been noted as tolerating basic to acidic soils (Munoz and Graves, 1988). Berseem clover grows in loam to clay soils (Munoz and Graves, 1988), but it performs best in medium loam soil (Knight, 1985).

Cultivars of berseem clover that exhibit basal branching (e.g., ‘Miscawi’, ‘Bigbee’, ‘Multicut’) can regrow from repeated cuttings (Knight, 1985). They are very responsive to mowing or grazing and can be mowed frequently for weed control or for animal feed (Miller, 1989). Berseem clover CP concentration remained stable through successive mowings (28-30%), slightly higher than crimson clover or alfalfa (Knight, 1985).

Berseem clover can be green-chopped, grazed, or used for silage and by all measures its nutritive value is excellent (Duke, 1981; Munoz and Graves, 1988; McLeod, 1982). Total N contribution of berseem clover can range from 55 to 450 kg/ha (Munoz & Graves, 1988). Zahradnik (1985) asserts that ‘Bigbee’ is a palatable and nutritious legume and that CP concentration is slightly greater than crimson clover or alfalfa. No cases of bloat from grazing berseem clover have been reported (Ghaffarzadeh, 1997).

White Clover (*Trifolium repens*)

Based on the account by Duke (1981), white clover usually behaves as a perennial, but it performs as an annual in warm climates and a biennial in cold climate. White clover cultivars are classified arbitrarily by size of the plants as small, intermediate, and large (Carlson et al., 1985).

‘Ladino’ clover is a variety of white clover (McLeod, 1982); intermediate types of white clover are more tolerant to heat than are ladino-type white clovers (Miller, 1984).

White clover grows best under cool, moist conditions (Carlson et al., 1985) and is about as hardy as red clover or alfalfa (McLeod, 1982). The species is said not to grow well in alkaline soil, and the best pH range is 6.0 to 6.5 (McLeod, 1982), 6 to 7 (Carlson et al., 1985), or 6.5 to 7.0 (Hofstetter, 1988), with the optimal pH to be 6.5 (Duke, 1981; Gibson and Cope, 1985).

White clover performs best under regimes of heavy grazing or mowing (Gibson and Cope, 1985). According to Miller (1984), in the Southeast, the root-knot nematodes *Meloidogyne* spp. can damage white clover roots.

Dry matter yield of white clover should equal or exceed that of red clover (1,650 to 2,250 kg/ha) (Hofstetter, 1988). White clover is usually grown in mixtures with grasses (Duke, 1981). The latter can be either temperate or tropical grasses (Bowdler and Pigott, 1990). Examples include bermudagrass, brome grass (*bromus inermis*), dallisgrass, Kentucky bluegrass, orchardgrass, tall fescue, or timothy (*Phleum pratense*) (Gibson and Cope, 1985). In mixtures with grasses, white clover will be encouraged by frequent mowing (Miller, 1984).

Red clover (*Trifolium pratense*)

Red clover is a short-lived perennial, usually two years in the south, except where it is an annual. It grows erectly with leafy plants 60 to 90 cm tall (Ball et al., 2007). Red clover is becoming increasingly important in the south of the US where it is used as a winter annual (Lacefield and Ball, 1999).

Red clover is primarily used for hay, pasture, silage, and soil improvement. It is a quick growing crop, easily established, and produces high nutritive value forage (Ball et al., 2007). Red clover grows best on well-drained loamy soils, but it will also grow on soils that are not as well-drained (Ball et al., 2007). Medium and fine textured soils are preferred by the plant over sandy or gravelly soils (Ball et al., 2007). Red clover will grow moderately well in slightly acid soils. However, maximum yields are

obtained when soil pH is 6.0 or higher (Ball et al., 2007). When grown where it is well-adapted, the yield of red clover is usually greater than that of any other clover (Lacefield and Ball, 1999).

The CP of red clover can be nearly as high as that of alfalfa. Red clover cut for hay at the 50% bloom stage usually exceeds 14 or 15% CP, but many times red clover is not harvested soon enough. It is under these conditions that unfavorable nutritive value results (Wheaton, 1993).

Red clover is most often grown in association with cool season grasses like orchardgrass, tall fescue, timothy, or smooth brome grass, but can be grown alone or with certain warm season perennial grasses like dallisgrass and johnsongrass (Ball et al., 2007).

Two types of red clover are grown in North America: mammoth (single cut) and medium (multi-cut). The medium type is most commonly used in the US and it will produce several cuts or grazedowns each year depending on location and growing conditions (Lacefield and Ball, 1999).

Red clover-grass pastures can provide high yields for grazing, but it will not tolerate continuous close grazing. Ideally, it should be rotationally stocked (Lacefield and Ball, 1999). Although bloat can occur, it is highly unlikely when animals are grazing a red clover-grass mixture. Occurrences of bloat are possible with a pure stand of red clover, when the pasture is lush and rapidly growing, or when extremely hungry animals are first turned on to a pasture (Lacefield and Ball, 1999).

GRASS-LEGUME MIXTURES

Grass grown for hay removes large quantities of N, P and other nutrients from the soil while grass grown for pasture removes lower quantities of nutrients since a large part of the nutrients consumed in the forage are redeposited on the pasture in the form of manure and urine. Legumes such as clovers have the ability to take N from the atmosphere and convert it into a form usable by plants. Including legumes in mixtures with grass may lower the amount of N fertilizer required to produce forages (Koenig et al., 2002).

Numerous studies report benefits from grass-legume mixtures. Annual ryegrass has been recommended for planting with annual legumes not only to promote N fixation, but also to improve

palatability of the resulting hay or pasture. Rye included in mixed pasture with ryegrass is reported to increase forage availability in early winter and increase total grazing days (Bagley et al., 1988). Graves et al. (1987) planted 'Multicut' berseem clover and annual ryegrass in mixtures in field trials at Davis (Yolo County, California). The study reported that annual ryegrass alone yielded about half as much biomass as 'Multicut' alone. The mixtures of 50% and 75% 'Multicut' with ryegrass yielded as much as 'Multicut' alone (15,500 kg DM/ha). Mixtures of 'Multicut' berseem clover and annual ryegrass combine advantages of both plant species by providing early winter production as well as extending the availability of high nutritive value forage through late spring (Graves et al. 1987). When seeded along with legumes (e.g., annual reseeding species) or some other grasses (e.g., perennial ryegrass), annual and perennial ryegrasses contribute to better control of weeds (Miller, 1984). Cereal rye can be sown with legumes or other grasses (Miller, 1984). For example, berseem clover can be grown in combination with white clover, oat, or rye (Duke, 1981). Mixtures of grasses and clovers are difficult to maintain because grasses may shade the clover and because the clover requires high soil moisture levels. If soil N is high, grasses will tend to predominate, whereas the clover will dominate if N is low (Miller, 1984).

Mooso et al. (1990), in a study comparing steer performance on ryegrass-white clover versus ryegrass-white clover-crimson clover, found no differences on ADG between treatments (0.97 kg). Similarly, in a three-year study in Louisiana, six locations were used to produce stocker beef cattle in a year-round basis from weanling calves using forages as the primary nutrient. Winter forages include cool-season annuals (ryegrass, wheat and cereal rye) and/or clovers (white, red, or arrowleaf clover). The average daily gain of cattle grazing winter forages was found to be 0.9 kg (Bagley et al., 1990).

The forages explained in the literature review were selected among other because of their nutritive value, adaptation and performance on Louisiana soils (Ball et al., 2007). In addition, seasonal production was also considered as a main factor to select the forages to use in an effort to extend and maximize the grazing season. Berseem clover, for instance, produces forage from November to

December and from March to June (earlier and also later than ryegrass) and cereal rye grows from November to April (earlier than ryegrass) (Ball et al., 2007).

BEEF CATTLE PRODUCTION SYSTEMS

Systems of commercial beef cattle production may be divided into three general categories: (1) the cow-calf segment which produces weaned feeder calves for further grazing and/or feeding, (2) the stocker phase of production in which body weight is added to recently weaned calves, resulting in feedlot-ready yearlings and (3) the finishing phase of production in which cattle are fattened for harvest (Troxel et al., 2010)

In the US, beef cattle production systems are best adapted to certain parts of the country. Cow-calf and stocker operations are best adapted to regions of large grazing and small grain crop production areas. The fattening of cattle is best suited to areas where grain crops are produced in abundance or where grains for fattening are available nearby in adequate supplies (Lasley, 1981).

COW-CALF OPERATIONS

Beef production in the eastern United States is primarily a cow-calf enterprise with essentially all feed consumed as forages (Wilson and Watson, 1985; Hoveland, 1986) with calves typically weaned and sold in late summer to early-mid autumn.

Cow-calf operators in the West and Southern Plains have significant cost advantages over operators in other regions because, with a longer grazing season, their herds require less supplemental forage during the winter. Cowherds in the Southeast are primarily on small (less than 50 head) and part-time operations (Short, 2001).

Two important factors that affect the profitability of a cow-calf enterprise are (1) calf crop percentage and (2) calf weaning weight. Together, these two factors represent reproductive efficiency of a herd, which is defined as the total kg of calf weaned divided by the number of cows exposed during the breeding season (Troxel et al., 2010).

Cow-calf producers should strive for at least a 90% calf crop, and an emphasis should be placed on cows delivering a live calf every 12 months. Cows that calve at intervals greater than 12 months are usually not profitable (Lasley, 1981). The successful cow-calf operation depends on permanent pasture or other low-cost roughage for feed (Troxel et al., 2010).

STOCKER OPERATIONS

Effects of light to heavy stocking rates are often clear because of differences in residual herbage, however, effects on livestock performance and economic returns are not easily observed (Gillen and McCollum, 1992; McCollum et al., 1999). Average daily gain is affected by stocking rate. At low stocking rates, ADG is maximized, but at heavier stocking rate, weight gains per hectare are maximized (Guerrero et al., 1984; Bransby et al., 1988; Gillen et al., 1992).

Stocking rate is a fundamental variable for management that affects vegetation, livestock, and economic responses (Bernardo and McCollum, 1987; Gillen and McCollum, 1992; McCollum et al., 1999).

The main objective is to produce as much growth and development as possible on pasture or hay and other roughages such as fodder and silage (Lasley, 1981). Basic principles involved in stocker operations are (1) adding 90 to 135 kg of weight per calf, (2) extensive and intensive use of high-nutritive value forage rather than the more expensive high-energy feed sources, (3) assembly of calves into more marketable groups – uniformity in breeding, gender, weight and quality and (4) more marketing flexibility for calf/yearling owners (Troxel et al., 2010).

Backgrounding (stocker) systems typically involve feeding cattle for moderate growth, allowing for maturation of muscle and bone while restricting fat deposition (Block et al., 2001), and allow body development before finishing, allowing cattle to attain greater carcass weights at harvest (Sainz et al., 1995). Stocker operations, more generally defined, are used by beef cattle producers for several reasons, including utilizing homegrown feeds, taking advantage of grazing opportunities,

delaying finishing to target a specific market, acclimating calves to eating from bunks and drinking from a fountain waterer, or promoting skeletal growth of small-framed cattle (Anderson, 1991).

Calves make efficient use of forages for growth during the stocker phase of production when year-round grazing systems are possible (Blaser et al., 1986; Hoveland, 1986). An opportunity for improving the profitability of beef production in the Southeast lies in stockering weaned calves on high-nutritive value, cool-season annual or perennial pastures. The large supply of weaned calves available in this region offers the opportunity for businesses to concentrate on stockering systems and retained ownership (Scaglia et al., 2009).

Retention of calves after weaning for use as stocker cattle in summer pastures improves profit to beef cow-calf operations by increasing the value of calves (Allen et al., 1992). Retaining a weaned calf crop over winter, however, requires feeding stored feeds (Allen et al., 1996; Hersom, 1999) before animals can graze spring pastures. Ridenour et al. (1982) demonstrated that grazing calves before finishing decreased days in the feedlot (finishing phase), but increased feed efficiency. In addition, improved uniformity in harvested cattle can be achieved by allowing calves to attain a greater body weight before the start of the finishing phase (Vaage et al., 1998). Backgrounding calves before finishing can also increase mature size (Owens et al., 1993).

Stocker operation may be most often defined as the process of growing and developing calves from weaning weights of 200 to 270 kg to yearling weights of 320 to 385 kg when the cattle are ready to enter a feedlot for finishing (Troxel et al., 2010).

FINISHING OPERATIONS

Cattle are usually finished for harvest confined in a drylot on full feed with grain (as the main ingredient in the diet) and limited roughage. Cattle usually go on feed as yearlings weighing 300 to 400 kg, average gaining 1.5 kg or more per day in the feedlot and finish weighing between 450 and 600 kg. The feeding period often spans 150 d, although large-framed, late-maturing cattle require a longer period and small-framed, early-maturing cattle finish sooner (Troxel et al., 2010).

Grains such as corn, barley and sorghum are the most used grains in feedlot diets. Corn, for example, is commonly processed in cattle finishing diets to increase utilization of starch, thereby improving animal performance. Huck et al. (1998) reported improvements in gain efficiency of 10 and 10.5% when steers were fed diets based on high-moisture corn and steam-flaked corn, respectively, compared with steers fed dry-rolled corn based diets. The elevated prices of grains have led the producers and researchers to find different alternatives in by-products. The rapid expansion of ethanol production, for example, has resulted in an abundance of co-products available to cattle feeders. Homm et al. (2008) reported that the use of a 40% dried distillers grains with solubles and 35% soybean hulls diet can achieve comparable performance and carcass characteristics to cattle fed a typical corn finishing diet.

Forage-fed beef in the United States is not new, although the vast majority of beef produced today continues to be grain-fed beef from feedlots. Consumer interest in the benefits of forage-finished beef has shown that a portion of the population demands this type of product enough to warrant further development of the production system (Cox et al., 2006).

