ABSTRACT

ARMSTRONG-PRICE, CAITLIN THERESA. Effect of Starch Addition to Concentrate Supplemented at Low Levels in Forage-Finished Beef Cattle on Growth Performance, Carcass Traits, Fatty Acid Profile and Meat Quality. (Under the direction of Matthew H. Poore).

The effect of low level starch supplementation on carcass characteristics in pasture-finished beef cattle is not currently known. An experiment was conducted to compare a fiber-based concentrate with a concentrate containing added starch from ground corn on cattle performance, carcass characteristics, and fatty acid profile. In a two year study (2015, 2016) Angus and Angus x Simmental crossbred yearling cattle (heifers n=23; steers n=40) were separated into four groups balanced by weight and sex before each group was randomly assigned to one of two treatments. Treatment 1 (TRT 1) received a concentrate pellet of 50% soybean hulls and 50% corn gluten feed while Treatment 2 (TRT 2) received a concentrate composed of 50% TRT 1 pellets and 40.5% ground corn and 8.5% soybean meal. Supplements were isonitrogenous and fed at 1% of BW (dry matter basis) which was recalculated based on body weight and adjusted every 28d. Groups were randomly allotted to predominately fescue pastures and rotationally grazed for an average of 180d in Year 1 (March to September 2015) and 245d in Year 2 (March to November 2016). The progressively heaviest 2 or 3 animals/group were selected and cattle were slaughtered on 4 dates between August to October in Year 1 and October to November in Year 2. An average of 1912.0 kg/ha biomass with 14.7 % CP and 66.7% TDN in Year 1 and 4345.6 kg/ha biomass with 11.4 % CP and 64.6 % TDN in Year 2 was available throughout the finishing periods and were statistically different ($P < 0.05$) between years. Hot carcass weights were recorded at slaughter and back fat, marbling score, and ribeye area were obtained between the 12th and 13th rib after 11d in Year 1 and 8d in Year 2 of dry aging. Two 2.5 cm thick

longissimus muscle samples were collected from each carcass at the 13th rib, vacuum sealed, and frozen at -16°C prior to slice shear force and subcutaneous fat color analyses. One longissimus muscle sample was ground, lyophilized, and homogenized prior to performing ether extract of crude fat and fatty acid profile analysis. Data were analyzed using GLM procedures in SAS. Growth performance was significantly different (P < 0.05) by year, regardless of treatment, for time to finish and initial BCS which were greater in Year 2, average daily gain, change in BCS, serum urea nitrogen, and dressing % which were all greater in Year 1. Initial BCS was significantly higher (P < 0.05) in TRT 2 and change in BCS was significantly greater (P < 0.05) in TRT 1 regardless of year. Neither final weight, final BCS, or carcass weight were significantly different (P > 0.05) for treatment, year, or treatment*year. Carcass data collected showed increased (P < 0.05) back fat deposited in TRT 1 cattle and significantly greater a* measurement for back fat color in TRT 2 regardless of year. Other back fat color measurements, L* and b*, and longissimus muscle area were not significantly different (P > 0.10) among treatment, year, or treatment*year. Kidney, pelvic, and heart fat was increased significantly (P = 0.0003) and back fat color measurement a* was significantly less (P < 0.0001) in cattle finished in Year 2. Carcasses had an average yield grade of 2.6, marbling score of 5.5, and USDA quality grade of low choice (17.2) which in addition to meat tenderness and crude fat content were not significantly different (P > 0.10) for treatment, year, or treatment*year. Cattle finished in Year 2 had significantly higher (P < 0.05) stearic acid and margaric acid regardless of treatment where other SFA were not affected by treatment, year, or treatment*year. Most MUFA and PUFA were not significantly different (P > 0.10). Palmitoleic, vaccenic, cis-vaccenic, ALA, EPA, and DHA as well as total omega-3 fatty acid, omega-6: omega-3 ratio, and the total unidentified fatty

acids were higher (P < 0.05) for cattle finished in Year 1 regardless of treatment. A significant treatment effect was observed in stearic and vaccenic being higher (P < 0.05) in TRT 2 compared to TRT 1 regardless of year. Significant treatment*year interactions (P < 0.05) were reported for vaccenic acid, ALA, DPA, total omega-3 fatty acid, and total MUFA. The presence of high quality forages for grazing during the finishing period may have a more significant impact on growth, carcass characteristics, and meat quality regardless of the addition of starch to a fiber-based concentrate. Supplementation of a fiber based concentrate without additional starch may be beneficial for creating a healthier fatty acid profile from a human health perspective.

Effect of Starch Addition to Concentrate Supplemented at Low Levels in Forage-Finished
Beef Cattle on Growth Performance, Carcass Traits, Fatty Acid Profile and Meat Quality

by
Caitlin Theresa Armstrong-Price

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APPROVED BY:

_____ _____
Dr. Matthew Poore   Dr. Sarah Ash
Committee Chair

_____
Dr. Carrie Pickworth

DEDICATION

This thesis is dedicated to my husband, Hough. I can't thank you enough for your

unwavering support and unconditional love.

BIOGRAPHY

Caitlin Theresa Reilly was born in Petersburg, VA but spent most of her childhood growing up in Burlington, NC with her parents Bonnie and Michael and her younger brother Connor Reilly. Despite growing up with a non-agricultural background she always showed an unwavering interest in the care of animals and chose to pursue a future in the veterinary field. In 2005 her family moved to Whispering Pines, NC where she attended high school and continued to strive for a future career as a large animal veterinarian. She was accepted into North Carolina State University, and was overjoyed at the opportunity to attend in the fall of 2009 and begin her undergraduate degree in the Animal Science program. Throughout her many experiences in the Animal Science program the most enjoyable were the opportunities to expand her knowledge of animal nutrition and foster her love for cattle while working at the NC State University Dairy Education Unit feeding calves and working long, often early hours in the milking parlor. Upon graduating in 2013 with a Bachelor of Science in Animal Science she accepted a position working as a veterinary assistant at Chatham Animal Hospital in Cary, NC. After one year she made the decision to no longer pursue a veterinary degree but to focus her efforts toward a graduate degree in animal nutrition at her alma mater, North Carolina State University. She married her college sweetheart, Hough Armstrong-Price in September 2016 and they currently live in Chapel Hill, NC. After receiving her Master of Science, she plans to pursue a career in the research and development sector of the pet food industry.

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I'd like to specifically thank my Committee Chair and Advisor, Dr. Matt Poore who took a chance on me as a non-conventional master's student who chose to work a full-time job while pursuing a part-time course load and performing field research. I have learned a great deal about myself as a person and my capacity as a student of higher learning throughout this experience and I have Dr. Poore, Dr. Carrie Pickworth, and Dr. Sarah Ash to thank for that opportunity.

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Thank you to all the amazing individuals that have supported and encouraged me to pursue my graduate degree and pushed me to complete what I set out to accomplish. A special thank you to Jennifer Curtis and Dean Askew for allowing us the opportunity to partner with Firsthand Foods and for all the hard work they've put into bridging the divide between local meat producers and consumers. I'd also like to thank the farm crew at Butner Beef Cattle Research Field Lab for the countless hours they've contributed to this research, without their help this none of this would have been possible. I hope that my journey will encourage the ambitions of other individuals unfamiliar with the cattle industry to learn the value of and appreciate the tireless determination exhibited every day by cattle producers.

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INTRODUCTION

In recent years greater consumer interest has been directed towards the establishment of a niche meat market that features beef raised in a forage-based system rather than the more conventional method of raising cattle in a feedlot on high grain diets. Consumers have become increasingly interested in the traceability of the meat product they are purchasing in addition to the potential health benefits that product may provide. Some consumers find immense value in locally grown and raised produce and meat products because of the possible environmental impacts surrounding the conventional methods of growing and raising food for human consumption (United States Department of Agriculture, Agricultural Marketing Service, 2007). This change in demand has created a niche market in which consumers are seeking a beef product that is healthy while remaining palatable that also has some measure of transparency in the labeling and disclosure of the animal's management history. As the market has shifted, some cattle producers have ventured to do the same by altering their management systems away from relying on concentrate alone to accomplish the degree of finishing necessary for cattle to produce meat products of acceptable quality. To accomplish such a feat, it is necessary for producers to include high quality forages which could be offered to cattle in a variety of forms including fresh, ensiled, or dried as hay (French et al., 2000). In the southeastern United States, a great deal of pastureland utilized for cattle production contains a variety of tall fescue infected with an endophyte known to cause performance and reproductive issues in grazing animals. These issues are more prevalent in the summer months when the toxin produced by the endophyte living within the plant is at its highest concentration. Allowing cattle adequate access to shade and access to

alternative species of forage during these periods to alleviate symptoms associated with fescue toxicosis could improve cattle performance that can be impacted by reduced feed intake and overall daily gain. (Aiken and Strickland, 2013).

Incorporating rotational grazing into the management system will allow producers the ability to maximize forage utilization and lower costs associated with feed supplementation. While raising cattle on forages alone is entirely feasible it often results in reduced potential for animal performance and less desirable carcass qualities. Depending on the maturity and species utilized in the system, forages can supply adequate crude protein and total digestible nutrients (Ball et al., 2002) necessary for cattle to reach a target level of finish with the exception of time required to reach that level compared to animals receiving concentrate supplementation.

Including concentrate with a high starch content in the diet of ruminants can create changes within the rumen environment that favor certain microbial species that specialize in the fermentation of starch. This environmental shift can result in decreased digestibility of fiber based substrates and a change in the fatty acids produced and subsequently deposited in the adipose tissue. (Dijkstra et al., 1994). Fatty acid profiles of animals raised on forage compared to those consuming diets high in concentrate have been discussed in detail in the literature. It has been determined that increasing the amount of concentrate in cattle diets will increase the amount of saturated fatty acids and omega-6 fatty acids compared to the amount of omega-3 fatty acids present in the meat product. A human diet consisting of a lower ratio of omega-6 to omega-3 fatty acids has been proven to reduce the risk of cardiovascular disease, diabetes, and boost the immune system (Simopolous, 2002; Food and Nutrition,

2005) supporting the thought that forage finished beef may possess greater potential health benefits compared to conventional beef in regards to the fatty acid profile. Additionally, although it is not an essential fatty acid, conjugated linoleic acid has shown significant effects on the reduction of tumorigenesis and the incidence of cancer in animal models (Bauman et al., 2000). Conjugated linoleic acid is also expected to be greater in animals raised on forage compared to concentrate.

Though much research is focused on the improvement and alteration of fatty acid profiles in meat products when animals are grazing various forage species compared to high concentrate diets, very little has been done in the area of low level concentrate supplementation to improve animal performance and carcass quality while maintaining a healthy fatty acid profile. Baublits et al. (2006) studied the effect of low level (1% BW on DM basis) supplementation of soyhulls in forage finished cattle and found that the addition of soyhulls greatly improved carcass traits while maintaining a beneficial profile similar to that of 100% grass finished cattle.

The objective of the current research was to study the effects of the addition of starch to a fiber based concentrate supplemented at low levels during a forage based finishing program on animal performance and carcass qualities including fatty acid profile to observe any beneficial changes as a result of including starch in the diet.

LITERATURE REVIEW

Introduction to Beef Cattle Production

Domesticated ruminant animals have been utilized in agricultural production systems for thousands of years. The family Bovidae classifies ruminant animals with horns which are not shed. It is within this family that the genus *Bos taurus*, better known as domesticated cattle, are classified (Herring, 2014). Archeological findings have estimated the domestication of cattle around 8,500 years ago (Church, 1988). Cattle have been utilized for labor, milk, meat, and hide by-products, making them essential to both historical and modern civilizations.

Beef cattle production is beneficial to the agricultural industry because cattle can thrive on land unsuitable for other food animals or crop production. The production environment, management inputs, and cattle genetics all contribute to the overall animal performance and success of the operation (Herring, A 2014). Commercial beef cattle production systems can be classified by three categories: Cow-calf, Stocker/grower, and Finisher. Finishing operations can attain cattle directly from cow-calf or stocker operations or in some unique situations, a single operation can raise cattle from birth through finishing to target weight for slaughter. Cattle can be finished by grazing entirely, grain supplementation with grazing, confined feeding of harvested forages, or confined feeding of high level grain concentrate diets (Herring, A 2014).

Breed of cattle selected for production can impact the animal's ability to thrive in a particular environment and affect their optimum performance capabilities. Cuvelier et al. (2006) reported that breed is a key component in the distinction between muscle tissue

characteristics and therefore impacts the finished product. The study utilized thirty-six *Bos taurus* bulls from the Belgian Blue, Limousin, and Aberdeen Angus breeds (n=12) slaughtered at 19 months of age after a finishing period of 5 months and compared growth performance and meat tissue characteristics. Results indicated that the Angus bulls possessed the highest intramuscular fat content (IMF) (2.4g /100g tissue) and highest proportion of adipose tissue and lowest muscle tissue proportion (23.6% and 62.2% respectively) compared to both Belgian Blue and Limousin breeds (Cuvelier et al., 2006). Dinh et al. (2010) observed the total saturated fatty acid content in meat from purebred Angus cattle (26mg/g) to be significantly higher compared to Brahman (10mg/g) and Romosinuano (10mg/g) cattle when all animals were consuming the same diet. Angus cattle are considered early maturing animals that possess the ability to deposit IMF at an earlier period compared to later maturing breeds such as Simmental, Charolais and Limousin. Dinh et al. (2010) observed a 50% increase in the amount of intramuscular fat deposited in the longissimus muscle by Angus cattle compared to Brahman or Romosinuano cattle. In contrast, the polyunsaturated fatty acid level, when measured on a percent basis, is significantly lower compared to levels seen in Brahman and Romosinuano breeds (Dinh et al., 2010). This difference could be the result of a greater level of fat deposition characteristic of Angus cattle compared to cross-bred cattle which could account for some of the increased levels of fatty acids present.

According the American Simmental Association, the breed can be characterized by the ability to thrive and adapt easily to various climates and for rapid growth development and meat quality, specifically improved yield grades and marbling ability (Atkins, 2014). A

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study conducted by Cunningham and Klei (1995) on the growth performance and genetic trends of purebred Simmental cattle in the United States between the years of 1978 and 1991 indicated that during that time period adjusted weaning weight gain increased overall. These results indicate that the Simmental breed has been selected for increased weaning weights through breeding programs, that will improve the value of the calves at sale (Cunningham and Klei, 1995). These collective characteristics contribute to the desirability of the Simmental genetic traits in a crossbreeding program with Angus genetics for American cattle producers. It is imperative that producers select for genetic potential that will exhibit improved performance on pasture and are predisposed to create increased amounts of polyunsaturated fatty acids compared to monounsaturated or saturated fatty acids to improve the fatty acid profile from a human health perspective. Breed differences related to the production of certain fatty acids can be attributed to gene expression and/or enzyme function and activity of enzymes like stearoyl CoA desaturase (Scollan et al., 2006b). In the study conducted by Chambaz et al. (2003) the intramuscular fat content was estimated on live Angus, Simmental, Charolais, and Limousin steers using ultrasonography to measure similar fattening and comparing differences in animal age and weight related to IMF retention. When an average IMF content of 3.25% was reached in the longissimus dorsi muscle, researchers observed a slower growth rate among Limousin cattle compared to Angus, Simmental, and Charolais. However, Limousin cattle also resulted in the heaviest carcasses and had the best conformation compared to other breeds studied. Animals all received the same medium energy density (11.2 MJ ME/kg DM) finishing diet composed of maize silage, grass silage, and concentrate ad libitum until desired IMF content was achieved. Angus cattle resulted in

the lowest carcass weights but provided the highest amount of overall fat deposition, while marbling was not statistically different among breeds. Angus cattle achieved target IMF level after 141d compared to the 267d required for Simmental steers, 281d for Charolais, and 346d for Limousin steers to reach the target level. (Chambaz et al., 2003).

Digestive Physiology

The quadrilocular stomach specific to ruminants is evidence in support of the highest point of evolutionary development in mammals (Church, 1988). The cranial 3 compartments: reticulum, rumen, omasum are lined with non-glandular mucous membranes and the caudal most compartment, the abomasum is lined with glandular mucosa and exhibits characteristics similar to a monogastric stomach. The rumen is the largest of the compartments and contains a multitude of microorganisms that subsist on the feedstuffs consumed by the animal and in exchange produce energy containing compounds readily available for use. Extensive microbial fermentation also occurs within the reticulum which is characterized by its honeycomb mucosal pattern (Harfoot, 1978). The large potential capacity of the rumen allows for the required retention time and volume for optimal degradation and fermentation of complex feed particles. Fluctuations in passage rate also influence the amount of microbial digestion occurring in the rumen which can be affected by the type of feedstuff being consumed. (Yokoyama and Johnson, 1988) The rumen microbiota is predominantly composed of many species of bacteria, protozoa, and anaerobic fungi which have evolved to inhabit and thrive in the rumen microbiome. The bacteria population inhabiting the rumen totals close to 10^{10} to 10^{11} cells per gram of rumen contents with the majority of species being obligate anaerobes. Facultative bacteria species are also present in numbers estimated close

to 10^7 to 10^8 cells per gram of rumen contents. Though many species possess the ability for fermentation of multiple substrate types the main groups are classified based on their cellulose, hemicellulose, pectin, amylose, urea, sugar, intermediate acids, protein, or lipid utilization. It is also known that many bacteria species rely on the fermentation by-products of other species to acquire energy and possibly form additional end-products such as methane or ammonia. Estimated number of protozoa species inhabiting the rumen are 10^5 to 10^6 cells/ml of rumen contents. Most species are ciliates with a portion of the population being flagellates. In addition to acting as a control on fermentation, protozoa also contribute to the hydrogenation and desaturation of fatty acids within the rumen. (Yokoyama and Johnson, 1988).

The predominant volatile fatty acids produced during microbial fermentation of organic matter are acetic, propionic and butyric acids. Isobutyric, valeric, isovaleric, 2-methylbutyric and other acids are also present in significantly smaller amounts. Acetic, propionic, and butyric acid can all contribute to the formation of ATP during the intermediate metabolism of these compounds but only propionic acid can function as a precursor for gluconeogenesis (synthesis of glucose). The composition of the substrate consumed by the animal greatly influences the amount and ratios of VFAs produced by ruminal microbes. The interaction between this and other factors including substrate availability and the rate of degradation by microbial species present can inhibit the complete understanding of the proportions in which these compounds are produced. Researchers have made attempts to gather evidence to prove that assumptions of VFA absorption rates should not be based

solely on molar proportions of VFAs present in the rumen but should consider changes in

rumen pH, microbial species substrate preference, and rate of degradation (Dijkstra, 1993).

The redox balance within the rumen is of particular interest because the balance between

reduction and re-oxidation reactions of nicotinamide adenine dinucleotide (NAD) directly

influences the energy yield and resulting fermentation products which drive the VFA molar

ratios present in the rumen (Dijkstra, 1994). Murphy (1984) conducted an experiment that

studied the fermentation products based on substrate composition of diets and discovered that

fermentation of roughage compared to the fermentation of concentrate containing starch

resulted in higher amounts of acetic acid and low levels of propionic acid produced. This

study was slightly oversimplified in the fact that only substrate presence in diet was

considered and other factors such as rumen pH or available protein could have altered the

fermentation product ratios (Murphy, 1984). Many additional studies have observed

microbial shifts due to changes in rumen pH which suggest a strong likelihood of pH and

substrate interaction. The rate at which substrates are degraded within the rumen has been

determined to consequently affect the rate at which these compounds are available for

microbial fermentation. (Dijkstra, 1994). Sutton et al. (1985) discovered that the presence of

non-structural carbohydrates in feed consumed by lactating dairy cattle can significantly

affect the fermentation potential of structural carbohydrates due to a decrease in rumen pH.

