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FORAGE SPECIES ALTERS ANIMAL PERFORMANCE, CARCASS QUALITY, AND FATTY ACID COMPOSITION OF FORAGE-FINISHED BEEF PRODUCED IN SUMMER MONTHS

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ABSTRACT

The objective of this study was to evaluate how forages grazed during the summer months alter live animal performance, carcass quality, consumer acceptability and fatty acid composition in finishing beef cattle. Angus-cross steers (n=60) were finished on alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM) during this two year trial. Using a complete randomized block design, ten 2-ha paddocks were blocked and assigned to forage species (2 reps per species). Each year, steers (n=3) were randomly assigned to paddocks and grazing began when adequate forage growth for individual species was present. Put and take grazing techniques were utilized. Steers were slaughtered when sufficient forage mass for individual forage species was no longer present to support animal gains or when average steer weight exceeded 568 kg. Data were analyzed using PROC MIXED of SAS. Average daily gains were higher for alfalfa (AL) than bermudagrass (BG), cowpea (CO), and pearl millet (PM) treatments, whereas chicory (CH) ADG were higher ($P = 0.02$) than BG and PM. Dressing percentages were greater ($P = 0.01$) for AL and CO than BG and PM, while CH was higher than BG. Cowpea carcasses had the highest ($P < 0.05$) quality grades and marbling scores. A blind consumer taste panel rated beef from AL, CO and PM higher ($P < 0.01$) in overall palatability than CH and BG. Postmortem aging decreased ($P < 0.01$) Warner-Bratzler shear force. Shear force scores were lower ($P = 0.05$) for AL and CO than BG and CH. CLA *cis*-9, *trans*-11 concentration was greater ($P = 0.05$) in BG and PM than other treatments. Chicory and CO treatments had greater concentrations of linolenic acid than other treatments, whereas AL was higher in concentration than PM ($P < 0.01$). Stearic acid was higher (P = 0.02) in concentration for CO than CH, PM, and AL. Stearic acid concentration was higher (P = 0.02) in BG than PM and AL, and CH was higher than AL.

DEDICATION

This thesis is dedicated to my wife, Carol, for her constant support and encouragement throughout my graduate research. I would further like to dedicate this thesis to my parents, Ralph and Jeanne, who instilled in me a love for agriculture and academic pursuit.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LITERATURE REVIEW

Introduction

Ruminant animals including cattle have evolved to efficiently utilize fibrous forages in their diets (Russell & Rychlik, 2001). Modern agriculture has substituted concentrates and grains for forages in the finishing diets of beef cattle to increase efficiency, uniformity, and acceptability of beef products. However, periods of high grain prices threaten the profitability of finishing beef cattle on high grain diets (Bowling et al., 1977).

Recent research has revealed a number of important human health benefits from the consumption of forage-finished beef products. Forage-finished beef products have lower total fat and higher concentrations of health promoting fatty acids and antioxidants (Yang et al., 2002; Duckett & Pavan, 2007). Because of these perceived health benefits, along with interest in perceived environmental sustainability of producing forage-finished beef, consumers are increasingly demanding forage-finished beef and paying a premium for these products.

Beef Production in the Southeast U.S.

Southeast Livestock Systems

Livestock production is an important agronomic industry in the Southeast United States. In South Carolina there are an estimated 400 thousand cattle that generated $145 million in total revenue during 2006 (NASS, 2008). European settlers introduced the cattle industry to the region, originally grazing cattle on native grasses (Ball et al, 2002).

The low persistence of native grasses and the introduction of row cropping reduced interest in cattle production in the region during the 19th and early 20th centuries (Hoveland & Anthony, 1977; Ball et al, 2002). By the mid-20th century conservation programs re-established pastures in the Piedmont, defined as the non-mountainous Appalachia region (Allen et al., 1996). These efforts were in response to serious soil-erosion caused by years of tillage and were effective in re-introducing cattle production back to the region (Allen et al., 1996).

Cattle production in the Southeast is primarily cow-calf operations with limited stockering operations and almost no finishing programs (Allen et al, 1996). Calves are typically weaned in late summer or early fall and shipped to the Midwest and Great Plains (Hoveland & Anthony, 1977). However, the production of forage-finished beef is increasing as an economically profitable enterprise for beef producers in the Southeast. Retaining weaned calves and fattening beef on pastures in the region could be economically advantageous in the face of soaring fuel and grain prices. There are also expanding markets in the region as consumers increasingly demand locally produced natural, organic and pasture-based animal products (Lacy et al., 2007).

Forage Species

Forage systems in the South include some 24 million ha of perennial pastures and 8 million ha of annual pastures (Ball et al, 2002). Tall fescue (*Lolium arundinacea* Schreb.), a cool season perennial grass, has been the backbone of Southeastern cool season pastures, while bermudagrass *(Cynodon dactylon* L.*)* has played an integral role in perennial summer pastures. Other agronomically important perennial grasses include orchardgrass (*Dactylis glomerata* L.), a cool season species, and bahiagrass (*Paspalum notatum* Flugge), a warm season species. Winter annuals such as small grains provide important winter grazing, while summer annuals including pearl millet (*Pennisetum glaucum* (L.)R Br.), sudangrass (*Sorghum bicolor* (L.) Moench), and forage sorghum (*Sorghum bicolor* (L.) Moench) have contributed to meet summer grazing needs. Annual clovers including crimson clover (*Trifolium incarnatum* L.) and arrowleaf clover (*Trifolium vesiculosum* Savi) supplement winter grazing, along with perennial clovers including red clover (*Trifolium pretense* L.) and white clover (*Trifolium repens* L.). In addition to clovers, other legumes grown in the region include alfalfa (*Medicago sativa* L.), Korean lespedeza (*Lespedeza stipulacea* (Maxim.) Makino) and Sericea lespedezia (*Lespedeza cuneata* (Dum. Cours.) G. Don) (Hoveland & Anthony, 1977; Monson & Utley, 1977; Allen et al, 1996; Ball et al, 2002).

These forage species have met the needs of traditional cow-calf operations in the Southeast. However, as new opportunities are arising for Southeast cattle operations to develop forage-based stocker and finishing systems, forage species need to be explored to meet higher nutritional needs of fattening beef cattle. Certain high quality cool season forage species exist in the Southeast region for finishing beef cattle including non-toxic fescue (Realini et al., 2005) and annual ryegrass (Kerth et al., 2007). However, traditional perennial summer forages including bermudagrass and bahiagrass, will likely not provide necessary caloric density for adequate performance of growing and fattening cattle. Grazing alternative forages including alfalfa, cowpea, chicory, and pearl millet may provide opportunities for finishing beef cattle in the Southeast.

Bermudagrass

Bermudagrass *(Cynodon dactylon)*, typically used as the foundation of Southeast forage systems, was probably introduced into North America by some of the first European explorers (Burton & Hanna, 1995; Taliaferro et al., 2004). Bermudagrass originates from southeastern Africa, but is widely distributed and diverse in variability (Burton & Hanna, 1995; Ball et al., 2002; Taliaferro et al., 2004). It is typically a rhizomatous warm season perennial grass, best adapted to the southern U.S., and is drought tolerant and utilized for both hay and grazing (Burton & Hanna, 1995; Ball et al., 2002). Bermudagrass grows best on heavier soils, and responds well to fertilizer and moisture (Burton & Hanna, 1995). However, it is quite tolerant of a wide range of soil pH (Burton & Hanna, 1995). Common bermudagrass is propagated by seed, while hybrid varieties are sprig established (Ball et al., 2002).

Bermudagrass nutritive quality can vary widely between stage of growth and variety (Utley et al., 1974; Burton & Hanna, 1995; Ball et al., 2002; Corriher et al., 2007). Common bermudagrass with mature seed heads may have CP levels between 6%-7%, while the same plants in the vegetative state may have CP levels twice this amount (Burton & Hanna, 1995). Numerous bermudagrass varieties were developed by Dr. G. W. Burton at the Coastal Plain Experiment Station in Tifton Georgia including Coastal and, most recently, Tifton 85 that are higher yielding, higher in nutritive value, and may provide a longer grazing season than the common ecotypes (Utley et al., 1974; Burton & Hanna, 1995; Hill et al., 2001; Ball et al., 2002; Corriher et al., 2007).

Grazing research studies report a wide range in gains per hectare and daily gains for yearling steers grazing bermudagrass. Annual gains per ha range from 372 kg ha^{-1} on Coastal (Utley et al., 1974) to 1027 kg ha^{-1} for the Grazer hybrid variety (Greene et al, 1990). Average daily gains in bermudagrass grazing studies range between 0.39 kg day^{-1} for common bermudagrass (Stephens, 1942) to 1.03 kg day^{-1} for Tifton 85 bermudagrass (Rouquette, 2005). However, despite the higher potential of new varieties such as Tifton 85, most studies report ADG below 0.70 kg day^{-1} (Stephens, 1942; Utley et al., 1974; Hill et al., 1993; Taliaferro et al., 2004). Thus, it can be concluded that bermudagrass may provide adequate nutrition for pregnant and lactating cows with CP requirements between 7-12% and TDN requirements between 50-60% (Ball et al., 2002; Corriher et al., 2007). However, for growing and fattening steers with CP requirements or 10% and higher and TDN requirements close to 70%, bermudagrass may not be an appropriate forage (Ball et al., 2002; Corriher et al., 2007).

Alfalfa

Often labeled the “Queen of Forages,” alfalfa (*Medicago sativa*) is not only considered the world’s oldest forage legume, but the most superior pasture legume due to high yield and quality, along with wide climatic and soil adaption (Van Keuren & Matches, 1988; Russelle, 2001). Originating in Iran and central Asia, alfalfa is an erect-growing, trifoliate, perennial legume (Ball et al., 2002). Alfalfa may have been utilized as early as 10,000 B.C, with written record first establishing its use as a forage crop in 1400 B. C. (Russelle et al., 2001). Alfalfa reached Central and South America in the 16th century and North America in the 18th and 19th centuries (Russelle et al., 2001).

In the southern United States, alfalfa has not been utilized to the same degree as in other regions of the country. This lack of utilization is partially due to the low persistence of perennial legumes; often with stand lives of only two or three years (Ball et al., 2002). Persistence is impaired in the South due to acidic soils, high insect populations, and numerous fungal pathogens (Wildman et al., 2003). In southern regions alfalfa is commonly grown with other grasses including tall fescue and orchardgrass to increase yield and seasonal production uniformity (Van Keuren & Matches, 1988; Hoveland et al., 1995). Another drawback for utilizing alfalfa, particularly under grazing, is the higher management levels required compared to other forages to maintain high productivity and reduce the risk of bloat (Van Keuren & Matches, 1988; Ball et al., 2002). Rotational grazing is often required for long lasting, healthy stands (Van Keuren & Matches, 1988).

Although grazed alfalfa is frequently utilized in other parts of the world for finishing beef cattle, such as in Argentina, in the U.S. alfalfa is predominantly utilized for hay production (Van Keuren & Matches, 1988; Hoveland et al., 1995). However, grazing varieties are being developed in the U.S. (Bouton et al., 1991; Bates et al., 1996). Grazed alfalfa provides the longest grazing season of any legume adapted to the Southeast U.S. (Ball et al., 2002), and produces ADG exceeding 1 kg day^{-1} and gains per hectare over 446 kg ha^{-1} (Hoveland et al., 1988; Bates et al., 1996).

Alfalfa is highly digestible and is a good source for protein with CP levels over 16% (Collins & Fritz, 2003; Van Keuren & Matches, 1988; Marten et al., 1988). It does not require nitrogen (Van Keuren & Matches, 1988); however, it does require large amounts of potassium (Ball et al., 2002). Alfalfa is also a good source of Ca, Mg, P, and pro-vitamin A and vitamin D (Van Keuren & Matches, 1988). Intake is higher with alfalfa than grasses of equal digestibility (Van Keuren & Matches, 1988). Despite the risk of bloat, studies show alfalfa to be a high quality forage for finishing beef cattle.

Cowpea

Cowpea (*Vigna unguiculata* L.) is a warm season, annual legume originating from Ethiopia (Ball et al., 2002). It is well adapted to the Southeast, being drought tolerant and also tolerant of low soil fertility and low pH, but requires well-drained soils (Leffel, 1973; Ball et al., 2002). It is similar to soybeans in management, although it is more viny and less upright (Ball et al., 2002) Cowpeas can provide good quality forage between June and August (Ball et al., 2002).

Cowpea has been widely used as a forage legume, utilized for hay, human consumption and pasture; however, in the U.S. it has decreased in popularity during the last half of the 20th century (Leffel, 1973; Duke, 1981). Very little research has been conducted with cowpea as a forage crop, although forage quality is good and hay yields can be as high as 5000 kg ha^{-1} (Miller & Hoveland, 1995). Muir (2002) noted that annually cowpea yielded between 511 and 3194 kg DM ha^{-1} with CP levels between 17% and 21%. Keisling and Swartz (1996) conducted a lamb grazing study and reported that lambs grazing cowpea had similar or higher carcass quality to lambs grazing sudangrass or finished in a feedlot.

Chicory

Chicory (*Chichorium intybus* L.) is a widespread, drought-tolerant, short-lived (2 to 4 years) perennial forb originating in Europe (Ball et al., 2002). Chicory has long been used in pastures as a forage species (Jung et al., 1996). However, early 20th century research concluded that chicory produced insufficient yields as a forage crop except during extreme drought conditions (Hume et al., 1995). During the 1970s, New Zealand researchers began revisiting chicory as a potential forage species after discovering high yields under rotational grazing (Hume et al., 1995). Ensuing plant breeding programs resulted in the development of the first forage chicory variety labeled 'Grasslands Puna' officially released in 1985 (Hume et al., 1995; Labreveux et al., 2004). Since the release of Grasslands Puna, other forage chicory varieties have been developed in New Zealand, Uruguay, and Europe (Rumball et al., 2003; Sanderson et al., 2003; Sulas, 2004)

Morphologically, chicory shoots arise from a rosette bud (Clapham et al., 2001). In the vegetative state, shoots appear as crinkled prostrate leaves that resemble dandelion leaves. (Ball et al., 2002) In the newer varieties of Choice and Puna II, leaves can emerge in a more upright manner (Rumball et al., 2003). In the reproductive state, chicory produces a tall stem (1.2 to 1.5 m) with a purple flower on top (Clapham et al., 2001). Chicory has a deep taproot, which is capable of good soil exploration (Ball et al., 2002).