Numerous research has been done regarding to forage-fed beef. The type of forage preferred by researchers has been as varied as the type of cattle breed used in every experiment. Cattle breed and forage, however, are generally the best-adapted species or breed to the specific area. Experiments in the southeastern US include breeds such as Hereford, Angus, Charolais and some crossbreeds with different fractions of Brahman influence. Furthermore, well-adapted forages like bermudagrass, bahiagrass during warm season and ryegrass during cool season are generally the forages of preference (Bidner et al., 1981; 1985; 1986; Crouse et al., 1984; Cox et al., 2006; Roberts et al., 2009). Finishing period, ADG, dressing percentage, lean and fat color, and quality and yield grade results will be discussed in the following chapters.

Current USDA regulations do not allow grain to be added to the diet if the meat is to be labeled as forage-fed. The standards for forage-fed beef establishes that grass and forage shall be the feed

source consumed for the lifetime of the ruminant animal, with the exception of milk consumed prior to weaning. The diet shall be derived solely from forage consisting of grass (annual and perennial), forbs (e.g., legumes, *Brassica*), browse, or cereal grain crops in the vegetative (pre-grain) state. Animals cannot be fed grain or grain byproducts and must have continuous access to pasture during the growing season. Hay, haylage, baleage, silage, crop residue without grain, and other roughage sources may also be included as acceptable feed sources. Routine mineral and vitamin supplementation may also be included in the feeding regimen. If incidental supplementation occurs due to inadvertent exposure to non-forage feedstuffs or to ensure the animal's wellbeing at all times during adverse environmental or physical conditions, the producer must fully document (e.g., receipts, ingredients, and tear tags) the supplementation that occurs including the amount, the frequency, and the supplements provided (USDA, 2007).

Roberts et al. (2009) proposed a finishing system that utilizes both forage and grain. Adding different amounts of grain (0.0%, 0.5%, 1.0%, 1.5% and 2.0% of body weight) to pasture diets, they found that increasing the amount of grain in the diet of finishing cattle resulted in a linear decrease in days on feed and a linear increase in ADG, yield grade, and flavor.

MEAT QUALITY AND CARCASS EVALUATION

The beef grading system in the US is an attempt to connect physical carcass traits with quality such as palatability (tenderness, juiciness and flavor) or amount of meat produced. There are two types of beef grades in the US: quality and yield grades. Quality grades indicate expected palatability or eating satisfaction of the meat. Yield grades are estimates of the percentage of boneless, closely trimmed retail cuts from the round, joint, rib and chuck. Beef carcasses may carry a quality grade, a yield grade or both a quality and yield grade (Burson, 2004).

Extensive studies (Murphey et al., 1960) conducted by USDA on the estimation of beef cutability became the basis for the USDA yield grade standards. Powell and Huffman (1968) and Cross et al.

(1973) concluded that the yield grades were the best means available for predicting cutability for use in a grading program.

Abraham et al. (1968, 1980), Winchester et al. (1967), Burton and Reid (1969) and Ridenour et al. (1982) have all shown that composition is highly dependent on live or carcass weight in animals of similar size and biological type. However, when cattle of various breeds and biological types are fed to constant weight, large differences in carcass composition are seen (Koch et al., 1976). Hankins and Howe (1946) found that the chemical composition and separable physical components of the 9th, 10th and 11th (9-10-11) rib cut were highly related to the composition of the entire carcass.

CARCASS TRAITS

Understanding beef carcass information begins with understanding how individual carcass traits are measured and how they impact carcass grades.

Hot Carcass Weight

Hot carcass weight (HCW) is the hot or un-chilled weight after harvest and removal of the head, feet, gastro-intestinal tract and internal organs. National Beef Quality Audit (2005) outlined a range of 295 to 385 kg as an industry target for carcass weight. Heavyweight (> 410 kg) and lightweight (< 273 kg) carcasses do not fit packer specifications and are severely discounted (Troxel et al., 2010).

Dressing Percentage

Dressing percentage is hot carcass weight as a percentage of the live weight of the animal at harvest. Dressing percentage typically ranges from 60 to 64% for the majority of grain fed cattle and 54 to 58% for forage fed cattle (Williams et al., 1979; Bidner et al., 1986; Bennett et al., 1995; Roberts et al., 2009).

Ribeye Area

Ribeye area (REA) is an indicator of muscling and an important factor in determination of yield grade. As ribeye area increases, retail product yield increases. Ribeye area is determined by measuring the area of the *longissimus dorsi* (ribeye) muscle exposed by cutting the carcass between the 12th and

13th ribs (Alberle et al., 2001), either by a direct grid reading of the eye muscle or by a planimeter reading from a tracing of the eye muscle. The grid reading is faster and is used much more frequently than the planimeter method (Boggs et al., 1998). More recently, electronic grading systems are found in some commercial packing plants. This new technology offers a potential opportunity for cattle producers to receive accurate carcass data on an individual basis. This system basically uses a digital camera to take a picture of the ribeye face and a software program to identify REA, as well as additional USDA yield grade information. Extensive research has proven this method to be accurate. An optimum range for ribeye area is 71 to 97 cm² (Troxel et al., 2010).

Fat Thickness

Fat thickness, otherwise referred to as backfat, is a measure of external fat thickness on a carcass (Boggs et al., 1998). Fat thickness is measured at a point three-fourths of the length of the *longissimus dorsi* muscle from the split chine bone. An optimum range for fat thickness is 0.5 to 1.3 cm (Troxel et al., 2010).

Internal Fat

Kidney, pelvic and heart (KPH) fat is also referred to as internal fat. Internal fat or KPH fat is expressed as a percentage of hot carcass weight (Troxel et al., 2010) and will range from 0.5 to 6% and averages about 2.0% (Boggs et al., 1998).

Intramuscular Fat

Intramuscular fat (IMF) is often called marbling. For official grading purposes, marbling is assessed in the *longissimus dorsi* muscle cut exposed between the 12th and 13th ribs. Marbling scores range from practically devoid to abundant (practically devoid, traces, slight, small, modest, moderate and abundant) and are divided into 100 subunits. Superscripts ranging from 00 (least amount of marbling) to 99 (greatest amount of marbling) are assigned to marbling scores (Troxel et al., 2010).

Maturity

Maturity refers to the physiological age of the animal rather than to the chronological age, which most of the times is unknown (Boggs et al., 1998). The physiological maturity of a carcass is determined by evaluating the size, shape and ossification of bone and cartilage (especially the split chine bone) and the color and texture of the lean tissue (Troxel et al., 2010). There are five maturity groups and they are designated by the letters A, B, C, D and E. The A (0 to 30 months) and B (30 to 42 months) maturities are from young cattle (Boggs et al., 1998). Carcasses displaying advanced skeletal maturity are referred to as “hardbones” and associated price discounts normally apply (Troxel et al., 2010).

TENDERNESS AND COOKING LOSS

Tenderness

Although tenderness is not used in Quality or Yield Grade calculations, it plays a key role in consumer satisfaction. Tenderness can be objectively estimated with a Warner-Bratzler shear force device. An industry target for tenderness is a Warner-Bratzler shear force value below 2.7 kg (Troxel et al., 2010).

Cooking Loss

Cooking is a process of heating beef at sufficiently high temperatures that denatures proteins and makes it less tough and easy to consume (Garcia-Segovia et al., 2006). Cooking loss refers to the reduction in weight of beef during the cooking process (Vasanthi et al., 2006).

The major components of cooking losses are thawing, dripping and evaporation (Bender, 1992; Barbantia and Pasquini, 2004; Obuz et al., 2004). Thawing loss refers to the loss of fluid in beef resulting from the formation of exudates following freezing and thawing. Such losses are lower following a rapid freezing compared with slow freezing. This is because of small ice crystallization formed by the rapid freezing (Hui, 2004).

Dripping is the loss of fluid and water evaporation from the shrinkage of muscle proteins (actin

and myosin) (Yu et al., 2005). Drip loss is of high importance due to its financial implications. Low water holding capacity reduces beef yield during processing and generally beef with high drip loss has an unattractive appearance, which leads to loss of sales (Lawrie, 1974).

Evaporation refers to the loss of fluid from the beef surface through its conversion to gaseous form. It changes the shape of beef through shrinkage and causes firmness and poor juiciness in beef (Yu et al., 2005).

Many studies have found similar cooking losses between forage- and grain-fed cattle (Bowling et al., 1977; Crouse et al., 1984; Berry et al., 1988). In contrast, Hedrick et al. (1983) found greater cooking losses for grain- versus forage-fed cattle that differed ($P < 0.05$) in backfat. Mandell et al. (1998), in a study comparing grain- versus forage-fed cattle with similar ($P > 0.05$) backfat, also found greater losses for grain-fed than forage-fed beef. Bowling et al. (1977) and Berry et al. (1988) found cooking losses of 25.4 to 28% for forage-fed. Hedrick et al. (1983) and Mandell et al. (1998), however, found lower values (20 to 24% and 18.2%, respectively).

USDA BEEF CARCASS GRADES

Quality Grade

The beef quality grades are Prime, Choice, Select, Standard, Commercial, Utility, Cutter and Canner. Marbling and carcass maturity are primary determinants of quality grade. More desirable grades are achieved with higher degrees of marbling and younger carcass maturity. It is important to note that carcasses with small or slight marbling and B maturity are Standard quality grade, whereas A maturity carcasses with small or slight marbling are Choice and Select quality grade (Troxel et al., 2010).

Yield Grade

Yield grades classify carcasses for differences in cutability or yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck. The five yield grades are numbered 1 through 5. Carcasses in yield grade 1 have the highest cutability, while carcasses in yield grade 5 have the lowest

cutability. The yield grade of a beef carcass is determined by considering four characteristics: (1) the amount of external fat (backfat), (2) the amount of kidney, pelvic and heart fat, (3) the area of the ribeye muscle and (4) the hot carcass weight. Yield Grades are based on the following equation:

Yield grade = $2.50 + (2.5 \times \text{adjusted fat thickness, inches, 12th rib}) + (0.2 \times \text{percentage kidney, pelvic and heart fat}) + (0.0038 \times \text{hot carcass weight, pounds}) - (0.32 \times \text{area of ribeye, square inches})$ (Boggs et al., 1998).

CARCASS EVALUATION AND PALATABILITY IN FORAGE-FED BEEF

Past research reported several problems associated with the use of forage compared with concentrate as the primary source for finishing cattle. Lower ADG (0.72 vs. 0.96 kg/d), longer finishing periods to reach a target endpoint (316 vs. 212 d), reduced dressing percentage (53 vs. 55), less acceptable lean and fat scores, and lower quality grade (10.1 vs. 9.0) are some examples (Bidner et al., 1981, 1986). In addition, other researchers have found palatability issues related to flavor when comparing animals finished on all forage diet to those finished on high concentrate diet (Bowling et al., 1977, 1978; Melton, 1990). However, Greibenow et al. (1997) pointed out conflicting research related to most of the problems associated with forage-fed beef. Muir et al. (1998) stated that feeding systems have little or no effect on palatability and carcass traits when cattle are finished to similar carcass weight or same backfat. Mandell et al. (1997) also noted confounding problems in many studies comparing forage vs. grain-finishing because of backfat finish and days on feed. In those studies, forage-fed cattle often had minimal amount of finish or were slaughtered at ages older than those of grain-fed cattle.

Some studies reported decreased BW gains in forage-finished cattle resulting in a longer finishing period to reach the same BW or fat thickness than those finished on grain (Bidner et al., 1981, 1986; Mandell et al., 1997; French et al., 2001). Moreover, Bidner et al. (1986) and McMillin et al. (1990) found reduced dressing percentages, yield grades and marbling in forage-fed steers compared with grain-fed steers. Several studies indicate no difference in tenderness (4.8 vs. 4.1 kg)

among diets (Schaake et al., 1993; Muir et al., 1998; French et al., 2000, 2001). However, others found forage feeding to increase shear force compared with grain feeding (Bowling et al., 1977; Bennett et al., 1995).

FATTY ACIDS IN FORAGE-FED BEEF

OMEGA 6 AND OMEGA 3 FATTY ACIDS

Omega-3 and Omega-6 fatty acids are considered essential fatty acids. In other words, they are essential to human health, cannot be manufactured by the body and must be obtained from food. Omega-3 and Omega-6 fatty acids play a crucial role in brain function, as well as normal growth and development. Also known as polyunsaturated fatty acids (PUFAs), they help stimulate skin and hair growth, maintain bone health, regulate metabolism, and maintain the reproductive system (Ehrlich, 2011).

There are three major types of omega 3 fatty acids that are ingested in foods and used by the human body: alpha-linolenic acid (ALA; C18:3), eicosapentaenoic acid (EPA; C20:5), and docosahexaenoic acid (DHA; C22:6). Once eaten, the body converts ALA to EPA and DHA, the two types of omega-3 fatty acids more readily used by the body (Ehrlich, 2011). Omega-3 fatty acids can be found in fish, such as salmon, tuna, and halibut, other marine life such as algae and krill, certain plants (including purslane), and nut oils (Chan and Cho, 2009).

Extensive research indicates that omega-3 fatty acids reduce inflammation and help prevent risk factors associated with chronic diseases such as heart disease, cancer, and arthritis. These essential fatty acids are highly concentrated in the brain and appear to be particularly important for cognitive (brain memory and performance) and behavioral function. Symptoms of omega-3 fatty acid deficiency include extreme tiredness (fatigue), poor memory, dry skin, heart problems, mood swings or depression, and poor circulation (Ehrlich, 2011).

There are several different types of omega-6 fatty acids, and not all promote inflammation. Most omega-6 fatty acids in the diet come from vegetable oils (eg, corn, sun flower, soy), such as

linoleic acid (LA; C18:2). Linoleic acid accounts for 85 to 90% of the dietary omega-6 PUFA (Harris et al., 2009), it is converted to gamma-linolenic acid (GLA; C18:3) in the body and it is then further broken down to arachidonic acid (AA; C20:4) (Ehrlich, 2011). Gamma-linolenic acid may actually reduce inflammation.