Feedstuffs utilized in beef cattle production

In the southeastern United States cattle are grazed largely on cool season perennial

grasses such as tall fescue, orchardgrass, and Kentucky bluegrass or warm season perennial

grasses including bermudagrass and Big bluestem. Pastures in this region can also be planted

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with cool season perennial legumes such as alfalfa, birdsfoot trefoil, and red clover which some studies have shown to reduce the negative impacts of fescue toxicosis on weight gain in finishing cattle (Beck et. al., 2012b). Tall fescue (*Lolium arundinacea*) has been frequently studied due to the heavy utilization of this forage species in the southeastern region of the United States by cattle producers. Researchers such as Duckett et al. (2013) and Dierking et al. (2010) both utilized this forage species in their studies of finishing cattle on pasture without concentrate supplementation. The most common variety, 'Kentucky 31', was originally discovered in 1931 in Menifee County, Kentucky by E.N. Fergus, a professor at the University of Kentucky and was released commercially in 1943 (Aiken and Strickland, 2015). It was discovered in 1973 by Robins, Bacon, and Porter of the United States Department of Agriculture that the plant had a symbiotic relationship with the endophyte *Acremonium coenophialum* (*Epichloē coenophiala)* which resulted in losses in animal productivity and produced symptoms such as vasoconstriction, poor reproductive performance, depressed milk yield, heat intolerance, poor weight gain, and rough hair coat (Ball et al., 1993) which were later collectively termed "fescue toxicosis". The forage was originally an attractive option for producers given its extended growing season, drought tolerance, pest resistance, and ability to thrive in poor soils of variable pH. These characteristics were later discovered to be the result of the symbiotic relationship with the endophyte which caused the release of ergot alkaloids within the stem and leaves of the plant. This endophyte can be found within 75% of tall fescue in the United States (Ball et al., 1993). In a four year study conducted by Beck et al. (2012) it was concluded that average daily gain of steers grazing novel endophyte tall fescue was improved by 0.21 kg/d in the fall

and 0.57 kg/d in the spring compared to steers consuming toxic endophyte tall fescue. In the same study researchers also noted that interseeding white clover or application of chemical nitrogen on toxic fescue pastures did not affect the average daily gain of grazing animals (Beck et al., 2012). Dierking et al. (2010) conducted a finishing study where steers were grazed on pasture comprised of monoculture tall fescue (*Lolium arundinaceum*), tall fescue stand with either red clover (*Trifolium pretense*) or alfalfa (*Medicago sativa*). The grazing period lasted between 110 and 124d and the average daily gain of cattle grazing the monoculture tall fescue was 0.24 kg/d which was significantly lower than the steers grazing fescue and red clover that gained 0.40 kg/d (Dierking, R.M. 2010). These results support the conclusion that interseeding legumes into tall fescue pastures could possibly negate the negative effects of fescue toxicosis. However, the average daily gain observed in these cattle suggests that the addition of legumes into a grass finishing program would not yield feasible results in cattle performance to be applicable within a viable finishing system. In a study conducted by Pavan and Duckett (2013), 13 Aberdeen Angus steers were finished on non-toxic infected fescue for 200d in a rotational grazing finishing program. Live weight was collected directly before harvesting and after cattle had been fasting for 12 hours. Carcass traits were observed after 48 hours on the left half of all carcasses and primal retail cuts were removed from the right carcass half after 7d of aging at 4°C. Average hot carcass weight, dressing percent, and USDA quality grade were 256 kg, 60%, and Select - respectively which are characteristic of cattle finished completely on forage with no additional concentrate supplementation. These values were markedly lower than the respective means reported from the National survey-2005 by Garcia et al. (2008). Overall the lowest total saturated fatty acid

amounts were observed within the eye of round (41.5%) and the greatest was found in the ground beef (49%) and under blade (48%). Based on the resulting fatty acid composition of the eight retail cuts evaluated, the eye of round featured the profile with the lowest levels of undesirable fatty acids and larger proportions of more sought-after polyunsaturated fatty acids. Ground beef was characterized by a profile of opposite value, having greater levels of undesirable fatty acids and lower levels of desirable PUFA, despite having increased amounts of conjugated linoleic acid (CLA) cis-9, trans-11. It was determined that leaner retail cuts maintained greater PUFA profiles as well as a more beneficial n-3:n-6 ratio. Based on the results of this study, a positive correlation between total fatty acid content (TFA) and total saturated fatty acid content and negative correlation between TFA and PUFA and MUFA suggest that a leaner retail cut of grass-fed beef would characteristically contain a healthier fatty acid profile. (Pavan, E. Duckett, S. 2013). Studies conducted show that raising cattle through finishing on pasture alone can take anywhere from 18 to 24 months compared to 80 to 180d in a feedlot production system. This can be attributed to the lowered energy concentration found in forage based diets. (Dierking, R.M. 2010). Duckett et al. (2013) reported that there was no alteration of carcass composition among steers grazing different forage species during a 40d finishing period. The treatments from this study consisted of steers grazing either alfalfa (*Medicago sativa L.*), pearl millet (*Pennisetum americanum L.*), or mixed pasture containing orchardgrass (*Dactylis glomerata L.*), bluegrass (*Poapratensis L.*), tall fescue (*Lolium arundinacea*) and white clover (*Trifolium repens L.*).

Red clover contains polyphenol oxidase (PPO) which is believed to contribute to the elevation of unsaturated fatty acid levels in ruminant milk and meat products of animals

consuming forage diets with large amounts of clover. It was observed by Dierking et al. (2010) that a potential cause of decreased levels of linolenic acid within intramuscular fat compared to other studies could have been a result of too few red clover being present in the pasture and therefore decreased the amount consumed which would have prevented the degradation of linolenic acid and increased the content in the IMF. Polyphenol oxidase is believed to aid in ruminal bypass of polyunsaturated fatty acids by either inhibiting lipolysis of membrane lipids and forming protective micellar barrier around lipids (Balci et al., 2006) or the binding of the PPO molecule to the polar head or carboxyl group of the fatty acid chain (Lee et al., 2008). The minimal level of red clover present in the diet to achieve increased passage of polyunsaturated fats through the rumen without undergoing biohydrogenation are between 16.5 and 25% based on the findings of Dierking et al. (2010) and Fraser et al. (2007). Dewhurst et al. (2003b) determined that 2.4 times more linolenic acid is able to escape ruminal biohydrogenation when cattle are consuming grasses and red clover compared to the 86 to 94% that would otherwise have undergone biohydrogenation. Forages are known to have higher concentrations of omega-3 polyunsaturated fatty acids whereas grains have a higher concentration of omega-6 polyunsaturated fatty acids (Manner et al., 1984).

It has been established that an increase in dietary sources of available glucose could promote de novo lipogenesis within intramuscular adipocytes and result in greater marbling of the meat. Supplementation of concentrates with a high starch content allows the manipulation of fat deposition to favor intramuscular depots rather than subcutaneous depots. Marino et al. (2006) determined that bulls fed high levels of concentrate with low levels of

forage experienced a significant increase in average daily gain and higher final body weights compared to bulls of the same age and breed fed low levels of concentrate and high levels of forage. In this study concentrate was composed of durum wheat flour shorts and forage was oat hay and mixed grass hay offered in addition to available pasture (Marino et al., 2006). A study performed by Duckett et al. (2013) concluded that body weight gain was significantly greater (P = 0.001) for Angus-cross steers finished on corn-silage and concentrate compared to steers of the same breed finished on pasture. This author also reported that steers receiving concentrate during finishing had larger fat depots in the carcass compared to steers finished on forage, including an increase in subcutaneous fat thickness at the 12th rib, KPH, and intramuscular fat (Duckett et al., 2013). Feeding systems that rely on grain-finishing maximize the availability of net energy and available glucose for fat synthesis as muscle growth declines in older animals thus contributing to a higher fat content than can be achieved by grass feeding or finishing alone (Scollan et al., 2006). Ruminal digestion of cereal grains can result in increased production of propionate. Of the main volatile fatty acids produced in the rumen, propionate is the only compound that can be utilized as a precursor for gluconeogenesis. The undegradable starch content of cereal grains also results in increased available glucose within the small intestine (Seal & Parker, 2000). The increase in propionate to acetate and the amount of available glucose will promote lipogenesis through the production of insulin (Istasse, MacLeod, Goodall, and Orskov, 1987) and increase the production of long chain fatty acids within the intramuscular adipocytes (Hocquette, Jurie, Bonnet, & Pethick, 2005).

Animal performance based on duration of finishing program

A study was conducted by Aberle et al. (1981) to determine the effects of time spent consuming a high energy diet on the carcass characteristics and palatability of cross-bred steer calves (8 months old). The treatments were designed to have all cattle finish at the same time/age but experience varying lengths of time consuming a high energy concentrate composed of limited corn silage and ad libitum high moisture corn properly balanced with added protein, vitamins and mineral sources, or a low energy diet composed of corn silage, ground corn cobs and added protein, vitamin, and mineral sources intended to restrict gain to 0.68 kg/d. Treatment 1 was offered the high energy diet for 210d; Treatment 2 was offered the low energy diet for 77d followed by the high energy diet for 140d; Treatment 3 was offered the low energy diet for a longer period of 153d followed by the high energy diet for 70d; and Treatment 4 was offered the low energy diet for the entirety of the finishing program (230d). Results analyzed based on carcass samples collected from the cooler post-mortem determined that animals receiving the low energy diet for longer periods of time (Treatment 3 and Treatment 4) had less total carcass fat, decreased ribeye area size, increased cutability, and the lowest quality grades of all treatment groups. Cattle that received the high energy diet for longer periods of time exhibited improved quality grades of high Select to low Choice compared to low Select for Treatment 3 and high Standard for Treatment 4. Consequently, steaks sampled from Treatment 4 cattle were less tender and received lower flavor scores based on shear values and taste panel evaluations. Cattle that consumed the high energy diet for 70 to 210d did not experience a difference in palatability traits, myofibril fragmentation index, or collagen solubility which suggests that rate of growth could be of

greater importance to meat palatability than the length of time cattle consume high energy feed. (Aberle et al., 1981).

The length of time spent grazing as well as the forage composition consumed prior to harvest contributes greatly to the effects on the final meat product. A study conducted by Noci et al. (2005) determined that as duration of grazing increased the average dressing percent experienced a quadratic decrease (53, 51.7, 50.87, 52.16 respectively for 0, 40, 99, 158d grazing). It was also observed that the pre-slaughter weight, the hot carcass weight and average daily gain were not significantly different therefore, unaffected by dietary treatment. This study concluded that prolonged pasture feeding improved subcutaneous adipose tissue fatty acid profile from a human health perspective. (Noci et al, 2005). In contrast to these results, a study conducted by Dierking et al. (2010) observed no differences in the fatty acid profiles in cattle grazing tall fescue, tall fescue with red clover, or tall fescue and alfalfa for 110 to 124d. It was speculated that the cattle may have been selectively grazing the legumes or the quantity of legumes present in the pastures were not sufficient to elicit a difference among treatment fatty acid profiles (Dierking et al., 2010). A study conducted by Duckett and Pavan (2008) utilized 28 Angus cattle grazed on non-toxic fescue pastures for 197d to evaluate the effects of energy sources derived from either corn oil or corn grain on digestibility, animal performance, and overall carcass quality. Negative controls utilized grazing the animals strictly on pasture for the full 197d. Forage dry matter intake (DMI) was significantly decreased ($P = 0.02$) on a DMI (% of body weight) basis when energy supplementation was incorporated into the diet compared to negative control cattle but not total DMI ($P=0.58$). There was a significant negative impact ($P < 0.005$) on NDF digestibility

within the grain corn supplemented cattle compared to the negative control cattle and the corn oil supplemented cattle. Overall, supplementation had a positive effect (P < 0.001) on increasing the ADG, final BW, HCW, LM area, subcutaneous fat thickness, KPH, dressing percent, USDA yield grade and quality grade compared to cattle receiving no supplementation during the winter stocker finishing program. Further evaluation of these cattle in a study conducted by Duckett et al. (2009) focused on the fatty acid profile of the subcutaneous fat as well as the effect of corn oil or corn grain supplementation on lipogenic gene expression. It was determined that corn oil supplementation had a significant impact (P < 0.01) on the increase of stearic acid content within the subcutaneous fat compared to the fat depots of animals receiving corn grain, concentrate, or strictly finishing on forage. Myristic and palmitic acid concentrations were both greater (P < 0.001) for animals receiving concentrate than corn grain or corn oil supplementation along with grazing pastures. Corn oil supplementation also had vast increases of MUFA content compared with cattle only consuming forages and increased the concentration of trans-11 vaccenic acid compared to all other treatments. (Duckett et al., 2009). Duckett et al. (2013) determined that cattle finished on forage species compared to corn-silage and concentrate for a 40d period exhibited significant differences in carcass and meat quality among treatment groups. This study was intended to evaluate the effect of short term grazing of varied forages compared to animals finishing during the same time period on concentrate. Despite being harvested at similar age and time the average daily gain, harvest weight and hot carcass weight were significantly greater (P < 0.001) for steers receiving concentrate compared to strictly forage diets. A grazing duration study conducted by Noci et al. (2005) reported that 60 Charolais heifers

grazing perennial ryegrass pastures for periods of 0, 40, 99, or 158 d showed no significant difference in average daily gain or hot carcass weights among all grazing periods. Prior to grazing pastures, treatments were offered grass silage ad libitum. Average crude protein of pastures was 12.3 - 14.5 %DM (Noci et al., 2005). Duckett et al. (2013) determined based on the linear increase in vaccenic acid and CLA, cis-9 trans-11 isomer as grazing duration increased seen in Noci et al. (2005) that a 40d finishing period was too short a time to observe significant alterations in the biohydrogenation intermediates deposited in adipose tissue.

A study conducted by Duckett et al. (1993) estimated that the optimal time on feed to achieve a palatable and lean cut of beef while minimizing the costs associated with external fat trimming. Hereford x Angus crossbred steers were finished on a high-concentrate diet for intervals of 28d for a total duration of 196d with 0d being the grass fed control group before slaughter and carcass evaluation was conducted. Cattle were offered a concentrate diet (87.5% DM, 1.84 Mcal/kg NEm, 1.19 Mcal/kg NEg) ad libitum during the finishing period. It should also be noted that prior to starting the trial all cattle were implanted with Compudose (Elanco Products, Eli Lilly, Indianapolis, IN) which contains 25.7 mg estradiol and 0.5mg oxytetracycline per dose and lasts up to 200d (May et al., 1992). The intramuscular fat content doubled ($P < 0.05$) between the 84 and 112d feeding period but did not differ ($P > 0.05$) between 0 to 84d or 112 to 196d on feed. Concurrently, a cubic increase in crude fat content was also observed across time on feed. It was observed that after 112d on feed marbling score did not increase at a significant rate ($P > 0.05$) and this was the first group of cattle to receive a USDA Choice quality grade with an average marbling score of

small. It is known that limiting time on feed can reduce associated costs of trim losses while still resulting in a product of acceptable quality and based on this research it can be expected that as time on feed increases animals will experience an increase in carcass weight, thickness of subcutaneous fat, and longissimus muscle area which all contribute to a higher yield grade (Duckett et al., 1993).

A study conducted by Bidner et al. (1981) found that by supplementing cattle with concentrate it was possible to decrease the number of days spent grazing in order to reach a target finish in Angus x Hereford steers. There were four treatments utilized in this study: Group A where cattle were finished on Ryegrass and Bermudagrass pasture; Group B where cattle grazed Ryegrass and Bermudagrass and received supplement at 1% average body weight on a dry matter basis; Group C where cattle grazed Ryegrass pasture for 60d and then were fed concentrate and 80% CP commercial feed for 70d until harvest; and Group D where cattle grazed Ryegrass and Bermuda pasture until they reached 385 kg on average and then moved to a feedlot and were fed concentrate and 80% CP commercial feed for 74d until harvest. Concentrate was composed of whole corn and urea in a 65.7 to 1 ratio. Researchers found that Groups B-D experienced an increased rate of gain overall and required 160d less to reach the target finishing weight of 476 kg compared to Group A. Carcasses were evaluated 48 hours post-mortem and it was determined that Groups B-D that received concentrate supplementation also had a significant increase ($P < 0.05$) in backfat and marbling but no significant differences ($P > 0.05$) in yield grade or quality grade compared to Group A grazing only forage. Tissue samples were collected at 6d post-mortem then vacuum sealed before evaluation was performed on the left chuck, left top round, and short loin with

tenderloin removed. No significant difference (P > 0.05) was observed in the instrumental

color of the backfat, muscle pH, Warner-Bratzler shear values, and sensory evaluation among

all treatment groups. Cattle from Group B consumed 216 kg/head and 376 kg/head more

concentrate over the feeding period than Group C and D respectively despite the similarities

in gains, final carcass traits, and meat quality. It was also observed that cattle in Group B

gained 0.2 kg/d more than all other groups while grazing Ryegrass and achieved the target

weight 13d sooner than Group C steers. Based on the results from this research and the

absence of improvements or differences within carcass quality of cattle receiving grain

supplementation it can be argued that feeding cattle at a lower level of supplementation for

the duration of finishing can decrease time to reach target weight and finish but will

conversely require a greater amount of total feed supplemented.

Animal growth patterns of protein synthesis and fat deposition

It is understood that available energy will be utilized based on an animal's energy

requirements for maintenance, protein growth, and fat deposition in that particular order.

Therefore, type of tissue growth is dependent on the level of available nutrients relative to

maintenance and with the limiting factor being protein growth with excess energy generally

deposited as fat. Protein deposition is understood to increase at a decreasing rate as an animal

matures. Adipose tissue deposition will increase at an increasing rate as an animal continues

growing (National Research Council, 1988; Gerrard and Grant, 2006). A study conducted by

Romao et al. (2014) evaluated subcutaneous adipose tissue samples collected from 8 British-

Continental steers fed a barley grain and silage diet and evaluated gene expression at 12 and

15 months of age for proteomic changes in adipose tissue. The results indicated that the

expression of proteins associated with lipid metabolism had a downregulation of synthesis of fatty acids at the cellular level for 15 compared to 12 months of age. Adipose tissue relies on both hyperplasia and hypertrophy of adipocytes for growth and development to occur. The main site for lipogenesis is within adipose tissue since 92% of fatty acid synthesis occurs there in ruminant animals (Ingle et al., 1972). These results were supported by similar findings by Neel et al. (2007). The subcutaneous fat depots were 42% smaller for the steers finishing on forage compared to concentrate finished animals (Duckett et al., 2007).