Forage chicory has a growth period between March and October in the Southeast, peaking in production between April and May (Ball et al., 2002). Chicory is considered a high quality forage crop and can produce high yields when fertilized with nitrogen even under drought conditions and acidic soils (Ball et al., 2002; Labreveux et al., 2004). Chicory yields range between 2,000 and 10,000 kg ha^{-1} DM depending on defoliation frequency, fertilization, year of production, and environmental factors (Clapham et al., 2001; Labreveux et al., 2004). Plant density and yield declines with each subsequent year of grazing after establishment year, with yields declining at a more gradual rate than plant density (Jung et al., 1996; Li et al., 1996). Sward declines are due to the hollowing of the crown with age leading to susceptibility to pathogens and disease. Defoliation regimes and soil fertility also play important roles in sward life expectancy. (Hume et al., 1995)

In pastures, chicory requires rotational stocking plus mowing to remove seedstalks for optimum animal performance and chicory persistence (Ball et al., 2002), with three to six week rest periods (Sulas, 2004). Chicory is not suited for hay production because of high forage water content. (Ball et al., 2002). Grazing intensity does not seem to affect chicory persistence as long as sufficient rest periods are provided for regrowth (Hume et al., 1995).

Live animal performance varies widely depending on forage quality (ratio of floral stems to leaves) and daily allowance (Clark et al., 1990). Clark et al. noted that when floral stems are present, high animal gains (1.5-2.0 kg day^{-1}) can only be expected with high forage residual (40%). Collins and McCoy (1997) suggested that animals gain better on chicory than on orchardgrass despite lower DM intake of chicory due to lower ruminal NH_3 concentrations and greater proportions of bypass proteins in chicory. Chicory has been reported to be highly palatable despite having moderate high levels of tannins (Foster et al., 2002).

Pearl Millet

Pearl millet (*Pennisetum glaucum)* is an annual bunch grass, grown for both grain and forage production (Budak et al, 2003). Pearl millet originates from the southern margins of the central highlands of the Sahara Desert in Africa (National Research Council, 1996). Of all the cereal crops, pearl millet has the greatest drought and heat tolerance, producing reliable yields within a short-season (60-90 d) (Burton et al, 1972; National Research Council, 1996; Budak et al., 2003).

Morphologically, pearl millet has a terminal inflorescence in the form of a panicle that is cylindrical in shape with varying degrees of seed compactness. The degree of tillering varies widely between varieties (Rachie & Majumudar, 1980). Plants can grow to heights of between one to five meters (Burton et al., 1972).

Despite being considered as the sixth most important cereal in the world, pearl millet grain is traditionally known as a subsistence crop, predominantly grown in arid and semiarid regions of Africa and India (National Research Council, 1996; Budak et al., 2000). Only in the United States has pearl millet been developed as a forage crop (Rachie & Majumudar, 1980). Objectives for the development of forage varieties of pearl millet include increased animal performance, increased percentage of leafiness, reduced plant height, increased forage quality and digestibility, and short-day photoperiod sensitivity (Burton, 1951; Jauhar, 1981). Starting in the first half of the 20th century, Burton developed numerous forage pearl millet hybrid varieties introducing the dwarf gene (Rachie & Majumudar, 1980; Jauhar, 1981; Burton, 1990). Currently, Tifleaf 3 is the most widely used forage hybrid (Hanna et al., 2005).

Pearl millet is frequently utilized as a summer annual forage crop in the Southeast U.S. due to adaptations to sandy soils, acidic soils, and drought conditions, along with resistance to foliage diseases in humid environments (Burton et al., 1972; Rachie & Majumudar, 1980; Burton, 1990; Budak et al., 2003). Pearl millet is high in nutritive quality only when harvested in the immature state, and is generally high yielding between June and September (Ball et al., 2002). It is also responsive to nitrogen fertilizer (Ball et al., 2002). Another advantage of pearl millet as a forage crop, unlike sudangrass and sorghum, are the low levels of prussic acid glucosides, which are poisonous to livestock (Burton et al., 1972; Rachie & Majumudar, 1980; Burton, 1990; Budak et al., 2003).

Consumer Demand for Forage-Finished Beef

With high quality forage systems, fattening cattle on pasture has the opportunity to create a value added product. Forage-finished beef is a rapidly developing, competitive market. Consumers are increasingly placing greater concern on extrinsic quality attributes of meat products (Bernues et al., 2003). Extrinsic cues including product brands, geographic origin, store, production information, and packaging are attributes other than the physical intrinsic attributes (color, appearance, and shape)

(Bernues et al, 2003). Driven by consumer concern including health and nutrition, food safety, and environmental concerns, markets are rapidly expanding for natural and organic products (Norwood, 2004). Natural and organic markets have been expanding at an average of 14% annually, while organic markets alone have been increasing at an average of 23% per year since 1990 (Norwood, 2004). In 2005 organic meat sales increased by 51%, largely attributed to the BSE scare (Organic Monitor, 2006).

Forage-finished and other alternatively produced meat products are a significant portion of natural and organic food sector (Lacy et al., 2007). Recent articles in popular news sources including Time and the Washington Post confirm the growing trend for interest in grass-fed beef as consumer willingness to pay a premium for products as health and environmentally sustainable attributes expands (Roosevelt, 2006; Black, 2007). Some producers are reporting receiving prices of $200 per 45.4 kg live weight or greater for forage-finished beef (Lacy et al., 2007).

Consumer and economic studies investigating the growing demand for forage-finished beef are limited. However, recent consumer panel studies indicate a certain proportion of the population prefers forage-finished beef over grain-finished beef and is willing to pay a premium for their preference. Umberger et al. (2002) conducted a consumer taste panel in Chicago and San Francisco to determine preferences between Argentine grass-fed beef and U.S. corn-fed beef. While 62% of the participants preferred the corn-fed beef, 23% of the participants preferred grass-fed beef and were willing to pay a premium for this preference (Umberger et al., 2002). Similarly, in both blind and informed consumer retail surveys in three Southeastern U.S. states, Cox et al. (2006)

concluded that 34% preferred forage-finished beef over grain-finished beef. A take-home study revealed close to half of the participant preferred forage- over grain-finished beef (Cox et al., 2006). These studies indicate a significant portion of the population prefers forage-finished beef over grain-finished beef.

History of Forage-Finished Beef

Interest in forage-finished beef is not new. Studies first appear on forage-finishing during the 1930s and 1940s (Brown, 1954). However, government subsidized grain production has led to the dominance of the feedlot industry in the United States (Runge, 2004). Interest is renewed in finishing beef on forages during periods of high grain prices (Bowling et al., 1977). As Oltjen et al. predicted in 1971, "In the future, it is quite possible that the cereal grains will become too expensive to feed to ruminants in large quantities because of the direct competition with the rapidly expanding human population." However, in the past forage-finished beef products have been labeled with several negative attributes.

Studies conducted in the 1970s comparing forage- to grain-finished beef revealed a trend of decreased overall acceptability of forage-finished beef compared to grain-finished beef (Bowling et al., 1977; Cross & Dinius, 1978; Bidner et al., 1981; Melton, 1983). In more recent decades meat products of ruminant animals have been discriminated against because of the overall saturation of the fatty acid profile (Enser et al., 1996). During the last decade, forage-finished beef research has focused on the positive attribute of finishing cattle on forages. These benefits include lower total fat and higher concentrations of health promoting fatty acids and antioxidants compared to concentrate or grain-finished beef (Yang et al., 2002; Duckett & Pavan, 2007).

Animal Performance, Carcass Quality and Sensory Attributes of Forage-Finished Beef

Live Animal Performance

Generally, literature comparing forage-finished to concentrate-finished beef reveals lower animal performance for forage-finished beef. The term "concentrate-finished beef" will be used to define diets largely composed of non-roughage feedstuff including grain. There are numerous studies comparing forage- to concentrate-finished beef; however, studies comparing how specific forages alter animal performance and carcass quality are scarce.

Average daily gains tend to be lower for forage-finished beef (Bowling et al., 1978; Bidner, 1981; Bennett et al., 1995). High roughage diets produce lower gains due to decreased net energy concentrations (Bidner, 1975; Melton, 1983). However, high quality forages have long been known to reduce the differences in live animal performance between forage-finished and concentrate-finished beef (Brown, 1954). Oltjen et al. (1971) reported similar gains between concentrate and pelleted alfalfa-finished beef, with beef finished on timothy hay exhibiting lower gains. Along with high quality forages, appropriate animal genetics can reduce difference between concentrate- and forage-finished cattle (Brown, 1954). Camfield et al. (1999) suggested matching forage-finishing with the lower-energy needs of small-framed, early-maturing animals.

Carcass Quality

Carcass quality is generally reported to be lower in forage-finished beef compared to concentrate-finished beef. Finishing cattle on forages produce smaller carcasses with less fat and muscling (Kerth et al., 2007). However, when slaughtered at a common endpoint (i.e. - backfat thickness or degree of marbling), carcass quality differences are minimal between forage- and concentrate-finished beef (Bennett et al., 1995). Forage-finished beef tends to have lower yield grades than concentrate-finished beef (Brown, 1954; Kerth et al., 2007). Quality grade responses differ among studies, with some studies reporting no difference (Reagan et al., 1977; Bidner et al., 1981; Cox et al., 2006), and other studies reporting forage-finished beef having lower quality grades than concentrate-finished beef (Craig et al., 1959; Bowling et al., 1978). Forage-finished beef is generally leaner, with less subcutaneous and KPH fat (Craig et al., 1959; Bowling et al., 1977; Bidner et al., 1981; Realini et al., 2004). However, Steen et al. (2003) reported that high quality ryegrass pasture produced forage-finished beef with 40% lower fat while performing at 80% daily carcass gain and similar lean and protein gains of concentrate-finished beef. This study suggests that forage-finishing increases lean production efficiency with less fat yet higher concentrations of health promoting fatty acids (Steen et al., 2003).

Degree of marbling is generally decreased in forage-finished beef compared to concentrate-finished beef (Reagan et al., 1977; Bidner et al., 1981; Kerth et al., 2007). Reagan et al. (1977) reported no difference in marbling between beef finished on either small grains or clover. Finishing animals to a common endpoint (2.54 cm back-fat) may reduce marbling differences (Cox et al., 2006). Generally, forage-finished beef has smaller ribeye area (Bowling et al., 1977; Bidner et al., 1981; Realini et al., 2004). Most studies report lower dressing percentages in forage-finished beef (Bowling et al., 1978) potentially due to greater ruminal fill (Oltjen et al., 1971).

Forage-finished beef generally has higher final pH than concentrate-finished beef. This may be due to lower muscle glycogen stores in forage-finished beef, which prevent carcasses from reaching a normal ultimate pH which potentially affects storage life (Melton et al., 1982; Daly et al., 1999). Other studies have reported no difference in pH between forage- and concentrate-finished beef (Bidner et al., 1981; Realini et al., 2004).

Sensory Attributes

Studies reporting sensory differences between forage- and concentrate-finished beef are inconsistent. There are long held perceptions that forage-finished beef tends to have off-flavors (Bowling et al., 1977; Davis et al., 1981; Melton et al., 1982; Melton, 1983; Marmer et al., 1984; Larick & Turner, 1989; Bennett et al., 1995; Mandell et al., 1998; Poulson et al., 2004), yellow fat (Wanderstock & Miller, 1948; Brown, 1954; Crouse et al., 1984; French et al., 2000; Poulson et al., 2004; Realini et al., 2004; Gatellier et al., 2005; Kerth et al., 2007), darker lean (Bowling et al., 1977; Bidner et al., 1981; Hedrick et al., 1983; Crouse et al., 1984; Bennett et al., 1995), low tenderness (Wanderstock & Miller, 1948; Bowling et al., 1977; Bowling et al., 1978; Cross & Dinius, 1978), course texture (Cross & Dinius, 1978), low juiciness (Cross & Dinius, 1978; Hedrick et al., 1983), and generally low consumer acceptability (Bowling et al., 1977; Bowling et al., 1978; Hedrick et al., 1983). However, these perceptions are not consistently reported between studies likely due to differing slaughter endpoints and differing feeding regimes.

Off-flavors reported in forage-finished beef are described as grassy, milky, fishy, and sour off-flavor (Melton, 1983; Bennett et al., 1995; Poulson et al., 2004). Higher PUFA content, particularly C18:3n-3, in grass-fed beef may be the cause of more rapid development of oxidative rancidity resulting in off-flavors (Bowling et al., 1977; Melton, 1983; Marmer et al., 1984; Larick & Turner, 1989). However, more recent studies have found no difference in flavor between forage- and grain-finished beef (Cox et al., 2006; Kerth et al., 2007). No difference in flavor was detected between legume- and grass-finished beef (Scollan et al., 2006). Oltjen et al. (1971) reported beef finished on pelleted alfalfa was more flavorful than concentrate- and timothy hay-finished beef.

Early studies regularly reported forage-finished beef to be less tender, courser texture, containing more connective tissue, and having higher Warner-Bratzler shear force (WBS) values (Wanderstock & Miller, 1948; Bowling et al., 1977; Bowling et al., 1978; Cross & Dinius, 1978). Bowling et al. (1977) suggested that with less subcutaneous fat thickness, forage-finished beef has increased postmortem contractions which increases the shortening of sarcomeres leading to increased toughness. However, many studies report no difference in WBS values between forage- and concentrate finished beef (Hedrick et al., 1983; Crouse et al., 1984; Mandell et al., 1998; Realini et al., 2004; Kerth et al., 2007). Aging (14 d) reduced tenderness differences between forage- and concentrate-finished beef (Cox et al., 2006). Oltjen et al. (1971) reported lower WBS scores for pelleted alfalfa-finished compared to grass- and concentrate-finished beef. Scollan et al. (2006) also reported legume-finished beef to be slightly more tender than grass-finished beef.