A healthy diet should consist of roughly one to four times more omega-6 fatty acids than omega-3 fatty acids, but the typical American diet tends to contain 10 to 30 times more omega-6 fatty acids than omega-3 (Ehrlich, 2011).

Research has established that EPA and DHA play a crucial role in the prevention of atherosclerosis, heart attack, depression and cancer (Simopoulos, 1991; Simopoulos, 2002; Conner, 2000). In addition, omega-3 consumption by individuals with rheumatoid arthritis has led to the reduction or discontinuation of their ordinary treatment (Kremer, 1989; DiGiacomo, 1989). Several studies have established a clear association between low levels of omega-3 fatty acids and depression. In fact, humans with a high level of omega-3 consumption have fewer cases of depression and decreased incidence of age-related memory loss as well as a reduction in impaired cognitive function and a lower risk of developing Alzheimer's disease (Kalmijn et al., 1997a; Kalmijn et al., 1997b; Yehuda et al., 1996; Hibbeln, 1998; Hibbeln and Salem, 1995).

Dietary recommendations for omega-6 and omega-3 PUFAs traditionally focused on the prevention of essential fatty acid deficiency, but are now increasingly seeking to define "optimal" intakes to reduce risk for chronic disease, particularly coronary heart disease (CHD). Both, The Institute of Medicine's Food and Nutrition Board, in their 2005 Dietary Reference Intake Report for Energy and macronutrients, and the 2005 Dietary Guidelines for Americans support an acceptable macronutrient distribution range of 5 to 10% and 0.6 to 1.2% dietary energy from omega-6 (LA) and omega-3 (ALA) PUFAs, respectively.

The American Heart Association (AHA), on the other hand, places primary emphasis on healthy eating patterns rather than on specific nutrient targets. Their recommendation for adults

without CHD is to eat fish (particularly fatty fish) at least twice a week; including oils and foods rich in ALA. However, AHA does support an omega-6 PUFA intake of at least 5% to 10% of energy in the context of other AHA lifestyle and dietary recommendations (Harris et al., 2009).

Advice to reduce omega-6 PUFA intakes is typically framed as a call to lower the ratio of dietary omega-6 to omega-3 PUFAs (Sears, 2003; Simopoulos, 2008). Although increasing omega-3 PUFA tissue levels does reduce the risk for CHD (Kris-Etherton et al., 2002; Mozaffarian and Rimm, 2006), it does not follow that decreasing omega-6 levels will do the same. Higher omega-6 PUFA intakes can inhibit the conversion of ALA to EPA (Liou et al., 2002), but such conversion is already quite low (Brenna, 2002), and whether additional small changes would have net effects on CHD risk after the other benefits of LA consumption are taken into account is not clear (Harris et al., 2009).

Diet can significantly alter the fatty acid composition in fed cattle. Cattle fed primarily forage enhanced the omega-3 content of beef by 60% and also produces a more favorable omega-6 to omega-3 ratio. Conventional beef omega-6 to omega-3 ratio ranged from 5.7 to 10.4 while forage-fed beef ranged from a 1.7 to 3.7 (Descalzo et al., 2005; Nuernberg et al., 2005; Garcia et al., 2008).

Research has shown that forage-based diets resulted in significantly greater levels of omega-3 within the lipid fraction of the meat, while omega-6 levels were left unchanged. In fact, as the concentration of grain increased in the grass-based diet, the concentration of omega-3 decreased in a linear fashion (Garcia et al., 2008; Alfaia et al., 2009; Leheska et al., 2008; Nuernberg et al., 2005; Ponnampalam et al., 2006; Descalzo et al., 2005). Those results also showed that the amount of total lipid (fat) found in a serving of meat was highly dependent upon the feeding regimen. Values of total lipid ranged from 1.5 to 2.8% of muscle for forage-fed beef compared to 2.6 to 4.4 for grain-fed beef. A serving (230 g) of forage-fed beef would provide 127 mg of omega-3, which accounts for 8% of the daily recommendation made by The Institute of Medicine's Food and Nutrition Board in their 2005 Dietary Reference Intake Report for Energy and Macronutrients while a serving of grain-fed beef would supply an estimated 11 mg or roughly 1% of the daily recommendation.

CONJUGATED LINOLEIC ACID

Conjugated linoleic acid (CLA) is a group of polyunsaturated fatty acids found in beef, lamb and dairy products that exist as general mixture of positional and geometric conjugated isomers of LA (Sehat et al., 1999). These compounds are produced in the rumen of cattle and other ruminant animals during the microbial biohydrogenation of linoleic and linolenic acids by an anaerobic rumen bacterium *Butyrivibrio fibrisolvens* (Pariza et al., 2000).

Nine different positional and geometrical isomers result from this process, in which *cis*-9, *trans*-11 is the most abundant and is the biologically active form. *Cis*-9, *trans*-11 makes up 75% or more of the total CLA in beef (Ip et al, 1994; Chin et al., 1992; Parodi, 1997). Ip et al. (1994) reported the anti-atherosclerotic evidence in CLA treated mice. They showed that CLA levels as low as 0.05% of the diet can have a beneficial effect in mice. A level of 0.5% reduced the total number of mammary tumors by 32%. These results also demonstrated that CLA administered through a dietary route was effective in providing protection against cancer in mice.

In a supplemental feeding study, results showed a lower level of LDL (known as “bad” cholesterol) in both rabbits and hamsters treated with oral CLA, which resulted in significantly less plaque formation in the aortic artery of treated animals (Steinhart, 1996). Presumably this reduction in plaque formation would therefore reduce the incidence of heart disease. Likewise, Kritchevsky et al. (2000) demonstrated that CLA levels as low as 0.1% of the diet can have beneficial effects by inhibiting atherogenic activity in rabbits. This study also showed a 30% regression of established atherosclerosis with a CLA level of 1% of the diet.

There is abundant data to demonstrate that CLA modulates body composition by reducing the accumulation of adipose tissue, primarily in experimental animals. In mice, rats, pigs and now humans, dietary CLA has been shown to reduce adipose tissue depots (Dugan et al., 1999; Park et al., 1997; Sisk et al., 2001; Smedman and Vessby, 2001). Although there is some controversy within the human

data, it is likely that dose, duration, isomeric composition, age and gender influence the outcome of CLA supplementation (Blankson et al., 2000; Zambell et al., 2000)

Conjugated linoleic acid is found naturally in a variety of ruminant meats (French et al, 2000) and dairy products (Dhiman et al, 1999) due to the anaerobic activity of the rumen bacterium *Butyrivibrio fibrisolvens*. This rumen organism is responsible for the biohydrogenation of linoleic and linolenic acids into the conjugated isomers referred to as CLA. Because linoleic and linolenic acid are precursors, diets rich in these compounds increase the concentration of the CLA within the fat depot of the animal. Lush green forages are high in this precursor; therefore, grass-fed ruminant species have been shown to produce 2 to 3 times more CLA than ruminants fed in confinement on concentrate-only diets (French, et al, 2000; Duckett, et al, 1993; Rule, et al, 2002; Mandell et al, 1998). In addition, microbial biohydrogenation of LA and ALA by *Butyrivibrio fibrisolvens* is highly dependent on rumen pH (Pariza et al., 2000). Grain consumption decreases rumen pH, reducing *B. fibrisolven* activity, conversely forage-based diets provide for a more favorable rumen environment for subsequent bacterial synthesis (Bessa et al., 2000). Ruminant pH may help to explain the apparent differences in CLA content between grain and forage-finished meat products (Daley et al., 2010).

Optimal dietary intake remains to be established for CLA (Daley et al., 2010). It has been hypothesized that 95 mg/d CLA is enough to show positive effects in the reduction of breast cancer in women utilizing epidemiological data linking increased milk consumption with reduced breast cancer (Knekt et al., 1996). Ha et al. (1989) published a much more conservative estimate stating that 3 g/d CLA is required to promote human health benefits (Ha et al., 1989). Ritzenthaler et al. (2001) estimated CLA intakes of 620 mg/d for men and 441 mg/d for women are necessary for cancer prevention. All these values represent rough estimates and are mainly based on extrapolated animal data. However, Shantha et al. (1994) reported concentrations of CLA of only 152 mg in 100 g of meat. Those results represent only 5% of the requirements estimated by Ha et al. (1989) and 24.5% for men and 36% for women of the requirements estimated by Ritzenthaler et al. (2001). What is clear is that

we as a population do not consume enough CLA in our diets to have a significant impact on cancer prevention or suppression (Daley et al., 2010). Reports indicate that Americans consume between 150 to 200 mg/d in their total diet (Ritzenthaler et al., 2001).

FORAGE-FED BEEF INDUSTRY

On a global scale, most beef is produced from pasture or rangeland feeding. This maximizes the ruminant's ability to convert cellulose-based material into a highly nutritious human food (Nicol, 1987). However, the vast majority of finished beef in the US today is grain-fed (Prevatt et al., 2006).

There are many factors that contribute to beef cattle production and marketing. Some of them include technological advances in grain crop production, grain prices, shipping costs (for animals and grain), cost per pound of merchantable beef, variability in animal performance, production risk and units and market power of large feedlots and packing plants (Prevatt et al., 2006).

Concerning animal performance, some of the limitations facing the forage-fed beef industry include the high cost of beef production per kg, achieving adequate animal rates of gain for marbling and availability of adequate forage nutrition value and quantity for animal weight gains. On the other hand, limitations concerning the consumer such as maintaining a consistent high-quality product, maintaining a reasonable level of edible meat yield, imports of forage-fed beef and educating consumers about the attributes of forage-fed beef are a big part of the equation (Prevatt et al., 2006).

Forage-finished beef has been discriminated for many reasons. Traditionally, meat with yellow fat and dark lean has been deemed a lesser quality product at the retail level (Bowling et al., 1977). Grains usually contain negligible amounts of carotenoids (Strachan et al., 1993), but lush green forages contain several carotenoids, primarily beta-carotene, which can be deposited in the fat and cause a yellowish-orange color. The lean can also have a dark purplish color that can lead to lesser palatability, off-flavor and decreased shelf-life (Sapp et al., 1996).

Palatability characteristics are important to the purchase intent of beef consumers (Oltjen et al., 1971; Bowling et al., 1977). Smith (1990) discouraged forage finishing because of deleterious effects

on carcass and beef quality, but others (Bidner et al., 1981, 1985, 1986; Crouse et al., 1984; Fortin et al., 1985) found no differences in palatability attributes between forage- and grain-finished beef. On the other hand, several researchers who conducted either trained or consumer sensory panels also reported that consumers in the US preferred grain-fed over forage-fed beef, specifically due to fewer incidence of sensory off-flavors, more desirable beef flavor, and greater overall acceptability (Bowling et al., 1977; Schroeder et al., 1980; Hedrick et al., 1983; Crouse et al., 1984; Schaake et al., 1993). The difference in flavor is driven by the effect of diet on fatty acid profile (Leheska et al., 2008). Mandell et al. (1997) reported slightly less beef flavor and more off-flavor in forage-finished beef than grain-finished beef.

Concentrate-fed animals grow at a faster rate because of higher energy intake. Forage-fed cattle tend to take longer to attain the same BW before harvest; therefore, they are usually older than their concentrate-finished counterparts. This is an important factor when considering quality attributes such as tenderness and flavor (Nour et al., 1994). Moreover, a comparison made by Harrison et al. (1978) about forage-fed, short-term grain-fed and long-term grain-fed revealed that long-term grain-fed cattle had heavier carcasses with a greater degree of marbling and quality grade, but lesser cutability scores because of excessive finish when compared with the carcasses of forage-fed steers.

The future development of a forage-fed meat industry, however, is a possibility. Recent consumer research has documented an interest in forage-fed beef. Umberger et al. (2002) and Cox et al. (2006) reported 23 and 34%, respectively, of US consumers preferred forage-fed over grain-fed beef. In addition, forage-fed beef has received recent attention because of its composition of certain fatty acids and fatty acid proportions that potentially positively impact health such as anticarcinogenic properties, body fat reduction and immune system modulation (Whigham et al., 2000).

Since the majority of cattle produced annually in the US are concentrate-fed, with relatively few cattle finished exclusively on grass, forage-fed beef has become a niche market that requires marketing and promotion to gain consumer acceptance (Mills, 2003).

CHAPTER III

FORAGE SYSTEMS FOR FINISHING STEERS IN SOUTH LOUISIANA

INTRODUCTION

Numerous studies have been conducted comparing forage-fed beef and grain-fed beef. Past research has found conflicting results on finishing period, ADG, dressing percentage, lean and fat color, and quality and yield grades associated with the use of forage as the primary feed source for finishing cattle (Bidner et al., 1981, 1985, 1986; Bowling et al., 1977; Crouse et al., 1984; Fortin et al., 1985; Greibenow et al., 1997; Mandell et al., 1997; Melton, 1990; Muir et al., 1998). On the other hand, research suggests that forage-based diets enhance total conjugated linoleic acid (CLA), omega-3 fatty acids and precursors for Vitamins A and E, and consumer interest in forage-fed beef products has grown (Daley et al., 2010). Moreover, little research has been done comparing forage-fed beef finished on different forages. Therefore, the objectives of this study were to evaluate three production systems differing in complexity and forage types, and to develop a finishing program in Louisiana that would allow producing 500-kg forage-fed steers at 17 to 19 months of age.