Carcass traits of finishing cattle

A study conducted by Crouse and Dikeman (1976) collected meat quality and carcass data from 1,121 steers of various *bos taurus* breeds to evaluate the ability of 18 different traits to accurately predict percentage of retail product. Based on the findings from this review, the traits directly collected from the cooler were LM area, estimated KPH, hot carcass weight, and marbling score were the most critical for predicting percentage retail product. This was based on a regression equation including all 5 variables which accounted for 79.2% of variation in percentage of retail product. Methods such as these studied by Crouse and Dikeman (1976) can be very useful in commercial carcass grading (expressed as yield grade) when a large number of carcasses are requiring evaluation or when interference with the carcass itself is not feasible (Crouse and Dikeman, 1976). In a similar study conducted by Dikeman (1998) that included a much broader range of cattle breeds and considered progeny cattle when creating a method of predicting retail product, fat trim, and bone within beef carcasses. In this study carcass data was collected from one half of carcasses from 610 steers for two fat trim levels (0.76 and 0.00 cm) including weights of

intermuscular and intramuscular fat. After prediction equations were developed it was determined that as the retail product was trimmed to either 0.76 or 0.00 cm of subcutaneous fat a decrease of 3.5% occurred in the percentage of retail product and there was a subsequent increase in full yield grade. Overall, it was determined that based on partial correlation coefficients, intermuscular fat was twice as important in accounting for variation within fabrication yield as subcutaneous fat (Dikeman et al., 1998). Determining carcass composition of animals consuming different types and amounts of feedstuffs for research can be difficult and cost prohibitive. This issue was addressed by Lunt et al. (1985) in a study that observed the level of accuracy achieved when different accepted methods of carcass composition prediction were applied to a serial slaughter study where cattle were finished on different diets. The study utilized thirty-two Hereford x Brahman steers which were finished to a certain weight before slaughter, with 16 animals consuming forage and 16 consuming a grain-based diet. Steers were slaughtered initially at 0 kg gained (n=8), at 68 kg gained (n=6), at 205 kg gained (n=6), at 273 kg gained (n=6). At twenty four hours postmortem each carcass was assigned a USDA yield grade and quality grade and the 9-10-11th rib section was removed from both sides to be processed for analysis. Quality grades ranged from Standard to Choice and yield grades ranged from 1.41 to 3.02. Physical-chemical separation of bone, lean, fat, and mixed lean and fat tissue was determined as the most accurate method with less variability when compared to the other methods. Researchers found no difference (P > 0.05) between carcass percentage as separable fat or separable lean between feeding regimens with the exception of the third slaughter interval (136 kg gained). It was also observed that grain fed steers possessed a larger amount of body fat and had a lower carcass

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weight percentage as lean tissue compared to forage fed animals. Steers finished on forage also exhibited an increase in carcass weight percentage as bone for the slaughter intervals of 136 kg or 273 kg gained compared to grain finished steers. It was also observed that grain fed animals experienced a greater increase in the lean-to-bone ratio during the 205 kg and 273 kg intervals than animals consuming forage which experienced no change in the lean-to-bone ratio over the duration of the feeding period (Lunt et al., 1985). Duckett et al. (2007) conducted a study that evaluated the meat composition, muscle color, and palatability of 198 Angus cross steers which were randomly allocated to either low (0.23 kg/d), medium (0.45 kg/d), or high (0.68 kg/d) stocker growth rates from December to April. At the conclusion of the winter stocker phase cattle were again randomly assigned to either a high concentrate diet or to a pasture-finishing system. Animals were harvested at the same time which resulted in all animals being of similar age. The total fat percentage found within the 9-10-11th rib section exhibited a 42% decrease (P = 0.001) in animals finished on forage due to a decreased presence of intermuscular and intramuscular fat. Despite the increase in off-flavor intensity observed in meat samples from pasture finished cattle, there were no significant differences in tenderness based on shear force value or panel evaluation for palatability (Duckett et al., 2007).

It is well established that postmortem aging of meat can be used to increase tenderness. According to consumer studies, tenderness of meat is the most important factor contributing to overall quality of meat. It is understood that tenderness can be influenced by four general factors including postmortem proteolysis, presence of connective tissue, intramuscular fat, and the contractile state of the muscle (Belew et al., 2003). Transformation

in the myofibrillar protein structure of muscle during the time between slaughter and meat consumption will largely influence overall meat tenderness. Structural alterations within the myofibrillar protein can be attributed to proteolytic enzymes during aging or conditioning. These enzymes breakdown minor muscle proteins which result in the fragmentation and weakening of the muscle structure, allowing it to be more readily masticated during consumption (Wood et al., 2007). Specifically, the calpain enzyme system consisting of m-, μ-, and skeletal muscle calpain and inhibitor calpastatin which contribute to the disassembly of the contractile protein apparatus (Gerrard and Grant, 2006). Tenderness of the meat can also be affected by the rate of chilling experienced by the carcass. More rapid cooling immediately after slaughter will result in the severe contraction of the sarcomere structure and produce a less tender meat product (Wood et al., 2007). The process of postmortem metabolism in muscle under normal conditions begins immediately after slaughter when large amounts of adenosine triphosphate (ATP) are released to facilitate the maintenance of homeostasis as ATP reserves are being depleted within the tissue. Unable to acquire oxygen, the tissue reverts to anaerobic metabolism and the glycolytic pathway and glycogenolysis are stimulated by the increase of cytosolic calcium and adenosine diphosphate (ADP). Glucose residues rendered from glycogen are metabolized through glycolysis to form pyruvate which is then further metabolized to lactate. Lactic acid forms after the hydrogenation of lactate which results in an increased reduction in muscle pH level until metabolites have been exhausted at which point ultimate pH has been established. (Gerrard and Grant, 2006). In 2003, Belew et al. established a full carcass evaluation of meat tenderness utilizing the Warner-Bratzler Shear Force method to account for decades of genetic and nutritional

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modification and changes in meat processing since the previous full carcass evaluation in 1945 by Ramsbottom, Strandine, and Koonz. Belew et al. (2003) concluded that tenderness varies largely across the full carcass and several muscles that were considered tough in the 1945 study were now the most tender according to the WBSF analysis, specifically *M. pectorales superficiales* and *M. obliquus internus abdominis*. The longissimus lumborum and longissimus thoracis were both considered "tender" with a WBSF result of 3.4 and 3.5 kg respectively which was similar to results collected from the 1945 study by Ramsbottom, Strandine, and Koonz (1945). The results are largely anticipated among the rib and loin muscles whose retail cuts hold high market value for tenderness (Belew et al., 2003). Marino et al. in 2013 conducted a study using crossbred beef cattle to determine the effects of aging duration on tenderness and muscle proteolysis in longissimus dorsi muscle. It was seen that increasing the duration of aging time from one to seven days decreased WBSF values (5.75 to 5.04 kg respectively) and increased myofibrillar fragmentation (52.55 to 128.16 respectively) both of which continued this pattern at a decreased rate through end of aging duration at 21d (Marino et al., 2013). Similar results were also seen in a study conducted by Jeremiah and Gibson in 2003 where postmortem handling and aging duration was assessed on wholesale rib and shortloin cuts of beef after aging for 7, 14, 21, and 28d intervals (Jeremiah and Gibson, 2003). Shear force analysis results observed in an experiment conducted in 1994 by Wheeler et al. determined tenderness to be significantly increased (P < 0.05) between Trace to Small marbling grades but not significantly different (P > 0.05) between Small, Modest, or Moderate marbling grades. This study also concluded that variation in level of tenderness was significantly decreased (P < 0.05) in meat samples

collected from *Bos taurus* compared to *Bos indicus* cattle and a positive correlation between tenderness and degree of marbling was observed (Wheeler et al. 1994). Mitchell et al. (1991) reported that forage finishing cattle with no supplemental concentrate resulted in a negative effect on overall meat tenderness. In contrast, Marino et al. (2006) saw no impact of diet while studying the effect different forage to concentrate ratios on beef tenderness when comparing young Podolian bulls slaughtered at similar ages and weights. Warner-Bratzler Shear Force analysis results showed that there was a reduction (P < 0.01) in values for the lower concentrate ratio cattle compared to the higher concentrate ratio cattle after 15d of wet aging meat samples. These values were collectively reduced significantly (P < 0.001) by increasing the aging time from 15d to 21d (Marino et al. 2006). Duckett et al. (2013) reported no significant difference in WBSF values for steaks from cattle finished on forage or concentrate for either 14d or 28d of wet aging. That particular study also observed no significant differences in WBSF among steers grazing different species of forage (Duckett et al., 2013). Similar results have also been reported by Mandell et al., (1998); Realini et al., (2004); and Duckett et al., (2009b) (similar age endpoint). French et al. (2000) reported that animals supplemented with low levels of concentrate during pasture finishing resulted in reduced WBSF values compared to animals receiving higher levels of forage with less concentrate and lower levels of forage with higher levels of concentrate after a 2d aging period. Prolonged aging eliminated this difference between treatments (French et al., 2000).

A study conducted by Baublits et al. (2005) observed the carcass characteristics of meat from cattle finished on fescue pasture alone compared to cattle finished on forage with soyhull supplementation. During the 2 year study, 108 British and British x Continental

steers and heifers that had been backgrounded on pasture with pelleted soyhull

supplementation were utilized with treatments balanced by frame size with all cattle having

an intermediate maturing rate. Treatments consisted of cattle finished on tall fescue pasture

without any additional supplementation (Control) or finished on tall fescue pasture or

orchardgrass pasture with each receiving supplementation of soyhulls at 1% body weight on

a dry matter basis. Supplementation of soyhulls improved (P < 0.05) final live weights of

cattle grazing both fescue and orchardgrass compared to cattle finished on fescue alone.

Feeding soyhulls also produced carcasses that graded choice for both forage types receiving

supplementation compared to fescue alone which produced standard grade carcasses. An

improvement in muscling and carcass weight was observed in the large frame animals

compared to medium and small framed animals without any differences seen in marbling

score or quality grade among all frame sizes (P > 0.05). A decrease (P < 0.05) was also

observed in amount of back fat present at the 12th rib for all Control carcasses compared to

both supplemented treatments with the highest (P < 0.05) yield grade observed within the

large frame Orchardgrass treatment and medium frame Fescue treatment cattle. The Control

carcasses all exhibited darker (P < 0.05) lean measurements compared to treatments

receiving supplementation but there was no difference (P > 0.05) among the instrumental

color b* value of back fat that measures yellowness. These results indicate that the level of

supplementation did not alter the quantity of carotenoids deposited within the adipose tissue

which has been shown to increase yellowness of back fat in grazing animals (Morgan et al.,

1969). The results of this study support the thought that increasing the available nutrients

through supplementation can significantly improve carcass quality for animals consuming fresh forage as the primary feedstuff (Baublits et al., 2004).

An additional study conducted by Baublits et al. (2006) observed the differences within the fatty acid profile and sensory characteristics of meat samples collected from the same group of animals utilized during the 2004 study. Animals were all finished to a similar endpoint and harvested on the same day after which carcasses were allowed to age in the cooler for 48 hours prior to sample collection. Meat samples were then vacuum sealed and allowed to wet age for 5d at 2°C before analyses were performed. There were no differences ($P > 0.05$) observed for tenderness among the Control (grazing tall fescue with no supplementation) and Fescue or Orchardgrass (grazing with pelleted soyhull supplementation) treatments or within biological type of cattle. One result of particular interest was the lack of difference ($P > 0.05$) in the CLA (18:2cis-9, trans-11) content between the Control and both supplemented treatments. This result indicates that the highly digestible fiber content of the soyhulls did not produce a negative effect on the amount of CLA present within the meat tissue that is often seen when comparing grazing cattle to conventionally finished cattle. Control cattle also possessed higher levels of EPA (20:5cis-5,8,11,14,17), DPA (22:5cis-7,10,13,16,19), and DHA (22:6cis-4,7,10,13,16,19) compared to both supplemented treatments which could be the result of a larger amount of the precursor for EPA and DHA synthesis, linolenic acid (18:3cis-9,12,15). This increase of available linolenic acid within the Control treatment samples is thought to happen due to the greater amounts of fresh forage consumed by these cattle in the absence of concentrate supplementation. Sensory characteristics of cooked samples were also evaluated and it was

concluded that the addition of soyhull supplementation resulted in a significant decrease (P < 0.05) in the "grassy" flavor found in the Control treatment samples.

Duckett et al. (2013) determined that steers finished on various forage species exhibited a reduced percentage of subcutaneous fat between the 9th and 11th rib compared to steers finished on corn silage concentrate (46% reduction, P = 0.028). This study reported that steers receiving concentrate during finishing had larger fat depots in the carcass compared to steers finished on forage, including an increase in subcutaneous fat thickness at the 12th rib, KPH, and intramuscular fat. This study also observed subcutaneous backfat color among treatment groups and found that L* values did not differ (P = 0.69) between treatment groups but b*(yellowness) values were increased and a* (redness) values were decreased in the forage treatment group compared to the group receiving concentrate (Duckett et al., 2013). The increase in yellow color of subcutaneous fat is likely caused by the abundance of carotenoids present within forages that can reach levels up to 500 ppm (dry matter basis) in green, fresh pastures. Dried or cut forages tend to have significantly reduced carotenoid levels (less than 50 ppm DM) and cereal grains contain even less with less than 5 ppm of dry matter. (Tume and Yang, 1996). This increase in yellow coloring was also reported by Realini et al. (2004) in steers fed forage compared to those consuming concentrate. Bennett et al. (1995) and Duckett et al. (2007) also described similar changes in subcutaneous color values.

Fatty acid profile

The fatty acid profile of beef can be attributed to the nature of the management system, such as being finished on pasture, the proportion of fibrous feedstuffs and the

characteristics of concentrate (Cuvelier et al., 2006). A study conducted by Manner et al. (1984) observed the differences within the fatty acid profiles of cattle fed a strictly forage or high grain diet during the finishing phase and how the profiles shifted based on tissue location within the carcass. Twenty yearling Brangus x Hereford x Angus steers were randomly allocated to one of two treatments: Treatment 1 receiving a high grain diet composed of 79% corn for 129d or Treatment 2 that was grazed on primarily winter wheat for 202d. Post mortem tissue samples were collected from the longissimus muscle (ribeye - 3 samples), the semitendinosus muscle (eye of round - 1 sample), and the psoas major (tenderloin - 1 sample) and analyzed for fatty acid content. Results indicated that grass-finished beef was leaner than grain-finished and grain finished possessed a higher concentration of both saturated and essential fatty acids. The adipose depots of forage-fed animals contained increased levels of branched and trans fatty acids compared to grain-fed but no difference in branched fatty acids were observed within muscle tissue samples from either treatment group. Trans fatty acids were also observed in substantial amounts within the meat tissue samples of grain-fed animals. Based on the evaluation of tissue location, psoas major contained the greatest amount of all fatty acid categories. (Manner, 1984).

Prolonged time spent consuming high forage diets can influence the fatty acid profile by augmenting the polyunsaturated fatty acid concentrations, decrease overall saturated fatty acid content, and ultimately increase amounts of conjugated linoleic acid and omega-3 fatty acids found in the beef product. A study conducted by French et al. (2000) observed the impact of animals grazing forage and the impact of concentrate supplementation in addition to forages on the fatty acid profile and CLA content present in the meat tissue. Researchers

utilized fifty continental crossbred steers and fed them 1 of 5 treatments during an 85d

finishing period prior to slaughter and carcass evaluation. Treatments consisted of grass

silage offered ad libitum with 4 kg of concentrate (SC), 1 kg hay with 8 kg of concentrate

(CO), 6 kg DM of grazed grass with 5 kg concentrate (CG), 12 kg DM of grazed grass with

2.5 kg concentrate (GC), 22 kg DM of grazed grass (GO) which cattle received daily. Silage

offered was perennial ryegrass and concentrate was comprised of 46% ground barley, 42%

unmolassed sugar beet pulp, 8% soybean meal, 1% fat. Intake of concentrate and/or silage

for individual animals was controlled using electronic gates. Treatment groups grazing

forages were rotationally grazed on 2ha pastures and daily forage intake was measured using

the difference between pre-grazing and post-grazing forage biomass. Tissue samples to be

analyzed were collected from the longissimus muscle and had all intermuscular and

subcutaneous fat removed prior to analysis. Forages and concentrate were also analyzed for

fatty acid content and it was observed that both grass and silage had similar profiles with

grass containing lower levels of saturated fatty acids and higher levels of unsaturated fatty

acids than grass silage. Concentrate had a larger saturated fatty acid content than both grass

and grass silage with 16:0 and 18:0 being the most prevalent. An increase in linoleic was also

observed with concentrate containing 16.5 g/100 g compared to the 14.0 g/100 g found in

grass and grass silage as well as increased levels of oleic acid compared to forages. This

study was designed in a manner that would avoid confounding effects of differences in the

amount of fat deposited during the finishing period by feeding animals at nutrient levels that

would result in similar end carcass weights and gains. Therefore, no differences in animal

performance during the 85d finishing period were observed. By decreasing the amount of

concentrate in grass-based diets researchers observed a linear increase ($P < 0.01$) in the polyunsaturated:saturated fatty acid ratio within intramuscular fat. However, there was no significant difference in the omega-6 fatty acid content of the IMF among any treatment and the linear decrease observed in the omega-6:omega-3 ratio as concentrate level was decreased in the diet is believed to be an effect of increase in omega-3 fatty acids present in forages consumed. Researchers also found that the amount of CLA present in IMF is likely affected by the amount of available 18:2 present in the diet in addition to rumen conditions that favor the growth of *Butyribivrio fibrisolvens* as they observed a linear increase ($P < 0.001$) in CLA content of IMF as the proportion of concentrate in the diet decreased. Grasses, especially fresh forage contain copious quantities of rapidly fermentable sugars and soluble fiber which create an ideal environment for improved production or a decreased utilization of CLA by the rumen (Kelly et al., 1998). The outcomes of this study support the notion that an increased level of forage present in the diet will positively affect the amount of polyunsaturated fatty acids and result in a higher concentration of CLA found in the IMF within meat tissue which will result in an improved fatty acid profile from a human health perspective (French et al., 2000). In a study conducted by Noci et al. (2005), grazing duration contributed to a linear increase ($P < 0.001$) in the CLA concentration in muscle fat on fresh tissue basis. It also increased concentration of C18:1 trans-11 in muscle fat and also linearly decreased the omega-6:omega-3 ratio in subcutaneous adipose tissue (2.00 to 1.32, $P < 0.001$) most likely because of the increased concentration of C18:3 n-3 (Noci et al., 2005).

Conjugated linoleic acid is the resulting intermediate of the biohydrogenation of unsaturated fatty acids performed by microbes within the rumen. Ruminants are also capable of synthesizing CLA biologically from trans-11 octadecenoic acid, which involves the delta-9 desaturase pathway that is present in both mammary and adipose tissue. Dietary factors contribute greatly to the proportion of CLA produced within the rumen and synthesized within the adipose tissue of growing cattle. (Bauman et al., 2000).

A study conducted by Gillis et al., (2007) determined that the total amount of CLA and cis-9 trans-11 isomer present in the meat was not different between treatments receiving corn oil or partially rumen-protected CLA salt. The study utilized thirty-six Angus x Hereford cross heifers to evaluate dietary effects in one of the three treatment groups (basal diet, corn oil with basal diet, or basal diet with partially rumen protected CLA) fed at either the final 32 or 60d prior to harvest. The results also indicated that C18:1 concentration was not altered with dietary lipid supplementation. This monounsaturated fatty acid can be converted to cis-9 trans-11 CLA isomer via an adipocyte biohydrogenation pathway (Gillis et al., 2007). Supplementation of livestock with CLA did not increase the CLA content of meat compared to the amount of CLA found in meat products from cattle grazing high quality pasture (Poulson et al., 2004).

Scollan et al. (2006) discovered that the level of CLA cis-9, trans-11 isomer present in the meat product is closely related to the amount of the isomer present within the rumen and the amount synthesized in the tissue from trans vaccenic acid by delta-9 desaturase (Scollan et al., 2006). Animals finished on concentrate have been observed to have increased oleic acid concentration in subcutaneous adipose tissue because of an up-regulation of

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stearoyl-CoA desaturase which is the primary enzyme responsible for the desaturation of stearic to oleic acid (Duckett et al., 2013). Duckett et al. (2009a) determined that the mRNA expression of the stearoyl-CoA desaturase enzyme is 46-fold greater within the subcutaneous adipose tissue of concentrate finished compared to forage finished steers.

In a study conducted by Dierking et al. (2010) the fatty acid content of pasture finished meat products were evaluated to determine how the addition of legumes to tall fescue pastures would impact the fatty acid profile. The results of this study concluded that despite the variation among fatty acid levels found within the forage species, this difference did not translate to the fatty acid composition of the beef among all treatments (Dierking et al. 2010).

Compared to cattle consuming diets containing high levels of grain the levels of CLA found in meat products from animals consuming only forages increases 1.6 to 2.9-fold (Engle and Spears, 2004; French et al., 2000; Lorenzen et al., 2007).

Some studies have evaluated the effect of supplementing the diet with oils high in omega 3 fatty acid on fatty acid profile within the final meat product. One such study reported by Scollan et al. (2006) observed that supplementing linseed oil increased the amount of long-chain polyunsaturated fatty acids and decreased the omega 6: omega 3 ratio and increased the amount of short chain polyunsaturated fatty acids.

Vanhataloa et al. (2007) reported that the fatty acid content of meat and milk products of animals consuming forages with different levels of fatty acids were not similar among treatments. This was also seen in studies conducted by (Boufaied et al., 2003; Dewhurst et al., 2001) using tall fescue pastures. A large portion of research that has been conducted on

the fatty acid profile found in forage species has been done with milk in dairy cattle (Elgersma et al., 2003a) and has shown differences in milk from animals grazing perennial ryegrass with high levels of linoleic and linolenic acid as well as decreased total saturated fatty acid amounts. Duckett et al. (2013) found that total fatty acid content, myristic, myristicoleic, oleic, trans-10 octadecenoic, cis-11 and -12 octadecenoic fatty acids of longissimus muscle were less ($P < 0.05$) in animals finished on forage compared to concentrate. Results from this study also concluded that forage finished beef has a marked increase in the CLA, cis-9, trans-11 isomer concentration (146% greater) as well as the concentration of all individual omega-3 fatty acids (linolenic, EPA, DPA, DHA) ($P < 0.001$) and decreased omega-6 to omega-3 polyunsaturated fatty acid ratio ($P = 0.001$). These results are supported by previous findings by Realini et al. (2004). Duckett et al. (2013) also noted that linoleic acid, arachidonic acid, and omega-6 polyunsaturated fatty acid concentrations were not affected by finishing diet. In contrast, Realini et al. (2004) observed that cattle raised completely on forage exhibited higher levels of linoleic, linolenic, arachidonic, and longer chain omega-3 polyunsaturated fatty acids than cattle receiving concentrate. Although the proportion of SFA were similar ($P > 0.05$) between pasture-fed and concentrated-fed beef there was a significantly higher ($P < 0.01$) percentage of PUFA observed in pasture-fed cattle. This research also noted that the total fatty acid content of concentrate fed steers was twice as great as forage fed steers (Realini et al., 2004).

Meat product quality

As polyunsaturated fatty acid (PUFA) levels increase within beef it may result in distinctive flavor changes after cooking due to the higher susceptibility of PUFA to oxidative

breakdown and creation of abnormal volatile compounds when exposed to elevated temperatures. Researchers discovered specifically that when C18:3 n-3 levels are increased in lamb and beef because of grass feeding, the intensity of the flavors increases in comparison with grain-fed animals that consume and deposit relatively more C18:2 n-6 (Wood et al., 2007). Similar observations were reported by Scollan et al. (2006) who stated that as the omega-3 polyunsaturated fatty acid levels increased so did the sensory characteristics of "greasy" or "fishy". There was also a reduction in shelf life color of the product. These researchers believe that maintaining an elevated level of vitamin E (alpha-tocopherol) in the diet could help stabilize the oxidative properties of omega -3 fatty acids to improve market value. Fresh forages can contain copious quantities of bioavailable alpha-tocopherol which can lead to increased levels within muscle (Faustman et al., 1998) tissue and could be beneficial to those producers raising grass fed beef (Scollan et al., 2006). The desire for an increase in omega-3 fatty acid content is met with the issue of reduced oxidative stability within these products, which ultimately leads to a decrease in shelf life and overall product quality. Antioxidant enrichment of these products has been studied extensively to prevent the likelihood of oxidative damage (Jakobsen, 1999). In a study conducted by Realini et al. (2000) vitamin E supplementation in cattle receiving concentrate resulted in alpha-tocopherol concentrations similar to that of forage fed animals and both were significantly greater ($P < 0.01$) than cattle receiving concentrate but no vitamin E supplementation. Scollan et al. (2006) conducted a review of beef production systems and methods used to enhance the health value of meat products while maintaining a quality product. Researchers determined that intramuscular fat is a crucial meat quality trait and is the adipocyte depot of

the most interest related to fatty acid profile and the effect on human health. (Scollan et al., 2006).

Implications of consumer demands

Consumers are the final step in the chain of production within the beef industry and it is imperative that the factors affecting their behavioral patterns are identified to best understand their product demands. Font-i-Furnols and Guerrero (2014) stated that consumer behavioral patterns can be divided into three categories: psychological (individual factor), sensory (product-specific factor), and marketing (environmental factor). In the United States consumers state many reasons for selecting beef for purchase from "grass-fed" cattle most of which are based largely on preconceived ideas including improved animal health and well-being, environmentally sustainable production systems, and/or selecting meat products with a modified nutritional profile favoring leaner beef containing higher levels of heart healthy compounds (United States Department of Agriculture, Agricultural Marketing Service, 2007). Regardless of its general attributes and accepted social distinction, meat products tend to have a negative associative effect due to the relation to the living animal, management practices, and slaughter conditions (Font-i-Furnol and Guerrero, 2014). Consumers in developed countries are widely removed from agricultural production systems and in areas of increased wealth, production efficiency and profitability can be hindered due to 'luxury' type issues that would not be of concern in developing nations (Herring, 2014). Despite environmental impact and animal welfare provoking negative sentiment and being applicable reasoning behind decreasing meat consumption, health concerns have been shown to be the largest reason for reducing consumption, altering source of meat consumed, or avoiding meat

altogether (Latvala et al., 2012). Guerrero et al. (2011) reported that a large percentage of consumers would choose to limit their consumption of certain products or even avoid them as opposed to consuming an apparently healthy and tasteless version. Consumers rely on certain quality cues to ascertain expected meat quality characteristics at the time of selection for purchase. Font-i-Furnol and Guerrero (2014) grouped these quality cues into intrinsic (color, amount of exterior fat present, and level of marbling) and extrinsic (cost, origin, and quality labels). The National Research Council (2015) reported that as the population and the demand for environmentally, economically, and sustainably produced animal protein sources continues to increase there will be a growing need for advances in animal agriculture. The need for increasing animal efficiency while minimizing both cost of production and environmental impact is paramount to creating an affordable product that is readily attainable to consumers. Byers et al., (1988) reported that to meet consumer demands, the beef industry must make efforts to produce a diverse range of products to battle the association with all beef as a "fatty" or unhealthy food option (National Research Council, 1988). As a result of consumer demands for a healthier more sustainable meat product, strategies for raising the level of conjugated linoleic acid, omega-3 polyunsaturated fatty acids, and reducing the amount of saturated fatty acids in beef products must be further explored.

Human health influence on meat production

Considering the recent awareness of the impact that dietary fat intake can have on human health and disease control, consumers have become more aware of the nutritional values of the food they are consuming. Current recommendations for a "Healthy U.S.-Style Eating Pattern" at the 2,000 calorie level is 26 ounces of meat per week (U.S. Department of

Health and Human Services and USDA, 2015). In previous decades. studies have reported on

the trend of increased consumer desire for leaner beef products (National Research Council,

1988; Spears, 1996). Despite the increase in demand for healthier beef options the amount of

beef consumed annually by Americans has experienced a steady decline from 12.7 billion kg

in 2002 to 11.3 billion kg in 2015 (USDA Economic Research Service, 2016). The

American Heart Association concluded that consumption of processed meats, but not red

meats, is associated with higher incidence of coronary heart disease and diabetes mellitus

based on the results of a systematic review and meta-analysis performed in 2010 (Micha, R

2010). In contrast, the 2015-2020 Dietary Guidelines for Americans (2015), suggest reducing

the intake of both fresh and processed forms of meat to reduce the risk of developing

cardiovascular disease. The Dietary Guidelines (2015) further report that these

recommendations are based on eating patterns that contain many interacting components that

create difficulty in isolating a singular factor as the cause of increased incidence of disease.

In 2003 the World Health Organization recommended that individuals seeking to reduce the

risk of cardiovascular disease should decrease total fatty acid intake and exchange saturated

with polyunsaturated fatty acids especially those characterized by containing large amounts

of omega-3 fatty acids (WHO, 2003). A meta-analysis of data collected from 11 prospective

cohort studies conducted in the United States, Europe, and Israel that included 344,696

participants showed that a 5% increase in energy consumption of carbohydrates in place of

saturated fats indicated a 7% increase in the risk of coronary heart disease. An additional

meta-analysis of prospective cohort studies discovered that an increased intake of

polyunsaturated fats in place of reduced saturated fat or carbohydrate consumption was associated with a lowered risk of coronary heart disease (Jakobsen, 2009).

Western diets are characterized by an omega-6 to omega-3 polyunsaturated fatty acid ratio of 15 to 1 and excessive amounts of omega-6 polyunsaturated fatty acids that contribute to the pathogenesis of conditions including cardiovascular disease, cancers, and inflammatory and autoimmune diseases. In a study that evaluated the mortality rate of secondary prevention of cardiovascular disease with the addition of increased omega-3 PUFA levels in the diet, researchers observed a 70% decrease in total mortality with a ratio of 4 to 1 omega-6 to omega-3 fatty acids (Simopolous, 2002). Studies have also indicated that in addition to linolenic acid other omega-3 polyunsaturated fatty acids such as EPA and DHA contribute significantly to the reduction of risk for cardiovascular disease and are important for the formation of normal brain and visual tissues during fetal development and the maintenance of these tissues throughout life (Calder 2004; Leaf et al., 2003). It has been reported by McAfee et al. (2011) that consumption of red-meat from grass fed animals will raise omega-3 polyunsaturated fatty acid content in plasma and platelets in human. A 32% reduction in plasma omega-6 to omega-3 ratio was observed when participants consumed 500 g/week of grass fed red meat for a 4 week period compared to those consuming similar amounts of concentrate fed red meat that showed a 56% increase in plasma level of omega-6 to omega-3 fatty acids (McAfee et al., 2011).

Williams and Burdge (2006) discovered that the precursor for the omega -3 series, linolenic acid can produce adequate amounts of EPA and DHA within the meat tissue through the omega-3 polyunsaturated fatty acid elongation-desaturation pathway. In support

of the beneficial health effects observed when EPA and DHA are present in the body, previous data collected by Ulbricht and Southgate (1991) suggested that not all saturated fatty acids possess the ability to increase cholesterol concentration in the bloodstream, resulting in hyperlipidemia. Specifically, myristic (C14:0) and palmitic acids (C16:0) have a cholesterol raising effect while stearic acid (C18:0) is shown to have no effect on blood cholesterol levels (Ulbricht & Southgate, 1991).

Conjugated linoleic acid has become a topic of recent interest from a human health perspective. Data summarized by Gillis et al. (2007) states that based on in vitro and rodent experiments the level of dietary CLA is 0.05% is required to reduce the occurrence of cancer in animal models. Based on calculations from expected CLA ranges in steak samples the amount present in a 3oz broiled ribeye would be around 44mg considering the amount of vaccenic acid converted to CLA. Taking the amount found in 3 ounces of beef into consideration, a reduction in the incidence of cancer would require consuming nearly 20 ounces of beef per day. The Food and Nutrition Board (2005) reports that there are no trans fatty acids (including CLA) that are considered "essential" to the human diet and therefore have no Recommended Daily Amount (RDA) or Adequate Intake (AI) level in place (Food and Nutrition, 2005). Although animal models have proven effective in their testing of CLA as an anticarcinogen and a tool for reduction of tumorigenesis (Bauman et al., 2000) there have been no human studies that provide evidence supporting the effects as being clinically relevant (Benjamin et al., 2015; Onakpoya et al., 2012).

In conclusion, cattle finished in a pasture based system may require additional concentrate to maximize feed efficiency and utilization of available forages and feed

resources while producing a quality product for human consumption. The feed resources incorporated in cattle diets can largely impact meat quality, carcass traits, and the fatty acid profile found in the meat product. The level of concentrate present in the diet compared to the amount of forages being consumed by cattle can alter the fatty acid profile in a way that could be beneficial to human health. Despite the increasing demand for healthier beef options, there have been no reflections of this increase on the annual consumption of beef in the United States that has experienced a marginal decline over the past decade. This trend signifies that while notable, this consumer demand is still mainly contributing to the growth of a niche meat market and is not yet reflected on a national scale.

MATERIALS AND METHODS

Objective

The objective of this research was to determine if the addition of starch to a fiber based concentrate during a pasture-based finishing program will improve animal performance, carcass traits, and meat quality without negatively impacting the fatty acid profile from a human health perspective.

Treatment and Design

A two year study (2015-2016) was conducted at the Butner Beef Cattle Field Laboratory in Bahama, NC. Sixty four Angus and Angus x Simmental cross cattle (n=36 Year 1; n=28 Year 2) with an average age of 15 months and average starting body weight of 322 kg were selected for this study and assigned to groups blocked by weight then sex. Six heifers and thirty steers were used in Year 1 and 18 heifers and 10 steers were used in Year 2.

Groups were then randomly assigned to one of two treatments (n=18 per treatment in Year 1 and n=14 per treatment in Year 2). One heifer from Treatment 2 in Year 2 was removed from the study during the finishing phase due to a hindlimb injury.

Cattle received supplement fed at 1% of body weight on a dry matter basis calculated from group average weight taken every 28d at which time amount fed would be readjusted for growth. Treatment 1 (TRT1) consisted of a pelleted supplement containing 48.5% corn gluten feed, 48.5% soyhulls, 3% limestone (Performance Livestock & Feed Company, Lawsonville, NC) and Treatment 2 (TRT2) concentrate was composed of 50% TRT1 pellets, 40.5% ground corn, 8.5% soybean meal, 1% limestone. Diets were formulated using the R.A.D. 2.0 ration balancing program designed by Dr. Jeannette Moore of North Carolina State University. The diets were balanced for crude protein content on a dry matter basis which was determined by laboratory analysis performed by Cumberland Valley Analytical Services on grab samples collected from pellets, ground corn, and soybean meal prior to the start of the study. Nutritive value of composite feed samples for treatment concentrate for both years of the study was analyzed by Cumberland Valley Analytical Services. Composite feed samples were collected using random sampling technique from feed samples taken each time feed was mixed during both years of the finishing phase of study.

This study was approved by the Institutional Animal Care and Use Committee at North Carolina State University. Project protocol number for Year 1 is 13-124-A and 16-212-A for Year 2.

Pasture Management

Pastures utilized for this study during the months of April to August and March to August in Year 1 and 2 respectively were predominantly KY-31 tall fescue plots divided into 0.81 hectare allotments. Prior to grazing tall fescue plots, cattle in Year 1 were supplemented with tall fescue hay (13.6% CP and 74.1% TDN) on large mixed species pasture consisting of bermudagrass, KY-31 tall fescue, and crabgrass from March 17, 2015 until April 13, 2015. Average hay bale weight was 427 kg with one bale offered per group in each individual pasture (4 bales total). Forage was allowed to accumulate over the winter months prior to grazing in Year 2 but was not stockpiled in Year 1 because of usage for another study concluding one month prior. During the final months of the finishing program, August to September and August to November in Year 1 and 2 respectively, animals were moved to larger mixed species pastures consisting of bermudagrass, KY-31 tall fescue, and crabgrass when available forage was exhausted in tall fescue plots.

Initial forage biomass estimates were collected using a 0.25 m² falling plate meter with 20 measurements taken during rotational grazing on the tall fescue plots and 50 measurements taken during continuous grazing in larger mixed pastures. All drop plate measurements were collected in a zig zag pattern. A subsample (6) of the drop heights were clipped to 5 cm from the soil surface using hand held shears within a 0.25 m² frame to determine the range of forage biomass available for grazing. Samples were placed in cloth bags (hot tare weight pre-determined) and dried for 48 hours in a 60°C forced air oven. Bags were then removed and immediately weighed hot to determine initial dry matter yield. These sample weights were used to create a regression equation that combined the sample drop

heights and dried weights to determine the average forage biomass available to animals. This sampling and regression equation technique was implemented every 14d during the finishing phase to determine pre-grazing forage biomass. Forage biomass during the finishing program was determined to show that all groups were exposed to similar amounts of forage during the finishing phase and no group had a distinct advantage.

Nutritive value of available forage was determined by collecting samples taken randomly by throwing a tread-in-post and clipping forage to a uniform height in the area where the post landed. Fifteen samples were collected when animals were rotationally grazed and 25 samples were collected during continuous grazing. All samples from an individual pasture were thoroughly mixed and random samples were composited and sent to the North Carolina Department of Agriculture for analysis. Nutritive value was assessed every 14d during the finishing phase for the pre-grazing area forages to determine if differences in diet quality occurred between both treatment groups.

Cattle Management

All animals selected for this study were 14 to 16 months of age with an average starting body weight of 322 kg and had been raised on pasture since birth and received no additional supplement prior to the start to the experiment. Animals were dewormed with Ivermectin and vaccinated for clostridial disease (Ultrachoice 7, Zoetis, Florham Park, NJ) and respiratory/reproductive diseases (Bovi-ShieldGold 5 FP VL5, Zoetis, Florham Park, NJ) 4 months prior to beginning the study. Cattle groups were randomly assigned to treatments and then randomly assigned to pastures of similar nutritive value and available forage biomass. Grazing area was visually estimated based on stocking rate (n=9 and n =7 per

pasture in Year 1 and Year 2 respectively) and groups were moved simultaneously using polywire electric fencing every 3 to 5d once the current area forages had been grazed to an estimated height of 3 inches. Back fencing was not implemented for this study. Animal groups were randomly assigned to new pastures every 21d in the winter months (February to March 19th in Year 2 only), every 14 to 28d in the spring months (March 20st to June 20th in Year 1 and Year 2 respectively) and every 14 to 21d in the summer months (June 21st to August for both years). High magnesium mineral (Camp Chemical Company, Roxboro, NC) was offered free choice in a mineral feeder throughout the duration of the finishing phase. Mineral was offered in 11.34 kg increments every 14d after intake weights were measured and recorded for each group at the time of moving polywire fencing or moving to new pasture. Animals had full access to water during the finishing phase. Temporary shades were utilized in all pastures from June-August in both years of the study to offer animals relief from the heat and sun exposure. Fly repellant ear tags (OPtimizer Insecticide Cattle Ear Tag, Y-Tex Corporation) were placed in June of both Year 1 and 2 and removed prior to transportation to slaughter facility.

Animal weights were collected on two consecutive days at the beginning of the study in Year 1 and Year 2 to establish the initial average animal weights. The group average was calculated using the initial average animal weight of the animals within respective groups. This initial group average was then used to calculate amount of feed per head per day offered to each group. This value was recalculated every 28d using the formula [group average * (kg DMI / (%DM feed/100)/ total as fed %) = per head feeding rate] (Ruminant Animal Diet Evaluator 1.1 Excel, J. Moore, NCSU, 1993). Feed was delivered to animals in group

feeding bunks so the feeding rate was calculated using the formula (per head feeding rate *

cattle number per group). Samples of concentrate for nutrient analysis were collected every

7d in Year 1 and 14d in Year 2 at the time feed was mixed and weighed into bags specifically

labeled for each group. Cattle received feed once daily in the morning.

Blood samples were collected from all animals every 28d on weigh day from the right

jugular vein via venipuncture with 21 gauge needles and sterile vacutainer serum tube

without additive (Becton Dickinson, Franklin Lakes, NJ). Blood was immediately placed on

ice after collection and thawed for 30 minutes before centrifugation. Centrifugal force was

applied to samples for 30 minutes at 3000 RPM for separation. Serum was extracted and

placed in 3 ml polystyrene tubes (BD Falcon, Franklin Lakes, NJ) and stored at -20°C for

later analysis. Serum will be used to analyze serum urea nitrogen (SUN) content.

Selection for Harvest

Cattle were selected for harvest based on heaviest body weight within each group,

with similar weights being selected based on body condition score and backfat measurement

collected by ultrasonography at the 12th and 13th rib at the time cattle were weighed.

Selected animals were balanced by group and treatment with no more than 10 cattle being

selected for each harvest date with 8 animals being the number most often selected. In both

Year 1 and 2, four harvest dates were utilized with each being between 7-14d apart due to

minimal hanging space in the slaughter facility cooler. Animals selected for harvest were

weighed consecutively to calculate final live weight. The first weight was collected 24 hours

before transportation, immediately after removal from pasture and feed and the second

weight was collected before transport to the slaughter facility. Animals were transported 64

miles to the slaughter facility. After harvest, hot carcass weight was collected and carcass halves were suspended by Achilles tendon in the facility cooler and allowed to dry age at 4°C for 11d in Year 1 and 8d in Year 2 with 0d being day of harvest. Dressing percentage was calculated by dividing hot carcass weight by average final live weight and multiplying by 100 to create a percentage.

Sample Collection and Preparation

At the time of sample collection the research team traveled to the slaughter facility in Siler City, NC to collect 2.5cm thick longissimus muscle (LM) samples from both sides of the carcass. The carcasses were first ribbed at the vertebra between the 12th and 13th rib with a manual bone saw and then split using a boning knife to expose the ribeye surface. Meat samples of uniform thickness were taken from the upper surface of the split carcass and placed into labeled sealable bags and placed on ice for no longer than 2 hours for transportation back to the laboratory in Polk Hall, North Carolina State University. In the lab, the left longissimus muscle was vacuum sealed in labeled Food Saver vacuum bags (FoodSaver Heat-Seal Pre-Cut Bags) using a food grade vacuum sealer (FoodSaver GameSaver Bronze Vacuum Packaging System) with external fat remaining intact. The right longissimus muscle had all subcutaneous and intermuscular fat removed before vacuum sealing in labeled Food Saver vacuum bags. All samples were then frozen at -20°C pending further analysis. One carcass from a TRT 2 heifer was not available for sampling due to accidentally being sold prior to the sampling date (n=14, TRT 1 and n=13, TRT 2) in Year 2.

Right LM samples were thawed to 4°C before being ground. Samples were ground using a food grade meat grinder (#541553 - 3/4HP Carnivore Commercial-Grade Electric

Meat Grinder, Cabela's Inc, Sidney, NE). Longissimus dorsi samples were cut into 2.6 cm²

cubes before grinding and the initial grind was performed with the 7mm grinding plate

according to manufacturer's recommendations for operation. Two additional grinds were

performed on the ground sample using the 4.5 mm grinding plate to achieve a finer grind. A

20.3 cm-diameter and 1.3 cm thick patty was then placed in a metal pan. Weights were

recorded on empty pans and again to obtain the weight of the meat sample before

lyophilization. Samples were lyophilized using a freeze dryer (VirTis 25L GPFD 24Dx48, SP

Scientific, Stone Ridge, NY). Lyophilization followed an eight step program beginning at (1)

-30°C and held for 45 minutes at 5 millitorr (mTorr) before increasing to (2) -20°C and held

for 45 minutes at 5 mTorr then increasing to (3) -15°C and held for 45 minutes at 5 mTorr

increasing to (4) 0°C held for 180 minutes at 5 mTorr increasing to (5) 10°C held for 360

minutes at 5 mTorr increasing to (6) 15°C held for 600 minutes at 5 mTorr increasing to (7)

30°C held for 600 minutes at 5 mTorr and finally increasing to (8) 40°C and held for 1200

minutes at 5 mTorr.

After lyophilization, freeze dried samples were re-weighed and dry matter was

calculated. Samples were individually ground and homogenized in a food grade blender

(Farberware® Single Serve Performance Blender, WM-15407, Needham, MA) until a

powder-like consistency was achieved. Homogenized samples were placed into pre-labeled

individual Whirl-Pak bags, sealed and stored at -20°C pending further analysis.

Carcass traits quantified

After dry aging was complete a qualified individual assigned carcass quality grades

after each carcass half had been split between the 12th and 13th rib and the ribeye surface

was allowed to bloom for 5 minutes. Grades were quantified based on comparison to USDA Marbling Picture cards (National Cattlemen's Beef Association). Grades were recorded and averaged to calculate overall carcass grade. Kidney pelvic heart (KPH) fat depots from both carcass halves were observed and assigned a score by the same qualified individual. The KPH was visually estimated and values averaged to calculate overall carcass KPH measurement. Ribeye area measurements were collected from both carcass halves, described as "Left" or "Right" LM. Measurements were collected by placing a sheet of 22.8 x 30.4 cm, 41 g/m² weight tracing paper (Artist's Loft Tracing Pad, Michael's Stores Inc) directly onto the ribeye surface and using a #2 graphite pencil to trace the exposed tissue area, excluding back fat and intermuscular fat depots present. Tracings were taken from both carcass halves and taken back to the lab to calculate area. Area was calculated using a USDA Ribeye Grid for Quick Measurement of Ribeye Area (Art Services) for both tracings and averaged together to calculate ribeye area. Backfat was measured in the cooler at the top of the loin using a USDA Preliminary Yield Grade Ruler (Instructional Materials Service) and recorded for both carcass halves then averaged together. Average yield grade was calculated for each carcass using the formula: YG = 2.5 + (1.5 x BF average) + (0.2 x KPH average) + (0.0038 x HCW) – (0.32 x LM Area average).

Fatty Acid Composition

The fatty acid profile of each freeze dried LM sample was determined by Clemson University Meat Science Lab, Clemson, SC. Samples were transmethylated according to the method of Park and Goins (1994). Fatty acid methyl esters (FAME) were analyzed in duplicate using an Agilent 6850 (Agilent, Santa Clara, CA) gas chromatograph equipped

with an Agilent 7673A (Agilent, Santa Clara, CA) automatic sampler. Separations of fatty

acid methyl esters were accomplished using a TRACEÔ TR-FAME capillary column (0.25

mm i.d., 0.20 mm film thickness, 120 m; Thermo-Fisher, Waltham, MA USA). Column oven

temperature program increased from 150 to 174°C at 1°C per min, from 174 to 179°C at

0.2°C per min, from 179 to 225°C at 2°C per min, and then held at 225°C for 15 min. The

injector and detector were maintained at 250°C. Sample injection volume was 1 mL and

hydrogen was the carrier gas with a flow rate of 1 mL per min. Samples were run twice with

a split ratio of 100:1 for trans C18:1 and long-chain fatty acids before being run again at split

ratio of 10:1 for conjugated linoleic acid (CLA) and omega-3 fatty acids. Individual fatty

acids were identified by comparison of retention times with internal standards (Matreya,

Pleasant Gap, PA; Larodan, Solna, Sweden). Fatty acids were quantified by incorporating an

internal standard, methyl tricosanoic (C23:0) acid, into each sample during methylation and

were expressed as a weight percentage of total fatty acids.

Instrumental color of subcutaneous adipose tissue

Subcutaneous adipose tissue samples were removed from the right LM sample and

stored in a vacuum sealed bag (FoodSaver Heat-Seal Pre-Cut Bags) with the left LM sample

in Year 1 and vacuum sealed and stored separately in Year 2. Samples were stored separately

in Year 2 to prevent contamination and discoloration by the purge produced when the LM

steak samples were being thawed inside the vacuum bags which was observed at this step in

Year 1. Once thawed to 4°C samples were analyzed for instrumental color using a Konica

Minolta chromameter (CR-400, Konica Minolta Inc., Tokyo, Japan) with a 11- mm diameter

measurement area using a D65 illuminant, which was calibrated using the ceramic disk

provided by the manufacturer. Values were recorded from 2 locations of exposed subcutaneous fat to obtain a representative reading. Measurements were recorded for L* (measures darkness to lightness; lower L* indicates a darker color), a* (measures redness; higher a* value indicates a redder color), and b* (measures yellowness; higher b* value indicates a more yellow color).

Slice Shear Force

Tenderness evaluation was conducted at the Meat Science Laboratory at North Carolina State University, Raleigh, NC. Frozen right LM samples were thawed at 6°C for 24 hours until internal temperature reached 4°C. Weight and temperature were measured once steaks had completely thawed. Steaks were then placed on a conveyorized impingement grill (1100 Series Impinger® II Conveyorized Oven, Lincoln Foodservice, Cleveland, OH) to begin the cooking process. The impingement grill was operated at a top heat of 210°C and bottom heat of 210°C to ensure even cooking on both sides of steak samples. The cook time was approximately 12.5 minutes until an internal temperature of 70°C was reached. After the steaks exited the belt grill, a needle thermocouple probe was inserted into the geometric center of the steak and the post-cooking temperature rise was monitored with a hand-held thermometer (Fisher Scientific, Hampton, NH). Cooked steaks were then reweighed and weights recorded. Slice shear force was measured as described by Shackelford et al. (1999) using a universal testing system (Instron model 5565, Canton, MA).

Ether Extraction of Crude Fat

Prior to crude fat extraction, labeled filter bags (ANKOM bags, ANKOM Technology, Macedon, NY) were placed on a scale and weights recorded. Filter bags were

then zeroed out on the scale and 1.5 to 2 g of corresponding sample was added to the bag and sample weight recorded. Bags were then heat sealed and prepared for analysis by placing in a drying oven at 105°C for 3 hours. Dried samples were then placed in desiccant jars for 10 minutes to cool and sample weights were recorded again. Samples were then extracted in duplicate with one blank and one low fat standard sample (ANKOM Standard, ANKOM Technology, Macedon, NY) included in each run according to manufacturer's recommendations (ANKOM XT15 Extractor, ANKOM Technology, Macedon, NY). After extraction samples were placed in drying oven at 105°C for 15 minutes then cooled in desiccant jars before post extraction sample weights were recorded. Crude fat extracted was calculated using the formula: $[(100 \times (W2 - W3) / W1) = \%$ Crude Fat$]$ with W1 representing original sample weight, W2 is the weight of the pre-extracted dried sample with filter bag, W3 is the weight of the dried sample with filter bag post extraction (AOCS Official Procedure Am 5-04, ANKOM Technology, Macedon, NY).

SUN analysis

Frozen serum samples were thawed for 3 hours until room temperature was reached before proceeding with the analysis to determine animal protein status. Serum urea nitrogen concentration (SUN) was determined via colorimetric analysis performed using the urea assay described by Zawada et al. (2009) and a plate reader (BioTek Synergy plate-reader, Winooski, VT).

Statistical Analysis

Data for forage and mineral and animal observations were analyzed using the procedure GLM of SAS (SAS Institute, Cary, NC) with forage or mineral sample or animal

being the experimental unit respectively. The model statement for forage and mineral data

analyses included treatment, year, and treatment*year interaction. The model statement for

animal data included treatment, pen, sex, harvest date, year, treatment (pen), and

treatment*year interaction. Effects for treatment, year and interactions between treatment and

year for significant effects were observed. A p-value of less than or equal to 0.05 was

considered significant and tendencies were considered with a p-value less than 0.10.

RESULTS

Feed Resources

Effects for available forage biomass, average dry matter (DM), crude protein (CP),

neutral detergent fiber (NDF), acid detergent fiber (ADF), total digestible nutrients (TDN),

and average mineral consumed per head/per day by treatment and year are reported in Table

2 including treatment by year interactions. Average forage biomass available during each

sampling date for both years of the finishing program is shown in Figure 1. Fluctuations in

average DM, CP, TDN, ADF, and NDF composition of available forages during each

sampling date for both years of the finishing program are shown in Figure 2. Available

forage biomass was less (P < 0.0001) during Year 1 compared to Year 2 as reported in Table

2 with no treatment or treatment by year interactions. Crude protein and total digestible

nutrients were higher (P <0.0001 and P = 0.014 respectively) in Year 1 compared to Year 2

with no differences observed between treatment or treatment by year interactions. Year two

experienced greater ADF and NDF values compared to Year 1 with no differences observed

between treatments or treatment by year interactions. Dry matter content of available forages

remained similar during both years of the finishing program and had no differences between treatment or treatment by year interactions.

Average nutritive value for composite samples of concentrate supplemented to each treatment by year are shown in Table 1. Main effect by treatment and year for average mineral consumed per head/per day during the finishing program are reported in Table 2 including treatment by year interactions. More mineral was consumed by cattle in both treatments during Year 2 compared to Year 1. Changes in average mineral consumed per head/per day for each sampling date during both years of the finishing program are shown in Figure 3.

Growth performance data

Results for growth performance of cattle during the forage finishing program by treatment, year, and treatment by year interactions for initial weight, final weight, time to finish before harvest, average daily gain (ADG), initial body condition score (BCS), final BCS, change in BCS, serum urea nitrogen content, carcass weight, and dressing percent are reported in Table 3. No differences ($P > 0.10$) were observed between treatment, year, or interaction for initial animal weight, final weight, and final BCS. Time in days for cattle to reach a target finish weight prior to harvest was less ($P < 0.0001$) for Year 1 compared to Year 2 with both Treatment 1 and 2 finishing around 183 or 180d respectively in Year 1 and 245 or 246d respectively in Year 2. Average daily gain was also lower ($P < 0.0001$) for Year 2 compared to cattle gaining in Year 1 regardless of treatment. There was also an observed increase ($P < 0.0001$) in the SUN levels of cattle in Year 1 with no differences in treatment or interaction between treatment or year. Carcass weights of cattle were also greater ($P = 0.079$)

in Year 2 compared to Year 1 regardless of treatment with no treatment by year interaction observed. Initial body condition score was lower (P < 0.0001) for cattle in Year 2 compared to Year 1 and higher (P = 0.002) for TRT 2 compared to TRT 1 with no year by treatment interaction. Change in body condition score was greater (P < 0.0001) in Year 2 compared to Year 1 and greater (P = 0.002) for TRT 1 compared to TRT 2. No treatment by year interaction was observed for change in BCS. Dressing percent was greater (P = 0.014) in Year 2 and higher (P = 0.0625) for TRT 1 compared to TRT 2 with a treatment by year interaction trend (P = 0.091) observed.

Carcass Traits.

Results for carcass traits of cattle collected after harvest by treatment, year, and treatment by year interaction for back fat thickness, kidney pelvic heart (KPH) fat, longissimus muscle (LM) area, and subcutaneous fat color measurements for L*, b*, and a* are reported in Table 4. No differences (P > 0.10) were observed between treatment, year, or interaction for LM area or subcutaneous fat color measurements for L and b*. Color analysis of subcutaneous fat for a* indicated an increase (P = 0.030) for TRT 2 compared to TRT 1 and an increase (P < 0.0001) was observed also in Year 1 compared to Year 2 with no treatment by year interactions present. Back fat was significantly greater (P = 0.028) in TRT 1 compared to TRT 2 regardless of year with no interaction between treatment and year observed. There was greater (P <0.0001) KPH observed between Year 1 and Year 2 regardless of treatment with Year 1 having 1.62 and 1.70% respectively and Year 2 having 2.47 and 2.14% respectively with no treatment by year interactions observed.

Fatty Acid Profile.

Results for fatty acid content by treatment, year, and treatment by year interaction are reported in Table 5. There were no changes observed in total fatty acid content (g/100g) or individual saturated fatty acids (SFA) C14:0, C15:0, C16:0, or C20:0, monounsaturated fatty acids (MUFA) C14:1, C18:1 trans-9, C18:1 trans-10, C20:1, polyunsaturated fatty acids (PUFA) C18:2, C18:3 Gamma, C20:3, C20:4, or total SFA, total odd-chain fatty acids (OCFA), PUFA, or total omega-6 fatty acid content. Concurrently there was an increase ($P < 0.05$) observed in Year 1 for C16:1 cis-9, C18:1 cis-11, C20:5, C22:6, and unidentified fatty acids compared to Year 2 regardless of treatment with no treatment by year interaction observed. There was also an observed increase ($P = 0.011$) in total omega-3 fatty acid content and a trend for greater ($P = 0.057$) C18:3 Alpha for Year 1 compared to Year 2 in addition to a treatment by year interaction ($P = 0.019$). A treatment by year interaction was also observed for C18:1 cis-9 ($P = 0.054$) and C22:5 ($P = 0.042$) with no differences between years or treatments. There was a trend increase in ($P < 0.10$) C17:0 with a significant increase ($P <0.05$) in C18:0 observed for Year 2 and TRT 2 compared to Year 1 and TRT 1 with no interactions between treatment and year observed. An increase ($P < 0.05$) was also seen in C18:1 trans-11 for Year 1 and TRT 2 compared to Year 2 and TRT 1 with a significant interaction between treatment and year. There was also a trend ($P = 0.065$) increase in C20:2 in TRT1 compared to TRT 2. An interaction ($P = 0.028$) between treatment and year was also observed for total MUFA content in addition to a trend increase ($P = 0.089$) in TRT 1 compared to TRT 2 with no difference between years. There was also a higher ($P < 0.0001$)

omega-6:omega-3 ratio observed in Year 2 compared to Year 1 with a trend interaction (P = 0.076) between year and treatment.

Meat Quality.

Results for meat quality traits by treatment, year, and interactions between treatment and year are reported in Table 6. There were no differences (P > 0.10) observed within calculated yield grade, marbling score, quality grade, slice shear force measurement for tenderness evaluation, or in crude fat extraction measurement of longissimus muscle intramuscular fat for treatment, year or interactions.

DISCUSSION

Forage quality and availability are key factors in animal performance when cattle are finished in a pasture based system. Although forage availability was more abundant in Year 2 (Figure 1) the overall quality of the forage was decreased significantly compared to the first year of the study (Table 2). One reason for this change could be due to cattle grazing pastures containing mostly fresh regrowth of tall fescue because the current finishing study followed a winter grazing study ending on January 29, 2015 using the same pastureland. Cattle were randomly assigned to replicate groups within treatment which were then randomly allocated to pastures with the first grazing day on March 30, 2015. In Year two cattle groups were again randomly allocated to pastureland with forages that had not been grazed since August of 2015 which provided cattle with large amounts of mature stockpiled fescue. The difference in crude protein (Figure 3), total digestible nutrients (Figure 6) and decreased ADF (Figure 5) and NDF (Figure 4) values observed in Year 1 can be explained by previous

research that determined forages of any species in stages of regrowth have higher digestibility compared to more mature plants of the same species (Goff et al., 2015; Ball et al., 2002). Ball et al. (2002) stated that species of plant contributes largely to its digestibility such that cool season grasses are more digestible than warm season grasses due to the higher rate of increasing lignin content within the cell wall. Based on maturity stage, Kentucky 31 tall fescue can decrease as much as 11% in CP and 19% in in-vitro DM digestibility (IVDMD) from the pre-boot (19% CP, 72% IVDMD) to the seed head stage of maturity (Ball et al., 2002). Plants in the reproductive stage of growth contain greater amounts of structural carbohydrates like cellulose and hemicellulose within the stems which depress the digestibility of these components within the rumen (Moore and Hatfield, 1994; Ball et al., 2002).

During both years, TDN and CP of forage was at the highest level at the start of the study with the exception of TDN in Year 2 which started with a slow increase until the end of April sampling date before decreasing again as shown in Figure 2. This could be explained by the characterization of cool season perennial forages like tall fescue nutritive value which is at its highest in late March to early May. According to Ball et al. (2002) tall fescue harvested at 4 weeks of regrowth have CP levels of 14%, TDN levels of 66%, ADF and NDF values of 31% and 58% respectively, and IVDMD levels of 63% which very closely resemble the values observed for Year 1 forage nutritive value (Table 2). According the NRC (2016), growing and finishing beef cattle have a CP requirement of 12.6% (DM) and a TDN requirement of 70% (DM) in order to obtain an average daily gain of 1.2kg/d and a shrunk body weight of 300kg. Based on these recommendations, forage alone exceeded the CP

requirement during Year 1 but the TDN requirement was slightly less than required levels in both Year 1 and Year 2.

The changes observed in forage quality could have contributed to many other differences seen between Year 1 and Year 2. Mineral consumption during Year 2 was significantly increased (Table 2, Figure 7) which could be an additional result of the reduced forage quality observed in Year 2. Mineral levels recommended for adequate supplementation should be 0.085 to 0.113kg/head/d (Camp Chemical Company, Roxboro, NC) and the amounts consumed by both treatments over both years on a kg/head/d basis were within this recommended range. Both treatments experienced similar pasture quality and forage availability in each year which resulted in no significant treatment differences. There have also been studies that indicate supplement feeding can impact dry matter intake of forages at certain levels (Pavan and Duckett, 2008; Hess et al., 1996; Elizalde et al., 1996) although forage intake was not measured in this study it has also been established that supplementation at low levels similar to the levels applied in this study may not impact intake enough to cause a significant decrease (Brokaw et al., 2001; Judkins et al., 1997). Differences in forage nutritive value between both years had a direct impact on the number of days required for animals to reach a target finishing weight and body condition for harvest. Cattle being finished in Year 2 required an additional 62d of grazing and supplementation to reach a similar final weight and BCS compared to cattle in Year 1 as reported in Table 3. Neel et al. (2007) evaluated effects on animal performance when cattle were finished on either pasture of mixed forage species or in a feedlot receiving concentrate composed of corn silage, whole corn, and soybean meal and final body weights of 475 and 541kg respectively

were reported. Cattle in that study had average daily gains of 0.85kg/d for pasture finished animals and 1.23kg/d for feedlot finished cattle. Cattle from the current study gained a daily average and finished at a weight between values for pasture and feedlot finished animals for both final weight and ADG which supports the idea that low level concentrate supplementation can be beneficial to improving weight gain in cattle on a forage finishing system (Neel et al., 2007). Pavan and Duckett (2008) reported an ADG of 1.00 kg/d during a 197d finishing period for cattle grazing endophyte-free fescue with 0.52% body weight (DM basis) supplementation of cracked corn and 0.99 kg/d during the same time period for cattle grazing fescue with soybean hulls plus 0.1% of body weight (DM basis) of corn oil which closely resemble the ADG values observed during Year 1 regardless of treatment. In this study cattle grazing only endophyte-free fescue had ADG of 0.76kg/d which is lower than ADG observed during Year 2 of the current study (Pavan and Duckett, 2008). Based on the literature, animals raised on high grain diets or those with minimal forage or fiber consumption have improved average daily gain, fat deposition within tissues, carcass weights (Duckett et al., 2013; Hedrick et al., 1983), and USDA quality grades (Aberle et al., 1981; Hedrick et al., 1983; Duckett et al., 1993). Cattle finished on high grain diets reach a target weight in less time than cattle finished on forage alone. Cattle in the current study finished on mostly forage of higher quality in Year 1 and lower quality in Year 2 with low levels of concentrate supplementation finished in 181 and 245d in Year 1 and 2 respectively. The average finishing time of 200 days was similar to data reported by Baublits et al. (2004) and Neel et al. (2007).

Compared to the differences observed in forage quality and availability, nutritive value of feed was similar between both years and treatment differences were apparent in starch content, TDN, non-fiber carbohydrate (%DM), net energy maintenance and gain which were numerically greater in TRT 2 while mineral, NDF, and ADF content were numerically lower in TRT 2 compared to the values contained in TRT 1. As these values were obtained from analysis of composite samples statistical analysis was unable to be performed. The starch content derived from the ground corn component of the TRT 2 diet could contribute to the increase in TDN and net energy for maintenance and gain observed but as results show, this increase did not significantly impact growth performance for TRT 2 cattle.

Additionally, serum urea nitrogen content (Table 4) was also impacted by the decreased quality of the forage in Year 2 with cattle having an average SUN of 5.11 mmol/L in Year 1 and 3.38 mmol/L in Year 2. Hammond et al. (1993) determined that cattle consuming only forage with no concentrate supplementation that had SUN levels less than 2.5 mmol/L compared to digestible energy intake were protein deficient and would likely have minimal ADG (Hammond et al., 1993). Though cattle were well above the level required for adequate weight gain, the lower values in Year 2 could be a contributing factor to the depressed average daily gain observed in Year 2.

In addition to lower serum urea nitrogen values, cattle utilized during the second year of the study had a lower body condition initially prior to receiving supplementation (BCS of 5.0 in Year 2 compared to 5.5 in Year 1) which contributed to the extended time required for finishing cattle to reach a similar BCS (Table 3) in Year 2. It can be assumed that if these

cattle had been exposed to forages of a similar quality in Year 2 the time necessary to establish an equivalent amount of condition would have been decreased and possibly similar to that of Year 1 cattle. Treatment differences were observed in TRT 1 cattle that began the study at a lower BCS and were consistently able to surpass TRT 2 cattle in the amount of body condition compiled during both years of the finishing program. This ability to compensate for the lack of initial body condition could be the result of improved nutrient absorption and digestibility of forages in the presence of the high fiber concentrate compared to the likely changes within the rumen as a result of the addition of starch. The improved ability to acquire body condition also contributed greatly to the increase in dressing percent of carcasses of TRT 1 cattle. According to literature, an average dressing percent expected for pasture finished cattle would be between 52-57 % depending on the time spent grazing and forage quality (Neel et al., 2007; Duckett et al., 2013; Baublits et al., 2004; Aberle et al., 1981). In contrast, animals from the same studies that received some degree of grain supplementation during the finishing phase had dressing percents between 62-63% (Duckett et al., 2013; Aberle et al., 1981) and 56-57% in cattle receiving 1% body weight (DM basis) supplemented soyhulls in addition to grazing forages (Baublits et al., 2004). The decreased dressing percent in TRT 2 could be a result of depressed forage digestibility in the presence of starch within the rumen. This would have caused more forage to remain in the rumen undigested, making the cattle appear heavier when weighed before harvest. Although cattle were all finished to a similar weight and body condition (Table 3), when the digestive tract was removed during harvest dressing percent was greater in TRT 1 cattle. Forage digestibility can be decreased as a result of non-structural carbohydrates in concentrate

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resulting in a reduction in the pH within the rumen and decreasing the digestibility of structural carbohydrates like cellulose and hemicellulose found large amounts in forages (Dijkstra, 1994; Sutton, 1985).

In addition to an increased BCS and dressing percent observed in TRT 1 cattle during post-harvest carcass evaluation, a significant increase in average subcutaneous fat deposited was noted between the 12th and 13th rib. Cattle raised strictly on grass produce an average of 0.18 to 0.56 cm back fat depending on length of time spent grazing and forage quality and cattle finished on grain can be expected to produce between 0.69 to 1.37 cm of back fat. (Baublits et al., 2004; Aberle et al., 1981; Duckett et al., 2013; Neel et al., 2007). Baublits et al. (2004) reported that cattle finishing on pasture with 1% body weight supplementation of soyhulls had an average back fat between 0.67 to 1.3 for cattle grazing orchardgrass pastures and between 0.90 to 1.07 cm for cattle grazing fescue pastures with animals being of varying biological type. Compared to cattle fed high grain diets these levels can be lower, but according to Duckett et al. (1993) amounts greater than 1.4 cm can result in trim losses when carcasses are processed for retail and additional time on feed does not always contribute to an improvement in meat product quality (Duckett et al., 1993). Kidney, pelvic, and heart fat depots were also significantly greater in cattle finished in Year 2 regardless of treatment which is most likely a result of the increased time spent grazing and receiving supplementation. Despite these differences in fat depots, average LM area was not affected by treatment or year.

In addition to the amount of adipose tissue deposited, instrumental color of subcutaneous fat was also evaluated in this study. When subcutaneous fat color was analyzed

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brightness of fat and yellowness were similar across both treatments and years (Table 4). An effect was observed for both year and treatment for the color a* measurement which quantifies redness in subcutaneous fat. Significant treatment differences could be accounted for due to the change in preparation method of samples taken during Year 2 to prevent purge contamination of the backfat samples. Subcutaneous fat analyzed in Year 1 had greater color a* values but were also greater in TRT 2 cattle across both years which indicates a stronger red color in animals receiving additional starch. Duckett et al. (2013) also reported an increase in the a* measurement of subcutaneous fat color when cattle were finished on a high concentrate compared to a forage diet (Duckett et al., 2013). Subcutaneous fat coloration in grass fed cattle is generally more yellow in color due to the increased level of beta-carotenes being consumed in fresh forages and subsequently deposited in the fat tissue (Priolo et al., 2001). In a study conducted by Duckett et al. (2013) the levels of beta-carotene and alpha-tocopherol were analyzed in cattle finished on concentrate compared to forage diets and resulted in levels of 0.057 and 1.40 ug/100g for concentrate and 0.499 and 3.12 ug/100g for forage respectively. Increased levels of water soluble vitamins have been reported by others (Yang et al., 2002; Duckett et al., 2009b; Daley et al., 2010) in pasture raised cattle compared to cattle consuming high concentrate diets. (Duckett et al., 2013). Average values for yellowness (b*) of subcutaneous fat in this study are reported in Table 4 and are less than values reported by others (Duckett et al., 2007; Duckett et al., 2013) for grass fed cattle but are slightly more than cattle raised on high grain diets. Baublits et al. (2004) reported no significant differences (P > 0.05) between cattle consuming tall fescue, tall fescue with 1% BW soyhull supplementation, or orchardgrass with an equivalent supplementation regimen

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for the amount of yellowness observed between subcutaneous fat. All values observed in that study were numerically higher than values reported in the current study regardless of treatment or year. (Baublits et al., 2004).

Although no apparent differences were observed within meat quality, traits evaluated were greater than averages reported in the literature for yield grade (Aberle et al., 1981; Neel et al., 2007), marbling score (Aberle et al., 1981; Baublits et al., 2004; Leheska et al., 2008; Duckett et al., 2013), and quality grade (Aberle et al., 1981; Baublits et al., 2004) compared to cattle raised strictly on grass.

Additionally, overall meat quality can be impacted by tenderness which can be potentially improved with aging after harvest. Aging time has the potential to impact slice shear force values (Marino et al., 2006), but it has been determined that dry aging longer than 14d has a decreased rate of improving tenderness values with no significant differences between forage or concentrate fed meat products for 14 or 28d of aging (Duckett et al., 2009b; Realini et al., 2004; Duckett et al., 2013). Despite the differences between dry aging time between both years of the trial, no significant interactions or main effects were observed in tenderness values in the current study (Table 4).

Another factor that contributes to the level of meat tenderness is the amount of intramuscular fat deposited within the muscle tissue. Intramuscular fat content, measured by the amount of crude fat extracted, were also similar between treatments across both years and are greater than values observed for grass finished cattle reported by Duckett et al. (2007) and Baublits et al. (2004). Crude fat extracted reported in this study (Table 4) were numerically less than values reported by Duckett et al. (2007) for cattle receiving a high

concentrate diet (18.77% DM basis) as well as values observed by Baublits et al. (2004) for cattle receiving low level soyhull supplementation during a forage finishing program.

When treatments are compared, total fatty acid content of longissimus muscle is statistically similar ($P > 0.05$) across both years of the finishing study and are more similar to total fatty acid content observed in grass fed cattle than the amount derived from animals fed concentrate (Duckett et al., 2009; Duckett et al., 2013). Total saturated fatty acid content was not different ($P > 0.05$) between treatment or year in addition to no differences ($P > 0.05$) between treatment or year for C14:0 (myristic acid), C15:0 (pentadecylic acid), C16:0 (palmitic acid), or C20:0 (arachidic acid). Levels of myristic acid were greater than those reported by Baublits et al. (2006) and similar to those reported by Duckett et al. (1993) for cattle receiving no or short term feeding of concentrate. Pentadecylic acid was similar to values reported by others (Dierking et al., 2010; Duckett et al., 1993; Leheska et al., 2008; and Duckett et al., 2009c) for grass fed cattle but much lower than values reported by Baublits et al. (2006). Levels of palmitic acid were similar to values observed by Baublits et al. (2006) for cattle receiving low level soyhull supplementation while grazing fescue or orchardgrass during a pasture finishing program and greater than cattle grazing tall fescue with no supplementation (Baublits et al., 2006). Arachidic acid levels observed were similar to those reported by Leheska et al. (2008) for grass fed LM and much greater than values observed for concentrate fed animals. In contrast, values observed for cattle in the current study were more similar to cattle that had been receiving a high concentrate diet for 196d than to grass fed cattle in the same study by Duckett et al. (1993).

Furthermore, average values for C17:0 (margaric acid) were increased in both Year 2 (P = 0.059) and TRT 2 (P = 0.072) which could be the result of an increased time on feed during Year 2 for both treatments and the greater level of starch present in the concentrate consumed by TRT 2. Values observed for margaric acid (Table 5) are lower than values reported in the literature (Duckett et al., 1993; Baublits et al., 2006; Leheska et al., 2008; Dierking et al., 2010) for both animals receiving concentrate and being finished on pasture. Duckett et al. (1993) studied the effect of time on feed on the fatty acid composition of LM and observed a significant increase in margaric acid from 0d (1.28%) (grass fed control) to 112d (2.48%) on a high concentrate diet which supports the idea that animals receiving concentrate containing starch for longer periods of time would exhibit a greater concentration of margaric acid. Observed levels of stearic acid were also determined to be significant between treatment and year. Greater concentrations of stearic acid were found in cattle finished in Year 2 regardless of treatment as well as cattle in TRT2 which received concentrate with a higher starch content compared to TRT 1 cattle. Cattle in Year 2 had access to forage for 62d longer than cattle in Year 1 although the forage was of lower quality in contrast. Decreased forage quality could have increased the utilization of the readily digestible starch content of TRT 2 concentrate promoting greater amounts of biohydrogenation to saturated fatty acids in the rumen to be absorbed and deposited in tissue as stearic acid. Grains contain a larger amount of C18:2 (linoleic acid) and C18:1 cis-9 (oleic acid) compared to forages (French et al., 2000) which often undergo hydrogenation by rumen microbes to form stearic acid. Stearic acid can also be formed from the hydrogenation of the C18:1 trans-11 isomer, vaccenic acid, that will occur within the rumen during digestion

(Bauman et al., 2000). Levels of stearic acid observed in TRT 2 cattle were similar to those reported by others (Duckett et al., 1993; French et al., 2000; Leheska et al., 2008; Duckett et al., 2009c; Duckett et al., 2013) and greater than those reported by Mitchell et al. (1991), Baublits et al. (2006), and Dierking et al. (2010).

Additionally, the monounsaturated fatty acids C14:1 (myristicoleic acid), C18:1 trans-9 (elaidic acid), C18:1 trans-10 (trans-10 octadecanoic acid), and C20:1 (eicosenoic acid) were determined to be similar ($P > 0.10$) across treatment and year. Levels of myristicoleic acid were similar to those reported by others (Duckett et al., 1993; Baublits et al., 2006; Leheska et al., 2008; Duckett et al., 2009c; Duckett et al., 2013) for grass fed cattle. The octadecanoic isomer C18:1 trans-10 was not detected on GLC analysis for either treatment in the current study which can be explained by its' presence in larger quantities in adipose tissue and milk of animals consuming high concentrate diets (Bauman et al., 2000).

Concurrently, during Year one there was a significant increase observed for C16:1 cis-9 (palmitoleic acid) which could be a result of the increased quality of available forage. Holloway and Wakil (1964) determined that palmitoleic acid in the presence of ATP could result in the formation of C18:1 cis-11 (cis-vaccenic acid) which is an isomer of C18:1 that behaves in a similar chemical manner to oleic and vaccenic acids (Holloway and Wakil, 1964). Considering the increase in overall forage quality (CP and TDN specifically) observed during Year 1 it is not surprising to report a significant increase ($P = 0.033$) in the level of cis-vaccenic acid observed during Year 1 regardless of treatment. Holloway and Wakil (1964) also reported that this isomer contributes up to 80% of the C18:1 isomers present in the inner mitochondrial membrane of mammalian cells in addition to being highly prevalent

in intestinal bacteria. They theorized that the cis-vaccenic acid would undergo trans isomerization prior to absorption by the animal and contribute to the C18:1 trans-11 (vaccenic acid) content in adipose tissue (Holloway and Wakil, 1964). Vaccenic acid levels were also significantly increased ($P < 0.005$) for cattle in Year 1 and those in TRT 2. A significant ($P = 0.004$) treatment by year interaction was also observed and signified that changes between treatments significantly impacted effect of year. The increase observed within Year 1 could be attributed to the increased forage quality observed compared to Year 2 and improvements within TRT 2 may be the result of higher starch content in the diet compared to TRT 1.

Additionally, linoleic acid which is found in higher levels in grains (French et al., 2000) than forages will be converted to C18:2 cis-9, trans-11 (conjugated linoleic acid) in the rumen during biohydrogenation by microbes and then rapidly hydrogenated further to form vaccenic acid. Saturation of vaccenic acid to stearic acid occurs at a much slower rate which allows for the accumulation of vaccenic acid in the rumen and is more available for absorption into bovine tissues. Once in the adipose tissue, vaccenic acid can contribute to the formation of conjugated linoleic acid (CLA) via the delta-9 desaturase pathway, which will be discussed in greater detail later (Bauman et al., 2000).

Concurrently, levels of C18:1 cis-9 (oleic acid) were not significantly different between treatments or across years but there was an interaction ($P = 0.054$) between treatment and year observed which implies an effect of treatment on year during the study. Bauman et al. (2000) also reported that oleic acid can be formed from stearic acid using the

delta-9 desaturase pathway within bovine adipose tissue. As mentioned previously, an increase in stearic acid was observed for both Year 2 cattle and those receiving TRT 2.

Overall, total MUFA content was increased (P = 0.089) for TRT 1 despite significant increases observed in MUFA levels for TRT 2 due to numerically greater values reported for oleic acid, palmitoleic acid, elaidic acid, and cis-vaccenic acid (Table 5). A significant interaction (P = 0.028) was also observed in total MUFA content implying a significant effect of the independent variable treatment on the independent variable year. Total MUFA content was similar to values reported by others (Mitchell et al., 1991; Duckett et al., 1993; Leheska et al., 2008; and Duckett et al., 2009c).

In contrast, the total polyunsaturated fatty acid content of LM did not differ significantly between year or treatment and compared to values observed by Duckett et al. (2013) were greater than animals raised on concentrate (3.74) and slightly less (6.18) than animals grazing only forages. Total PUFA content includes both omega-6 and omega-3 fatty acids which have been determined to be essential fatty acids for human health since the human body cannot create them endogenously (Food and Nutrition, 2005). Multiple omega-6 fatty acids were observed as lacking significance between treatments and years including C18:2 (linoleic acid), CLA, C18:3 (gamma-linolenic acid), C20:3 (dihomo-gamma-linolenic acid, DGLA), and C20:4 (arachidonic acid). Despite the fact that linoleic acid is found in large quantities in grains and smaller amounts in forages, there was no observed treatment difference (P = 0.309) in its presence within adipose tissue. Linoleic acid, gamma-linolenic acid, DGLA, and arachidonic acid are all characterized as omega-6 fatty acids which could

be a contributing factor to the lack of significance in total omega-6 fatty acid content between both treatment groups across both years of the study.

A fatty acid of great interest in recent history is CLA which has been reported at higher levels for animals consuming forage compared to those receiving concentrate supplementation (French et al., 2000; Scollan et al., 2006; Duckett et al., 2009c; Duckett et al., 2013). Although levels reported in the current study were more similar to amounts observed in animals consuming concentrate (French et al., 2000; Duckett et al., 2009c; Duckett et al., 2013) treatment differences were also not observed in the study by Baublits et al. (2006) where grass fed cattle were compared to cattle grazing forage but receiving 1% BW soyhull supplementation similarly to TRT 1 cattle in the current study. Values reported by Baublits et al. (2006) were slightly greater (0.63-0.70) than values observed for either treatment (Table 5) and based on these results it can be concluded that the inclusion of starch at low levels in concentrate does not negatively impact CLA content compared to a fiber based concentrate. Conjugated linoleic acid describes a family of geometric and positional isomers of linoleic acid that contain a single cis and trans double bond that occur in the absence of an intervening carbon atom not associated with one of the double bonds (Food and Nutrition Board, 2005). Conjugated linoleic acid derived from ruminant products contributes largely to the intake of CLA by humans and has been established as having anticarcinogenic properties when studied in experimental animals as well as reduction of body fat accretion, antidiabetic effects, reduced incidence of atherosclerosis, and improved immune function (McGuire and McGuire, 2000). Although animal models have exhibited promising positive results, clinical studies in humans have not resulted in any clinically

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relevant evidence to support the inclusion of CLA as a necessary component of the human diet (Onakpova et al., 2011; Benjamin et al., 2015).

A significant interaction was observed between treatment and year for C18:3 (alpha-linolenic acid) in addition to an increase (P = 0.057) in the quantity observed in cattle finished during Year 1. Alpha-linolenic acid (ALA) is found largely in many fresh forages and an increase within Year 1 could be the result of an increase in available young forages that contain more digestible plant proteins for ruminal degradation compared to the more mature forages available to cattle in Year 2 that contained a higher amount of indigestible fiber. In fact, total omega-3 fatty acid content and more specifically C20:5 (eicosapentaenoic acid, EPA) and C22:6 (docosahexaenoic acid, DHA) were observed in greater amounts in cattle finished during Year 1 compared to Year 2. These longer chain PUFA are formed by the elongation of linolenic acid within the adipose tissue utilizing the delta-5 and delta-6 desaturase pathways. These enzymes are common for both omega-6 and omega-3 fatty acids which compete for use and the presence of either group in larger amounts can shift enzyme activity in favor of one over the other (Food and Nutrition, 2005). An increase in these long chain omega-3 PUFA suggests that an increased amount of linolenic acid could have shifted this pathway to favor the elongation of omega-3 fatty acids like EPA and DHA.

Additionally, treatment differences were observed for the omega-6 PUFA, C20:2 (eicosadienoic acid), which were reflected in an increase (P = 0.065) within TRT 2, which could be the result of the greater presence of starch found in that diet. French et al. (2000) determined that both concentrate and forages contain a certain level of linolenic acid that serves as a precursor to the longer chain eicosanoid omega-6 fatty acids. Although there was

no significant effect of treatment on linoleic acid content, the amount present during finishing could have been converted to eicosadienoic acid via the delta-6 desaturase pathway within tissue (Food and Nutrition, 2005) in cattle consuming TRT 2. A significant interaction between the effect of treatment by year was also observed in the omega-3 fatty acid C22:5 (docosapentaenoic acid, DPA) which suggests that some changes between treatments affected results observed in each year.

Considering the significant increases observed in the amount of total omega-3 PUFA in cattle finished in Year 1 without differences reported for the omega-6 PUFA content for either year or treatment, it is not surprising that the ratio of omega-6: omega-3 fatty acids are significantly lowered in Year 1 cattle. This finding also supports the thought that as more omega-3 fatty acids are present within the adipose tissue the elongation pathway will shift to favor those PUFA over omega-6, which creates a beneficial fatty acid profile from a human health perspective. Simopolous et al. (2002) determined that a ratio of 4:1 (omega-6: omega-3) is the most beneficial for human health based on studies that show a marked decrease in mortality due to cardiovascular disease. Compared to salmon, which is a great source of omega-3 fatty acids such as EPA and DHA, the omega-6: omega-3 ratio of grass fed and conventionally raised cattle can range from 2:1 to 3:1 and 4:1 to 5:1 respectively (French et al, 2000) and wild caught salmon is reported to have a ratio of 0.10 and farm raised salmon around 0.18. Simopolous et al. (2002) also reported that chicken egg yolk found in American supermarkets contained a 19.9 ratio of omega-6: omega-3 which is well above the recommended ratio to avoid incidence of human health problems. Since the paleolithic era when humans were consuming a ratio around 0.79 omega-6:0, omega:3, humans are

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currently consuming ratios of 16.74 in the United States, 15.0 in northern Europe and UK, and 4.0 in Japan. This could be attributed to our increased reliance on cereal grains as a main source of energy and feed for livestock raised for human consumption. (Simopolous et al., 2002). Based on this knowledge and the current recommendations for a ratio of 4:1, consuming meat from cattle raised in Year 1 regardless of treatment would be more beneficial from a human health perspective (Table 5). The Food and Nutrition Board (2005) states the Adequate Intake amount of essential omega-6 and omega-3 fatty acids to be 17g/d for men, 12g/d for women and 1.6g/d for men, and 1.1g/d for women respectively (Food and Nutrition, 2005). Considering these recommendations, to reach the target adequate intake men would need to consume 454.6 g/d to meet their omega-6 requirement and 136g/d for their omega-3 requirement of meat from cattle finished in Year 1. Women would need to consume 320.8 g/d to meet omega-6 and only 94 g/d to meet their omega-3 requirement when meat is also from cattle in Year 1. The amount of unidentified fatty acids was also observed to be significantly greater for Year 1 compared to Year to regardless of treatment which could be the result of a greater number of long chain PUFA peaks being observed in the chromatograms for Year 1. Some small peaks cannot be positively quantified as a percent of the total fatty acids reported during the analysis so these peaks are classified as "unidentified" in order to maintain the most accurate reporting of results regarding other known fatty acid peaks.

IMPLICATIONS OF RESEARCH

Attempts to improve meat quality and carcass traits in cattle consuming high forage diets have been studied extensively considering various forage species, levels of quality, and length of time allowed for grazing but the addition of starch at low levels in fiber-based concentrate supplementation had not yet been addressed. Supplying cattle with concentrate has been proven to improve growth performance and to help achieve desirable carcass and meat qualities acceptable for the retail market. Highly digestible energy sources found in concentrates have been reported to cause shifts in the rumen environment and subsequently affect the microbial species degrading the feedstuffs consumed by the animal. These shifts in microbial fermentation products can affect the fatty acid profile found in animal products consumed by humans and can contain greater amounts of fatty acids less beneficial for human health.

This research concludes that the addition of starch to a fiber-based concentrate supplemented at low levels during forage-based finishing did not significantly improve overall cattle growth performance, carcass traits or meat quality. In actuality providing cattle with concentrate higher in fiber without added starch can improve the dressing percent and amount of subcutaneous fat deposited during the finishing period without any additional improvements in quality grade, marbling score or yield grade. This research also concluded that more improvements were seen in the fatty acid profile towards being a healthier product as a result of improved forage quality regardless of the presence of starch in low level supplementation. Forage quality also greatly impacted the potential for animal growth performance and length of time required to achieve a target level of finish regardless of

starch inclusion. Cattle producers should consider incorporating high quality forages into their grazing management systems to improve cattle performance, product quality and avoid the extra feed and processing costs associated with incorporating starch as a component of a high fiber concentrate.

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TABLES

Table 1. Nutritive composition of composite samples collected to represent concentrate diets supplemented during pasture-finishing program by treatment and year.

Variable	TRT 1		TRT 2	
	YR 1	YR 2	YR 1	YR 2
DM (%)	88.8	89.4	88.0	88.8
CP (%DM)	17.2	18.5	19.1	19.0
NDF (%DM)	51.0	48.2	26.8	29.8
ADF (%DM)	29.6	28.8	15.3	15.5
TDN (%DM)	67.2	67.6	74.1	74.0
Ash (%DM)	9.61	9.04	7.24	6.55
Calcium (%DM)	1.48	1.61	1.21	1.18
Phosphorous (%DM)	0.65	0.78	0.52	0.54
Magnesium (%DM)	0.37	0.40	0.26	0.26
Potassium (%DM)	1.53	1.53	1.15	1.17
Sodium (%DM)	0.07	0.06	0.04	0.04
Cu (ppm)	8	7	8	7
Fe (ppm)	391	321	215	208
Mn (ppm)	24	27	22	26
Zn (ppm)	79	79	52	55
Non-Fiber Carbohydrate (%DM)	22.2	24.3	46.8	44.7
Starch (%DM)	9.1	7.5	30.3	32.3
Net Energy Maintenance (mcal/lb)	0.70	0.71	0.80	0.80
Net Energy Gain (mcal/lb)	0.43	0.43	0.52	0.52

TRT 1 indicates cattle receiving fiber-based supplementation; TRT 2 indicates cattle receiving starch-based supplementation.

Table 2. Average nutritive value and amount of available forages and average mineral consumed by cattle receiving low level supplementation during a pasture finishing-program as affected by treatment, year, and interaction of treatment by year.

Variable	TRT 1		TRT 2		SEM	P-value		
	YR 1	YR 2	YR 1	YR 2		TRT	YR	TRT*YR
Biomass (kg/ha)	1967.11	4298.19	1856.80	4393.06	62.09	0.977	<0.0001	0.707
Dry Matter (DM) (%)	31.33	34.37	31.49	34.34	0.46	0.974	0.152	0.965
Crude Protein (CP) (%)	14.54	11.37	14.86	11.38	0.17	0.822	<0.0001	0.838
Neutral Detergent Fiber (NDF) (%)	56.10	59.43	55.24	58.97	0.35	0.654	0.019	0.892
Acid Detergent Fiber (ADF) (%)	31.78	35.16	31.54	34.94	0.21	0.805	0.0005	0.989
Total Digestible Nutrients (TDN) (%)	66.61	64.51	66.84	64.69	0.19	0.808	0.014	0.971
Mineral consumed (kg head/day)	0.03	0.05	0.03	0.04	0.001	0.917	0.019	0.541

TRT 1 indicates cattle receiving fiber-based supplementation; TRT 2 indicates cattle receiving starch-based supplementation.

Table 3. Cattle growth performance including initial and final body weight, time to finish, average daily gain, initial, final, and change in body condition score, hot carcass weight, and dressing percent as affected by treatment, year, and interaction of treatment by year.

Variable	TRT 1		TRT 2		SEM	P-value		
	YR 1	YR 2	YR 1	YR 2		TRT	YR	TRT*YR
No. animals	18	14	18	13				
Initial weight (kg)	319.05	321.02	323.34	323.45	1.77	0.642	0.920	0.922
Time to finish (d)	182.72	244.14	179.83	245.56	0.45	0.686	< 0.0001	0.495
Final weight (kg)	496.00	525.18	510.42	520.15	2.30	0.616	0.147	0.430
ADG (kg/d)	0.96	0.85	1.03	0.80	0.01	0.644	< 0.0001	0.118
Initial BCS[1]	5.36	4.92	5.66	5.04	0.02	0.025	0.0002	0.479
Final BCS	6.34	6.54	6.41	6.44	0.01	0.781	0.154	0.253
Change BCS	1.04	1.67	0.76	1.39	0.02	0.002	< 0.0001	0.986
Carcass Weight	285.34	312.64	295.31	299.58	1.53	0.804	0.079	0.164
Dressing %[3]	56.87	59.53	57.04	57.65	0.11	0.0625	0.014	0.091

TRT 1 indicates cattle receiving fiber-based supplementation; TRT 2 indicates cattle receiving starch-based supplementation.

[1]Body Condition Score (BCS) is scored on a 1-9 scale, 1 being emaciated and 9 being extremely obese (Eversole et al., 2009).

[3]Dressing % = (Carcass Weight/Final Weight) * 100.

Table 4. Carcass and meat quality traits including back fat, kidney pelvic heart fat, longissimus area, subcutaneous fat color measurements L*, a*, and b*, calculated yield grade, marbling score, quality grade, tenderness, and crude fat content of longissimus muscle samples collected post-harvest after dry-aging period and serum urea nitrogen content collected from cattle finished on forage as affected by treatment, year, and interaction of treatment by year.

Variable	TRT 1		TRT 2		SEM	P-value		
	YR 1	YR 2	YR 1	YR 2		TRT	YR	TRT*YR
No. animals	18	14	18	13				
Time dry-aged (d)	11	8	11	8				
Back Fat (cm)	0.91	0.98	0.80	0.88	0.01	0.028	0.275	0.954
KPH (%)	1.62	2.47	1.70	2.14	0.03	0.283	0.0003	0.182
Longissimus Area (cm^2)	68.42	78.26	73.90	75.06	0.53	0.623	0.103	0.167
Subcutaneous Fat Color								
Color L	71.71	72.87	71.42	71.22	0.30	0.451	0.796	0.693
Color a*	0.70	-2.41	2.62	-1.91	0.13	0.030	< 0.0001	0.335
Color b*	15.94	16.33	14.94	16.76	0.21	0.76	0.403	0.565
Yield Grade	2.71	2.70	2.45	2.55	0.03	0.125	0.839	0.761
Marbling Score	5.50	5.61	5.33	5.69	0.02	0.702	0.119	0.373
USDA Quality Grade	17.19	17.33	16.93	17.28	0.03	0.248	0.198	0.561
Slice Shear Force (kg)	20.54	21.65	18.57	21.55	0.37	0.521	0.381	0.666
Crude Fat Extract (%)	12.74	13.51	11.16	14.48	0.24	0.773	0.179	0.367
SUN^2 (Mm)	5.12	3.53	5.09	3.23	0.04	0.262	< 0.0001	0.495

TRT 1 indicates cattle receiving fiber-based supplementation; TRT 2 indicates cattle receiving starch-based supplementation.

Yield Grade (YG) is measured on a scale of 1-5, with 1 being the highest yielding carcass and 5 being the lowest.

Marbling Score (MS) is measured on a 0-100 scale on each tier of marbling: slight$^{50-100}$ = 4.50+; small$^{50-100}$ = 5.00+; modest$^{50-100}$ = 6.00+.

USDA Quality Grade (QG) is measured on a scale of 15-19 with select- =15; select +=16; choice- = 17; choice = 18; choice+ = 19.

[2]Serum Urea Nitrogen (SUN)

Table 5. Longissimus muscle fatty acid composition as affected by treatment, year, and interaction of treatment by year.

Variable	TRT 1		TRT 2		SEM	P-value		
	Year 1	Year 2	Year 1	Year 2		TRT	YR	TRT*YR
No. animals	18	14	18	13				
Total Fatty Acids[1] (g/100g)	10.62	10.48	9.43	11.17	0.13	0.748	0.480	0.378
Fatty Acids								
C14:0, %	2.53	2.29	2.44	2.35	0.03	0.860	0.294	0.592
C14:1, %	0.55	0.41	0.44	0.44	0.01	0.254	0.192	0.147
C15:0, %	0.37	0.38	0.39	0.40	0.003	0.140	0.545	0.928
C16:0, %	27.82	27.74	27.22	27.37	0.11	0.294	0.956	0.852
C16:1 cis-9, %	3.30	2.78	2.97	2.85	0.02	0.191	0.028	0.139
C17:0, %	0.56	0.57	0.56	0.65	0.004	0.072	0.059	0.147
C18:0, %	15.00	16.92	16.49	17.53	0.09	0.007	0.008	0.380
C18:1 trans-9, %	0.15	0.08	0.10	0.03	0.01	0.207	0.226	0.997
C18:1 trans-10, %	0.00	0.00	0.00	0.00	---	---	---	---
C18:1 trans-11, %	2.35	2.18	3.19	2.04	0.03	0.005	0.0004	0.004
C18:1 cis-9, %	37.67	36.82	35.34	37.48	0.13	0.145	0.432	0.054
C18:1 cis-11, %	1.15	1.01	1.08	1.05	0.01	0.556	0.033	0.156
C18:2 (n-6), %	2.35	2.87	2.95	2.68	0.001	0.309	0.665	0.160
C18:2 cis-9, trans-11, % (CLA)	0.27	0.27	0.31	0.24	0.01	0.895	0.356	0.233
C18:3 Alpha (n-3), % (ALA)	0.47	0.48	0.55	0.40	0.01	0.886	0.057	0.019
C18:3 Gamma (n-6), %	0.006	0.004	0.008	0.002	0.001	0.945	0.478	0.686
C20:0, %	0.17	0.26	0.12	0.11	0.02	0.560	0.155	0.288
C20:1, %	0.14	0.14	0.13	0.14	0.002	0.639	0.595	0.691
C20:2 (n-6), %	0.02	0.03	0.04	0.03	0.001	0.065	0.810	0.219
C20:3 (n-6), %	0.26	0.29	0.32	0.27	0.01	0.405	0.871	0.260
C20:4 (n-6), %	0.68	0.87	0.85	0.84	0.02	0.413	0.439	0.369
C20:5 (n-3), %	0.17	0.12	0.22	0.09	0.004	0.576	0.001	0.145
C22:5 (n-3), %	0.36	0.36	0.45	0.27	0.01	0.920	0.040	0.042
C22:6 (n-3), %	0.04	0.03	0.05	0.03	0.001	0.113	0.016	0.794
Unidentified, %	3.80	3.04	3.86	2.69	0.06	0.651	0.045	0.640
Saturated, %	45.36	47.27	46.22	47.38	0.13	0.400	0.930	0.626

Table 5 (continued)

Odd-Chain, %	0.93	0.95	0.95	1.05	0.01	0.594	0.126	0.362
MUFA, %	41.65	40.15	38.87	40.91	0.14	0.089	0.751	0.028
PUFA, %	4.63	5.32	5.74	4.86	0.09	0.376	0.863	0.122
Omega-6 PUFA, %	3.31	4.06	4.16	3.83	0.07	0.327	0.635	0.201
Omega-3 PUFA, %	1.05	0.98	1.28	0.79	0.02	0.762	0.011	0.037
n-6:n-3 ratio	3.20	4.20	3.09	4.76	0.03	0.111	< 0.0001	0.076

TRT 1 indicates cattle receiving fiber-based supplementation; TRT 2 indicates cattle receiving starch-based supplementation.

MUFA: Σ (C14:1, C16:1 c9, C18:1 t9, C18:1 t10, C18:1 t11, C18:1 c9, C18:1 c11, C20:1).

PUFA: Σ (C18:2, C18:2 c9t11, C18:3, C20:2, C20:3, C20:4, C20:5, C22:5, and C22:6).

Omega-6 PUFA: Σ (C18:2, C18:3 Gamma, C20:2, C20:3, and C20:4).

Omega-3 PUFA: Σ (C18:3 Alpha, C20:5, C22:5, and C22:6).
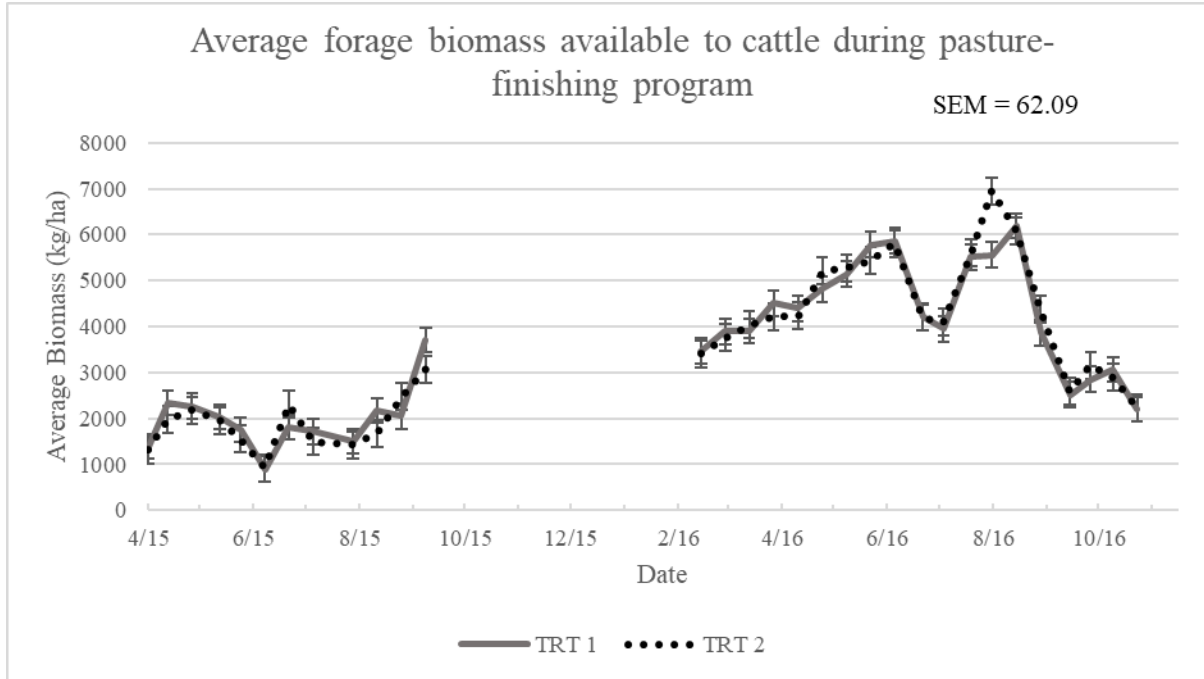
Figure 1. Treatment differences in average available forage biomass in pastures grazed by cattle during a pasture-finishing program in 2015 (Year 1) and 2016 (Year 2) supplemented with 1% BW of concentrate with or without added starch.
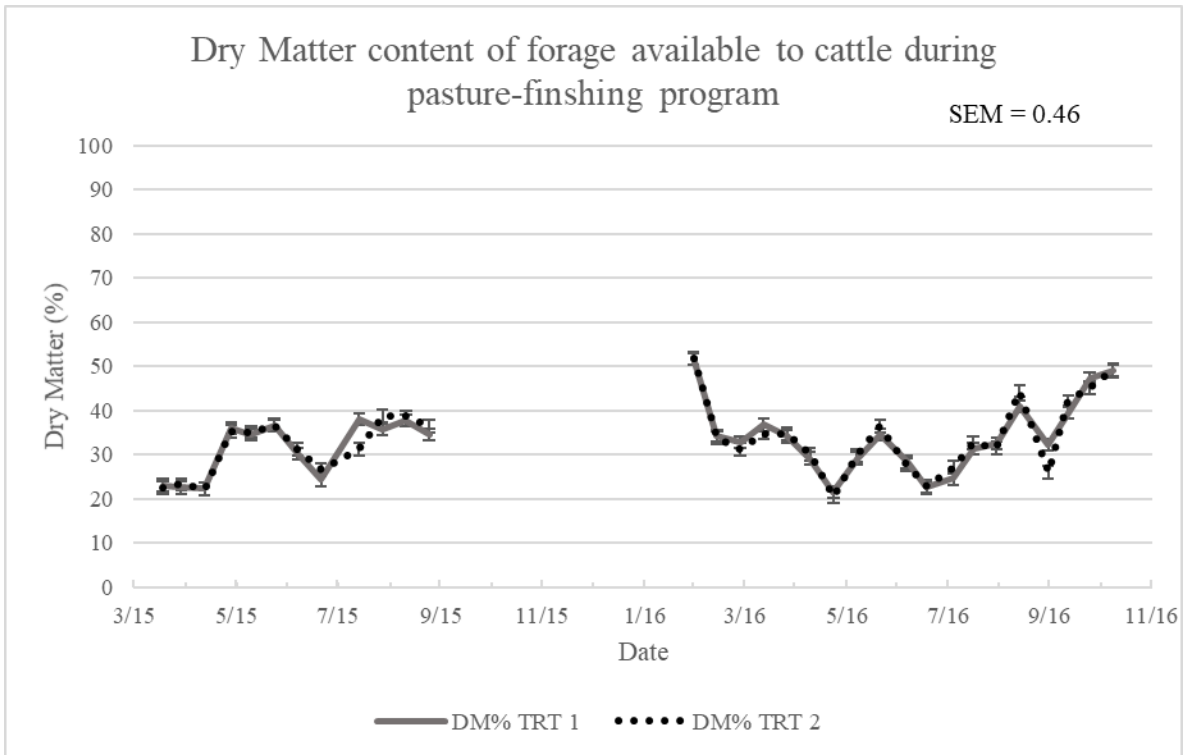
Figure 2. Treatment differences in dry matter content of forages available to cattle grazing during 2015 (Year 1) and 2016 (Year 2) of a pasture-based finishing program supplemented with 1% BW of concentrate with or without added starch.
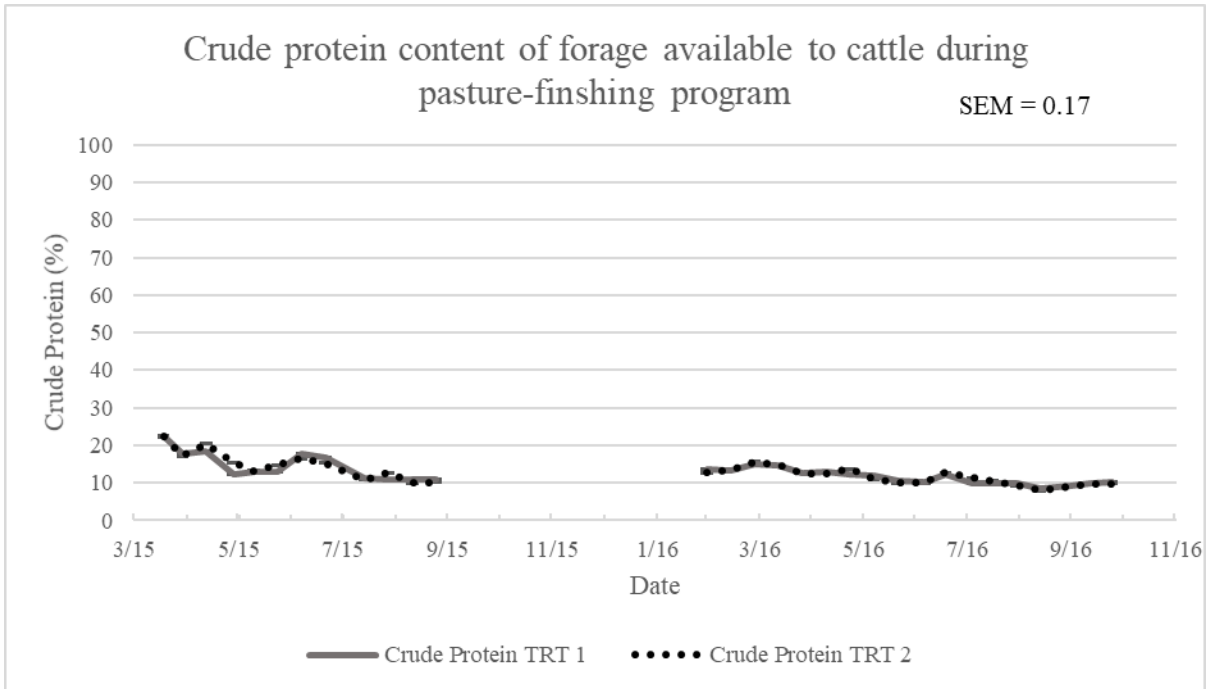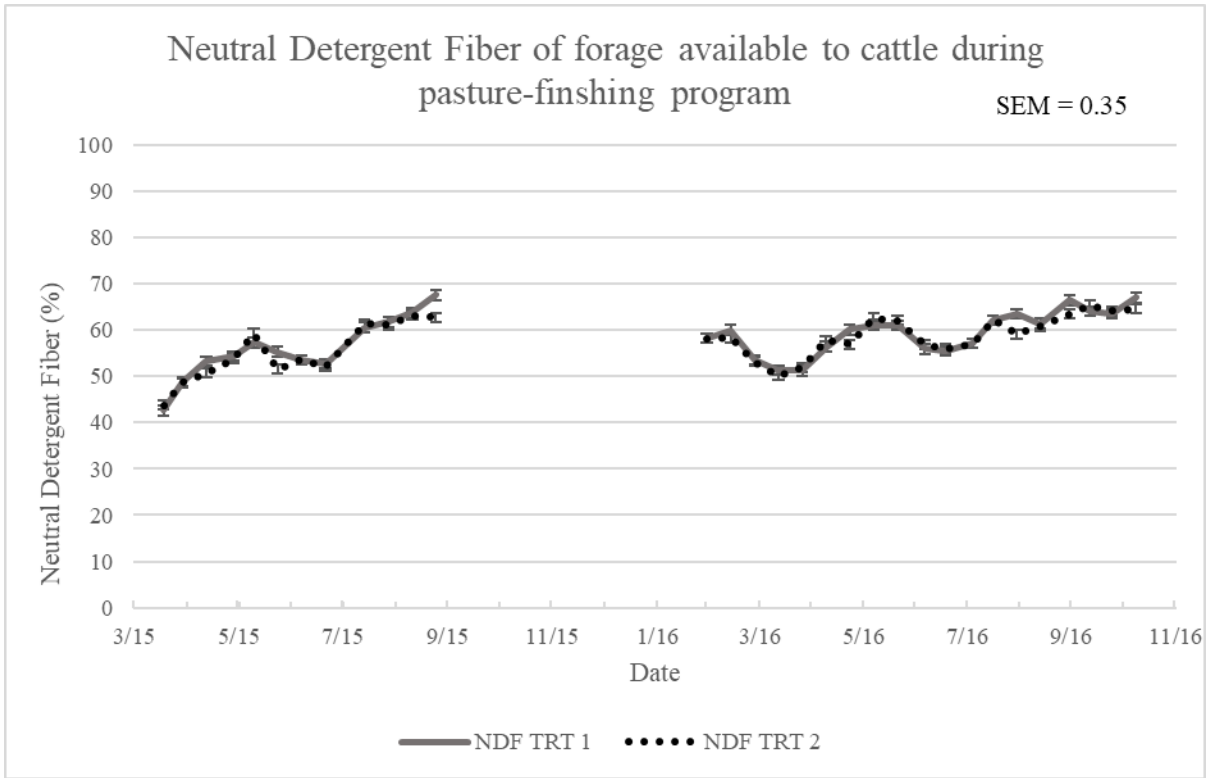
Figure 3. Treatment differences in crude protein content of forages available to cattle grazing during 2015 (Year 1) and 2016 (Year 2) of a pasture-based finishing program supplemented with 1% BW of concentrate with or without added starch.
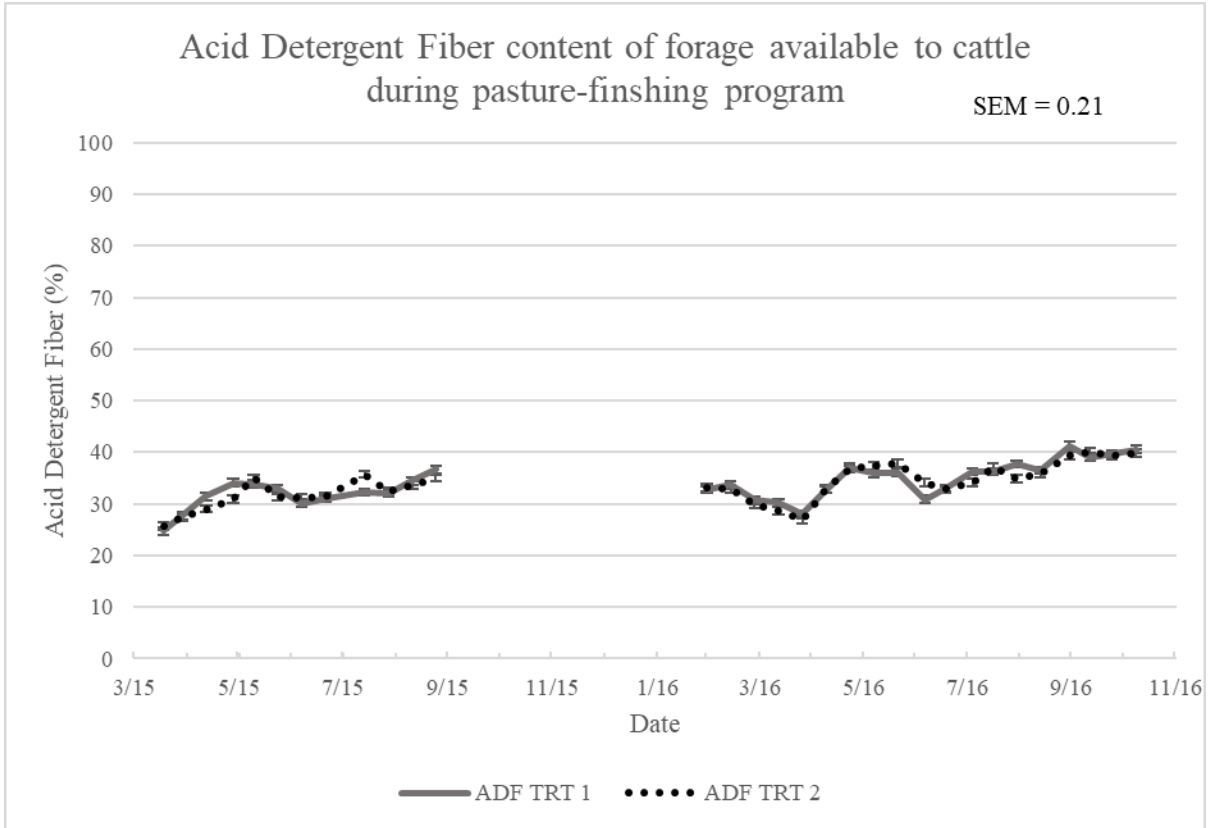
Figure 4. Treatment differences in neutral detergent fiber content of forages available to cattle grazing during 2015 (Year 1) and 2016 (Year 2) of a pasture-based finishing program supplemented with 1% BW of concentrate with or without added starch.

Figure 5. Treatment differences in acid detergent fiber content of forages available to cattle grazing during 2015 (Year 1) and 2016 (Year 2) of a pasture-based finishing program supplemented with 1% BW of concentrate with or without added starch.
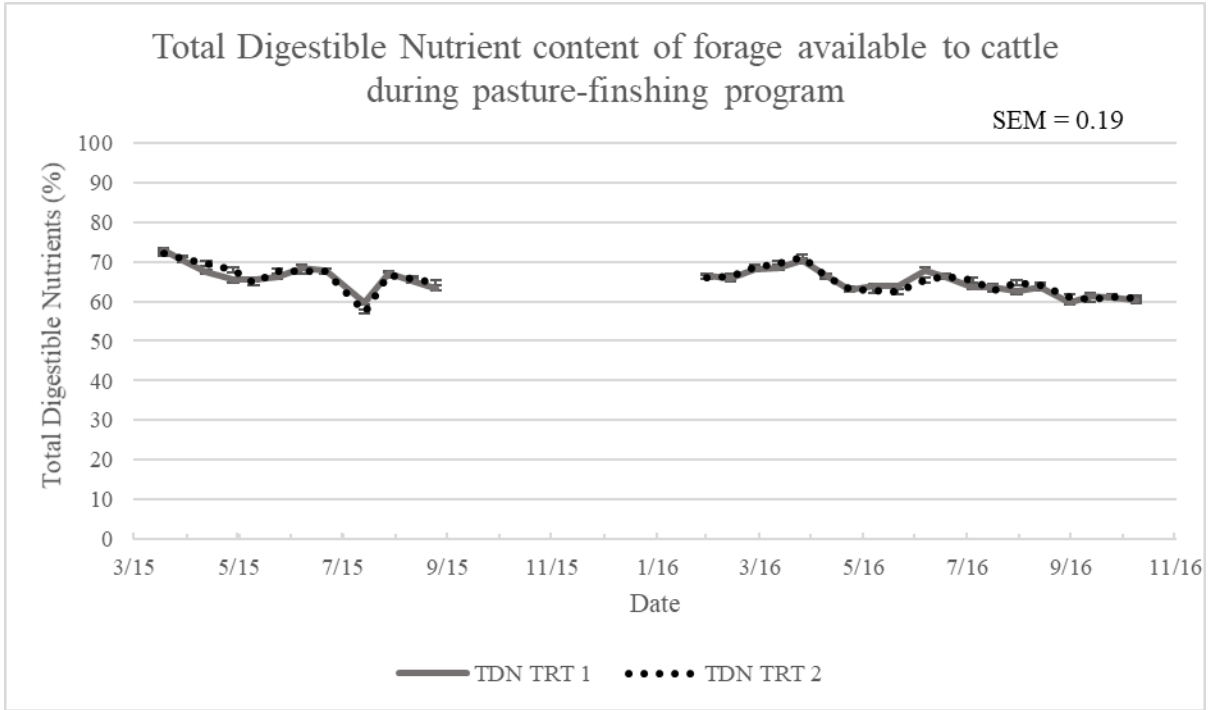
Figure 6. Treatment differences in total digestible nutrient content of forages available to cattle grazing during 2015 (Year 1) and 2016 (Year 2) of a pasture-based finishing program supplemented with 1% BW of concentrate with or without added starch.
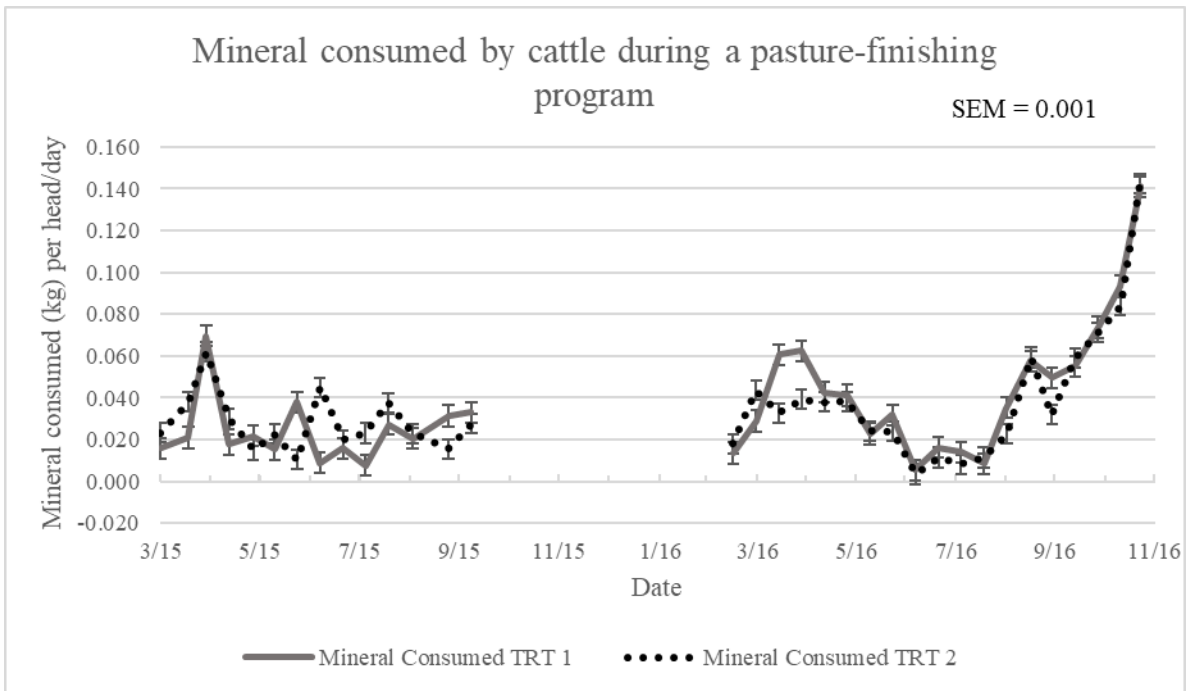
Figure 7. Treatment differences in average high-magnesium mineral consumed by cattle during 2015 (Year 1) and 2016 (Year 2) on a per head/day basis during a pasture-based finishing program where cattle were supplemented with 1% BW of concentrate with or without added starch.