Yellow fat reported in forage-finished beef has been associated with accumulated carotene from green leaf tissue (Yang et al., 1992). The higher b* values reported for fat color in forage-finished beef correlate to either more yellow (Wanderstock & Miller, 1948; Brown, 1954; Crouse et al., 1984; French et al., 2000; Poulson et al., 2004; Realini et al., 2004; Gatellier et al., 2005; Kerth et al., 2007), or creamier (Bennett et al., 1995) subcutaneous fat color. Other studies have reported no differences in fat color between forage- and concentrate-finished beef (Bidner et al., 1981; Daly et al., 1999).

Lean of forage-finished beef initially has lower L* values than concentrate-finished beef corresponding to darker lean (Bowling et al., 1977; Reagan et al., 1977; Bidner et al., 1981; Hedrick et al., 1983; Crouse et al., 1984; Bennett et al., 1995). Daly et al. (1999) reported no differences in lean color between forage- and concentrate-finished beef. Reagan et al. (1977) noted that clover- and concentrate-finished beef had brighter muscle coloration than grass-finished beef. It has also been reported that due to higher vitamin E content, forage-finished beef retains its redness for a longer period of time (Poulson et al., 2004; Realini et al., 2004).

Antioxidant Content

Gatellier et al. (2004) suggested that oxidation in meat is the cause for the greatest loss in quality attributes including flavor, color, texture and nutritive value. Forage-finished beef is particularly susceptible to oxidation, due to the high levels of PUFA concentrations (Gatellier et al., 2004; Yang et al., 2002). However, green leaf tissue is high in tocopherol (vitamin E) concentrations and other natural antioxidants that protect against oxidation (Daly et al., 1999; Gatellier et al., 2004). Studies have reported significantly higher vitamin E concentrations in forage-finished beef compared to concentrate-finished beef, which might protect forage-finished beef against off-flavors (lipid-oxidation) and increasing color stability (Daly et al., 1999; Gatellier et al., 2004; Mercier et al., 2004; Poulson et al., 2004; Realini et al., 2004). Scollan et al. (2006) reported lower vitamin E concentrations in legume-finished beef than grass-finished beef.

Fatty Acid Composition in Beef Cattle as Influenced By Diet

Ruminant Lipid Overview

Beef and lamb have an unfavorably low PUFA to SFA (P:S) ratio (0.11 and 0.15 respectively) compared to pork (0.45) (Enser et al., 1996). A dietary P:S ratio of 0.45 or higher is recommended for human health (Department of Health, 1994). The low P:S ratio in ruminants is a result of biohydrogenation of dietary unsaturated fats in the rumen (Enser et al., 1998). Following ruminal lipolysis, microbial enzymes act on free fatty acid double bonds, removing and reposition bonds creating unsaturated isomers, MUFA, and finally completely removing double bonds in the form of SFA (Hatfield et al., 2008).

The predominant fatty acids in beef are oleic (C18:1), palmitic (C16:0), and stearic (C18:0) (Realini et al., 2004).

Health experts recommend reducing SFA in human diets. Saturated fats are linked to increased serum low-density lipids (LDL) which increases the risk for coronary heart disease in humans (Keys, 1970). Saturated fats also raise total blood cholesterol levels, except for stearic acid (C18:0) which does not raise blood LDL cholesterol levels and is considered neutral (Duckett & Pavan, 2007). Monounsaturated fatty acids containing one double bond are considered beneficial to human health. Monounsaturated fatty acids are considered antithrombogenic, lowering LDL cholesterol and raising high density lipids (HDL) (Mensink and Katan, 1989; Ulbricht and Southgate, 1991).

Polyunsaturated fatty acids are also antithrombogenic (Ulbricht and Southgate, 1991). However, within PUFA, omega-3 FA are considered more beneficial to human health than omega-6 FA. Omega-3 FA are highest in fish and plant lipids and are antithrombogenic, lowering LDL cholesterol (Mensink and Katan, 1989; Ulbricht and Southgate, 1991). Omega-6 FA, most common in grain and vegetable oils, are antiatherogenic which reduce both LDL and HDL cholesterol (Mensink and Katan, 1989; Ulbricht and Southgate, 1991). Health experts recommend lowering omega-6 FA in human diets, reducing the omega-6 to omega-3 FA ratio (n-6:n-3) to 4 or less (Department of Health, 1994).

Conjugated linoleic acids defined as positional and geometric isomers of linoleic acid with two conjugated double bonds have important human health promoting properties (Dannenberger et al., 2004; De La Torre et al., 2006). Produced by incomplete biohydrogenation of linoleic acid in the rumen, CLA are predominantly found in ruminant products (Moya-Camarena and Belury, 1999). As reviewed by Pariaz et al. (2000), CLA, particularly cis-9, trans-11 and trans-10, cis-12, have been linked to multiple biological functions including the inhibition of carcinogenesis, reduced rate of fat deposition, altered immune response, and reduced serum lipids.

Fatty Acid Profile: Forage- and Concentrate-Finished Beef

Finishing beef on forages generally leads to a more favorable fatty acid profile compared to concentrate-finished beef. Perhaps most important to human health, total fat content is reduced when beef is finished on forages compared to beef finished on concentrates to a similar endpoint, reducing SFA, MUFA, and omega-6 FA on a per serving basis (Duckett & Pavan, 2007). Realini et al. (2004) reported concentrate-finished beef has twice as much LM fatty acid content as forage-finished beef. The only reported health promoting fatty acid to be lower in forage-finished beef compared to concentrate-finished beef is oleic (C18:1) acid, the predominant MUFA which comprises 30-50% of total FA in beef (Melton et al., 1982; Mitchel et al, 1991; Duckett et al., 1993; Mandell et al., 1998, French et al., 2000).

Reports are mixed regarding the effect of finishing mode on the P:S ratio in beef lipid profile. Enser et al. (1998) reported that forage-finished beef has a lower P:S ratio compared to concentrate-finished beef due to concentrate-finished beef having higher proportions of linoleic (C18:2, n-3) acid, and forage-finished beef having higher concentrations of stearic (C18:0) acid. Similarly, earlier forage fed beef studies report increased SFA content (Melton et al., 1982; Marmer et al., 1984). Other studies report significant increases in PUFA content, predominantly linolenic (C18:3, n-6) acid, in forage-finished beef while SFA content decreases or remains the same as concentrate-finished beef, thus increasing the P:S ratio (Duckett et al., 1993; French et al., 2000; Noci et al., 2005). Other PUFA with higher concentrations in forage-finished beef include arachidonic (C20:4), eicosapentaenoic (C20:5, EPA), and docosapentaenoic (C22:5, DPA) (Realini et al., 2004).

In forage-finished beef, omega-3 PUFA, particularly linolenic acid, is significantly increased which lowers the n-6:n-3 ratio (Melton et al., 1982; Enser et al., 1998; Mandell et al., 1998; French et al., 2000; Dannenberger et al., 2004; Realini et al., 2004; Gatellier et al., 2005). While both concentrate- and forage-finished beef often have n-6:n-3 ratios equal or lower than the recommended 4.0 for human consumption, forage-finished beef has significantly lower n-6:n-3 ratios than concentrate-finished beef (Dannenberger et al., 2004; French et al., 2000).

Forage-finishing increases concentrations of CLA in ruminant tissue; both total CLA and CLA isomer cis-9, trans-11 (French et al., 2000; Realini et al., 2004), by as much as 466% (Poulson et al., 2004). Dietary supplementation of oleaginous seeds such as linseed also has been shown to increase CLA content in ruminant products (De La Teorre et al., 2006), especially oils rich in linoleic acid (Mir et al., 2004). However, since forage-finished beef has lower total fatty acid concentrations, differences are less pronounced between forage- and concentrate-finished beef on a per serving basis (Mir et al., 2004). In addition, vaccenic (C18:1, trans-11, VA) acid, the predominant natural trans fatty acid in ruminant products, is receiving distinction from artificial trans fatty acids which increase LDL and lower HDL. This distinction is because VA is beneficially converted to CLA, cis-9 trans-11 in humans. Forage-feeding increases VA in beef (Duckett & Pavan, 2007).

Fatty Acid Profile: Forages

Very little research has been conducted investigating how specific forages alter the fatty acid profile in beef cattle. The high levels of PUFA in forage-finished beef are linked to the high levels of PUFA in green leaf tissue. Forage lipid fractions are predominantly composed of long-chain unsaturated fatty acids, with α-linolenic acid comprising an estimated 60% of the total fatty acid profile (Clapham et al., 2005; Hatfield et al., 2008). Linoleic and palmitic acids are the second and third most significant fatty acid in forage species (Clapham et al., 2005). Fatty acid content in plants ranges between 10- 30 g kg^{-1} DM, with fresh forages containing higher concentrations of total fatty acids, palmitic, linoleic, and α-linolenic acids than wilted grass or hay (Dewhurst et al., 2001; Hatfield et al., 2008). Clapham et al. (2005) reported highest total FA concentrations in chicory compared to triticale, orchardgrass, perennial ryegrass, tall fescue, galega, white clover, rape, turnip, borage, and plaintain.

Proportion and concentration of fatty acids in forages is highly variable, influenced by species, variety, stage of growth, and seasonality (Clapham et al., 2005; Dewhurst et al., 2001; Hatfield et al., 2008). Stage of growth rather than species appears to have a larger effect on FA content and CP in plants, with forages in the vegetative state having the highest fatty acid concentrations (Dewhurst et al., 2001; Clapham et al., 2005). Shorter regrowth periods increase total fatty acid concentrations, particularly unsaturated fats (Dewhurst et al., 2001). Generally, α-linolenic concentrations and fractional contributions decline during the harvest season, while percentage of palmitic and linoleic acids increase (Clapham et al., 2005; Hatfield et al., 2008).

Both α-linolenic and linoleic acids are precursors to beneficial fatty acids in ruminant meat (Dewhurst et al., 2001). Thus, increasing the proportion of forages in ruminant diets increases the proportion of both omega-3 PUFA and CLA in ruminant tissue and milk (Dhiman et al., 2000; Clapham et al., 2005). Cattle may consume equivalent amounts of fatty acids in fresh forages as would be supplemented in a mixed diet (Hatfield et al., 2008). Grasses tend to have higher proportions of linolenic acid and lower proportions of linoleic acid compared to clovers and chicory (Clapham et al., 2005). Scollen et al. (2006) proposed that increasing linolenic acid content in meat from forage feeding is dependent on both increasing linolenic acid content in forages and reducing the extent of ruminal biohydrogenation.

Fatty Acid Profile: In Beef as Influenced by Different Forages

To date, few studies have reported the effect that specific forages have on altering the fatty acid profile in finishing beef cattle. Scollan et al. reported no difference in SFA and MUFA content between legume- or grass-finished beef (Scollan et al., 2006). Legume-finished beef has higher concentrations of PUFA than grass-finished beef (Scollan et al., 2006). Linolenic acid concentrations were higher in legume-finished compared to grass-finished beef (Scollan et al., 2006). C18:2 n-6 concentrations were higher in legume-finished compared to grass-finished beef (Scollan et al., 2006). Legume finished beef has a lower n-6:n-3 ratio (2.30) compared to grass-finished beef (3.28) (Scollan et al., 2006).

Research Challenges

As markets continue to expand for forage-finished beef, beef producers will require forage species and varieties that will efficiently produce high quality beef. Traditional warm season perennial pastures in the Southeast U.S. should not meet the nutritional requirements of growing and fattening beef cattle. Forage research must find alternative high quality forages which may include alfalfa, chicory, cowpea and pearl millet to allow for the year around production of beef on pasture.

There is a large amount of literature establishing the differences between forage- and concentrate-finished beef. However, there are few studies comparing how different forage species alter live animal performance, carcass quality and fatty acid composition in beef cattle. Understanding the effects of individual forage species on live animal performance, carcass quality and fatty acid composition is crucial for efficiently producing high quality beef that optimizes health promoting fatty acids.

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CHAPTER 2

ALTERNATIVE FORAGE SPECIES FOR THE SUMMER GRAZING ALTER ANIMAL PERFORMANCE, CARCASS QUALITY AND CONSUMER ACCEPTABILITY IN FINISHING BEEF CATTLE

Abstract

Angus-cross steers (n=60) were finished on either alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM) during a 2-yr grazing study to assess the effects of these forages on live animal performance and economic analyses. Using a complete randomized block design, ten 2-ha paddocks were blocked and assigned forage species (2 reps per species). Each year, steers (3 per rep) were randomly assigned to paddocks and grazing began when adequate forage growth for individual species was present. Put and take grazing techniques were utilized. Steers were slaughtered when sufficient forage mass for individual forage species was no longer present to support animal gains or when average steer weight exceeded 568 kg. Data were analyzed using PROC MIXED of SAS. Average daily gains were higher ($P = 0.02$) for AL than BG, CO, and PM, whereas CH was higher than BG and PM. Gains per hectare tended to be higher ($P = 0.07$) for AL than CO. In 2007, PM had more grazing days ($P = 0.02$) than all other treatments, while PM and BG treatments had more grazing days ($P = 0.01$) than all other treatments in 2008. Gross margin ($ ha^{-1}) was greater ($P = 0.02$) for AL, BG, CH, and CO than PM. Total cost of production ($ ha^{-1}) was highest ($P = 0.01$) for PM with AL, BG and CH being higher than CO. Breakeven sales price was higher ($P < 0.01$) for CO than AL, BG, and CH. Breakeven sales price was also higher (P

< 0.01) for PM and BG than AL and CH, and CH was higher than AL. Results indicate that while PM and BG produced more grazing days, AL and CH produced higher ADG.