MATERIALS AND METHODS

SITE DESCRIPTION

This study was conducted from June 2009 to May 2010 and from June 2010 to May 2011 at the Louisiana State University Agricultural Center Iberia Research Station located in Jeanerette, Louisiana (29°57'54" W latitude; 91°42'54" N longitude; altitude 5.5 m). Soils were silty clay loam with flat topography with improved drainage. The Station is located approximately 13 km south of LA Highway 90. It is 6.4 km due east off of Darnall Road on LA Highway 87 and is situated approximately 12.8 km east of New Iberia, Louisiana. Monthly (for 2009, 2010 and 2011) and historic average monthly temperature and rainfall at Iberia Research Station are presented in Figure 3.1 and Figure 3.2, respectively.

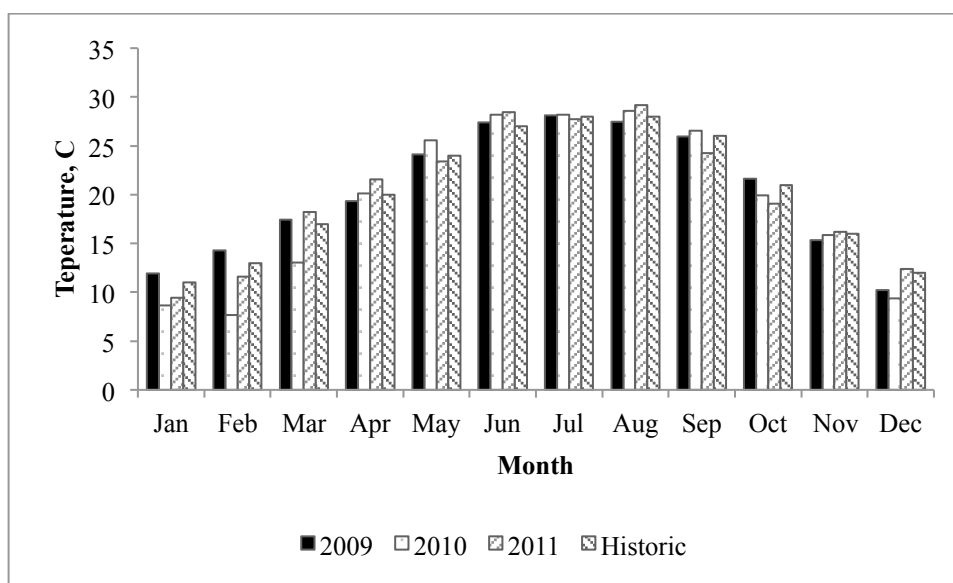


Figure 3.1 Monthly (for 2009, 2010 and 2011) and historic average monthly temperature at Iberia Research Station.

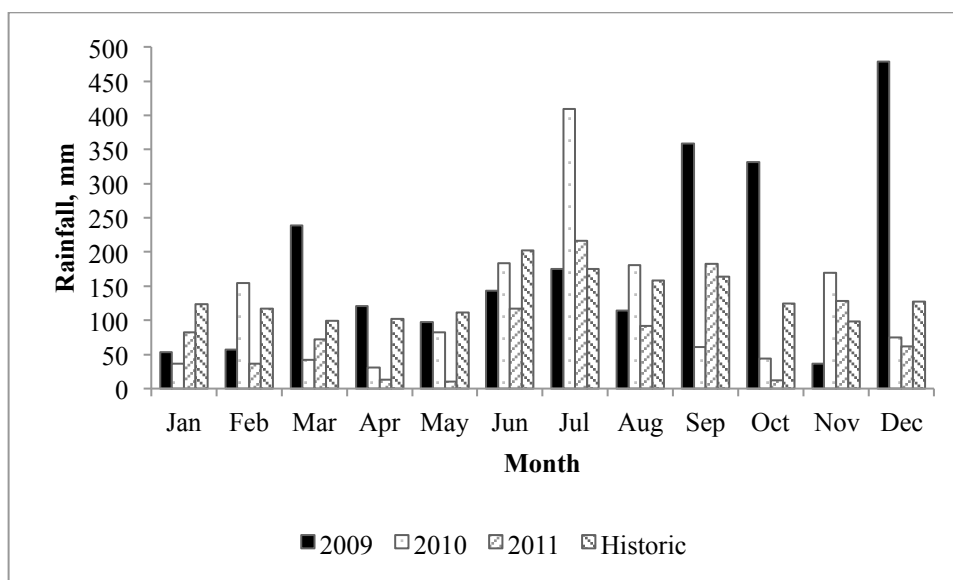


Figure 3.1 Monthly (for 2009, 2010 and 2011) and historic average monthly rainfall at Iberia Research Station.

DESCRIPTION OF ANIMALS

Spring weaned steer calves (n=54; 257 ± 2.5 kg; 3/8 Gelbvieh, 3/8 Red Angus, and 1/4 Brahman) were used in the evaluation of three forage systems (S1, S2, and S3) for finishing on a 100% forage diet for two consecutive years. Steers were divided into 9 groups based on initial BW (d0) and randomly assigned to replicates within system (3 replicates per system). All systems had the same stocking rate (1.01 ha/head).

FORAGE SYSTEMS

The three system treatments represented different forage systems with different degrees of management complexity and expertise required for appropriate utilization of resources. All systems had the same total area (18 ha per system; 6 ha per replicate). System 1 and 2 had 3 paddocks (Paddocks A, B and C had 45, 35 and 20% of the area, respectively) and System 3 had 5 paddocks (Paddocks A, B, C, D and E representing 20, 20, 45, 7.5, and 7.5% of the area, respectively). Steers in S1 grazed bermudagrass (45% of area) during summer, and ryegrass (35% of area) and ryegrass sod-seeded into bermudagrass paddocks (20% of area) in winter. Steers in S2 grazed bermudagrass (45% of area) in summer, dallisgrass/clover mix (berseem, red and white clovers, 20% of area) during fall and spring, and ryegrass/cereal rye/clover mix (berseem, red and white clovers, 35% of area) during winter. Those in S3 had access to bermudagrass (20% of area), sorghum-sudan hybrid (7.5% of area), and forage soybean during summer (7.5% of area), dallisgrass/clover mix (20% of area) during fall and spring, and ryegrass/cereal rye/clover mix (45% of area) during winter. Excess forage was cut for hay and fed within system when necessary.

ESTABLISHMENT OF PASTURES, FERTILIZATION STRATEGY AND HERBICIDE APPLICATION

Summer Pastures

Three varieties of bermudagrass ('Alicia', 'Jiggs' and 'Tifton85') were already established before the study and one replicate per system was assigned to each variety. All pastures with bermudagrass were fertilized with 244 kg of urea per hectare once and then twice more whenever they were grazed or harvested for hay. In December 2009 and 2010, 'Marshall' ryegrass, was sod-seeded into bermudagrass ('Alicia') for the pastures in S1 using a John Deere no-till drill JD 1590, with 4.5 m of planting width and large and small seed-boxes at rate of 33.6 kg/ha. Two applications (December and February, respectively) of urea (146 kg/ha each one) were used on this pasture for the ryegrass every year.

The pasture assigned for sorghum-sudan hybrid was sprayed with Ranger Pro (41% Glyphosate, 4.7 L/ha, Monsanto, St. Louis, MO) while the pasture assigned for soybean was sprayed with Roundup Power Max (48.7% Glyphosate, 4.7 L/ha, Monsanto, St. Louis, MO) to suppress or kill existing forages. ‘Sweet Sunny’ sorghum-sudan was planted at a rate of 18 kg/ha and ‘Laredo’ soybean was planted at a rate of 67 kg/ha in their respective pastures using a John Deere no-till drill JD 1590, with 4.5 m of planting width and large plus small seed-boxes. A single dose of urea (182 kg/ha) was applied on the sorghum-sudan pasture but none was applied on the soybean pasture. Because of the presence of armyworms on the area, these two pastures were sprayed once with Sevin (Carbaryl (1-naphthyl N-methylcarbamate) 43.0%, Bayer, Research Triangle Park, NC) at a rate of 1.4 kg/ha in August 2009 (First year of the project).

Fall and Spring Pastures

The areas designated for dallisgrass/clover mix were sprayed with 4.7 L/ha of Gramoxone (Paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium dichloride) 30.1%, Syngenta, Greensboro, NC), 9.35 L/ha of Gly Star (Glyphosate, N-(phosphonomethyl)glycine, in the form of its isopropylamine salt 41.0%, Albaugh, Ankeny, IA), 9.35 L/ha of Grazon P+D (picloram: 4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid, triisopropanolamine salt 10.2%; 2,4-dichlorophenoxy acetic acid, triisopropanolamine salt 39.6%, Dow Agrosiences, Indianapolis, IN) and 0.1 kg/ha of Outrider (Sulfosulfuron 75%, Monsanto, St. Louis, MO) to suppress or kill existing forages in an effort to establish the desired species in the pastures.

Dallisgrass was planted in April 2009 at a rate of 13.5 kg/ha using a John Deere no-till drill JD 1590, with 4.5 m of planting width and large plus small seed-boxes. In November 2009, after the grazing period and/or the hay harvest, the clover mix was planted with the same equipment with the rates described below (Table 3.1).

For the second year of the project (2010), dallisgrass was re-planted in August, but maintained the same rate. No fertilization was applied to these pastures in any year.

Table 3.1 Planting rates of clover mix for S2 and S3 spring pastures

Item	Variety	Rate (kg/ha)
Berseem clover (<i>Trifolium alexandrium</i>)	‘BigBee’	22.5
Red clover (<i>Trifolium pratense</i>)	‘Kenland’	16.8
White clover (<i>Trifolium repens</i>)	‘Ladino’	5.6

Winter Pastures

All the winter pastures were sprayed with N-(phosphonomethyl) glycine (glyphosate) (2.34 L/ha – 4.7 L/ha) to kill the volunteer grasses at the beginning of the fall for both years. They were all planted as described in Table 3.2 with the same no-till drill used in the spring pastures. Urea (146 kg/ha) was applied in December followed by a second application at the same rate in February for both years.

HAY PRODUCTION

Hay was harvested during the summer (June to August) in all the systems whenever there was an excess of grass (estimated by visual observation according to forage availability for the animals until next regrowth), but always maximizing grazing days and minimizing days of hay feeding. Individual round bales were labeled with the forage system and replicate origin from which they came and were individually sampled when fed. Hay was fed using circular hay feeders (2.6 m in diameter, 1.3 m in height, with 18 feeder openings) when there was no available forage mass. It was estimated by visual observation to be less than 6 cm of canopy height and/or less than 800 kg/ha of forage mass available. Round hay bales were made using a John Deere JD 275 disc mower and a John Deere JD 567 round baler.

Table 3.2 Planting rates of ryegrass, cereal rye and clover mix for S2 and S3 winter pastures.

Item	Variety	Rate (kg/ha)
Ryegrass (<i>Lolium multiflorum</i>)	‘Marshall’	33.7
Cereal rye (<i>Secale cereale</i>)	‘Elbon’	33.7
Berseem clover (<i>Trifolium alexandrium</i>)	‘BigBee’	16.8
Red clover (<i>Trifolium pratense</i>)	‘Kenland’	11.2
White clover (<i>Trifolium repens</i>)	‘Ladino’	5.6

HERD MANAGEMENT

All systems were managed for maximal grazing days and minimal days of hay feeding. All pastures were rotationally stocked and grazed until pre-determined stubble height (7 to 10 cm for bermudagrass, 15 to 20 cm for sorghum-sudan, 15 to 20 cm for forage soybeans and 10 to 15 cm for ryegrass/clover) through the grazing period. Hay produced within a given system was fed *ad libitum* in round bale feeders to the steers in that same system.

Steers (2009 and 2010) were vaccinated against infectious bovine respiratory syncytial virus, infectious bovine rhinotracheitis, bovine viral diarrhea virus, parainfluenza, and leptospirosis with Bovi-Shield FP 4+VL5 (Pfizer Animal Health, New York City, NY). They were also vaccinated with Vision 8 (Merk Corporate, Animal Health, Summit, NJ). Lastly, bovine *Pneumonic pasteurellosis* was prevented with Once PMH (Bayer Corporation, Agriculture Division, Animal Health, Shawnee Mission, KS). All of these vaccines were administered within two week after the animals arrived at the experimental station (June).

Internal and external parasite control was maintained with a single dose of Cydectin pour-on (Boehringer-Ingelheim Vetmedica, Inc., St. Joseph, MO) in July and two doses of Ivomec Plus Injection for Cattle (Merial Inc., Duluth, GA) in October and February for both years, respectively.

Steers were allowed *ad libitum* access to water and to a mineral and vitamin supplement. Vigortone 3V5 S (Ca 20-24%, P 3.5%, NaCl 18.2-21.8%, Mg 1%, K 0.1%, Cu 2,000 ppm, Se 26.40 ppm, Zn 7,500 ppm, vitamins A 881,057 IU/kg, vitamin D 44,052 IU/kg and vitamin E 441 IU/kg, Provimi Norh America, Brookville, OH) was used for all systems during the summer. During the winter, Purina Range Mineral HI-M HI-SE (Ca 8.0-9.6%, P 4.0%, NaCl 5.5-6.5%, Mg 14%, K 0.4%, Mn 1,750 ppm, Cu 1,100 ppm, Co 50 ppm, I 43 ppm, Se 23 ppm, Zn 3,300 ppm, vitamins A 110,132 IU/kg, vitamin D 11,013 IU/kg and vitamin E 50 IU/kg, Purina Mills, Gray Summit, MO) was used for S1 while Sweetlix Bloat Guard pressed blocks (Poloxalene 6.6%, crude protein 4.0%, crude fat 0.5%, crude fiber 12.5%, salt 19.5-23.0%, K 1.8%, Iodine 43ppm, Selenium 13 ppm, Sweetlix, Mankato,

MN) were used for S2 and S3 to prevent possible bloat caused by red and white clovers. No additional supplements were used.