Introduction

The production of forage-finished beef is increasing as an economically profitable enterprise for beef producers in the Southeast United States (Lacy et al., 2007). There is growing interest in grass-fed beef as consumers are increasingly willing to pay a premium for products with perceived health and environmentally sustainable attributes (Norwood, 2004; Roosevelt, 2006).

Interest in finishing beef cattle on forage diets is not new. Interest often peaks during periods of high grain prices (Bowling et al., 1977). In past decades, studies comparing forage- to concentrate-finished beef revealed a trend of decreased overall acceptability of forage-finished beef compared to concentrate-finished beef (Bowling et al., 1977; Melton, 1983). During the last decade, research has focused on positive attributes of finishing cattle on forages. These benefits include lower total fat and higher concentrations of health promoting fatty acids and antioxidants compared to concentrate-finished beef (Yang et al., 2002; Duckett & Pavan, 2007).

Cattle production in the Southeast United States is primarily cow-calf operations with limited stockering operations and almost no finishing programs (Allen et al, 1996). Forages most commonly grazed during the summer months in this region include bermudagrass (*Cynodon dactylon* L.) and bahiagrass (*Paspalum notatum* Flugge). These forages have met the nutritional needs of cow-calf operations, but may not meet the nutritional needs of finishing beef cattle.

Certain high quality cool season forage species exist in the Southeast region for finishing beef cattle including non-toxic tall fescue (*Lolium arundinacea* Schreb.) (Realini et al., 2005) and annual ryegrass (*Lolium multiflorum* Lam.) (Kerth et al., 2007). However, for year-round production of forage-finished beef, alternative high quality forage-species grazed during the summer months need to be investigated. Also, numerous studies have investigated differences between forage-finished and concentrated-finished beef, but few studies have investigated how different forages influence live animal performance and economic profitability in finishing beef cattle. Therefore, the objective of this study was to evaluate how alternative forages grazed during the summer months alter live animal performance and economic profitability in beef cattle.

Materials and Methods

Experimental Design

Five forage species (alfalfa (*Medicago sativa* L.), bermudagrass (*Cynodon dactylon*), chicory (*Chichorium intybus* L.), cowpea (*Vigna unguiculata* L.), and pearl millet (*Pennisetum glaucum* (L.)R Br.)) were assessed through summer grazing for influence on live animal performance, carcass quality, consumer acceptability and economic profitability in finishing beef cattle. The experiment was conducted at the Clemson University Simpson Research Station in Anderson County, SC. Using a

Complete Randomized Block Design with two replications, ten 2-ha paddocks were blocked and forage species were randomly assigned within each block. Paddocks were blocked according to soil type and topography.

Forage Establishment and Management

Prior to the experiment, the ten 2-ha paddocks were predominantly common and coastal bermudagrass varieties. During the fall of 2006, paddocks randomly assigned to alfalfa and chicory were sprayed and killed with glyphosate. Chicory and alfalfa seed was no-till planted into killed paddocks in late September after the necessary soil amendments were made according to soil tests. Chicory (Puna II) was planted at a seeding rate of 4.5 kg ha^{-1} and alfalfa (Alfagraze 300RR) was seeded at a rate of 22.4 kg ha^{-1} using a Great Plains no-till drill. Due to a weak stand, chicory was reseeded again at the end of October with a seeding rate of 6.72 kg ha^{-1}. Chicory in replicate A had to be re-established in September, 2007 at a seeding rate of 8.4 kg ha^{-1}.

In late April 2007 the paddocks assigned to cowpea and pearl millet treatments were sprayed and killed with glyphosate. The existing bermudagrass predominantly of the common and coastal varieties was used for the bermudagrass treatments. The bermudagrass paddocks were also sprayed with glyphosate in April before green-up to remove other plant species, predominantly tall fescue. In May, Cowpea (Iron & Clay) mixed with innoculant (Nitragen “EL” culture) was established into clean tilled paddocks at a rate of 56 kg ha^{-1}. Pearl Millet (Tifleaf 3) was established at the same time into clean tilled paddocks at a rate of 28 kg ha^{-1}. Due to the expected abundant forage mass of pearl millet, the 2-ha paddocks assigned to pearl millet were cut in half into 1-ha paddocks. Pearl millet and cowpea paddocks were overseeded with a cereal rye/ryegrass mixture for winter grazing in fall of 2007. In May, 2008 after paddocks had been killed with glyphosate, cowpea and pearl millet were no-till drilled following the 2007 seeding rates. In 2008, paddocks that were assigned to cowpea in 2007 were rotated to pearl millet, and paddocks assigned to pearl millet in 2007 were rotated to cowpea.

The necessary P and K amendments were made to all paddocks at forage establishment according to soil tests. Bermudagrass and pearl millet each received two application of 67 kg N ha^{-1} in spring and summer in both years. In July 2008, bermudagrass and pearl millet treatments were sprayed with grazeon to control broadleaf weeds. Chicory received two application of 67 kg N ha^{-1} in winter and spring in both years. In early spring, chicory was sprayed with Select herbicide to control grass. Chicory was mowed as needed after grazing to control bolting.

Grazing Research

The protocol for procedures involving research animals for this project was approved by the Clemson University Animal Care and Use Committee.

Angus-cross steers (n=60) from the Clemson University beef herd were used in this two-year grazing study. Each year, 30 steers were backgrounded on cereal rye/ryegrass pasture during the winter before being randomly assigned and finished on one of five forage treatments. Steers were placed on fescue pasture prior to being placed on treatment. Steers were stratified into three groups representing a high, medium and low weight group, and one steer from each group was randomly assigned to a paddock (3 steers per rep). A 12-h fasted weight was obtained and steers were treated for internal parasites (Ivermectin) immediately before being placed on treatment. In 2007, the turn on date for alfalfa and chicory was early April, while in 2008 grazing began in late March for alfalfa and early April for chicory. In 2007, due to dry conditions, the turn on date for bermudagrass was in late June, while in 2008 grazing began in mid-May. In both years, pearl millet and cowpea grazing began in late June.

Steers were provided with fresh water, shade, and a free choice mineral supplement (Table 2.1). In addition to the mineral supplement, steers on alfalfa treatment were given access to a bloat block (Table 2.2) to prevent bloat. Steers were treated for flies (CyLence) as needed.

Alternate stocking and put and take stocking techniques were utilized for plant regrowth and persistence. Utilizing alternate stocking techniques, each paddock was divided in half with a single polywire fence and steers were rotated between each side at 14 or 28-d intervals depending of plant regrowth. With put and take grazing management, based on forage availability, stocking rate was adjusting by adding or removing extra grazers from paddocks as needed while the three tester steers remained on assigned paddocks for the duration of the grazing season.

Forage Sample Collection

During the grazing period, forage samples and steer weights were collected at 14 and 28-d intervals respectively. Average daily gains were estimated by calculating the difference between the 12-h fasted start weight and the 12-h overnight fasted weight prior to slaughter divided by the total number of days on treatment. Grazing days was the summation of the total number of days each steer grazed within each paddock, including testers and extra grazers. Gains per hectare was calculated by multiplying ADG for steers in each paddock by the number of grazing days for each paddock divided by the paddock size. Forage samples included quadrat samples to estimate forage mass and grab samples to determine chemical composition. Quadrat samples were dried at 95°C, and weighed. Grab samples were freeze dried and ground through a Wiley mill with a 2-mm screen. Ground samples were estimated for moisture content and analyzed for percent CP, NDF, ADF, fatty acid content, and mineral content.

NDF & ADF Analyses

Freeze dried and ground forage grab samples were analyzed for percent NDF and ADF. Forage was weighed out (0.5 g) in duplicates and sealed in F57 filter bags (ANKOM Techonology). Samples were first analyzed for percent NDF using an ANKOM fiber analyzer and neutral detergent solution with alpha-amylase and sodium sulfite. After rinsing three times with H_2O and soaking in acetone, samples were dried and weighed. Samples were then analyzed for ADF using a similar procedure as NDF analysis, with the exception of acid detergent solution instead of neutral detergent solution without alpha-amylase and sodium sulfite. Percent NDF and ADF were calculated on a DM basis. (Procedure A, Van Soest et al., 1991)

Fatty Acid Composition

Forage total lipid content was extracted in duplicates using an ANKOM Fat Extractor. Freeze dried and ground forage samples containing 10 mg of total lipid were transmythelated (Park & Goins, 1994). Fatty acid analysis was performed using an Agilent 6850 gas chromatograph equipped with an internal sampler (Agilent, Wilmington, DE) (Duckett et al., 2002). Fatty acids were quantified based upon the inclusion of an internal standard (methyl tricosanoate) during methylation. Total FA content was expressed as mg g^{-1} of sample on a DM basis, while individual fatty acids were expressed as percent of total FA content.

Mineral Composition and Crude Protein Content

Freeze dried and ground forage grab samples were weighed (1 g) in duplicates and sent to the Clemson University Agricultural Service Laboratory for mineral and CP analysis. Minerals and CP were expressed as either ppm or percent of sample on a DM basis.

Economic Analyses

Using a similar model as Bagley et al. (1987), cost and return analyses were generated using average input and beef prices for 2007 and 2008. Field operation and herbicide costs were calculated using the Mississippi State Budget Generator (2008). Fertilizer costs were estimated using the University of Georgia summer annual forage budgets (Lacy, personal communication, 2008). Actual prices were used for seed costs.

The in-value for steers was calculated using average prices for 2007 and 2008 heavy feeder steers (Wall, personal communication, 2008). The out-value for steers was calculated using average 2007 and 2008 carcass prices adjusted for premiums and discounts for quality and yield grades (Lacy, personal communications, 2008).

Gross margin per ha was calculated multiplying stocking rate by in-value subtracted from stocking rate multiplied by out-value. Cost per gain (kg) was calculated by dividing total cost ha^{-1} by gain (kg) ha^{-1}. Total variable costs ha^{-1} included all pasture management costs except for prorated establishment year costs for perennial species. Prorated costs were generated by dividing the establishment year costs over the lifespan of the forage sward. Total costs ha^{-1} equaled variable costs added to prorated costs. Return over variable costs (ROVC) ha^{-1} was calculated by subtracting total variable costs from the gross margin per hectare. Return over total costs (ROTC) ha^{-1} was calculated subtracting total costs from the gross margin ha^{-1}. The breakeven sales price ha^{-1} was generated by adding the in-value to total variable costs divided by the stocking rate, and dividing this number by the out-weight. This number was then calculated by 100 to be expressed as a breakeven price per 45.4 kg for live animals.

Statistical Analyses

Data was analyzed as a complete randomized block design using the GLM procedure (SAS Inst. Inc., Cary, NC). The main effect was forage treatment and paddocks were the experimental units for live animal, forage and economic analyses data. Least square means were generated and separated using the PDIFF option of SAS.

Results and Discussion

Forage Chemical Composition

Precipitation during both the 2007 and 2008 summer months was around half the normal 30-yr average for the Upstate of South Carolina (Figure 2.1). The drought had a direct impact on forage yield and quality, thus affecting many of the results of this two year summer grazing study. Mineral composition of forages is presented in Table 2.3. Similar to other studies, chicory compared to the other four forages had the highest concentrations of many of the analyzed minerals (P, K, S, Zn, Cu, and Na) (Crush and Evans, 1990; Jung et al., 1996). Chemical composition of forages is shown in Table 2.4. There were treatment × year interactions ADF and CP. Interactions were expected due to differing rainfall and temperature patterns between years.

For NDF, bermudagrass (65.48%, data not shown) had the highest percentage, pearl millet had the second highest (49.83%, data not shown), alfalfa and cowpea did not differ (28.01% and 26.40% respectively, data not shown), and chicory (19.49%, data not shown) had the lowest percentage ($P < 0.01$). Bermudagrass in both 2007 and 2008 had the highest percent ADF, pearl millet in 2007 had the second highest ADF, 2008 pearl millet and alfalfa in both years did not differ, 2008 chicory and cowpea in both years was the second lowest ADF, and 2007 chicory had the lowest percent ADF ($P < 0.01$).

Crude protein as a percent of DM was highest in 2007 cowpea, with 2008 cowpea and alfalfa in both years containing the second highest percent ($P < 0.05$). Alfalfa in 2008 did not differ from pearl millet in both years and 2008 chicory ($P < 0.05$). Chicory and pearl millet in both years did not differ in percent CP ($P < 0.05$). Bermudagrass in both 2007 and 2008 had the lowest percent CP ($P < 0.05$).

Herbage fatty acid composition of forage treatments varied widely between forage species and year, with most fatty acids have treatment × year interactions. Herbage fatty acid composition is presented in Table 2.5. Total fatty acid content in forages ranged from 16.64 to 31.60 mg g^{-1} and was highest in 2007 cowpea, 2007 pearl millet, and 2007 chicory, and lowest in bermudagrass in both years, and 2008 cowpea ($P < 0.01$). Clapham et al. reported a similar range of total FA for a variety of forages including chicory (2005). Similar to other studies, α-linolenic acid was the predominant FA in the five forage species (Clapham et al., 2005; Dewhurst et al., 2001). As Clapham et al. (2005) reported, chicory in 2008 had the highest concentration of α-linolenic acid, and pearl millet in both years had the second highest concentration ($P < 0.05$). Bermudagrass in 2007 had the lowest α-linolenic acid concentration, and 2007 cowpea and 2008 alfalfa had the second lowest concentration ($p < 0.05$). As Scollan et al. (2006) reported, forages are the predominant source of omega-3 (*n*-3) PUFA.

After α-linolenic acid , palmitic and linoleic acids are the next most abundant FA in forages. Palmitic acid did not have treatment × year interactions, but differed between year and treatment. Palmitic acid was higher ($P < 0.05$) in 2007 (16.08%, data not shown), than in 2008 (14.93%, data not shown). Between treatments, palmitic acid was highest in cowpea, second highest in alfalfa, bermudagrass, and pearl millet, and lowest in chicory which did not differ from alfalfa ($P < 0.01$). Linoleic acid was highest in bemudagrass in both years, and lowest in concentration in cowpea during both years (P < 0.05).

Four other FA reported that when combined comprise on averages under 6% of total FA in forages include myristic, palmitoleic, stearic, and oleic acids. Myristic acid was highest in concentration in 2008 bermudagrass and 2007 alfalfa, while 2008 alfalfa did not differ from 2007 alfalfa, and lowest in concentration in 2007 pearl millet and 2007 chicory (P < 0.05). Palmitoleic acid was highest in concentration in cowpea during both years, and lowest in concentration in bermudagrass during both years (P < 0.05). Stearic acid was highest in concentration in 2008 cowpea, second highest in 2007 alfalfa, and lowest in chicory during both years (P < 0.01). Oleic acid did not have treatment × year interactions, but treatments did differ. Alfalfa and bermudagrass had higher concentrations of oleic acid (2.54% and 2.23% respectively, data not shown) than chicory, cowpea, and pearl millet (1.49%, 1.62%, and 1.57% respectively, data not shown) (P < 0.05).

Live Animal Performance

Results for live animal performance are presented in Table 2.6. Steers grazing alfalfa had higher ADG than steers grazing bermudagrass, cowpea and pearl millet, and steers grazing chicory had higher ADG than bermudagrass and pearl millet with cowpea having intermediate gains (P < 0.05). Alfalfa also tended to produce more beef (kg) per hectare than cowpea with bermudagrass, chicory and pearl millet being intermediate (P <

0.1). Similarly, Oltjen et al. observed that steers fed alfalfa hay had higher ADG than steers fed timothy hay (1971).

Alfalfa and chicory steers gaining over 1 kg per day agrees with past grazing studies (Bates et al., 1996, Clark et al., 1990). The lower ADG for steers grazing bermudagrass is also supported by the literature (Hill et al., 1993; Taliaferro et al., 2004). Ball et al. (2002) noted that pearl millet is only high in nutritive quality when in the immature state, thus explaining lower gains over the entire grazing season. However, this study did not support the high ADG (up to 1 kg) and gains per hectare (600 kg ha^{-1}) potential of pearl millet that Burton (1970) suggested, potentially as a result of the drought. Little is known about the potential performance of steers grazing cowpea. Bates et al. (1996) recorded similar gains per hectare for grazed alfalfa ranging between 225-442 kg ha^{-1} (1996).

There were treatment × year interactions for initial weights, grazing days and average forage mass. Initial steer weights were heavier in 2007 than 2008 ($P < 0.01$). Initial weights were heavier for steers grazing bermudagrass, cowpea and pearl millet than alfalfa and chicory ($P < 0.05$) due to the later initiation of grazing for bermudagrass, cowpea and pearl millet. All treatments had increased grazing days in 2008 with the exception of cowpea. Cowpea and pearl millet treatments were severely affected by the drought in 2008, contributing to fewer grazing days for cowpea and lower average available forage and ADG for both cowpea and pearl millet compared to 2007 results. In 2007, pearl millet had higher ($P < 0.05$) average available forage than all other treatments. Treatments did not differ in 2008 ($P > 0.1$). Cowpea had the greatest variability in average available forage between years ranging from 816 to 2268 kg ha^{-1}. Similarly, Muir (2002) also noted this large variability with cowpeas annually yielding between 511 and 3194 kg DM ha^{-1}.

Pearl millet had more grazing days than all other treatments in 2007 ($P < 0.05$), while pearl millet and bermudagrass treatments had more grazing days than all other treatments in 2008 ($P < 0.05$). In 2007, bermudagrass had more grazing days than chicory while alfalfa and cowpea treatments had intermediate grazing days ($P < 0.05$). In 2008, alfalfa produced more grazing days than cowpea with chicory having intermediate grazing days ($P < 0.05$). Pearl millet supported a higher stocking rate than all other treatments, while bermudagrass supported a longer grazing period than other treatments.

Economic Analyses

Economic analyses for the five forage treatments are presented in Table 2.7. Cost per gain (\$ kg^{-1}) did not differ between treatments ranging from \$1.71 per kg for alfalfa to \$2.67 per kg for pearl millet. Pearl millet had the lowest ($P < 0.05$) and the only negative price for gross margin ha^{-1}. This was due to lower carcass prices then the in-value for the steers at the beginning of the grazing period. Total cost of production was lowest for cowpea due to low fertilizer requirements, and highest for pearl millet because of high fertilizer requirements and annual establishment costs ($P < 0.05$). For all treatments, ROTC was negative, with pearl millet having the greatest losses in ROTC ($P < 0.05$). Breakeven sales prices were highest for cowpea and pearl millet and lowest for alfalfa ($P < 0.05$).

The negative numbers for ROVC and ROTC and low prices for gross margin ha^{-1} compared to total and variable costs may not accurately represent a forage-finishing system. Carcass prices were estimated using traditional commodity markets. However, forage-finished beef can be sold as a value-added product as consumers are increasingly willing to pay a premium for products with perceived health and environmental benefits (Roosevelt, 2006; Black, 2007). Some producers are reporting receiving prices in excess of $200 per 45.4 kg for live animals for forage-finished beef (Lacy et al., 2007). All breakeven sales prices for this study are well below premiums that producers could receive for forage-finished beef. These premiums would likely make all forage treatments profitable enterprises. Furthermore, in a year with normal rainfall, stocking rates would likely increase, which would increase gross margin ha^{-1}.

Implications

Alfalfa, chicory, and cowpea treatments all had the higher forage digestibility (low NDF and ADF) than bermudagrass and pearl millet, while alfalfa and chicory also had higher ADG than bermudagrass and pearl millet. Alfalfa and chicory both maintained gains over 1 kg per day over the grazing period. However, bermudagrass and pearl millet treatments produced more grazing days than other treatments due to bermudagrass having a longer grazing season and pearl millet having higher average forage mass.

The drought during the 2007 and 2008 summer grazing periods undoubtedly affected many of the results of this forage-finished beef study. Despite the drought, this study was able to produce acceptable beef maintaining daily gains often exceeding 1 kg per day. Different forage species may be more appropriately suited for producing high quality beef without concentrate supplementation.

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Table 2.1. Composition of Sweetlix B-1440 Free Choice mineral supplementation

Item	Guaranteed analysis
Lasalocid, mg kg^{-1}	1586
Calcium, minimum %	13.00
Calcium, maximum %	15.00
Phosphorous, minimum %	6.50
NaCl, minimum %	19.00
NaCl, maximum %	21.00
Magnesium, minimum %	1.00
Postassium, minimum %	2.00
Sulfur, minimum %	1.00
Copper, minimum ppm	400
Iodine, minimum ppm	45
Selenium, minimum ppm	24
Zinc, minimum ppm	1600
Vitamin A, minimum IU kg^{-1}	220,264
Vitamin D-3, minimum IU kg^{-1}	55,066
Vitamin E, minimum IU kg^{-1}	55

Table 2.2. Composition of Sweetlix Bloat Guard® Pressed Block

Item	Guaranteed analysis
Poloxalene, g kg^{-1}	65.95
Crude Protein, minimum %	4.00
Crude Fat, minimum %	0.05
Crude Fiber, maximum %	12.50
NaCl, minimum %	19.50
NaCl, maximum %	23.00
Postassium, minimum %	1.80
Iodine, minimum ppm	43
Selenium, minimum ppm	13

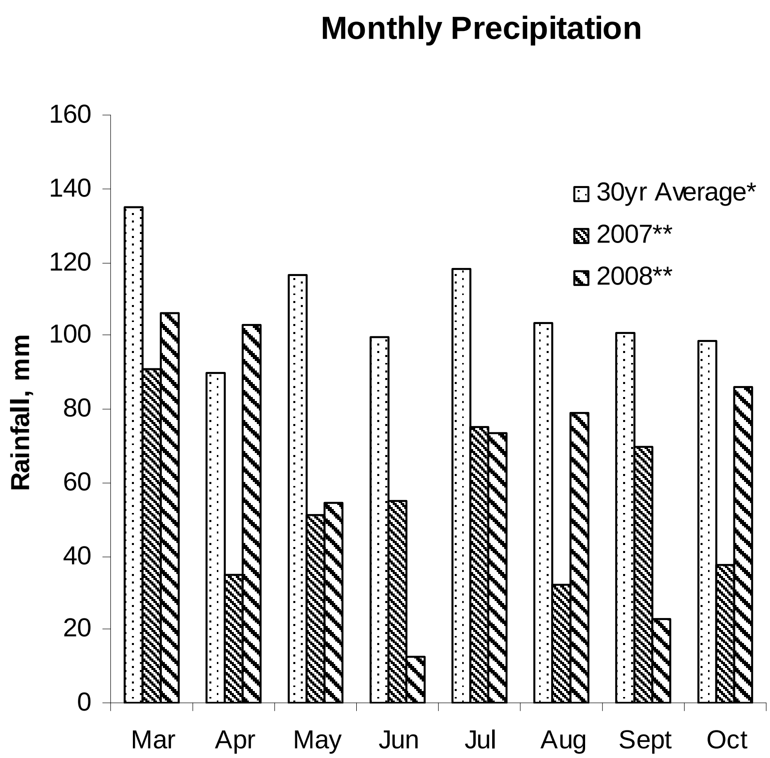

Figure 2.1. Monthly precipitation (mm) during the 2007 and 2008 grazing periods.

*1971-2000, Greenville-Spartanburg Airport, South Carolina (rssWeather.com)

**2007 and 2008 Sandy Springs, SC (http://www7.ncdc.noaa.gov)

Table 2.3. Mineral composition of herbage in forage species from 2007 and 2008 summer grazing research

		% DM					ppm				
Forage*	Year	P	K	Ca	Mg	S	Zn	Cu	Mn	Fe	Na
AL	2007	0.32^{cde}	2.83^{c}	1.09^{e}	0.30	0.36	41.79^{de}	8.25^{ef}	72.05	121.41	86.87^{bcd}
	2008	0.36^{bc}	2.51^{d}	0.90^{f}	0.27	0.32	38.08^{e}	6.60^{g}	44.43	150.56	109.57^{bc}
BG	2007	0.22^{f}	1.91^{e}	0.52^{h}	0.29	0.41	33.58^{f}	5.43^{hi}	40.77	123.35	81.92^{bcd}
	2008	0.17^{f}	1.51^{f}	0.48^{h}	0.28	0.40	27.91^{g}	4.57^{i}	36.29	95.29	138.11^{b}
CH	2007	0.41^{a}	4.71^{a}	1.56^{c}	0.41	0.59	61.86^{a}	14.66^{a}	75.79	101.87	611.52^{b}
	2008	0.31^{de}	3.80^{b}	1.34^{d}	0.44	0.57	48.60^{c}	9.22^{de}	80.98	132.24	816.75^{a}
CO	2007	0.37^{ab}	2.45^{d}	2.17^{a}	0.69	0.30	45.11^{cd}	7.73^{f}	128.38	150.87	18.08^{e}
	2008	0.27^{e}	2.35^{d}	1.91^{b}	0.75	0.28	43.86^{d}	6.40^{gh}	64.82	270.19	17.01^{e}
PM	2007	0.34^{bcd}	2.96^{c}	0.74^{g}	0.52	0.26	65.75^{a}	10.65^{bc}	73.62	243.68	58.32^{cde}
	2008	0.21^{f}	2.87^{c}	0.52^{h}	0.35	0.26	52.79^{b}	9.54^{cd}	74.76	168.07	45.91^{de}
SEM		0.01	0.06	0.02	0.03	0.01	1.19	0.32	9.63	28.01	16.00
P-value											
	TRT (T)	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.02	<0.01	<0.01
	Year (Y)	<0.01	<0.01	<0.01	0.27	0.02	<0.01	<0.01	0.03	0.43	<0.01
	T × Y	0.01	<0.01	0.02	0.06	0.64	0.01	<0.01	0.07	0.11	0.01

[*]Forage treatments: alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)

[a,b,c,d,e,f,g,h,i] Means with different superscripts in the same column differ ($P < 0.05$)

Table 2.4. Concentration of NDF, ADF and CP in herbage of forage species from 2007 and 2008 summer grazing research

		% DM		
Forage	Year	NDF	ADF	CP
Alfalfa	2007	26.7	19.2^{c}	24.96^{bc}
	2008	29.3	20.8^{c}	27.96^{b}
Bermudagrass	2007	64.4	28.1^{a}	15.53^{e}
	2008	66.5	27.8^{a}	14.84^{e}
Chicory	2007	16.4	13.2^{e}	20.73^{d}
	2008	22.6	16.4^{d}	22.79^{cd}
Cowpea	2007	26.6	17.2^{d}	31.22^{a}
	2008	26.2	16.8^{d}	27.06^{b}
Pearl Millet	2007	51.1	24.9^{b}	22.97^{cd}
	2008	48.6	20.9^{c}	22.61^{cd}
SEM		1.03	0.56	0.70
P-value				
TRT (T)		<0.01	<0.01	<0.01
Year(Y)		0.06	0.94	0.82
T × Y		0.06	0.01	0.03

[a,b,c,d,e] Means with different superscripts in the same column differ (P < 0.05

Table 2.5. Concentration of fatty acids in herbage of forage species from 2007 and 2008 summer grazing research