FORAGE SAMPLING ANALYSIS

Over the growing season, forage mass and height was determined at monthly intervals in paddocks where cattle were grazing or immediately before cattle entered into a new paddock. Standing herbage mass and height were estimated every 28 d by randomly harvesting and measuring five 1 m² squares cut to a 2.5 cm stubble height by garden hand clippers. Pastures were not sampled when visual observation of canopy height was considered to be less than 6 cm and/or forage mass available lower than 800 kg/ha; in these cases, hay bales were sampled instead.

Samples (both forage and hay) were dried in an air oven at 55 °C for 48 h and weighed to determine the percentage of dry matter (DM). They were then ground in a laboratory mill (Thomas Willey, Model 4) and passed through a 2-mm screen. Forage samples from each system/replicate and sampling date were submitted for nutritive value analysis. Those from 2009 were sent to LSU Southeast Research Station and those from 2010 to Dairy One Forage Laboratory. Near Infrared Reflectance Spectroscopy (NIRS) (AOAC-989.03., 1996) was used to estimate the nutritive values of all the samples in both laboratories. Crude protein, ADF, NDF percentages were determined for 2009 and 2010 samples.

ANIMAL PERFORMANCE, HARVESTING AND CARCASS EVALUATION

Starting in June 2009 and 2010, all the steers were weighed every 28 d to monitor performance, and ADG. In May 2010 (first year of the study), 18 steers (6 steers per system) were selected based on body weight (those that were closest to the mean) and harvested in a three-week period. Steers were transported to Roucher's Meat Supply in Plaquemine, Louisiana (147 km or 2 h away from Iberia Research Station) to be humanely harvested and inspected.

In May 2011 (second year of the study), 18 steers (6 steers per system) were selected based on body weight (those that were closest to the mean) and harvested in a two-week period. They were harvested and inspected in the same place and in the same way as those in 2010. Right after harvesting (for both years), the hot carcass weight (HCW) of each steer was taken and the carcasses were placed in a 2 ± 1 °C cooler. Dressing percentage was calculated as:

$$\text{Dressing \%} = (\text{hot carcass weight} / \text{live weight}) * 100$$

Each individual carcass was ribbed between the 11th and 12th ribs and a trained grader evaluated backfat at $\frac{3}{4}$ length of *longissimus* muscle, preliminary yield grade, *longissimus* area, kidney, pelvic and heart percentage, adjusted backfat at $\frac{3}{4}$ length of *longissimus* muscle, lean color and marbling 24 h after harvesting using USDA official grade standards (USDA, 1997). Yield grade was calculated as:

$$\begin{aligned} \text{YG} = & 2.5 + (2.5 \times \text{adjusted backfat at } \frac{3}{4} \text{ length of } \textit{longissimus} \text{ muscle, in.}) + (0.20 \times \text{KPH\%}) \\ & - (0.32 \times \text{ribeye area, sq. in.}) + (0.0038 \times \text{hot carcass weight, lbs.}) \end{aligned}$$

COOKING PROCESS AND SHEAR FORCE

After evaluation, the primal rib was removed from the right side of each carcass and the sample was divided into three parts; one was assigned for total fat extraction and fatty acids analysis while the other two were assigned for 7 and 14 d Warner-Bratzler shear force determination and cooking process. The 7 d and 14 d samples were cut (2.54 cm thick) and individually vacuum packaged and placed in a 3 ± 1 °C cooler and then removed and placed in a -25 ± 1 °C freezer after 7 and 14 days, respectively. After the last group of samples was placed in the freezer, they all remained there until the cooking process. The steaks from 7 and 14 d (Only 7 d for second year of study) were analyzed for Warner-Bratzler shear force using the AMSA research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat (1995). Frozen steaks were removed from the freezer and allowed to thaw 24 h at 4 °C. To measure cooking loss, the raw steaks were weighed and put on a pre-heated grill. Each steak was individually cooked on a Farberware-open hearth broiler to

71 °C internal temperature monitored with copper constantan thermocouples, cooled at room temperature and re-weighed for cooking loss calculation. Cooking loss percentage was calculated as:

$$\text{Cooking loss \%} = [(\text{weight of raw steak after thawing} - \text{weight of cooked steak}) \div \text{weight of raw steak after thawing}] \times 100.$$

After the cooking process, the steaks were put in a zip-lock bag and placed at 4 °C for 24 h. An HD 250 machine (Texture Technology Corp., Scarsdale, NY) with Warner-Bratzler shear apparatus was used to shear the steaks. Four cores (1.3 cm in diameter) were taken from each *longissimus* muscle parallel to the muscle fibers and sheared in the middle of the core perpendicular to the fibers.

TOTAL FAT AND FATTY ACID ANALYSIS

One third of the sample that was taken from every carcass during harvesting (only for the first year of the study) was sent to Southern University Agricultural Research and Extension Center for laboratory analysis of total fat and fatty acids profile. Total fat was determined following AOAC #983.23 standards (AOAC, 2005). Fatty acid profile was determined using a Varian Saturn 2100T GC/MS and followed the AOCS Ce 1b-89 official method standards (Revised in May 2009).

STATISTICAL ANALYSIS

Forage Analysis

Data were divided into three different periods (summer forages, fall-hay, and winter forages). Measurements were taken over time (every 28 days). Statistical analyses reported below were applied to every 28 d-period until the bermudagrass was grazed (summer), until the winter forages were available (fall), and until the end of the experiment (winter).

Response variables were forage mass, percent dry matter (DM), forage height, crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF). Forage mass, forage DM and forage heights were analyzed only for summer and winter periods.

Pasture Management

Response variables of interest for pasture management were grazing days (GD) (for summer and winter periods and as a total of the experiment), days on hay (DH), number of round bales of hay produced (HP) and number of round bales of hay fed (HF).

Animal Performance

Average daily gain (ADG), weight at d 0 (Wd0), final body weight (FBW) and weight gain per ha (WG/ha) were the variables of interest for animal performance. Data were divided into three periods (Summer forages, fall-hay and winter forages) when analyzing ADG. It was calculated every 28 d period following the same pattern as for forage. Weight gain per ha was only analyzed as a total for the experiment.

Carcass, Cooking Process and Shear Force

Response variables of interest for carcass information were dressing percentage, hot carcass weight (HCW), backfat at $\frac{3}{4}$ length *longissimus* muscle (LM), preliminary yield grade (PYG), LM area, kidney pelvic and heart fat percentage (KPH), yield grade (YG), lean color, marbling, cooking loss and WB shear force.

All response variables for forage analysis, pasture management, animal performance, carcass information, cooking loss and WB shear force were analyzed in the model with system (S1, S2 and S3), year (Y1 and Y2) and their interactions as fixed effects. Weight at d 0 was included in the model as a covariate for ADG and FBW as a covariate for all the carcass information, cooking loss and WB shear force. Replicate within system per year was considered the experimental unit for all analyses.

All dependent variables were analyzed using the MIXED procedure of SAS with mean separation conducted using Tukey ($\alpha = 0.05$). The covariance structure selected was compound symmetry and values reported are least square means.

Total Fat and Fatty Acid Analysis

Response variables of interest for this analysis were total fat, saturated fatty acids (SFA), mono unsaturated fatty acids, vaccenic acid (C18:1 *t*11), polyunsaturated fatty acids (PUFA), omega 6 fatty acids, omega 3 fatty acids, CR-SFA, PUFA/SFA, PUFA/CR-SFA, omega-6 to omega-3 ratio and total conjugated linoleic acid (CLA).

All response variables were analyzed only for Y1 and in the model with only system (S1, S2 and S3) as a fixed effect. Replicate within system was considered the experimental unit for all analyses. All dependent variables were analyzed using the MIXED procedure (Littell et al., 1996) of SAS with mean separation conducted using Tukey ($\alpha = 0.05$). The covariance structure selected was compound symmetry and values reported are least square means.

RESULTS

In both years, dry matter percentage, forage mass and forage height were analyzed on a 28 d basis for summer (d0, d28, d56 and d84) and winter forages (d0, d28, d56, d84 and d112), but not for the fall period since animals were fed hay. Crude protein, ADF and NDF were determined for all the forage samples taken during the experiment, including those from the fall period (hay samples).

During the first year, animals from S3 in d28 should have grazed sorghum-sudan. Because of inclement weather, the grass became taller (2 m tall) and more mature than desirable (1.1 to 1.2 m) and they were not able to get on the field at the adequate time. The steers never grazed it and the samples were not taken since they were not going to represent the experimental design.

During the second year, animals from S1 in d28 had to be removed from grazing ryegrass because visual observation of canopy height was considered to be less than 6 cm (they were fed hay for two weeks). The samples were not used for forage dry matter, mass and height. In addition, because of excessive rainfall during December of the first year (more than three times the historical average), the winter grazing season for that year was reduced approximately a 20 d compared to the second year.

Thus, samples of d 112 corresponded only to the second year of the study. Total fat and fatty acid analysis was determined only for animals from the first year of the experiment.

FORAGE ANALYSIS

Dry Matter Percentage

For the summer period, on d0, forage DM percentages were affected by YxS effect. On d28, however, greater ($P < 0.05$) forage DM percentages were found in S1 than in S2 (31 and 26%). No differences ($P > 0.05$) in forage DM percentages among systems or years were found on d56 and d84.

For the winter period, YxS interaction had a significant effect ($P = 0.02$) on DM percentages of d0. No differences ($P > 0.05$) in forage DM percentages were found on d28 and d56 between systems. In d84, forage DM percentages were affected by year and forage DM for Y2 was greater ($P < 0.05$) than for Y1. There was a system effect on d112 and greater ($P < 0.01$) forage DM percentages were found for S1 than for S2 and S3 on d112 (44, 35 and 29 %, respectively and only for Y2).

Table 3.3 Least square means of forage dry matter percentages for S1, S2 and S3 and for Y1 and Y2 for summer and winter periods.

								<i>Pr</i> > F		
Item	S1	S2	S3	SEM	Y1	Y2	SEM	Y	S	Y*S
Summer period										
Day 0	30.00	29.70	26.17	1.40	34.30 ^x	22.90 ^y	1.10	<0.0001	0.1351	0.0479
Day 28	30.21 ^a	26.2 ^b	.	1.33	.	27.20	1.08	0.1405	0.0142	0.8624
Day 56	37.67	35.83	32.67	1.59	35.44	35.33	1.30	0.9529	0.1226	0.4765
Day 84	37.83	37.33	40.33	2.91	37.78	39.22	2.37	0.6750	0.7427	0.5690
Winter period										
Day 0	26.33 ^a	22.67 ^b	22.33 ^b	0.80	24.78	22.78	0.70	0.0642	0.0105	0.0198
Day 28	.	23.75	24.50	1.98	24.00	.	1.44	0.6483	0.8543	0.9269
Day 56	23.67	21.67	21.17	1.42	22.00	22.33	1.16	0.8420	0.4434	0.2607
Day 84	31.00	33.33	36.50	4.30	27.56 ^y	39.67 ^x	3.50	0.0317	0.6729	0.7038
Day 112	44.00	34.67	29.00	1.95	.	35.89	1.12	.	0.0046	.

^{a,b}Least-square means in the same row with different superscripts differ ($P < 0.05$).

^{x,y}Least-square means in the same row with different superscripts differ ($P < 0.05$).

Forage Mass

During the summer period, year had a significant effect (Table 3.4) in the forage mass of d0 sample date, and more ($P < 0.01$) forage mass was found in Y1 than in Y2 among the 3 systems. No

significant differences ($P > 0.05$) in forage mass were found on d28. In d56, forage mass was found to be greater ($P < 0.01$) for Y2 than for Y1. Forage mass for S1 was also greater ($P < 0.01$) than for S2 and S3 in both years. Forage mass in d84 was affected ($P < 0.05$) by the YxS effect.

Table 3.4 Least square means of forage mass (kg/ha) for S1, S2 and S3 and for Y1 and Y2 for summer and winter periods.

								<i>Pr</i> > F		
Item	S1	S2	S3	SEM	Y1	Y2	SEM	Y	S	Y*S
Summer period										
Day 0	3577.2	3445.3	3759.2	486.9	5030.1 ^x	2157.7 ^y	397.5	0.0003	0.9014	0.5164
Day 28	3656.5	3231.7	.	428.6	.	3327.7	349.0	0.8418	0.6177	0.4831
Day 56	5597.8 ^a	4134.7 ^b	3847.1 ^b	269.5	3888.2 ^y	5164.8 ^x	220.0	0.0015	0.0013	0.2334
Day 84	3987.5	3132.2	3523.8	296.0	3414.9	3680.8	241.6	0.4516	0.1660	0.0398
Winter period										
Day 0	1328.7 ^b	1838.3 ^{ab}	2122.2 ^a	182.0	1672.8	1853.3	148.6	0.4072	0.0282	0.1450
Day 28	.	1826.8	2033.8	272.4	1949.3	.	198.9	0.3653	0.4917	0.7383
Day 56	1952.2	2544.7	2330.3	258.6	3098.7 ^x	1452.6 ^y	211.1	0.0001	0.2969	0.4734
Day 84	3034.3 ^b	3461.5 ^{ab}	4426.7 ^a	313.2	4882.7 ^x	2399.0 ^y	255.7	<0.0001	0.0238	0.2432
Day 112	3579.3	3904.7	3335.0	550.1	.	3606.0	317.6	.	0.7723	.

^{a,b}Least-square means in the same row with different superscripts differ ($P < 0.05$)

^{x,y}Least-square means in the same row with different superscripts differ ($P < 0.05$)

On d0 of the winter period, forage mass for S3 was greater ($P < 0.05$) than for S1, and S2 was intermediate. Forage mass was not different ($P > 0.05$) among systems on d28, but more ($P < 0.0001$) forage mass was found in Y1 than in Y2 among the three systems on d56. On d84, forage mass for S3 was greater ($P < 0.05$) than for S1, and S2 was intermediate. There was also a year effect and forage mass was greater ($P < 0.0001$) for Y1 than for Y2. Forage mass was not different ($P > 0.05$) among systems on d112 (for Y2, only).