		% of Total FA							
Forage*	Year	C14:0	C16:0	C16:1c9	C18:0	C18:1c9	C18:2	C18:3	mg g^{-1}
AL	2007	0.50[ab]	14.54	1.72[c]	2.62[b]	2.92	13.30[d]	45.25[de]	23.32[d]
	2008	0.41[bc]	14.88	1.81[c]	2.28[d]	2.17	14.77[bc]	43.47[e]	25.51[cd]
BG	2007	0.25[de]	16.25	1.12[d]	1.74[e]	2.44	15.15[ab]	38.47[f]	19.03[e]
	2008	0.58[a]	14.69	1.15[d]	1.74[e]	2.01	15.63[a]	45.46[d]	16.64[e]
CH	2007	0.15[ef]	13.99	1.81[c]	0.99[g]	1.50	14.09[c]	48.17[cd]	28.11[abc]
	2008	0.30[cd]	13.89	2.04[b]	0.97[g]	1.49	14.10[c]	57.27[a]	24.00[cd]
CO	2007	0.22[de]	18.75	2.51[a]	2.53[c]	1.42	9.57[f]	42.18[e]	31.60[a]
	2008	0.28[cde]	17.34	2.43[a]	2.90[a]	1.81	10.14[ef]	45.49[de]	17.98[e]
PM	2007	0.04[f]	16.87	1.78[c]	1.55[f]	1.70	10.83[e]	50.14[bc]	30.94[ab]
	2008	0.25[de]	13.84	1.57[c]	1.51[f]	1.45	10.40[e]	52.96[b]	26.52[bcd]
SEM		0.04	0.50	0.05	0.02	0.18	0.21	0.90	1.30
P-value									
TRT (T)		<0.01	<0.01	<0.01	<0.01	0.02	0.01	0.01	0.05
Year (Y)		<0.01	0.02	0.68	0.71	0.09	0.02	<0.01	<0.01
T × Y		0.02	0.10	0.03	<0.01	0.09	0.04	0.02	0.01

*Forage treatments: alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)
[a,b,c,d,e,f,g] Means with different superscripts in the same column differ (P < 0.05)

Table 2.6. The effect of forage treatment on live animal performance

Item	Year	Treatment[*] AL	BG	CH	CO	PM	SEM	P-value
Initial Weight, kg	2007	431[b]	492[a]	434[b]	487[a]	486[a]	6.31	0.005
Initial Weight, kg	2008	382[c]	463[a]	412[b]	476[a]	470[a]	7.83	0.035
Final Weight, kg	------	538	579	517	555	525	12.60	0.110
Average daily gain, kg day-1	------	1.28[a]	0.76[c]	1.13[ab]	0.88[bc]	0.56[c]	0.085	0.018
Gains per hectare, kg ha-1	------	218[d]	164[de]	153[de]	101[e]	151[de]	18.41	0.071
Grazing Days, days ha^{-1}	2007	150[bc]	170[b]	115[c]	129[bc]	224[a]	13.36	0.023
Grazing Days, days ha^{-1}	2008	186[b]	268[a]	155[bc]	101[c]	331[a]	20.45	0.007
Average forage mass, kg ha^{-1}	2007	1997[b]	1281[b]	1974[b]	2268[b]	4181[a]	335.05	0.021
Average forage mass, kg ha^{-1}	2008	2085	1721	1686	816	1428	237.54	0.107

[a,b,c] Means with different superscripts in the same rows differ ($P < 0.05$)
[d,e] Means with different superscripts in the same rows differ ($P < 0.1$)
[*]Forage treatments: alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)

Table 2.7. Economic analysis of five different forage treatments for finishing beef cattle

	Treatment[*]						
Item	AL	BG	CH	CO	PM	SEM	P-value
Gross Margin ($ ha^{-1})[1]	$232.27[a]	$65.29[a]	$189.68[a]	$105.54[a]$	(218.36)[b]	50.66	0.016
Cost per gain ($ kg^{-1})[2]	$1.71	$2.19	$2.12	$2.56	$2.67	0.25	0.215
Total variable costs ($ ha^{-1})[3]	$35.30[d]	$279.08[b]	$159.51[c]	$282.17[b]	$381.42[a]	9.68	<0.001
Total costs ($ ha^{-1})[4]	$337.89[b]	$342.58[b]	$336.21[b]	$282.17[c]	$381.42[a]	9.68	0.014
ROVC ($ ha^{-1})[5]	$196.98[a]	$(213.79)[b]	$30.17[a]	$(176.64)[b]	$(599.77)[c]	54.18	0.003
ROTC ($ ha^{-1})[6]	$(105.62)[a]	$(277.29)[a]	$(146.53)[a]	$(176.64)[a]	$(599.77)[b]	54.18	0.014
BE sales price ($ 45.4 kg^{-1})[7]	$77.15[d]	$93.12[b]	$83.58[c]	$99.36[a]	$98.19[ab]	1.49	0.002

[*]Forage treatments: alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)

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

[1]Includes stocking rate from grazing trial multiplied by the in-value of steers estimated as average annual prices for heavy feeder steers.

[2]Includes total cost divided by gains per hectare from the grazing trial.

[3]Includes fertilizer and herbicide inputs, machinery, seed, labor and interest expenses.

[4]Includes variable costs and prorated establishment year costs over the lifespan of the forage sward.

[5]Return over variable costs (ROVC) includes total variable costs subtracted from gross margin per hectare.

[6]Return over total costs (ROTC) includes total costs subtracted from the gross margin per hectare.

[7]The breakeven (BE) sales price was generated by adding the in-value to total variable costs divided by the stocking rate, and dividing this number by the out-weight. This number was then calculated by 100 to be expressed as a breakeven price per 45.4 kg live weight.

CHAPTER 3

FORAGE SPECIES ALTER FATTY ACID COMPOSITION AND ANITIOXIDANT CONTENT IN FINISHING BEEF CATTLE

Abstract

Angus-cross steers (n=60) were finished on one of five forages (alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)) during the summer months of a 2-yr grazing study to assess the effects of these forages on carcass quality, consumer acceptability, and mineral, fatty acid, and antioxidant concentration in the LM. Using a complete randomized block design, ten 2-ha paddocks were blocked and assigned forage species (2 reps per species). Each year, steers (3 per rep) were randomly assigned to paddocks and grazing began when adequate forage growth for individual species was present. Put and take grazing techniques were utilized. Steers were slaughtered when sufficient forage mass for individual forage species was no longer present to support animal gains or when average steer weight exceeded 568 kg. Data were analyzed using PROC MIXED of SAS. Carcass dressing percentages were higher for AL and CO than BG and PM, with CH being higher than BG ($P = 0.01$). Subcutaneous fat thickness was greater ($P < 0.01$) for AL, CH, and CO than BG and PM. Cowpea carcasses had the highest ($P < 0.05$) quality grades and marbling scores. Postmortem aging increased tenderness ($P < 0.01$). There were treatment × age interactions for WBS scores aged at 1, 3, 7, 14 and 28 days ($P < 0.05$). A blind consumer taste panel rated beef from AL, CO and PM higher ($P < 0.01$) in overall palatability than CH and BG. Total cholesterol and α-tocopherol concentrations did not significantly

differ between treatments (P > 0.1). The LM from BG treatments had higher concentrations of minerals (Ca, Mg, Zn, and Na) than beef from other treatments (P < 0.05). CLA *cis*-9, *trans*-11 was greater in concentration in BG and PM treatments than all other treatments (P = 0.02). *Trans*-11 vaccenic acid tended to be greater in concentration in BG and PM than AL, with CH and CO being intermediate (P = 0.07). Chicory and CO treatments had higher concentration of linolenic acid than other treatments, while AL was higher in concentration than PM (P < 0.01). Stearic acid was higher in concentration in CO than CH, PM, and AL, while BG was higher than PM and AL, and CH was higher than AL (P = 0.02). Concentrations of MUFA tended to be higher in AL and PM than CH with BG and CO being intermediate (P = 0.08).

Introduction

Markets are expanding for forage-finished beef as consumers are increasingly demanding products with perceived health and environmental benefits (Norwood, 2004; Roosevelt, 2006). In past decades, studies comparing forage- to concentrate-finished beef revealed a trend of decreased overall acceptability of forage-finished beef (Bowling et al., 1977; Melton, 1983). During the last decade, forage-finished beef research has focused on positive attributes of finishing cattle on forages. These benefits include lower total fat and higher concentrations of health promoting fatty acids and antioxidants compared to concentrate-finished beef (Yang et al., 2002; Duckett & Pavan, 2007).

Beef and lamb have an unfavorably low PUFA to SFA (P:S) ratio (0.11 and 0.15 respectively) compared to pork (0.45) (Enser et al., 1996). A dietary P:S ratio of 0.45 or higher is recommended for human health (Department of Health, 1994). However, finishing beef on forages increases PUFA concentrations that are beneficial to human health. In forage-finished beef, deposition of omega-3 (*n*-3) PUFA, particularly linolenic acid, is higher than in concentrate-finished beef, which lowers the *n*-6:*n*-3 ratio (French et al., 2000; Realini et al., 2004). Forage-finishing increases concentrations of total CLA and CLA *cis*-9 trans-*11*, a potent anticarcinogen, in ruminant tissue (Realini et al., 2004), by as much as 466% (Poulson et al., 2004).

There are many studies comparing concentrate- to forage-finished beef, research is limited comparing how different forage systems alter the carcass quality and chemical composition in finishing beef cattle. Therefore the objective of this study was to evaluate how alternative forages grazed during the summer months in the Southeast United States alter the carcass quality and chemical composition including fatty acid composition and anitioxidant content in finishing beef cattle.

Materials and Methods

Animal Management and Data Collection

The protocol for procedures involving research animals for this project was approved by the Clemson University Animal Care and Use Committee.

Angus-cross steers (n=60) from the Clemson University beef herd were used in a two-year grazing study to assess how five different forage species including alfalfa (*Medicago sativa* L.), bermudagrass (*Cynodon dactylon* L.), chicory (*Chichorium intybus* L.), cowpea (*Vigna unguiculata* L.), and pearl millet (*Pennisetum glaucum* (L.)R Br.) alter tenderness, mineral composition, fatty acid composition and antioxidant content in finishing beef cattle. Each year, 30 steers were backgrounded on cereal rye/ryegrass pasture during the winter before being randomly assigned and finished on one of five forage treatments. Steers were placed on fescue pasture prior to being placed on treatment. Using a Complete Randomized Block Design with two replications, ten 2-ha paddocks were blocked and forage species were randomly assigned within each block. Paddocks were blocked according to soil type. Steers were stratified into three groups representing a high, medium and low weight group, and one steer from each group was randomly assigned to a paddock (3 steers per rep). Forage establishment and grazing management is reported in the previous chapter.

Steers were slaughtered when there was either insufficient forage mass present or when the 12-h fasted average steer liveweight exceeded 568 kg. Steers were transported to the Clemson University meat laboratory following an overnight withdrawal from pasture. Hot carcass weights were collected at slaughter.

Carcass data was collected after 48-h postmortem. The interface between the 12^{th} and 13^{th} rib was used to collect carcass data including ribeye area, marbling score, subcutaneous (SQ) fat thickness, pH, lean and SQ fat thickness. The LM from the left side of each carcass was removed and disected into 2.54 cm steaks. Steaks were vacuum packaged for subsequent Warner-Bratzler Shear Force (WBS) measurements and aged at 2°C for assigned postmortem aging and proximate analyses. Sirloin roasts were collected from the left side of each carcass after 14-d aging at 2°C, vacuum packaged and frozen for subsequent consumer taste panel analysis.

Instrumental Color

At 48-h postmortem, instrumental color readings were recorded for L* (darkness to light, with lower numbers indicating darkness), b* (yellowness, with higher numbers representing increased yellowness), and a* (redness, with higher numbers indicating increased redness). A Minolta chromameter (CR-310 Minolta Inc., Osaka, Japan) was used to collect color reading from the exposed LM at the posterior of the 12th rib and the subcutanious (s.c.) fat covering the 12th rib (Duckett et al., 2007). Color values were collected from three different locations on the exposed LM and subcutaneous fat at the 12th rib.

Tenderness: Warner-Bratzler Shear Force

Five steaks (2.5 cm thick) were collected from the LM muscle and vacuum packaged for tenderness analysis. Steaks were stored in a cooler at 2°C for 1, 3, 7, 14, and 28 d post slaughter and then frozed at -20°C. Steaks were thawed at 2°C for 24 h before being cooked to an internal temperature of 71°C on an electric grill. After cooking, steaks were allowed to cool to room temperature before 1.27 cm cores (6 per steak) were removed. Cores were sheared at a perpendicular angle to the long axis of the core using a Warner-Bratzler shear force machine (Standard Shear Model 2000 D, G-R Manufacturing Co; Manhattan, Kansas) (Duckett et al., 2007).

Consumer Taste Panel

Consumers (n = 90) attending a South Carolina Cattlemen's Association Convention participated in a taste panel to evaluate overall palatability and preference of beef produced from the five forage treatments. Participants were not given any information about the project. Each individual was asked to evaluate meat from samples A, B, C, D, and E representing the five forage treatments. In preparation, sirloin roasts (3 roasts per treatment) were thawed at 2°C for approximately 48 h and cooked to an internal temperature of 65°C. Roasts were transported to the location of the Cattlemen's Association Convention in closed containers and cut into 1 cm cubes. The consumer survey included basic demographic information including age, gender, education level and income of participants. For each sample, participants rated overall palatability by making a mark on a continuous 10 cm line, with each end represented by a frown (☹) for dislike or a smiley face (☺) for like using a continuous scale. Participants were also asked to rate an overall preference of the five samples.

Fatty Acid Composition

A steak (2.54 cm thick) representing the 12^{th} rib of the LM was vacuum packaged and frozen (-20°C) for subsequent proximate analysis. All fat and connective tissue was removed from the exterior of the steak. After thawing for 24 h at 2°C, the steak was chopped and freeze dried before being ground. Total lipid content was extracted in duplicates using an ANKOM Fat Extractor.

According to the method of Duckett et al. (2002) lean samples containing 10 mg of total lipid were transmythelated (Park & Goins, 1994). Fatty acid analysis was performed using an Agilent 6850 gas chromatograph equipped with an automatic sampler (Agilent, Wilmington, DE). Fatty acids were quantified based upon the inclusion of an internal standard (methyl tricosanoate) during methylation. Total FA content was expressed as g 100 g^{-1} of sample on a wet basis, while individual fatty acids were expressed as a percent of total FA content.

Mineral Composition

Freeze dried and ground samples representing the 12th rib of the LM were weighed (1 gram) in duplicates and sent to the Clemson University Agricultural Service Laboratory for mineral analysis. Minerals were expressed as mg 100 g^{-1} on a wet basis.

α-*Tocopherol Analysis*

Concentrations of α-tocopherol in muscle samples was determined using the procedure outlined in Lee et al. (2005). Freeze dried and ground sample (0.25 g) representing the 12th rib of the LM was analyzed for α-tocopherol content. After saponification and extraction of hexane, samples were analyzed by conditions. α-Tocopherol content was expressed in μg g^{-1} of sample on a wet basis.

Cholesterol Content Analysis

Total cholesterol of muscle samples was analyzed using the procedure outlined by Du and Ahn (2002). Freeze dried and ground sample (0.25 g) representing the 12th rib of the LM was analyzed for total cholesterol content. After saponification and extraction of hexane, samples were analyzed using an Agilent 6850 gas chromatograph equipped with an automatic sampler. Total cholesterol content was expressed in mg g^{-1} of sample on a wet basis.

Statistical Analysis

Carcass characteristics, fatty acid, antioxidant, cholesterol, WBS and color data were analyzed as a complete randomized block design using the GLM procedure (SAS Inst. Inc., Cary, NC). The main effect was forage treatment, and animal was the experimental unit. Consumer taste panel analysis was a complete randomized design using the GLM procedure of SAS with forage treatment as the main effect and panelists as the experimental unit. Warner-Bratzler Shear Force values were analyzed using a repeated measures analysis. Least square means were generated and separated using the PDIFF option of SAS.

Results and Discussion

Results for forage chemical composition, live animal performance, and economic analyses for this study are presented in the previous chapter. The Southeast United States experienced a severe drought during the 2007 and 2008 summer grazing periods of this study, potentially influencing results. Rainfall data is presented in the previous chapter.

Carcass Characteristics

Carcass data for this study is presented in Table 3.1. Live animal weights at slaughter and HCW did differ between treatments. Carcasses from alfalfa, chicory, and cowpea treatments had higher ($P < 0.05$) SQ fat thickness than bermudagrass and pearl millet treatments. Similarly, carcasses from alfalfa, chicory and cowpea treatments had higher dressing percentages than bermudagrass, with pearl millet carcasses not differing from chicory or bermudagrass ($P < 0.05$). Treatments with the higher dressing percentages and SQ fat thickness corresponded to treatments that produced that highest ADG and had higher forage quality (lower NDF and ADF as presented in previous chapter). Yield grades did not differ between treatments. Carcasses from cowpea produced the highest marbling scores ($P < 0.05$) and quality grades ($P < 0.01$), while chicory carcasses produced the lowest marbling scores and quality grades. Final carcass pH did not differ between treatments.

Longissimus muscle color and SQ fat color is presented in Table 3.2. Forage treatments did not influence SQ fat color ($P > 0.1$). However, alfalfa LM had higher b* (yellow) values than bermudagrass and pearl millet, and cowpea had higher ($P = 0.05$) b* values than pearl millet. Alfalfa LM also had higher ($P < 0.05$) a* (red) values than bermudagrass, chicory and pearl millet, with cowpea having higher a* values than pearl millet. There was a trend for LM from alfalfa and cowpea treatments to have lighter ($P < 0.1$) LM (higher L* values) than pearl millet. Reagan et al. (1977) reported that legume-finished beef had brighter lean color than grass-finished beef. In 2008, SQ fat color was lighter (higher L*) than in 2007 ($P < 0.05$).

Tenderness Results

Warner-Bratzler shear force (WBS) scores are presented in Tables 3.3 and Figure 3.1. Scores decreased between all days aged (1, 3, 7, 14, and 28 d). There were treatment × age interactions for WBS scores ($P < 0.05$). For 1 d, bermudagrass had higher ($P <0.05$) WBS scores than alfalfa, cowpea, and pearl millet, and pearl millet and chicory were higher than cowpea. Day 3 WBS scores were highest ($P < 0.05$) for bermudagrass than all other treatments. Day 7 WBS scores were highest ($P < 0.05$) for bermudagrass and chicory, while alfalfa and pearl millet was higher than cowpea. Chicory and pearl millet had higher ($P < 0.05$) Day 14 WBS scores than alfalfa and cowpea. Finally, cowpea had the lowest ($P < 0.05$) 28 d WBS score of all treatments.

These tenderness scores agree with Scollan et al. (2006), reporting that legume-finished beef had increased tenderness over grass-finished beef. Similarly, Oltjen et al. (1971) reported lower WBS values for alfalfa hay-finished beef compared to beef finished on timothy hay. Tenderness scores corresponded with consumers rating that beef from alfalfa, cowpea and pearl millet had higher overall palatability than beef from chicory and pearl millet.

Taste Panel Results

The demographic description of the 90 individuals who participated in the consumer taste panel is presented in Table 3.4. Participants tended to be older, have higher incomes and higher levels of educations and were predominantly male. Results from the consumer taste panel are presented in Table 3.5. For overall palatability, more individuals ranked beef samples from alfalfa, cowpea, and pearl millet treatments higher ($P < 0.01$) than bermudagrass and chicory treatments. For preference, the highest proportion of participants chose meat from alfalfa as most preferred, while the lowest proportion of participants chose meat from bermudagrass as most preferred. Similarly, Oltjen et al. (1971) reported steers finished of alfalfa hay were more flavorful than steers finished on timothy hay. Larick and Turner (1990) suggest that increased PUFA concentrations lower oxidative stability, leading to oxidative rancidity and less desirable flavor in beef. Chicory had higher *n*-3 PUFA deposition, thus potentially explaining the low preference for chicory meat samples.

Mineral Composition

Mineral composition of the LM for steers finished on alfalfa, bermudagrass, chicory, cowpea, and pearl millet is presented in Table 3.6. Concentrations of P, K, Cu, Mn, Fe, and S did not differ between treatments ($P > 0.1$). Steers grazing bermudagrass had higher ($P < 0.05$) concentration of Ca, Mg, Zn, and Na compared to all other treatments.

Cholesterol Composition

Concentration of total cholesterol in the LM is presented in Table 3.7. Treatment and year were not significantly different; however, treatment × year interaction was significant ($P < 0.05$). Steers grazing cowpea and bermudagrass in 2007 and alfalfa, chicory, cowpea and pearl millet in 2008 had the highest ($P < 0.05$) concentrations of total cholesterol. Alfalfa, chicory and pearl millet steers in 2007 and bermudagrass steers in 2008 had the lowest concentrations of total cholesterol. Concentrations of total cholesterol ranged from 47.93 to 55.08 mg g^{-1}. This range agrees with Duckett et al. who reported a range of 43.08 to 59.19 mg g^{-1} for cattle finished on varying days of time on feed (1993).

Fatty Acid Composition

Fatty acid composition as a percent of the total FA profile of the LM for steers finished on five forage treatments is presented in Table 3.8. Gravimetric concentration of total fatty acid did not differ between treatments ($P < 0.1$). There were differences between years for the individual FA with total PUFA, *n*-6:*n*-3 ratio, P:S ratio, percent of unidentified FA, CLA *cis*, *cis*, CLA *trans*, *trans*, *trans*-10 octadecenoic acid, and eicosapentaenoic (EPA) acid being higher ($P < 0.05$) in 2008 than in 2007 across all treatments. In additions, there was a trend for arachidonic acid, docosapentaenoic **(**DPA) acid, PUFA *n*-6 to be higher ($P < 0.1$) in 2008 than 2007. However, in 2007, myristic, myristoleic, palmitic, and palmitoleic acids along with sum of known FA were higher than in 2008 ($P < 0.05$). There was a trend for linoleic acid and MUFA to be higher ($P < 0.1$) in 2007 than 2008. There was treatment × year interactions for *n*-6:*n*-3 ratio with pearl millet and chicory in 2008 having the highest ratios and alfalfa and cowpea in 2007 having the lowest ratios ($P < 0.01$). These ratios are all well below the recommended dietary *n*-6:*n*-3 ratio of 4 or less for human consumption (Department of Health, 1994).

Concentration of stearic acid was highest in steers grazing cowpea and bermudagrass and lowest in alfalfa and pearl millet, while chicory was not different from bermudagrass or pearl millet ($P < 0.05$). Concentration of α-linolenic acid, the predominant *n*-3 fatty acid in beef adipose tissue, was higher in steers grazing chicory and cowpea, and lowest in pearl millet and bermudagrass, while alfalfa did not differ from bermudagrass ($P < 0.01$).

Steers grazing bermudagrass and pearl millet had the highest concentration ($P < 0.05$) of CLA *cis*-9, *trans*-11 than in the other three treatments ($P < 0.05$). The CLA *cis*-9, *trans*-11 isomer is unique to bovine FA profiles as a result of ruminal biohydrogenation of linoleic acid and is higher in concentration in beef finished on forage diets (Duckett and Pavan, 2007). This isomer has also been linked to multiple biological functions including the inhibition of carcinogenesis, reduced rate of fat deposition, altered immune response, and reduced serum lipids (Pariza et al., 2000). In addition, CLA *cis, cis* was lowest ($P = 0.05$) in concentration in alfalfa compared to the other four treatments.

While oleic acid, the predominant MUFA, did not differ between treatments, there was a tendency for concentration of MUFA to be higher in steers grazing alfalfa and pearl millet than in chicory, with bermudagrass and cowpea treatments being intermediate ($P < 0.1$). *Trans*-11 vaccenic acid, precursor to CLA *cis*-9, *trans*-11, tended to be higher in bermudagrass and pearl millet than alfalfa with chicory and cowpea having intermediate concentrations ($P < 0.1$). Pentadecanoic acid followed a similar trend, tending to be higher in deposition in bermudagrass and pearl millet than alfalfa and chicory, with cowpea being intermediate ($P < 0.1$). The P:S ratio did not differ ($P > 0.1$) between treatments and ranged between 0.12 for bermudagrass to 0.18 for cowpea. This range is at the high end of P:S ratios reported for forage-finished beef (French et al., 2000; Realini et al., 2005) and above the average P:S ratio for beef (0.11) (Enser et al., 1996). Ratios for concentrate-finished beef is usually higher due to higher concentrations of linoleic acid in concentrate-finished beef and higher concentrations of stearic acid in forage-finished beef (Enser et al., 1998).

Scollan et al. reported that increasing legumes as a percent of the diet of cattle leads to increased deposition of *n*-6 and *n*-3 PUFA leading to an increase in the P:S ratio (2006). Lee et al. (2004) suggested that higher deposition of PUFA from cattle grazing red clover may be due to reduced ruminal biohydrogenation as a result of the protective effect of the enzyme polyphenol oxidase (PPO) in red clover. The protective effects of PPO reduce the biohydrogenation of PUFA by reducing plant lipolysis and proteolysis (Lee et al., 2004). This may partially explain why steers grazing bermudagrass and pearl millet had higher deposition of fatty acids that are a result of biohydrogenation (CLA, *trans*-11 vaccenic acid, pentadecanoic acid), while steers grazing legume treatments (alfalfa and cowpea) and chicory had higher deposition of linolenic acid.

Antioxidant Composition

Concentration of α-Tocopherol in the LM is presented in Table 3.9. α-Tocopherol concentrations differed in the LM between years ($P < 0.05$), with higher concentration in 2008 than in 2007. There was no significant treatment difference, but values varied widely. In 2007, α-tocopherol concentrations had a much smaller range (3.41 μg g^{-1} in cowpea and 5.13 μg g^{-1} in bermudagrass) than in 2008 (6.69 μg g^{-1} in bermudagrass and 35.24 μg g^{-1} in cowpea) ($P > 0.1$). However, treatments in neither year significantly differed ($P > 0.1$).

These, unusually high concentrations are not supported by the literature with Scollan et al. (2006) reporting α-tocopherol concentration of 3.4 mg kg^{-1} and Realini et al. (2004) reporting 3.91 μg g^{-1} in pasture-finished cattle. Forage feeding has been linked to both increased PUFA deposition and antioxidant (α-tocopherol, carotenoid, and flavenoid) deposition in beef cattle (Wood & Enser, 1997). However, while Scollan et al. (2006) reported that PUFA deposition increased while feeding red clover silage instead of grass silage, Vitamin E concentrations decreased in red clover versus grass silage.

Implications

Alfalfa, cowpea and chicory carcasses had higher dressing percents and fat thickness than pearl millet and bermudagrass. Cowpea carcasses had the highest quality grades and marbling scores with many carcasses grading Choice. Consumers most often preferred meat from alfalfa, while alfalfa, cowpea and pearl millet all received higher overall acceptability scores than chicory and bermudagrass in a consumer taste panel.

Proximate analyses of the LM reveals varying differences in the mineral composition and fatty acid composition of beef finished on alfalfa, bermudagrass, chicory, cowpea and pearl millet. Total cholesterol and α-tocopherol concentrations did not significantly differ between treatments, although there were treatment × year interactions for total cholesterol and year differences for α-tocopherol concentrations. There was an unexpectedly large range in α-tocopherol concentrations in 2008 that needs to be further explored.

Results suggest that beef from bermudagrass was more highly mineralized (higher in Ca, Mg, Zn, and Na) than beef from other treatments. Furthermore, a number of isomers and odd chain fatty acids associated with ruminal biohydrogenation were higher in deposition in the grass treatments (bermudagrass and pearl millet). *Trans*-11 vaccenic acid tended to be higher in concentration, while CLA and CLA *cis*-9, *trans*-11. These isomers have been linked to important human health benefits. Chicory and cowpea treatments, and to a lesser extent alfalfa had higher depositions of linolenic acid, the predominant omega-3 PUFA.

There is a need for further research of forage species that will not only produce high quality, acceptable beef, but will also produce beef with more favorable fatty acid and antioxidant profiles for human consumption. Numerous studies have established differences in fatty acid deposition between beef finished on forage versus concentrate diets. However, this study is one of the first studies to report differences in fatty acid deposition of beef finished on different forages. How specific forages alter the deposition of fatty acids and antioxidants must continue to be studied.