Forage Height

Systems forage heights were not significantly different ($P > 0.05$, Table 3.5) at the beginning of the summer period (d0 and d28). On d56, however, there was a year effect and greater ($P < 0.0001$) forage heights were found for Y2 than for Y1. Forage heights were also greater for S1 ($P < 0.05$) than for S2 and S3 in that same sampling date. On d84, forage heights were also greater ($P < 0.001$) for Y2 than for Y1. During the winter period, forage heights on d0 were affected ($P < 0.01$) by YxS effect. On

d28, forage heights were not significantly different ($P > 0.05$) among systems. Forage heights were greater ($P < 0.001$) for Y2 than for Y1 on d56, but greater ($P < 0.0001$) for Y1 than for Y2 on d84. Forage heights were not different ($P > 0.05$) among systems on d112 (for Y2, only).

Table 3.5 Least square means of forage heights (cm) for S1, S2 and S3 and for Y1 and Y2 for summer and winter periods.

								<i>Pr</i> > F		
Item	S1	S2	S3	SEM	Y1	Y2	SEM	Y	S	Y*S
Summer period										
Day 0	45.11	42.58	45.22	2.73	42.55	46.06	2.23	0.2884	0.7471	0.6844
Day 28	44.40	40.41	.	3.00	.	43.80	2.45	0.0943	0.2682	0.2571
Day 56	37.93 ^a	31.02 ^b	31.25 ^b	1.94	26.62 ^y	40.17 ^x	1.58	<0.0001	0.0447	0.9505
Day 84	28.36	30.12	31.44	3.04	22.18 ^y	37.76 ^x	2.48	0.0008	0.7771	0.9588
Winter period										
Day 0	14.64 ^b	18.63 ^a	20.48 ^a	0.82	16.4 ^y	19.44 ^x	0.67	0.0074	0.0009	0.0012
Day 28	.	17.35	17.43	2.10	15.52	.	1.54	0.9904	0.2748	0.5474
Day 56	32.41	32.02	29.02	2.21	24.14 ^y	38.16 ^x	1.80	0.0001	0.5145	0.1855
Day 84	46.82	42.33	45.09	2.13	67.54 ^x	21.95 ^y	1.74	<0.0001	0.3579	0.0514
Day 112	.	.	.	62.95	62.39	54.83	4.45	.	0.4102	.

^{a,b}Least-square means in the same row with different superscripts differ ($P < 0.05$)

^{x,y}Least-square means in the same row with different superscripts differ ($P < 0.05$)

Forage CP

During the summer period, forage CP was affected ($P < 0.01$, Table 3.6) by YxS interaction on d0. There were no significant differences ($P > 0.05$) on forage CP among systems on d28. On d56, forage CP was greater ($P < 0.05$) for Y2 than for Y1. There were also significant differences between systems and forage CP for S3 were greater ($P < 0.05$) than for S1 and S2 was intermediate. There were no significant differences ($P > 0.05$) on forage CP among systems on d84.

No significant differences in forage CP were found on d0 of the fall period, but YxS interaction affected the samples on d28. For the winter period, on d0, forage CP was greater ($P < 0.01$) for Y2 than for Y1. There were no significant differences ($P > 0.05$) on forage CP among systems on d28. On d56, forage CP was also greater ($P < 0.05$) for Y2 than for Y1. On d84, samples were affected ($P < 0.0001$) by YxS interaction. Significant differences on forage CP among systems were found on d112

and values for S3 were greater ($P < 0.05$) than for S1 while those for S2 were intermediate (for Y2, only).

Table 3.6 Least square means of forage CP percentage for S1, S2 and S3 and for Y1 and Y2 for summer, fall and winter periods.

								<i>Pr</i> > F		
Item	S1	S2	S3	SEM	Y1	Y2	SEM	Y	S	Y*S
Summer period										
Day 0	10.76 ^b	10.95 ^b	12.33 ^a	0.32	9.23 ^y	13.47 ^x	0.26	<0.0001	0.0096	0.0099
Day 28	11.78	13.83	.	1.21	.	13.73	0.99	0.0808	0.3217	0.3662
Day 56	7.38 ^b	8.3 ^{ab}	8.95 ^a	0.32	7.76 ^y	8.67 ^x	0.26	0.0279	0.0140	0.1723
Day 84	10.62	9.13	7.92	1.19	7.87	10.58	0.97	0.0713	0.3087	0.2074
Fall period										
Day 0	10.00	7.65	8.18	0.76	8.33	8.89	0.62	0.5387	0.1132	0.4467
Day 28	8.68 ^a	6.62 ^b	6.73 ^b	0.47	6.78	7.91	0.38	0.0584	0.0147	0.0166
Winter period										
Day 0	12.50	15.35	15.83	1.04	12.42 ^y	16.7 ^x	0.85	0.0038	0.0869	0.0779
Day 28	.	14.07	16.87	1.80	15.74	.	1.47	0.4970	0.4750	0.9148
Day 56	14.58	15.65	18.53	1.05	14.44 ^y	18.07 ^x	0.86	0.0113	0.0531	0.0578
Day 84	10.95 ^b	12.65 ^{ab}	13.9 ^a	0.72	9.54 ^y	15.45 ^x	0.59	<0.0001	0.0414	0.0141
Day 112	7.47 ^b	11.6 ^{ab}	14.33 ^a	1.08	.	11.13	0.62	.	0.0116	.

^{a,b}Least-square means in the same row with different superscripts differ ($P < 0.05$)

^{x,y}Least-square means in the same row with different superscripts differ ($P < 0.05$)

Forage ADF

Along with forage CP in the summer period, forage ADF was affected ($P < 0.05$, Table 3.7) by YxS interaction on d0. For the remaining sample dates (d28, d56 and d84) forage ADF was not different among systems, but constantly greater ($P < 0.05$) for Y2 than for Y1 in all of them. Forage ADF was greater ($P < 0.01$) for Y2 than for Y1 for the first sample date of the fall period (d0).

Similar to CP values, ADF values were significantly affected by YxS interaction ($P < 0.05$) on d28 of the fall. Forage ADF was greater ($P < 0.01$) for Y2 than for Y1 in the first 3 sample dates of the winter (d0, d28 and d56) with no significant differences ($P > 0.05$) among systems. There were no significant differences ($P > 0.05$) on d84, but ADF was different on d112 and S1 was greater ($P < 0.05$) than S3 (for Y2, only).

Table 3.7 Least square means of forage ADF percentage for S1, S2 and S3 and for Y1 and Y2 for summer, fall and winter periods.

Summer, fall and winter periods.										
Item	S1	S2	S3	SEM	Y1	Y2	SEM	Pr > F		
								Y	S	Y*S
Summer period										
Day 0	38.12	37.87	36.31	0.64	33.86 ^y	41 ^x	0.52	<0.0001	0.1405	0.0195
Day 28	36.45	36.75	.	1.29	.	40.81	1.05	0.0026	0.7244	0.1232
Day 56	39.61	39.68	39.75	0.70	36.06 ^y	43.31 ^x	0.57	<0.0001	0.9909	0.6422
Day 84	38.75	37.75	38.05	1.28	36.46 ^y	39.91 ^x	1.04	0.0372	0.8528	0.1841
Fall period										
Day 0	37.15	39.40	40.50	1.73	34.66 ^y	43.38 ^x	1.41	0.0009	0.4059	0.3523
Day 28	38.8 ^b	44.92 ^a	43.83 ^a	1.19	38.01 ^y	47.02 ^x	0.97	<0.0001	0.0078	0.4490
Winter period										
Day 0	20.31	21.23	20.30	0.79	13.26 ^y	27.98 ^x	0.64	<0.0001	0.6428	0.1443
Day 28	.	27.05	23.75	2.05	21.33	.	1.68	0.0003	0.0798	0.0794
Day 56	25.93	24.57	27.70	1.07	23.56 ^y	28.58 ^x	0.87	0.0016	0.1590	0.8293
Day 84	33.42	32.72	34.05	0.80	32.78	34.01	0.65	0.2055	0.5164	0.4916
Day 112	43.93 ^a	39.53 ^{ab}	36.27 ^b	1.43	.	39.91	0.82	.	0.0248	.

^{a,b}Least-square means in the same row with different superscripts differ ($P < 0.05$)

^{x,y}Least-square means in the same row with different superscripts differ ($P < 0.05$)

Forage NDF

As it was for forage CP and ADF, during the summer period, forage NDF was affected ($P < 0.01$, Table 3.8) by YxS interaction on d0. Opposite to forage ADF, forage NDF was greater ($P < 0.05$) for Y2 than for Y1 on d28, but no significant differences ($P > 0.05$) were found among the systems. There were no differences ($P > 0.05$) in forage NDF on d56 and d84.

As it was for ADF, in both sampling dates of the fall (d0 and d28) forage NDF was greater ($P < 0.01$) for Y2 than for Y1. During the winter, NDF on d0 was also greater ($P < 0.0001$) for Y2 than for Y1. Samples of d28 were affected by YxS effect ($P < 0.05$).

There were no significant differences ($P > 0.05$) on forage NDF among the systems on d56, but samples of d84 were affected by YxS effect ($P < 0.05$). On d112, as it was for forage ADF and forage CP, forage NDF was significantly different among systems (72.5, 62.33 and 56.17% for S1, S2 and S3, respectively and for Y2, only).

Table 3.8 Least square means of forage NDF percentage for S1, S2 and S3 and for Y1 and Y2 for summer, fall and winter periods.

Summer, fall and winter periods.										
Item	S1	S2	S3	SEM	Y1	Y2	SEM	Pr > F		
								Y	S	Y*S
Summer period										
Day 0	68.95 ^a	67.85 ^{ab}	63.62 ^b	1.22	65.01 ^y	68.6 ^x	1.00	0.0258	0.0223	0.0047
Day 28	67.80	67.65	.	1.40	.	70.01	1.15	0.0135	0.7043	0.4081
Day 56	69.90	69.63	70.97	0.96	69.27	71.07	0.79	0.1318	0.5986	0.5680
Day 84	68.55	68.35	68.60	1.01	68.78	68.22	0.83	0.6424	0.9830	0.3453
Fall period										
Day 0	67.42	70.17	71.15	1.49	66.28 ^y	72.87 ^x	1.22	0.0025	0.2272	0.7037
Day 28	67.98	69.85	70.80	1.26	66.36 ^y	72.73 ^x	1.03	0.0009	0.3120	0.9347
Winter period										
Day 0	38.68	38.52	39.03	1.16	34.13 ^y	43.35 ^x	0.95	<0.0001	0.9500	0.2261
Day 28	.	45.77 ^a	39.75 ^b	3.10	39.61	.	2.54	0.0009	0.0069	0.0365
Day 56	47.33	44.22	43.65	1.66	45.74	44.39	1.35	0.4917	0.2760	0.1465
Day 84	58.62	54.13	55.92	1.50	60.58	51.87	1.22	0.0003	0.1450	0.0276
Day 112	72.5 ^a	62.33 ^b	56.17 ^b	1.77	.	63.67	1.02	.	0.0018	.

^{a,b}Least-square means in the same row with different superscripts differ ($P < 0.05$)

^{x,y}Least-square means in the same row with different superscripts differ ($P < 0.05$)

PASTURE MANAGEMENT

Significant differences ($P < 0.05$, Table 3.9) were found in GD during the summer period among the systems. Summer grazing days for S1 and S2 were significantly greater ($P < 0.05$) than for S3. That caused an effect in total GD and DH making them significantly different ($P > 0.05$) among the systems.

Table 3.9 Least square means of grazing days (for summer and winter periods and as a total), total days on hay, total hay produced and total hay fed for S1, S2 and S3 and for Y1 and Y2.

Item	S1	S2	S3	SEM	Y1	Y2	SEM	<i>Pr > F</i>		
								Y	S	Y*S
Summer grazing days	146 ^a	146 ^a	127 ^b	4.49	141	138	3.67	0.5738	0.0151	0.9636
Winter grazing days	105	105	105	.	92	118
Total grazing days	246 ^{ab}	251 ^a	231 ^b	4.49	233 ^y	253 ^x	233	0.0026	0.0279	0.5781
Total days on hay	50 ^{ab}	45 ^b	64 ^a	4.49	62 ^x	44 ^y	3.66	0.0052	0.0279	0.5781
Total round hay bales produced	68 ^a	45 ^b	15 ^c	3.61	28 ^b	58 ^a	2.95	<0.0001	<0.0001	0.0031
Total round hay bales fed	5.16	5.00	5.83	0.46	7.00 ^x	3.66 ^y	0.38	<0.0001	0.4275	0.8789

^{a,b}Least-square means in the same row with different superscripts differ ($P < 0.05$)

^{x,y}Least-square means in the same row with different superscripts differ ($P < 0.05$)

Animals in S2 grazed more days and spent fewer days on hay ($P < 0.05$) than animals in S3 during the experiment and S1 was intermediate. There was also a year effect ($P < 0.05$) in total GD and animals in Y1 grazed fewer ($P < 0.01$) days than those in Y2. The number of round bales of hay produced was affected ($P < 0.01$) by the interaction YxS. More ($P < 0.0001$) round hay bales were fed in Y1 than in Y2, but there were no significant differences ($P < 0.05$) among systems.

ANIMAL PERFORMANCE

Animals from Y1 started with a significantly greater ($P < 0.0001$, Table 3.10) body weight on d0 (Wd0) compared to those from Y2. Average daily gains on d0 to d28 for the summer period were significantly greater ($P < 0.05$, Table 3.11) for S1 and S2 than for S3. There were no differences ($P > 0.05$) in ADG from d28 to d56. Animals in Y2 gained more ($P < 0.05$) than those in Y1 from d56 to d84 and from d84 to d112.

Table 3.10 Least square means of weight at d0 (kg), final weight (kg) and weight gain per ha (kg/ha) for S1, S2 and S3 and for Y1 and Y2.

Item	S1	S2	S3	SEM	Y1	Y2	SEM	<i>Pr > F</i>		
								Y	S	Y*S
Weight at d0	262.96	260.32	264.3	2.50	276.71 ^x	247.67 ^y	2.12	<0.0001	0.5637	0.5446
Final weight	460.96	458.19	451.49	7.14	448.74	465.02	5.93	0.0737	0.6480	0.3650
Weight gain per ha	197.03	195.92	215.92	16.95	170.62 ^y	235.05 ^x	14.01	0.0066	0.6705	0.1901

^{x,y}Least-square means in the same row with different superscripts differ ($P < 0.05$)

During the fall, animals in Y2 also gained more ($P < 0.05$) from d0 to d28, but there were no differences ($P > 0.05$) in ADG from d28 to d56 or from d56 to d84 (for Y1, only). For the winter period, no differences were found in ADG from d0 to d28. From d28 to d56, ADG was significantly different ($P < 0.05$) among the systems and there was also a year effect ($P < 0.0001$). Animals on S1 in Y2 had to be removed from grazing because visual observation of canopy height was considered to be less than 6 cm (they were fed hay for a couple of weeks). There was also a year effect in ADG from d56 to d84 and ADG for Y2 were greater ($P < 0.05$) than for Y1. No differences were found in ADG from d84 to d112 (for Y2, only).

For the total summer period, ADG for Y2 were greater ($P < 0.0001$) than for Y1 but no significant differences ($P > 0.05$) were found among the systems. On the contrary, ADG for Y1 was greater ($P < 0.05$) than for Y2 for the total winter period, but no significant differences ($P > 0.05$) were found among the systems either. There was no year effect ($P > 0.05$) for the total fall period, but ADG for S1 was greater ($P < 0.05$) than S3, and ADG for S2 was intermediate.

No significant differences ($P > 0.05$) were found in ADG for the total experiment among the systems, but animals in Y2 gained ($P < 0.0001$) more than those in Y1. Consequently, WG/ha was greater ($P < 0.0001$) for Y2 than for Y1, but not significantly different ($P > 0.05$) among the systems. No significant differences ($P > 0.05$) were found in FBW.

Table 3.11 Least square means of ADG (kg/d) for summer, fall and winter periods (for every 28day sub-period and as a total for every period) and as a total of the study for S1, S2 and S3 and for Y1 and Y2.

								<i>Pr > F</i>		
Item	S1	S2	S3	SEM	Y1	Y2	SEM	Y	S	Y*S
Summer period										
d0 to d28	0.41 ^a	0.47 ^a	-0.1 ^b	0.15	0.20	0.32	0.12	0.4864	0.0375	0.6262
d28 to d56	0.36	0.52	0.63	0.16	0.47	0.54	0.14	0.7301	0.5122	0.3129
d56 to d84	0.49	0.38	0.42	0.12	0.09 ^y	0.76 ^x	0.10	0.0002	0.8053	0.2321
d84 to d112	0.29	0.06	0.15	0.10	0.03 ^y	0.31 ^x	0.09	0.0392	0.3077	0.2696
Fall period										
d0 to d28	0.18	0.17	0.12	0.06	0.02 ^y	0.30 ^x	0.05	0.0008	0.6828	0.8394
d28 to d56	0.07	-0.05	-0.16	0.06	-0.06	-0.03	0.05	0.7102	0.0721	0.0696
d56 to d84	-0.56	-0.82	-0.86	0.31	-0.74	.	0.18	.	0.7624	.
Winter period										
d0 to d28	0.98	1.08	1.08	0.16	1.16	0.93	0.13	0.2514	0.8757	0.7174
d28 to d56	1.05 ^b	1.6 ^a	1.53 ^a	0.12	1.82 ^x	0.97 ^y	0.10	<0.0001	0.0142	0.0684
d56 to d84	1.69	1.77	1.58	0.10	1.51 ^y	1.84 ^x	0.09	0.0176	0.4293	0.9752
d84 to d112	1.51	0.80	1.70	0.31	.	1.34	0.18	.	0.1764	.
Total periods										
Summer	0.39	0.37	0.30	0.02	0.21 ^y	0.50 ^x	0.02	<0.0001	0.1213	0.7931
Fall	0.25 ^a	0.08 ^{ab}	0.00 ^b	0.06	0.09	0.13	0.05	0.5481	0.0267	0.8017
Winter	1.31	1.44	1.45	0.07	1.50 ^x	1.30 ^y	0.06	0.0339	0.3426	0.4442
Total study	0.67	0.67	0.63	0.02	0.58 ^y	0.74 ^x	0.02	<0.0001	0.3237	0.1576

^{a,b}Least-square means in the same row with different superscripts differ ($P < 0.05$)

^{x,y}Least-square means in the same row with different superscripts differ ($P < 0.05$)

CARCASS, COOKING PROCESS AND SHEAR FORCE

No significant differences ($P > 0.05$, Table 3.12) were found in LM area, KPH, YG, lean color and marbling. Dressing percentage and carcass weight from S3 were greater ($P < 0.05$) than those from S1 and S2 was intermediate.

Backfat and PYG were affected by YxS interaction ($P < 0.05$). In addition, cooking loss and WB shear were significantly affected ($P < 0.01$) by year effect and they were both greater ($P < 0.01$) for Y1 than for Y2.

Table 3.12 Least square means of carcass data, cooking loss and WB shear force for S1, S2 and S3 and for Y1 and Y2.

Item	S1	S2	S3	SEM	Y1	Y2	SEM	<i>Pr > F</i>		
								Y	S	Y*S
Dressing, %	53.71 ^b	55.68 ^{ab}	56.38 ^a	0.60	55.83	54.68	0.53	0.1639	0.0112	0.3686
Hot carcass weight, kg	262.63 ^b	272.59 ^{ab}	275.45 ^a	2.96	272.97	267.47	2.62	0.1791	0.0129	0.3767
Backfat, mm	4.52	5.08	3.52	0.60	6.21 ^x	2.53 ^y	0.57	0.0002	0.2454	0.0483
Preliminary Yield Grade	2.38	2.48	2.28	0.07	2.44	2.32	0.06	0.1755	0.2239	0.0498
<i>Longissimus</i> muscle area, cm ²	63.27	60.35	65.89	2.01	64.35	61.99	1.79	0.3952	0.1775	0.9500
Kidney, pelvic and heart fat, %	1.24	1.50	1.11	0.21	1.32	1.23	0.18	0.7523	0.4463	0.3872
Yield grade, YG	2.23	2.61	2.08	0.16	2.35	2.27	0.14	0.6895	0.0694	0.2866
Lean color ^d	215.41	200.39	210.04	29.20	178.13	239.10	25.87	0.1329	0.9338	0.1706
Marbling ^e	247.95	244.51	239.63	16.95	251.36	236.70	15.03	0.5272	0.9434	0.2605
Cooking loss, %	25.86	28.03	27.11	1.32	29.63 ^x	24.37 ^y	1.16	0.0060	0.5073	0.4777
WB Shear, kg	4.71	4.91	5.01	0.41	6.27 ^x	3.48 ^y	0.36	<0.0001	0.8724	0.8699

^{a,b}Least-square means in the same row with different superscripts differ ($P < 0.05$)

^{x,y}Least-square means in the same row with different superscripts differ ($P < 0.05$)

^dLean color: A maturity = 100-199, B maturity = 200-299, dark cutters = 500

^eMarbling score: Practically devoid = 100-199, traces = 200-299, slight = 300-399, small = 400 to 499, etc.

TOTAL FAT AND FATTY ACID ANALYSIS

No significant differences ($P < 0.05$, Table 3.13) were found for total fat, SFA, MUFA, vaccenic acid (C18:1 t11), PUFA, omega 6, omega 3, omega-6 to omega-3 ratio, CR-SFA, PUFA/SFA and total CLA for S1, S2 and S3 (for Y1, only).

Table 3.13 Least square means of total fat as a percentage of muscle, SFA, MUFA, vaccenic acid (C18:1 *n*-7), PUFA, omega 6, omega 3, CR-SFA, and total CLA as a percentage of total fat, and omega-6 to omega-3 and PUFA/SFA ratios for S1, S2 and S3 for the first year of the experiment.

Item	S1	S2	S3	SEM	Pr>F
Total Fat	5.60	4.50	4.56	0.53	0.5158
SFA	50.40	51.00	54.58	2.08	0.4106
MUFA	39.70	38.04	33.04	2.33	0.1830
C18:1 <i>n</i> -7	5.41	5.14	4.31	1.69	0.8611
PUFA	5.62	7.17	7.45	0.85	0.3405
Omega 6	3.36	4.75	4.55	0.69	0.3691
Omega 3	2.18	2.47	2.92	0.33	0.3651
CR-SFA	23.12	24.08	24.21	0.95	0.6947
PUFA/SFA	0.11	0.14	0.14	0.02	0.4463
PUFA/CR-SFA	0.24	0.31	0.32	0.04	0.4066
Omega 6 : Omega 3	1.51	1.88	1.65	0.24	0.6262
Total CLA	1.29	1.64	1.92	0.16	0.1227

DISCUSSION OF RESULTS

Forage samples were taken every 28 days in conjunction with cattle weights and there were some exceptions as mentioned before. During the first year, animals in S3 never grazed sorghum-sudan and the samples were not taken since they were not going to represent the experimental design. During the second year, animals in S1 on d28 were removed from grazing ryegrass because visual observation of canopy height was considered to be less than 6 cm (they were fed hay for a couple of weeks).

Temperatures during both years of the experiment (2009-2010 and 2010-2011) were very similar month-by-month. February and March, however, were cooler for Y1 (7.7 and 13.1 for February and March, respectively) than for Y2 (11.6 and 18.22 for February and March, respectively).

On the other hand, yearly rainfall was different for the two years of the experiment. Rainfall for the first three months of the summer (June, July and August) was greater for Y2 (183, 408 and 180 mm, respectively) than for Y1 (143, 175 and 114 mm, respectively). Rainfall in July for Y2 (408 mm) was more than twice the historical average value for that month (175 mm). In September and October, however, rainfall was greater for Y1 (358 and 331 mm, respectively) than for Y2 (61 and 44 mm, respectively) and more than twice the historical average rainfall for those two months (164 and 125

mm, respectively). December's rainfall for Y1 (479 mm) was more than three times the average historical value (127 mm) while it was almost only half of it for Y2 (75 mm). During January and March, it rained less than half in Y1 (37 and 42 mm, respectively) than what it rained in Y2 (83 and 72 mm, respectively), while it rained more than twice as much during February, April and May (154, 31, 82 mm, respectively) in Y1 than the rain received in Y2 (36, 13 and 10 mm, respectively).

FORAGE ANALYSIS

Differences in rainfall and fertilization date (weather dependent) may have contributed to the differences found in forage mass, forage height, CP, ADF and NDF among the years in almost every sampling date. For the summer period (bermudagrass pastures), fertilizer was applied closer to the sampling dates followed by greater rainfall in Y2 than in Y1, which could have led to greater values of forage mass, CP, ADF and NDF. Bermudagrass plants were also shorter and less mature (as noticed in forage height) in Y1 than in Y2 adding to the difference in ADF and NDF between the two years during the summer period. The present study found lower values of CP (10.1%), greater values of ADF (38.2%) and similar values of NDF (69%) for bermudagrass (S1) than previous studies. Hill et al. (1997) found values ranging from 14.9 to 17.5% for CP, from 33.1 to 32.4% for ADF and from 72.5 to 71.0 for NDF for the total summer grazing season comparing three cultivars in a two-year study. Twidwell (2010) stated that values of CP and NDF for 'Russell', 'Coastal', and 'Tifton85' bermudagrass were found to be 11.6, 12.3 and 12.5 for CP and 70, 69 and 70 for NDF, respectively, for Homer, LA. He also reported that his values were similar to other studies made in Alabama.

Differences could be attributed to two main factors: season length and weather conditions. Most previous studies focused on finding performance of steers in a shorter season (May to August or early September) than the one designed for this experiment (June to November). Their main purpose was to maximize performance of steers only rather than maximizing performance of steers and extending the grazing period at the same time. The last two extra months considered in the present experiment, provided the lowest nutritive quality forage (lower CP and greater ADF and NDF) to the animals

affecting the nutritive value averages. In addition, the studies made by Hill et al (1997) and Twidwell (2010) were performed in Georgia and north Louisiana, respectively. Values of temperature and humidity in both places are lower than those at the Iberia Research Station (South of Louisiana) and it has been reported that high temperatures adversely affect nutritive value of bermudagrass by increasing plant maturity and lignification (Henderson and Robinson, 1982a).

On the other hand, CP was greater for S3 than S1, and S2 was intermediate throughout the summer period except for the last sampling date (affected by YxS effect). Animals in S3 had less area designated to bermudagrass than those in S1 and S2, which increased the stocking rate on bermudagrass paddocks. Animals were able to keep the plants younger than those on the other systems which increased the nutritive value of the grass. In addition, for d0 and d28, animals in S2 grazed dallisgrass/clover mix and animals in S3 grazed either sorghum-suddan, dallisgrass/clover mix or soybean which have greater values of CP than those of bermudagrass (Ball et al., 2007). Differently, ADF and NDF were similar among the systems throughout the summer period.

During the fall, the hay that was made from the bermudagrass fields from each system was fed to the animals of each individual same system. More hay was made earlier in the season for S1 than for S2 and S3 because of more area available for bermudagrass. That could increase the nutritive value of the hay (greater CP and lower ADF) and explain the results of the study. Crude protein was greater for S1 than for S3 and ADF was lower for S1 than for S3. System 2 was intermediate in both cases.

For the winter period, d0 for Y1 started at the end of January while d0 for Y2 started 20 days earlier. Since December's rainfall for Y1 was more than three times the historical average and the pastures were flooded for several weeks, the germination of the plants was retarded. This effect was reflected in the pasture height, ADF, NDF percentages. They were greater for Y2 than for Y1 throughout the winter period because of plant maturity. In addition, fertilization for Y1 was done later than planned because the fields were flooded. That made the fertilization date closer to the sampling

date for Y2 than for Y1. For the same reason, greater values of CP for Y2 than for Y1 were found in every sampling date throughout the winter period.

The present study found lower values of CP for ryegrass (S1) than those reported by Roberts et al. (2009) in an Alabama study. They reported values of CP starting at 20% in January, peaking at 27% in March and decreasing linearly to 10% in May compared to 12.5, 14.5 and 7.5% for this study, respectively. Similarly, Redfearn et al. (2002) reported greater values of CP compared to this study. They stated that CP concentration differed significantly among harvest with general decrease from 26 to 12% as the growing season progressed. Roberts et al. (2009) also reported that ADF and NDF concentrations increased linearly throughout the grazing season from 16 and 34% in January to 33 and 62% in May, respectively. This study found ADF and NDF to be 20.3 and 39% in January to 44 and 73% in May, respectively.

The addition of clovers and cereal rye to the ryegrass did not affect the CP, ADF or NDF concentrations for the first part of the winter period (systems were not significantly different). However, S3 had greater CP and lower ADF and NDF concentrations than those for S1 in the last two sampling dates of the winter period. Concentrations of CP, ADF and NDF for S2 were intermediate. The use of clovers in the forage mix helps to extend the forage grazing season conserving high forage nutritive values at the end of the winter grazing season. According to Ball et al. (2007), berseem, red and white clovers grazing season extends until June while the ryegrass grazing season finishes in May. The use of clovers in the forage mix provided not only a more digestible diet, but also more forage mass for animals in S2 and S3 at the end of the winter period.

In addition, during the first half of the winter period, forage mass for Y2 was greater than that from Y1. However, forage mass for Y1 was greater than for Y2 in the second half. Although the last half of the winter period for both years was drier (less rainfall) than the average historic rainfall, it rained eight times more in Y1 than in Y2 leading to greater yields for Y1 than for Y2 (Ball et al., 2007). Moreover, Redfearn et al. (2002) reported 60% of total forage production of ryegrass occurring

in late-season (March-May) growth and approximately 30% of the total production occurring during in April alone. In the present study, the last three samples of the winter reported that forage mass for Y1 was two times more than for Y2.

PASTURE MANAGEMENT AND ANIMAL PERFORMANCE

Although weight on d0 for animals in Y1 was greater than in Y2, final weight for both years was not different. Because of the experimental design, animals started with similar weight on d0 among the systems each year. During the summer period, since S3 had less area available for summer forages, animals in S3 grazed fewer days than those in S1 and S2. In addition, for d0 and d28 (by experimental design) animals in S3 grazed either sorghum-suddan, dallisgrass/clover mix or soybean. Animals in Y1, however, could not graze sorghum-sudan reducing the forage available for them. During d0 to d28, ADG for S3 was lower than for S1 and S2 because some animals from S3 were sick and lost weight at the beginning of Y1. However there were no more significant differences among the systems during the summer period concluding that the addition of sorghum-suddan, dallisgrass/clover mix or soybean did not make a difference in animal performance for the total period. On the other hand, ADG for Y1 was lower than for Y2. As explained before, forage mass and nutritive value (greater CP, and lower ADF and NDF) was greater for Y2 than for Y1 which could have led to the differences among the years.

In the study made by Hill et al. (1997) it was stated that ADG was unaffected ($P > 0.1$) by bermudagrass cultivar with values ranging from 0.65 to 0.74 kg/d. In addition, Twidwell (2010), in a review of bermudagrass forage and animal performance, also found similar ADG for steers grazing bermudagrass ranging from 0.63 to 0.82 kg/d after concluding a 4-year study evaluating steer performance on 4 different cultivars ('Brazos', 'Grazer', 'Coastal' and 'Tifton 44') in Homer, LA. In a different study, Bagley et al. (1987) found ADG to be 0.46 kg/d using fall born steers grazing bermudagrass in different research stations around Louisiana (including the Iberia Research Station). The present study, however, found lower values of ADG (0.39 kg/d) than those three studies.

As stated before, those studies were performed in Georgia and in north Louisiana, respectively. Values of temperature and humidity in both places are lower than those at the Iberia Research Station (South of Louisiana). It has been reported that high temperatures adversely affect nutritive value of bermudagrass by increasing plant maturity and lignification (Henderson and Robinson, 1982a). Additionally, Henderson and Robinson (1982a) also reported that reduced cattle weight gain can be partially attributed to the adverse effects of high ambient temperature and humidity on dry matter intake.

During the fall period, animals in S3 were fed hay earlier than those in S1 and S2 because of lack of summer forage availability. Therefore, total days on hay were greater for S3 than for S1 and S2. Although all the systems lost weight at the end of the fall period (d56 to d84), the ADG for all the groups for the whole fall period was positive (greater than zero), and greater for S1 than for S3 (S2 was intermediate). As explained before, the nutritive value (high CP and low ADF) of the hay produced from S1 was greater than the hay produced for S2 and S3 which could explain these results.

For the winter period, as explained before, d0 for Y2 started 20 days earlier than for Y1. In addition, pasture height, ADF, NDF were greater for Y2 than for Y1 throughout the winter period due to plant maturity. Moreover, there was more forage mass available for animals in Y2 than for those in Y1 during the first half of the winter period, but less during the second half. According to Redfearn et al. (2002), 60% of total forage production of ryegrass occurs in late-season (March-May). In our study, animals in Y1 had twice more forage mass during March and April than those in Y2. That could have led to more forage available, better utilization of the forage by the animals, and greater ADG for animals in Y1 than for those in Y2 during the winter period.

There have been several studies conducted to determine animal performance on annual ryegrass. The present study (S1) found greater ADG (1.31 kg/d) than earlier studies for the total winter period. Roberts et al. (2009) finished steers on annual ryegrass and reported ADG to be 1.04 kg/d from December to May. Different from the present study, they started the grazing season in December

where the temperatures and forage availability are lowest which possibly lead to lower ADG values. Hafley (1996) reported ADG to be 0.92 kg/d for steers grazing annual ryegrass at the same research station as the present study. Although the grazing seasons were similar in time of the year and period length, the stocking rate was greater (5.4 steers/ha) for Hafley (1996) than for the present study. In addition, planting rates and fertilization practices were also different and lower for Hafley (1996) which probably lead to the differences in ADG. Beck et al. (2007) reported ADG of 0.53 kg from December to March in Arkansas. As mentioned before, 60% of total forage production of ryegrass occurs in late-season (March-May). The present study, however, extended the grazing season until May which could lead to greater values of ADG than those found by Beck et al. (2007). Also in Arkansas, Coffey et al. (2002) reported ADG of 1.0 kg for stocker steers grazing “Marshall” annual ryegrass from December to April. However, they counted December and the first half of January in the winter period where they fed hay at libitum and a grain sorghum-based supplement to the animals. Although the animals were supplemented, lower values of ADG during that period could lead to lower ADG for the total winter period compared to the present study.

There were no significant differences among the systems during the winter period concluding that the addition of the clover mix and cereal rye to the ryegrass did not make a difference in animal performance for the total period. Mooso et al. (1990) reported ADG of weanling calves grazing ryegrass/clover mix to be 0.97 kg/d in a two-year study from November to May. However, the present study (S2 and S3) found greater ADG (1.44 and 1.45 kg/d for S2 and S3, respectively).

Since weight on d0 for animals in Y1 was greater than for animals in Y2 and final weight for both years was not different, ADG for animals in Y2 was greater than for Y1. However, there were no differences in ADG among the systems for the total study. That indicates that animal performance was not affected by system.

The current study (S1) found lower values of total ADG (0.67 kg/d), and FBW (461 kg) than those found by Bidner et al. (1986) (0.72 kg/d and 488 kg) finishing fall born steers on all-forage diet

(bermudagrass in the summer and ryegrass in the winter). Final weights, for both years of the present study ranged from 439 to 470 kg, and were lower than the goal projected (500 kg). Lack of forage mass and nutritive value at certain times during the grazing season (summer for Y1 and winter for Y2) contributed to lower than expected gains during those periods.

CARCASS, COOKING PROCESS AND SHEAR FORCE

Confounding problems in many studies comparing forage vs. grain-finishing have been found because of backfat finish and days on feed. In those studies, forage-fed cattle often had minimal amount of finish or were slaughtered at ages older than those of grain-fed cattle (Mandell et al., 1997).

For dressing percentage (54 to 55%), carcass weight (268 to 273 kg) and YG (2.27 to 2.35), our animals exhibited values that were consistent with other studies in which cattle were forage-fed finished (Bowling et al., 1977, Bidner et al., 1986, Bennett et al., 1995 and Roberts et al., 2009).

Backfat values for Y1 (6.25 mm) were similar to those reported by Bowling et al. (1977), Bidner et al. (1986) and Mandell et al. (1998) (4.0 to 5.9 mm) for forage-fed beef. Average daily gains for Y1 were similar to those studies probably leading to the similarity in backfat. Animals in Y2, however, had lower backfat values (2.53 mm) and ADG values also.

Longissimus muscle areas for animals in this study (62 to 64 cm²) were similar to those reported by Bowling et al. (1977) who harvested their animals at the same USDA quality grade and Bidner et al. (1985) (61 to 64 cm², respectively) who harvested their animals at the same final weight. However, Crouse et al. (1985), Bennett et al. (1995) and Mandell et al. (1998), who harvested their animals to a common backfat, reported greater values (69.6, 70.8 and 70.8 cm², respectively) for forage-fed beef. Course et al. (1985) and Bennett et al. (1995) supplemented their animals with a grain-based, growing diet (until about 19 mo of age and for 6 mo, respectively) which could lead to greater *longissimus* muscle areas.

Degrees of marbling for this study were similar to those found by Bidner et al. (1985 and 1986) and Mandell et al (1998) who found them to be traces for forage-fed beef. Those two studies had their

animals harvested at a similar backfat (4 to 5 mm) to those in the present study. Crouse et al. (1984) and Bennett et al. (1995), who harvested their animals at backfat of 10 to 11 mm, however, found marbling to be slight. As mentioned before, animals in Crouse et al. (1984) and Bennett et al. (1995) experiments were supplemented with grain-based diets for a long period before the finishing grazing period which could lead to the differences in intramuscular fat.

Cooking losses were similar to those found by Bowling et al. (1977) and Berry et al. (1988) (25.4 to 28%), but greater to those found by Hedrick et al. (1983) and Mandell et al. (1998) (20.3 %) for forage-fed beef.

Crouse et al. (1984), Bidner et al. (1986) and Mandell et al. (1998) reported WB shear force values for forage-fed beef of 4.6, 4.0 and 4.3 kg, respectively. Warner-Bratzler shear force values for this study were greater for Y1 (6.27 kg), but lower for Y2 (3.48 kg) compared to those previous studies. However, no differences were found among the systems which implies that it could have been due to a systematic error since the data reported was only for two years. Three more years of data are expected and they may possibly give a better explanation for determining the source of the difference.

According to Miller et al. (2001), WB shear force tenderness values for Y2 would have resulted in a 99% consumer satisfaction for beef tenderness while those for Y1 would have resulted only in a 25% consumer satisfaction. Platter et al. (2005) used a WB shear force marketing category classification of tenderness that would have placed Y2 results on the “slightly tender” category and those for Y1 would have been categorized as “very tough”.

TOTAL FAT AND FATTY ACID ANALYSIS

Growing consumer interest in forage-fed beef products has raised a number of questions with regard to the differences in nutritional quality between forage-fed and grain-fed cattle. Research spanning three decades suggests that forage-based diets can significantly improve the fatty acid composition and antioxidant content of beef, although with variable impacts on overall palatability (Daley, 2010).

Forage-based diets have been shown to enhance total CLA, *trans* vaccenic acid (C18:1 *t*11), a precursor to CLA, and omega-3 fatty acids on a g/g fat basis. While the overall concentration of SFA was not different between feeding regimens, forage-finished beef tend toward a higher proportion of cholesterol neutral stearic FA (C18:0), and less cholesterol-elevating SFA such as myristic (C14:0) and palmitic (C16:0) fatty acids (Daley, 2010).

The present study found greater values of total fat (4.5 to 5.6%), SFA (50 to 54%), CLA (1.29 to 1.92%) and C:18 *t*11 (4.3 to 5.4%), lower percentages of PUFA (5.6 to 7.4%), but similar values of omega 6 (3.3 to 4.7%), omega 3 (2.1 to 2.9%) and omega 6: omega 3 ratio (1.5 to 1.9) for forage-fed beef than several studies whose objectives were to contrast the lipid profiles of cattle fed either a grain or forage diets and reported data in similar units of measure (Descalzo et al., 2005, Nurenberg et al., 2005, Ponnampalan et al., 2006, Leheska et al., 2008 and Garcia et al., 2008). These values correspond only to the first year of the study. Four more years of data are expected for a better understanding of the differences.

IMPLICATIONS

Alternative methods of finishing cattle may be a possibility for the beef industry as long as there are profits for producers and the beef quality satisfies consumers. This two-year study evaluated three production systems that differed in complexity and forage type, and intended to develop a finishing program for forage-fed beef in Louisiana. Only a few significant differences were found in pasture nutritive value, animal performance, carcass traits and fatty acid profiles among the forage systems. Year seemed to have more of an effect than forage system. Even though FBW for both years of the present study were lower than expected, forage finishing might be a possible means to produce beef in Louisiana provided that feeding expenses are economically viable for the producer.

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