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Table 3.1. The effect of forage treatment on carcass quality

	Treatment*						P-value		
Item	AL	BG	CH	CO	PM	SEM	TRT(T)	YEAR(Y)	T × Y
Live Weight, kg	530	567	509	548	513	12.38	0.106	0.165	0.594
Carcass Weight, kg	329	327	307	342	307	8.49	0.142	0.020	0.838
Dressing Percent	60.8[a]	57.6[c]	60.4[ab]	62.3[a]	58.9[bc]	0.01	0.013	0.005	0.159
Fat Thickness, mm	7.70[a]	5.61[b]	7.56[a]	6.99[a]	4.53[b]	0.26	0.004	0.404	0.071
Ribeye Area, cm^2	78.15	79.12	73.53	80.95	77.29	1.90	0.247	0.070	0.546
KPH Fat	1.83[e]	1.83[e]	1.92[e]	1.75[e]	1.25[f]	0.13	0.088	0.749	0.310
Yield Grade	2.45	2.23	2.55	2.38	1.89	0.17	0.238	0.248	0.253
Marbling	450.0[b]	455.0[b]	433.3[c]	505.0[a]	473.3[ab]	9.62	0.034	0.139	0.354
Quality Grade[1]	3.50[c]	3.75[bc]	3.17[d]	4.33[a]	3.83[b]	0.08	0.004	0.110	0.245
pH	5.57	5.60	5.61	5.50	5.54	0.05	0.587	0.787	0.469

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

[e,f] Means with different superscripts in the same rows differ ($P < 0.1$)

*Forage treatments: alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)

[1]Quality Grade: 3 = Low Select, and 4 = High Select

Table 3.2. The effect of forage treatment on subcutaneous fat color and longissimus muscle color

	Treatment[*]						P-value		
Item	AL	BG	CH	CO	PM	SEM	TRT(T)	YEAR(Y)	T × Y
SQ Fat Color									
L*	72.12	71.87	72.35	70.51	71.47	0.84	0.614	0.028	0.121
a*	8.17	11.83	7.54	10.55	10.40	1.02	0.152	0.073	0.189
b*	22.18	22.29	23.49	23.34	23.11	0.64	0.533	0.235	0.093
LM Muscle Color									
L*	38.54[d]	37.72[de]	37.26[de]	38.24[d]	36.62[e]	0.37	0.093	0.485	0.023
a*	25.95[a]	24.71[bc]	24.42[bc]	25.58[ab]	23.58[c]	0.33	0.032	0.198	0.198
b*	10.14[a]	8.95[bc]	9.11[abc]	10.00[ab]	8.53[c]	0.28	0.051	0.161	0.169

[*]Forage treatments: alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)
[a,b,c] Means with different superscripts in the same row differ ($P < 0.05$)
[d,e] Means with different superscripts in the same rows differ ($P < 0.1$)

Table 3.3. The effect of forage treatment × days aged on Warner-Bratzler shear force scores (kg) of the LM

	Days Aged*						P-value		
Treatment	1	3	7	14	28	SEM	TRT(T)	AGE(A)	T × A
AL	5.01^{bc}	4.63^{b}	3.90^{b}	3.35^{b}	3.06^{a}	0.25	0.052	<0.001	0.041
BG	6.26^{a}	5.97^{a}	4.81^{a}	3.71^{ab}	3.22^{a}	0.25	0.052	<0.001	0.041
CH	5.70^{ab}	4.72^{b}	4.40^{a}	4.08^{a}	3.57^{a}	0.25	0.052	<0.001	0.041
CO	4.43^{c}	4.60^{b}	3.34^{c}	3.32^{b}	2.84^{b}	0.25	0.052	<0.001	0.041
PM	5.56^{b}	4.88^{b}	3.91^{b}	4.05^{a}	3.31^{a}	0.25	0.052	<0.001	0.041

[a,b,c] Means with different superscripts in the same column differ ($P < 0.05$)
*Days aged: steaks stored at 2°C before being frozen for 1, 3, 7, 14, and 28 days post slaughter

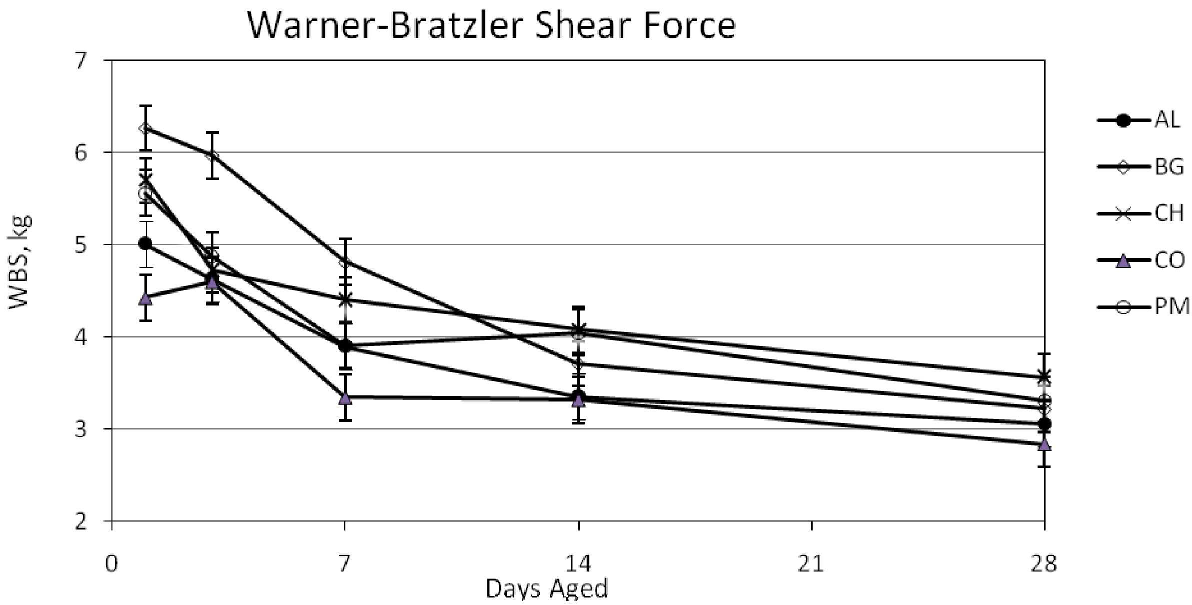

Figure 3.1. Effect of forage-finishing system (alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)) and days aged (1, 3, 7, 14, and 28) on tenderness of the LM.

Table 3.4. Demographic description of consumer taste panel participants

Demographic	Percentage of participating consumers
Income ($)	
<20,000	5.62
20,000-24,999	2.27
25,000-29,999	2.27
30,000-34,999	0.00
35,000-39,999	1.14
40,000-49,999	10.23
50,000-59,999	13.64
60,000-69,999	7.95
70,000 or greater	56.82
Age	
18-24	5.62
25-29	6.74
30-34	6.74
35-39	8.99
40-44	12.36
45-49	12.36
50-54	13.48
55-59	15.73
60-64	11.24
>65	6.74
Gender	
Male	73.03
Female	26.97
Education	
Completed High School	11.11
Some College	14.44
Completed Junior College	6.67
Completed B.S. or B.A.	28.89
Graduate School	38.89
Beef consumption, times per week	
1-2	22.22
3-4	47.78
5-6	14.44
7-8	7.78
9-10	4.44
>10	3.33
Total Number of Participants	90

Table 3.5. Consumer taste panel scores for overall palatability and preference

	Treatment[*]						
Item	AL	BG	CH	CO	PM	SEM	P-value
Overall palatability[1]	62.65[a]	48.7[b]	51.14[b]	61.63[a]	57.71[a]	2.127	<0.001
Preference[2]	38.89	6.67	10.00	21.11	23.33		0.431

[1]Taste panel participants scored (0-100) sirloin samples from each treatment for overall palatability
[2]Overall preference as percent (%) of total number of consumer panel participants (n=90)
[a,b] Means with different superscripts in the same rows differ ($P < 0.05$)
[*]Forage treatments: alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)

Table 3.6. The effect of forage treatment on mineral composition (mg/100 g) of the LM

	Treatment*						
Mineral	AL	BG	CH	CO	PM	SEM	P-value
P	186.75	197.25	186.33	193.33	186.58	4.70	0.456
K	351.75	373.75	349.25	369.33	349.83	7.97	0.234
Ca	3.75^{b}	6.67^{a}	3.42^{b}	3.50^{b}	3.92^{b}	0.41	0.020
Mg	22.08^{b}	24.58^{a}	22.33^{b}	22.67^{b}	21.91^{b}	0.34	0.022
S	191.33	200.33	192.00	196.75	187.83	3.13	0.203
Zn	3.47^{b}	4.05^{a}	3.47^{b}	3.65^{b}	3.48^{b}	0.077	0.021
Cu	0.054	0.066	0.055	0.056	0.058	0.005	0.539
Mn	0.004	0.017	0.003	0.222	0.084	0.14	0.507
Fe	1.78	2.65	1.84	1.89	1.98	0.36	0.500
Na	33.45^{b}	37.95^{a}	32.66^{b}	34.83^{b}	32.81^{b}	0.72	0.027

[a,b] Means with different superscripts in the same rows differ ($P < 0.05$)
*Forage treatments: alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)

Table 3.7. The effect of forage treatment on concentration of total cholesterol in the LM

Treatments	Year	Total Cholesterol, mg g^{-1}
Alfalfa	2007	48.49^{b}
	2008	52.93^{a}
Bermudagrass	2007	54.29^{a}
	2008	51.55^{b}
Chicory	2007	49.69^{b}
	2008	53.57^{a}
Cowpea	2007	55.08^{a}
	2008	52.04^{a}
Pearl Millet	2007	47.93^{b}
	2008	53.14^{a}
SEM		1.06
P-value		
TRT (T)		0.481
Year (Y)		0.371
T × Y		0.024

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

Table 3.8. The effect of forage treatment on fatty acid profile (% of Total FA) in the LM

	Treatment*						P-value		
Item	AL	BG	CH	CO	PM	SEM	TRT(T)	YR(Y)	T × Y
g/100g	2.35	2.83	2.18	2.38	2.16	0.32	0.632	0.223	0.391
C14:0	2.77	2.39	2.65	2.43	2.32	0.20	0.531	0.020	0.8592
C14:1	0.65	0.51	0.58	0.46	0.54	0.07	0.422	0.021	0.615
C15:0	0.42[f]	0.50[e]	0.46[ef]	0.42[f]	0.49[e]	0.02	0.072	0.463	0.337
C16:0	26.63	25.42	25.84	26.19	24.54	0.56	0.257	0.052	0.628
C16:1	3.28	3.11	3.07	3.10	3.36	0.14	0.575	0.020	0.512
C18:0	14.16[d]	15.31[ab]	14.92[bc]	15.54[a]	14.68[cd]	0.16	0.019	0.130	0.437
C18:1 *trans*-10	0.10[ef]	0.11[ef]	0.04[f]	0.11[ef]	0.18[e]	0.02	0.069	0.020	0.136
C18:1 *trans*-11	2.01[f]	3.03[e]	2.35[ef]	2.40[ef]	2.82[e]	0.18	0.071	0.790	0.248
C18:1 *cis*-9	35.75	35.58	33.81	34.53	35.60	0.43	0.108	0.154	0.217
C18:1 *cis*-12	0.27	0.22	0.25	0.22	0.28	0.03	0.622	0.362	0.001
C18:2	2.93	2.60	4.12	3.13	3.08	0.29	0.112	0.073	0.257
C18:2 *cis*-9, *trans*-11	0.38[b]	0.52[a]	0.40[b]	0.40[b]	0.55[a]	0.02	0.015	0.151	0.104
C18:2 *cis, cis*	0.04[b]	0.09[a]	0.08[a]	0.08[a]	0.10[a]	0.01	0.049	0.012	0.123
C18:2 *trans, trans*	0.23	0.26	0.25	0.24	0.30	0.02	0.354	0.002	0.712
C18:3	1.03[b]	0.90[bc]	1.46[a]	1.32[a]	0.86[c]	0.04	0.002	0.830	0.564
C20:4	1.22	1.00	1.25	1.09	1.33	0.16	0.668	0.068	0.429
C20:5	0.37	0.33	0.36	0.35	0.36	0.06	0.986	0.050	0.553
C22:5	0.73	0.63	0.66	0.65	0.68	0.08	0.908	0.071	0.415
C22:6	0.06	0.06	0.05	0.05	0.06	0.01	0.716	0.200	0.630
SUM	95.18	94.81	94.78	94.88	94.46	0.41	0.806	0.016	0.537
Unidentified FA	4.82	5.17	5.22	5.12	5.54	0.41	0.806	0.016	0.537
SFA	43.59	43.12	43.42	44.16	41.54	0.69	0.253	0.180	0.584
MUFA	39.67[e]	39.20[ef]	37.46[f]	38.09[ef]	39.50[e]	0.45	0.084	0.081	0.181
PUFA	5.87	5.01	7.47	6.18	5.90	0.57	0.203	0.015	0.412
PUFA *n*-6	4.15	3.60	5.37	4.22	4.41	0.44	0.245	0.068	0.313
PUFA *n*-3	2.19	1.91	2.52	2.38	1.96	0.17	0.222	0.156	0.595
n-6:*n*-3 ratio	1.89	1.90	2.12	1.80	2.26	0.09	0.102	0.012	0.009
P:S ratio	0.14	0.12	0.18	0.14	0.14	0.02	0.307	0.016	0.480

[a,b,c.d] Means with different superscripts in the same row differ ($P < 0.05$)
[e,f] Means with different superscripts in the same rows differ ($P < 0.1$)
*Forage treatments: alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)

Table 3.9. The effect of forage treatment on α-tocopherol content in the LM

	Treatment*						P-value		
Item	AL	BG	CH	CO	PM	SEM	TRT(T)	YR(Y)	T × Y
Tocopherol, μg g^{-1}	13.74	5.91	12.59	14.95	9.62	6.06	0.827	0.015	0.828
2007 Tocopherol, μg g^{-1}	4.60	5.13	3.41	4.66	3.41	0.43	0.134		
2008 Tocopherol,, μg g^{-1}	22.88	6.69	21.78	25.24	15.84	12.49	0.830		

*Forage treatments: alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM)