TENDERNESS, SENSORY, AND FATTY ACID ATTRIBUTES OF PASTURE VERSUS GRAIN FINISHED BEEF AGED 14 AND 28 DAYS

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TENDERNESS, SENSORY, AND FATTY ACID

ATTRIBUTES OF PASTURE VERSUS GRAIN

FINISHED BEEF AGED 14 AND 28 DAYS

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Abstract: The objective of this study was to evaluate the effects of two finishing systems, grain and pasture, and postmortem aging on the sensory, tenderness, display color, and fatty acid profiles of beef from their carcasses. All cattle (n = 473) were on a forage diet during the stocker period. They were randomly assigned to either a grain based or pasture-based finishing diet. Conventionally finished cattle were fed for 94 d, and pasture cattle were fed for either 88 or 130 d. Average age of cattle at slaughter was 18.2 mo for concentrate finished and 18.9 mo for alfalfa finished. Strip loins (n = 445) were cut into 2.54 cm thick steaks and vacuum packaged. Display color was evaluated from a sub-set of steaks during 1 year of the study (n = 60). The data were analyzed using the Mixed and Glimmax Procedures of SAS. No interaction for treatment x year was indicated, so data were analyzed by finishing system and aging time (if applicable). Carcasses from cattle finished on a grain diet were fatter ($P < 0.05$) than those finished on pasture. Also, no differences, ($P > 0.05$), was found for Warner-Bratzler shear force (WBS) or sensory tenderness. There was an interaction between finishing type and days aged ($P < 0.05$) for both initial and sustained juiciness. Panelists rated 14 d grain finished as the strongest ($P < 0.05$) for beefy/brothy flavor. Additionally, 28 d pasture and grain finished steaks were rated the strongest for grassy flavor ($P < 0.05$). There was a display day x packaging x finishing diet interaction ($P < 0.05$) for muscle color, surface discoloration, and muscle darkening. There was a significant difference showing grain finished beef had more fat ($P < 0.05$), but no difference ($P > 0.05$) for protein, moisture, and collagen. The fatty acid chemical analysis found a difference ($P < 0.05$) for PUFA n-3, CLA, and n-6:n-3. There was a numerical difference, but no statistical difference ($P > 0.05$) for MUFA with grain finished being higher. Finally, SFA, PUFA n-6, VA, and OT had no differences ($P > 0.05$) between finishing system.

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CHAPTER I

INTRODUCTION

"There is a growing public interest globally in when, where, how and by whom animals that ultimately yield or generate meat are raised and sustained during their productive lives," Dr. Gary Smith (2015). For centuries, consumers purchasing decision for food and beef based on the price, taste, convenience, and nutritional value. Although, all of these are still factors among purchasing decisions, today consumers are also concerned with the environment in which the animal was raised, the sustainability of the practice of raising the animal and the overall welfare of the animal. Furthermore, Sitienei et al. (2015) concludes that the key driver for the growing interest in grass finished beef in the U.S. has to do with the increasing number of health-conscious consumers, as well as the general public's interest in the environmental impact of agriculture. With the peak in interest from consumers, grass fed beef has become extremely popular, although the percentage of the industry is still small. In 2014, the U.S. beef industry consisted of 0.07% grass fed beef, while grain fed made up 93.72%, the remaining percentages were made up of programs such as natural, never ever, and organic (Smith, 2015).

The grain fed sector of the beef industry in the U.S. commonly consists of a backgrounding or stocker stage where cattle are fed forage, and then sent to the feedlot where they are given a higher energy, grain based diet. These cattle are typically in a feedlot on a grain-based diet for 160 to 180 d (Williamson et al., 2018). Grain fed beef typically has more marbling, a brighter cherry-red colored lean, and a whiter fat color compared to grass finished beef (Mandell et al., 1998). Additionally, research has shown that the increase in energy from the concentrate diet correlates to improved carcass quality and increased tenderness (Larick et al., 1987). All these factors have led to an appearance and taste consumers, especially in the U.S., are accustomed. Many U.S. consumers prefer the taste of grain fed beef (Daley et al., 2010).

The grass finished sector of the industry in the U.S. typically consists of cattle only eating forages throughout their life. These cattle typically produce carcasses with more yellow fat color, a darker colored lean, and less marbling (Mandell et al., 1998) compared to carcasses from grain finished beef. Even with these differences in appearance, a study by Umberger et al. (2009b) found that some consumers consider the nutritional value, food safety and eating quality to be greater in grass fed beef, and these consumers were 12.1% more likely to purchase grass fed beef. The demand for these niche market products such as, local, natural, organic and grass fed, has increased greatly by consumers who are concerned about their food (Bjorklund et al., 2013).

Finally, in recent years a great deal of emphasis has been placed on the variation that exists between the feeding types regarding their fatty acid profiles. Daley et al. (2010) explains that research spanning three decades suggests a diet consisting of grass only can significantly improve the fatty acid composition and antioxidant content of the beef. Additionally, grass finished beef presented a more desirable saturated fatty acid (SFA) lipid profile, higher conjugated linolenic acid (CLA) and a better n-6:n-3 ratio, which is important to nutritionists (Daley et al., 2010). Excessive amounts of n-6 polyunsaturated fatty acids (PUFA) and a very high n-6:n-3 ratio promote pathogenesis of many diseases including cardiovascular disease, cancer, and inflammatory and autoimmune diseases; while n-3 fatty acid suppresses these (Simopoulos, 2002) However, other studies have found grass finished beef to have significantly lower levels of monounsaturated fatty acids (MUFA) and greater SFA levels (Rule et al., 2002 and Leheska et al., 2008). Given the conflicting findings, it is important to evaluate the differences in the fatty acid profiles of the two finishing types.

Where food is sourced continues to be a hot topic and a driver behind the beef industry. There have been conflicting findings between the benefits finishing cattle in a feedlot or a pasture, and the final product they produce. Therefore, the objective of this study was to evaluate the effects of the two feeding types, pasture and grain finished, and postmortem aging on the sensory, tenderness, display color, and fatty acid profiles.

CHAPTER II

REVIEW OF LITERATURE

Comparison of beef finishing systems

Grain finished beef makes up about 95% of the cattle finished in the U.S. (Williamson et al., 2018; NCBA, 2018). Typically, these cattle spend the backgrounding or stocker stage on a forage diet prior to being sent to a feedlot (Umberger et al., 2002). It is estimated that even cattle finished on grain spend about two-thirds of their lives consuming grass in a pasture setting (Williamson et al., 2018). Once in the feedlot, the cattle typically spend 160 to 180 d on a high concentrate diet typically consisting of grains, especially corn (Williamson et al., 2018). Normally, cattle finished on a grain based diet gain body weight faster and therefore require fewer days to reach an optimum finishing point (Cruz et al., 2013). Cattle finished in a feedyard on a concentrate diet reach market weight approximately 6 to 12 mo. earlier than cattle finished on grass (NCBA, 2018). In the feedlot setting on a concentrate diet, cattle typically gain 1.3 kg per day (Lawrence and Ellis, 2008). Cattle finished on grass spend their entire life eating only forages. Typically, it takes more days for cattle finished on grass to reach their optimum finishing point or slaughter weight (Berthiaume et al., 2006; Martine and Rogers, 2004). The ability for cattle to efficiently gain weight in the feedlot has helped them reach a desired finish point and slaughter faster than grass finished beef (Cruz et al., 2013; Berthiaume et al., 2006; Bennett et al., 1995). Furthermore, cattle finished on grass require more resources, such as land, water, and forages to reach their desired finishing point (NCBA, 2018).

Carcass characteristics between the cattle in the two finishing systems have been found to have variation. Cattle fed a concentrate or grain based diet have both final live and carcass weights that are heavier than grass fed cattle (Mandell et al., 1998; Berthiaume et al., 2006). Carcasses from grain fed cattle also have larger ribeye areas and greater fat depths (Realini et al., 2004). Additionally, it has been found cattle finished on grass have a less kidney/pelvic/heart fat (KPH) and lower numerical yield grades (Garmyn et al., 2010). However, some results have found no differences in carcass weight, ribeye size, KPH percentage or final yield grade (Maughan et al., 2012; Miller et al., 1996).

Also, there are distinct differences in carcass quality between the two finishing types. The type of finishing diet impacts the final quality grade with steers finished on grass typically having lower USDA quality grades (Cruz et al., 2013). Cruz et al. (2013) also found steers finished on grass to grade high-Select and those finished on grain to grade low-Choice more frequently. A similar trend was found by Crouse et al. (1984) where heifers finished on grass had a lower marbling score than those finished on grain. Furthermore, cattle finished on grass typically have yellow fat and soft-coarse-dark lean (Crouse et al. 1984; Mandell et al. 1988; Martin and Rogers, 2004), which reduces consumer appeal at retail. Duckett et al. (2007) believed that the darker color of pasture-fed meat versus concentrate may be attributed to lower muscle glycogen levels.

Retail display between the two systems has resulted in conflicting findings. Insani et al. (2008) reported that a* (-a = green to +a = red) values were higher in steaks from pasture fed cattle than concentrate after 7 days of display. Insani et al. (2008) suggested that the higher levels of antioxidants in pasture finished beef could have caused the greater color stability. However, Duckett et al. (2007) found longissimus muscle was less red for pasture-raised meat than for concentrate-fed.

A great deal of variation exists between the palatability of the two finishing systems. Some of this variation could exist because of the positive correlation between fat content, increased marbling and palatability. In a large study conducted by Smith et al. (1984), they found carcasses with a higher degree of marbling had lower shear force values and higher sensory ratings, especially having a more desirable flavor. This indicates that flavor is influenced by marbling, and many studies have found that the marbling score is higher in cattle finished on grain compared to grass (Crouse et al., 1984; Cruz et al., 2013).

Flavor has been researched extensively; an entire lexicon has been developed to compare the flavor profiles between rib steaks (*Longissiums dorsi* muscle) of grass and grain fed cattle (Maughan et al., 2012). The lexicon found grass fed cattle to have higher intensity for barny, bitter, gamey, and grassy flavors, as well as less intensity for juicy and umami. The lexicon identifies hexanal as the chemical compound that makes up what panelists and consumers term grassy flavor (Maughan et al., 2012). This is supported by the findings of Adhikari et al. (2011), which identifies hexanal as the strong aroma associated with the green attribute in beef flavor. Furthermore, hexanal is noted to be the component that gives the freshly mown grass aroma (HMBD, 2018). Ultimately, the variation that exists in flavor can be attributed to the differences in chemical composition of the meat from the fat content to the fatty acid profile (Maughan et al., 2012).

Tenderness differences between the finishing systems has been variable. Crouse et al. (1984) found no differences in sensory traits, and found tenderness to be very similar between the two feeding systems. Cruz et al. (2013) found similar results where shear force, cooking loss, juiciness, flavor, and overall palatability were not different between the finishing rations. Others have found cattle finished on grain to have a higher degree of marbling, lower Warner-Bratzler shear force (WBS) values and increased palatability and flavor (Miller et al., 1996; Berry et al., 1988; Garmyn et al., 2010), as well as increased sensory tenderness values for both initial and overall tenderness in grain fed beef (Berry et al., 1988; Garmyn et al., 2010). A study by Sitz et al. (2005) utilized grain fed beef from the U.S. aged for 8 to 11 d, barley fed beef from Canada aged 24 d, and grass-fed beef from Australia aged 67 to 73 d. Samples were matched by WBS values, this allowed consumers to place focus on the flavor of the beef (Sitz et al., 2005). Marbling scores did differ between feeding regimes; steaks from grain fed cattle had increased marbling (Sitz et al., 2005). This, along with the different aging times, could correlate to the sensory differences that were noted for flavor, juiciness, tenderness, and overall acceptability (Sitz et al., 2005). Surprisingly, consumers still rated Australian beef to be the toughest and concentrate fed beef to be the most tender, even though WBS values did not differ (Sitz et al., 2005).

Relationship between Warner-Bratzler shear force and sensory ratings for predicting tenderness

Warner-Brazler shear force (WBS) is one of the most commonly referred to and widely utilized tools for objectively evaluating tenderness, and it was the basis of many other tenderness mechanisms that have been designed (NCBA, 2008).The idea of shearing a sample of cooked meat as an indicator of tenderness was established in the late 1920s by K. F. Warner and his colleagues (Warner, 1952). L. J. Bratzler later developed the specifics of blade shape, thickness, dullness of cutting edge, shearing speed, etc., (Bratzler, 1932). Since then, a number of studies have been conducted to evaluate the effects of various parameters and to standardize WBS (Wheeler et al., 1997).

Tenderness has been found to result in 50% of the variation in overall palatability and consumer satisfaction, therefore, many different studies have been conducted to correlate sensory panel ratings and WBS values. It has been found that the strongest relationship exists between peak load of WBS and trained sensory panelists (Shackelford et al., 1995). These ratings are similar to those found by Sullivan and Calkins (2007) where all steaks with a sensory score of 6 to 8 also had a WBS score of less than 4.49 kg. This study identified anything between 3.89 kg and 4.59 kg to be rated intermediate for tenderness. Miller et al. (1995) found similar results for steaks cooked in consumer's homes, where it was identified that steaks with WBS of 4.6 kg or greater were rated as tough. It was further concluded that the acceptable shear force value was anything less than or equal to 4.3 kg (Miller et al., 1995). Furthermore, a relationship has been found between WBS and consumer satisfaction showing that a value of < 3.0 kg = 100% satisfaction, 3.4 kg = 99 %, 4.0 kg = 94 %, 4.3 kg = 86%, and 4.9 kg = 25% (Miller et al., 2001).

The relationship between WBS values and sensory panel rating is very strong, which is helpful in working to improve overall tenderness and palatability ratings. There is also a strong correlation between tenderness and other palatability traits such as connective tissue and juiciness. This is all important in having multiple measurements to identify and quantify products that will ultimately be desirable to consumers.

Postmortem aging impact on palatability

For decades, postmortem aging has been studied and utilized to increase tenderness, by changing the myofibrillar protein ultra-structure (Tatum et al., 1999; Xiong et al., 1996). Nishimura et al. (1995) suggest that aging improves tenderness due to the degradation of intermuscular connective tissue, which occurs due to the structural weakening of the endomysium and perimysium, which resulted in a lower shear force and greater tenderness. It is important to consider the muscle and quality grade of the product in order to reach optimum tenderness (NCBA, 2006). Aging can be very valuable in increasing consumer satisfaction (Steinburg et al., 2009). Increasing aging time improved both sensory and WBS values for tenderness, as well as increased flavor, juiciness and acceptability (French et al., 2001). Similar results were found by Xiong et al. (1996), where tenderness and juiciness both increased with aging time. However, Xiong et al. (1996) found that off flavor became stronger in grass finished beef after aging. This can have negative impacts on overall palatability of the product. It is important to understand the ideal postmortem aging time to reach ultimate tenderness based on the muscle type and quality grade (NCBA, 2006). Ultimately, postmortem aging has been found to have a positive impact on palatability, especially tenderness.

Post-mortem aging also has an been found to have an impact on final meat flavor. Spainer and Miller (1996), found flavor and textural changes occur during postmortem aging. During aging meat shows a significant alteration in the level of chemical compounds and also an increase in lipid oxidation. Lipid oxidation is a result of the oxidative reaction of oxygen with unsaturated fatty acids generating reactive substances responsible for sensory and nutritional deterioration. Lipid oxidation produces an undesirable odor, color and taste (Kanner and Rosenthal, 1992). Postmortem aging has been found to gradually decline flavors such as beefy, brothy, browned/caramel, and sweet; which are typically noted as desirable (Spanier et al., 1997) while also moderately increasing flavors of bitter and sour; as well as, aromas of painty and card board (Spanier et al., 1997), which are undesirable.

Fatty acid profiles of grass and grain finished beef

Consumer interest in the fat content and nutritional quality in foods has increased the amount of research and focus on fatty acid profiles between grass finished and grain finished animals, including beef (Daley et al., 2010). It is important to have some fat in the diet; it is a source of energy, helps with absorption of vitamins and minerals, and aids in building cell membranes, muscle movement and decreasing inflammation (Harvard Medical School, 2018). Although all fats have similar chemical structure, it is the lengths and shape of the chemical chain and the number of hydrogen atoms connected to the carbon atoms that make them different (Harvard Medical School, 2018). The fats that are identified as good for the diet are monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), while saturated fatty acids (SFA) in excess can be bad for the diet and trans fatty acids are always bad (Harvard Medical School, 2018). Red meat is a common source of SFA in the American diet and therefore, significant research has focused around the variation that exists between red meat from animals finished in different ways (Harvard Medical School, 2018). Fatty acid profiles have been evaluated as they pertain to the cholesterol levels, cardiovascular disease, and overall health of consumers. Health officials world-wide have recommended reducing SFA and cholesterol intake while also increasing omega-3 (n-3) fatty acids and MUFA in order to reduce the risk of heart disease (Groff and Gropper, 1999 and Griel et al., 2006).

Previous research has found variation in the fatty acid profiles of meat from cattle finished on grass and those finished on grain. Some studies have found grass finished beef to have higher n-3 fatty acids and SFA concentration, while having lower MUFA levels and total lipid amounts (Leheska et al., 2008, Ponnampalam et al., 2006, and Nuernberg et al., 2005) compared to grain finished beef; while other studies have found grain finished beef to have higher MUFA levels and lower SFA concentration (Melton et al., 1982, Leheska et al., 2008). Finally, one study found grass-fed beef to have a lower concentration of SFA and a greater level of MUFA (French et al., 2000). Ultimately, there are conflicting findings between the finishing systems of beef and the variation in fatty acid profile of beef from cattle produced in those systems.

Sustainability of cattle finishing

The United States Environmental Protection Agency (2016) defines sustainability as, “everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. To pursue sustainability is to create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations.” While the National Cattlemen’s Beef Association (2019) defines sustainability as producing safe, nutritious beef while balancing environmental stewardship, social responsibility and economic viability. There is variety in the definition of sustainability as it pertains to beef cattle in the U.S. Dr. Sarah Place (2019) states that, “the U.S. beef industry is diverse and wide-ranging. What works as the most sustainable management system in one region can be quite different in another.”

Sustainability has become an increasingly popular topic of discussion for the beef industry and the production systems in the industry. Typically, people associate feedlots as the sector of the industry that is not sustainable. Cattle spend the majority of their lives consuming grass in a pasture setting. However, the system cattle are finished on can have an impact on the carbon footprint they leave (Broocks et al., 2016). The time cattle spend in the finishing phase, the type of feed the consume, and their final body weight can impact their carbon footprint (Broocks et al., 2016). As a result of the increased energy intake from the feed in the feedlot, the cattle grow faster, and ultimately reach their desired finishing point 2 to 6 mo earlier than those finished on grass (Capper, 2012). This along with the cattle consuming less forage and having heavier carcass weights translates to an 18.5 to 67.5% lower carbon footprint compared to grass finished beef (Broocks et al, 2016). However, there are still sustainability advantages that must be discussed when cattle are finished on grass. Grass finished beef utilize forages that are inedible to humans and upcycle it into an edible protein, as a result of this if you consider the carbon sequestration it can lower the carbon footprint of grass finished beef by 42% (Broocks et al., 2016).

In the past few months, sustainability has become a major focus of conversation about the human diet. Some of this focus is a result of the EAT-Lancet Commissions report that was released in January 2019 and focuses on transforming the diet in order to increase sustainability. One of the key messages to achieve this goal is to reduce the consumption of red meats and sugars by 50% by the year 2050 (Willett et al., 2019). Although, this seems like a simple solution to increase sustainability, there is proof that meat, especially beef, is part of a healthy, sustainable diet.

Environmentally, cattle play an important role in sustainability, as they are capable of upcycling, or turning inedible plants, into high energy protein (Andreini, 2019). Ninety percent of the feed used to finish cattle is inedible to humans (NASEM, 2016). Additionally, they consume by-products: distillers grains, wheat middlings, etc., that would otherwise increase the waste of these industries and ultimately increase the products sent to landfills (Andreini, 2019).

Nutritionally, a 85.05 g serving of lean beef provides 10 essential nutrients that can often be difficult to obtain in adequate quantities from plant-based food sources alone (USDA, 2018 and Andreini, 2019). Furthermore, the majority of consumers are already eating beef within the global dietary guidelines (McNeil and Van Elswyk, 2012). Ultimately, eliminating meat from the diet can put consumers' health at risk, as a plant only based diet will result in an increase in calories and a decrease in micronutrients (McNeill and Van Elswyk, 2012). It has been found that animal proteins in the human diet improve growth and development especially in children (CAST, 1999). Ultimately, meat and beef, either grass or grain finished, play an important role in a healthy sustainable diet for consumers.

Consumer preferences and economic impact

Consumers are continually becoming more aware of where their food comes from and the nutritional value associated with it. The demand for grass finished beef has increased due to the belief that it has increased health benefits, because it is leaner and has a higher conjugated linoleic acid and n-3 fatty acid proportion (Fincham et al., 2009). Furthermore, consumers are intrigued by the belief that grass finished cattle are more humanely raised and have a more positive impact on the environment. Even with the continued discussion around the growth of the grass finished sector of the beef industry, there are many challenges with utilizing only this system and having supply to meet consumer demands. Some of the major challenges include shortages of processors that are close to the producers and will harvest grass-finished cattle, a lack of a clear marketing system, pasture management challenges, and the extra time required to get the cattle to anticipated slaughter weights (Sitienei et al., 2015). Also, Sitienei et al. (2015) concluded that based on location, other problems may arise, such as: limitations on availability of land for grazing, increased cost of finishing cattle on grass, increased labor needs, transportation and distribution challenges, strong market competition from grain finished beef, and a lack of steady demand of grass finished beef.

Furthermore, cattle finished in a feedyard have been noted to be more economically sustainable. Given the improvements in nutrition, health, welfare and genetics, today's industry produces the same amount of beef with 33% fewer cattle than in 1977 (NCBA, 2019). Given the increased energy of the feedlot ration, cattle reach their desired finishing point 2 to 6 mo earlier than those finished on grass, which ultimately lowers production costs (Capper, 2012). Finally, grain finished beef cattle provide 19% more human-edible protein than they consume (NCBA, 2018).

Even with this knowledge of the challenges that exist, many studies have been conducted to evaluate consumers' willingness to pay more, for grass finished beef (Feuz et al., 2004 and Umberger et al., 2009). It is critical to understand the beef consumers' preferences. Ultimately, the consumers' decision to purchase will impact the entire industry.

Conclusion

In conclusion, consumers are increasingly aware of the beef they believe is best for multiple reasons. Previous research has found conflicting differences that exist between the grain and pasture finishing system. Ultimately, the consumer is most important and therefore it is important to meet their demand. If they prefer beef finished in a grass system, we need to accurately represent the product being produced from that system. Therefore, this study evaluated the differences between grain and pasture finishing systems ova 4 years.

CHAPTER III

TENDERNESS AND SENSORY CHARACTERISTICS OF PASTURE VERSUS GRAIN FINISHED BEEF AGED 14 AND 28 DAYS

Abstract

The objective of this study was to evaluate the effects of the two feeding types, grain and pasture finished, and postmortem aging on the sensory, tenderness, and display color over multiple years. All cattle (n = 473) were on a forage diet during the stocker period. They were randomly assigned to either a conventional grain based or alfalfa pasture-based finishing diet. Conventionally finished cattle were fed for 94 d, and alfalfa finished cattle were on pasture for either 88 or 130 d. Average age of cattle at slaughter was 18.2 mo for grain finished and 18.9 mo for alfalfa finished. Strip loins (n = 445) were cut into 2.54 cm thick steaks and vacuum packaged. During year 1, display color was evaluated and an additional steak was cut and randomly assigned to a packaging type (n = 60). No interaction was found between year and finishing type for carcass or sensory data, so data were analyzed by finishing type and aging time. Carcasses from cattle finished on a grain diet were fatter ($P < 0.05$) than those finished on a pasture. There were no differences in ($P > 0.05$) marbling score, ribeye area, hot carcass weight, kindey/pelvic/heart fat percentage, and yield grade. Also, no differences ($P > 0.05$) were observed for Warner- Bratzler shear force tenderness values or initial or overall for

sensory analysis. There was an interaction between finishing type and days aged (P < 0.05) for both initial and sustained juiciness. Grain finished steaks, aged 14 d were rated lower than all others for initial and sustained juiciness (P < 0.05). Panelists rated 14 d grain finished as the strongest (P < 0.05) for beefy/brothy flavor. Additionally, 28 d pasture and grain finished steaks were rated stronger for grassy flavor (P < 0.05) than 4 d aged steaks from grain finished cattle, while 28 d grain finished and 14 d pasture finished steaks were similar.

Introduction

Past palatability and sensory research have found conflicting results of tenderness between beef produced from pasture and grain finishing systems. Many studies found steaks from grain-finished cattle to have lower Warner-Bratzler shear (WBS) force values (Berry et al., 1988; Sapp et al., 1999; Garmyn et al., 2010; Bjoeklund et al., 2013); while other studies found no difference in WBS values of steaks from the two finishing types (Realini et al., 2004; Mandell et al., 1998). Many studies have found differences in flavor, juiciness and overall palatability between the two feeding types. A study conducted by Miller et al. (1996) found carcasses from cattle on grain diets to have a greater amount of marbling than cattle finished soley on grass, which is typically correlated with increased palatability and flavor. Studies by Davis et al. (1981), Berry et al. (1988), Umberger et al. (2002), and Sitz et al. (2005) found the overall palatability ratings for the grain finished cattle to be much higher than the pasture finished cattle.

Postmortem aging can also play a major role in the tenderness, flavor and overall palatability of the meat. A study by Sitz et al. (2005) utilized different feeding types and aging periods, the study found that consumers could note the off-flavors and off-odors occur in the myofibrillar proteins. Additionally, studies by Sapp et al. (199) and French et al. (2001) found similar results with an increase in aging time leading to improvements in shear force values as well as increased taste panel ratings for tenderness, texture, flavor, juiciness, and overall acceptability. Many factors pertaining to the overall palatability of the meat for both feeding types have been extensively researched and are continually being researched, all have concluded that differences exist, especially in flavor and overall palatability; while tenderness may be impacted more by aging time than finishing ration. The objectives of the current research were to evaluate the effects of the two feeding types, grain and pasture finished, and postmortem aging on the sensory, tenderness, and display color.

Materials and Methods

Cattle Management and Feed Rations

All procedures involving animals throughout the study were approved by the Institutional Animal Care and Use Committee (GRL-2015-6-19-2). All animals were handled in accordance with the standards set by the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010).

Cattle utilized in this study were finished in El Reno, OK at the USDA research station. During the stocker period cattle were on a complete forage diet. For finishing, cattle were randomly split and assigned to either a conventional grain based or an alfalfa pasture diet. The conventional grain diet (% DM basis) included 82.4% corn, 8.85% alfalfa hay, 3.0% cottonseed meal, 5.0% cane molasses, and 0.75% calcium carbonate.

Pasture finished cattle grazed regrowth alfalfa (after the first cutting), as well as, regrowth of other subsequently hayed or grazed alfalfa areas. Conventional cattle were fed for 94 d, and pasture cattle were on alfalfa pasture for either 88 or 130 d. Over the 4 y trial, cattle were comprised of multiple breed types. The breeds were comprised of Angus dam with an Angus sire, Angus dam with a Red Angus sire, high percentage Angus dam with an Angus sire, F1 dam to Charolais sire, Red Angus dam to Red Angus sire, or old, large framed cows sired by Charolais or Angus bulls. Steers and heifers were utilized in the study, and they were 17 - 20 mo of age at slaughter, and an average age 18.2 mo for concentrate finished and 18.9 mo for alfalfa finished.

Processing and Product Preparation

Each year (4 y), the cattle were shipped to slaughter in two groups. The first group consisted of 88 d alfalfa finished cattle and all conventional finished cattle fed 94 d. The second group consisted of 130 d alfalfa finished cattle. The cattle were slaughtered at a commercial beef processing facility in Amarillo, TX. West Texas A&M University collected carcass data: hot carcass weight (HCW), marbling score, quality grade, adjusted preliminary yield grade (APYG), fat thickness, ribeye area (REA), kidney/pelvic/heart fat (KPH), and yield grade. One strip loin (n = 445) from each carcass available to be fabricated at the facility was collected by West Texas A&M University. Strip loins were held postmortem in Canyon, TX for 7 to 10 d postmortem and then transported on ice to the Robert M. Kerr Food and Agricultural Products Center at Oklahoma State University (FAPC, OSU). Upon arrival to OSU, d 11, strip loins were cut into 6, 2.54 cm thick steaks using a gravity slicer (model SE-12, Bizerba USA, In., Sandston, VA). All steaks were vacuum packaged in 3-mil high barrier Cryovac vacuum bags (Sealed Air-Cryovac, St. Louis, MO) using a Multivac C500 vacuum packager (MultiVac, Wolfertschwenden, Germany). Each face steak was individually vacuum packaged after 14 d postmortem, used to determine the fatty acid profile. The other steaks were randomly assigned to 14 d Warner-Bratzler shear force (WBS), 14 d sensory analysis, 14 d proximate analysis, 28 d WBS, and 28 d sensory analysis; and were vacuum packaged individually. The steaks were aged in their individual vacuum packages at 4ºC for the specified aging time. All steaks were frozen at the end of their aging time at -20ºC. All steaks included only the *Longissimus dorsi* muscle.

In 2017, an additional steak was cut, 7 steaks per strip loin from the first set of cattle, 2.54 cm thick steaks using a gravity slicer (model SE-12, Bizerba USA, In., Sandston, VA). Each face steak was individually vacuum packaged, after 14 d postmortem, and then used to determine the fatty acid profile. The other steaks were randomly assigned to 14 d WBS, 14 d sensory analysis, 14 d proximate analysis, 28 d WBS, and 28 d sensory analysis, or 11 d display; and were vacuum packaged individually.

Instrumental Tenderness (Warner-Bratzler Shear Force)

At the time of analysis, the steaks randomly assigned to 14 d and 28 d Warner-Bratzler Shear Force (WBS) were thawed at 4ºC for approximately 24 h. Steaks were then cooked utilizing an XLT Impingement Oven (model 3240-TX, BOFI Inc., Wichita, KS). They were cooked at 200ºC to an internal temperature of 68ºC and allowed to temper to 71ºC. Steak temperatures were taken as the steaks exited the oven, if the steak had not reached 68ºC, they were returned to the conveyor until they reached the optimum temperature. Steaks were then held at 4ºC for 18 h to cool. Six cores (1.27 cm in diameter) were taken by hand from the center portion of each steak, parallel to the longitudinal orientation of the muscle fibers. Shearing occurred perpendicular to the longitudinal orientation of the muscle fibers. An Instron Universal Testing Machine (Model 5943, Instron Corporation, Norwood, MA) was used with a Warner-Bratzler Meat Shear fixture. The crosshead speed was 200 mm/min and the Bluehill 3 software was utilized. Maximum load (kg) were recorded for each core and mean maximum load was calculated using the 6 WBS cores from each steak.

Trained Sensory Panel

Taste panels were conducted on samples from 3 y (n = 334). Panelists were trained to evaluate tenderness, juiciness, connective tissue amount, and various flavor attributes prior to serving on the panel (AMSA, 2016). Seven panelists participation each session and were asked to evaluate no more than 15 samples per session. Panelists were asked to evaluate initial and sustained juiciness (8 = extremely juicy, 0 = extremely dry), initial and overall tenderness (8 = extremely tender, 0 = extremely tough), connective tissue (0 = abundant connective tissue, 8 = no connective tissue), beefy/ brothy flavor (3 = strong presence, 0 = no presence), and grassy off-flavor (3 = strong presence, 0 = no presence).

Steaks were thawed at 4ºC for approximately 24 h prior to cooking and then cooked in an XLT Impingement Oven (model 3240-TS, BOFI Inc., Wichita, KS) at 200ºC to an internal temperature of 68ºC. Steaks were cut into 1-cm^3 cubes, 2 cubes were placed in each sample cup, assigned a random number and placed in warmer to maintain temperature through sensory evaluation. Samples were evaluated under red lighting and panelists were provided deionized water and unsalted tops saltine crackers to cleanse their palettes between samples.

Packaging and display conditions

Steaks (n = 60) assigned to retail display, 11 d postmortem, were randomly assigned to PVC, HiOx (80% oxygen and 20% carbon dioxide), or CO (0.4% carbon monoxide, 69.5% nitrogen, and 30% carbon dioxide) packaging and placed in a white coffin-style display case. Packaged steaks were stored under continuous fluorescent lighting (Philips fluorescent lamps; 12 watts, 48 inches, color temperature = 3,500°K; Phillips, China) at 4°C ± 1°C for 4 d. Light intensity ranged from 710-1150 lx (Extech Instruments Corporation, Waltham, MA). Temperature was monitored continuously using 6 temperature LogTag readers (LogTag TRIX-8 Temperature Data Recorder; MicroDAQ, Contoocook, NH) to ensure temperature remained between 32 and 45°C.

Both HiOx and CO modified atmosphere packaging were performed using a MAP system utilizing Rock Tenn DuraFresh™ rigid trays, sealed with clear multi-layer barrier film in a Mondini semi-automatic tray-sealing machine and certified gas blends (Stillwater Steal, Stillwater, OK). Steaks packaged in PVC were placed in white Styrofoam trays with absorbent soaker pads and polyvinyl chloride over-wrap using a single roll film wrap machine (Winholt WHSS-1, 115V; Winholt, Woodbury, NY). Each steak was evaluated for color attributes (visual) at 24 h intervals throughout retail display for 0, 1, 2, 3, and 4 d.

Visual color analysis

A trained panel (n = 6) conducted daily visual color evaluations. All panelists passed the Farnsworth Munsell 100-hue test. Panelists scored each steak to assess muscle darkening (MD) using a 7-point scale (1 = no darkening, 7 = very dark) on d 0. They were also asked to evaluate muscle color (MC) using a 7-point scale (1 = extremely bright cherry red, 7 = extremely dark red) and surface discoloration (SD) using a 7-point scale (1 = no discoloration [0%], 7 = extensive discoloration [81-100%]) each d for 4 d.

Statistical Analysis

Least squares means and SE were generated using the MIXED procedure of SAS (SAS 9.4; SAS Inst., Cary, NC). Carcass data, instrumental tenderness, and trained sensory panel analysis were first evaluated by year. There was no year by finishing systems interaction, therefore, main effect of treatment was evaluated across all years. For instrumental tenderness and trained sensory panel analysis, finishing system and aging served as the fixed effect. Panel session was the random effect for trained sensory panel analysis, and carcass was the random effect for instrumental tenderness. Frequency of WBS values and marbling score were evaluated and reported as percentages. For trained sensory panel analysis, there was an interaction between finishing system and postmortem aging. For visual color analysis the fixed effects included day, packaging, finishing system and their interactions. For all analyses, when a significant F-test was identified ($P < 0.05$), least squares means were separated using a pairwise t-test (PDIFF option).

Results and Discussion

Carcass Characteristics

Results for carcass characteristics are presented in Table 3.1. Carcasses from cattle finished on a grain diet were fatter ($P < 0.05$) than those finished on a pasture diet. They had both a higher ($P < 0.05$) fat thickness and APYG. This result agrees with previous findings where grain finished cattle were also noted to be fatter than those finished on grass (Larick et al., 1987). The other carcass characteristics: yield grade, marbling score, REA, KPH fat percentage, and HCW had no variation ($P > 0.05$) between finishing type. Similar results were found by Maughan et al. (2012) and Miller et al. (1995), where they recorded no differences in HCW, REA, KPH percentage or final yield grade between the finishing systems.

The difference that exists between fat thickness, REA, and HCW resulted in a similar overall yield grade. Pasture finished cattle were trimmer. However, grain finished had a numerically larger REAs and only a slightly higher HCW. Ultimately, making the final yield grade between the two finishing types extremely similar and both an average of a yield grade 1. Although, not statically different the cattle finished on grain did have a numerically higher marbling score. Frequency percentages of marbling score are presented in Figure 3.1. The majority of pasture finished cattle had a marbling score of slight (USDA Select), while the majority of grain finished cattle had a marbling score of small (USDA Low Choice). Also, a higher percentage of grain finished cattle had a marbling score of 40 or greater indicating more grain finished cattle graded Choice.

Realini et al. (2004), Larick et al. (1987), and Garmyn et al. (2010) found grain fed cattle to have more marbling.

Cattle in this study were conventionally fed for 94 d, which is far less than what is typical in the U.S. Conventionally finished cattle are typically in the feedlot for 100 to 200 d, or 3 to 6 mo, before slaughter (Umberger et al., 2002). Finishing cattle longer allows for more intramuscular fat to deposit in the meat. If finished similar length to industry, grain finished cattle in this study may have had a higher marbling score.

Instrumental Tenderness

Results for WBS values by treatment and aging are displayed in Table 3.2. There were no differences between treatments ($P > 0.05$). However, all of aging and treatments were extremely tender and well below the 3.5 kg threshold of tender (Miller et al., 2001). Tenderness classes for WBS were established following guidelines by Miller et al. (2001): WBS value of < 3.0 kg = 100% consumer satisfaction, 3.4 kg = 99%, 4.0 kg = 94%, 4.3 kg = 86%, and 4.9 kg = 25%. Because the WBS values were so low in this study, the following classes were used to evaluate percentages of each treatment: < 2.0 kg, 2.0-2.49 kg, 2.5-2.99 kg, 3.0-3.49 kg, > 3.0 kg. Frequency percentages of WBS values are presented in Figure 3.2. The majority of 14 d grain finished steaks were < 2.0 – 2.49, 28 d grain finished were between 2.0-2.99, and 14 and 28 d pasture finished were between < 2.0-2.49. The results are supported by findings from Berry et al. (1988) and Realini et al. (2004) which also found there were no differences in tenderness when comparing pasture versus grain finished beef shear force values. These results vary from those found by Sapp et al. (1999) and French et al. (2001), who both found increased aging times to improve WBS values. Also, others have found cattle finished on grain to have lower WBS values (Miller et al., 1995; Berry et al., 1988; Garmyn et al., 2010).

Trained Sensory Analysis

Results of treatment and aging interaction effect on sensory traits for years 2015, 2016, 2017 are displayed in Table 3.3. There was an interaction between finishing type and days aged ($P < 0.05$) for both initial and sustained juiciness. Grain finished steaks, aged 14 d were rated lower than all others for initial and sustained juiciness ($P < 0.05$). However, numerically the differences are very small and all still rate moderately juicy for initial juiciness and slightly juicy for sustained juciness. Berry et al. (1988) found steaks from concentrate finished cattle to have higher juiciness ratings than steaks from grass finished cattle.

There was no difference ($P > 0.05$) for initial and overall tenderness, similar to the WBS findings. Furthermore, panelists detected no difference for connective tissue amount ($P > 0.05$). Cruz et al. (2013) found similar results, where shear force, cooking loss, juiciness, flavor, and overall palatability were not different between finishing types. Also, Crouse et al. (1984) found no differences in sensory traits and found tenderness to be very similar between the two feeding systems. Finally, there were significant differences in flavor profiles for both beefy/brothy flavor and grassy flavor. Panelists rated 14 d grain finished as the strongest ($P < 0.05$) for beefy/brothy flavor. Additionally, 28 d pasture and grain finished steaks were rated stronger for grassy flavor ($P < 0.05$) than 14 d grain finished steaks. Steaks from 28 d grain finished and 14 d pasture finished cattle were also similar ($P > 0.05$). Steaks from 14 d grain finished carcasses rated the lowest ($P < 0.05$). Variation, especially for grassy flavor, may be impacted most by off-flavor due to aging. Sitz et al. (2005) and Campo et al. (1999) also found that aging influences the occurrence of off-flavors in grass fed beef, especially those with extended postmortem aging.

Some studies suggest the overall palatability rating to be higher for grain fed beef (Berry et al., 1988; Umberger et al., 2002; Sitz et al., 2005). However, Scollan et al. (2006) and Sitz et al. (2005) suggest that flavor acceptability maybe related to individual preference and influenced by cultural norms. In the U.S., consumers have built a preference for grain finished beef flavor while other countries prefer grass fed beef (Scollan et al., 2006 and Sitz et al., 2005). A more recent study by Duckett et al. (2013) suggests that trained sensory panelists found beef from grass finished cattle to lack beef flavor and to have a greater off flavor than the beef from grain finished cattle. Campo et al. (1999) found that aging influences the occurrence of off flavors in grass fed beef. Finally, Xiong et al. (1996) found after 10 d of aging grain fed beef had no detectable flavor difference but grass fed had nearly double the off flavor.

Visual color analysis

A significant packaging x display day x finishing diet interaction ($P < 0.05$) resulted in a visual color difference for both muscle color (Figure 3.3) and surface discoloration (Figure 3.4). Irrespective of finishing system, HiOx had the most color stability and remained the brightest colored throughout display ($P < 0.05$). Additionally, pasture finished, PVC packaged steaks had the least color stability and were the darkest ($P < 0.05$) by d 3. Duckett et al. (2007), found longissimus muscle was less red for pasture-raised meat than for concentrate-fed. There was significant ($P < 0.05$) surface discoloration for HiOx and CO packaging for both finishing systems on d 3; while PVC did not have a difference ($P > 0.05$) until d 4. However, PVC was the most discolored ($P < 0.05$) on d 3 and 4 compared to HiOx and CO for both finishing types.

Figure 3.5 shows a significant packaging x display day x finishing diet interaction ($P < 0.05$) which resulted in muscle darkening variation. Both PVC and HiOX had less ($P < 0.05$) muscle darkening than CO for both finishing systems. Pasture finished steaks packaged with the addition of CO were the darkest ($P < 0.05$). These results align with previous findings where grass fed beef had a darker, purple color of the lean (French et al., 200; Realini et al., 2004).

Conclusion

From the results of this study, we can conclude that finishing diet has an effect on some of the key components for palatability. A difference was noted for juiciness and flavor between the two finishing systems. Like expected the grain finished had a stronger beefy/brothy flavor, while the pasture finished had a stronger grassy flavor. The WBS values suggest that samples from both finishing systems are extremely tender. Consumers preferences can be impacted by a variety of factors. It is important to provide consumers with options and accurate information about the beef they are consuming.

Table 3.1. LS means ± SEM for carcass characteristic comparisons of grain and pasture finished cattle (n = 473)

Item	Grain finished	Pasture finished	*P*-value
Yield grade	1.89 ± 0.23	1.60 ± 0.38	0.23
Marbling score[x]	41.76 ± 4.36	35.96 ± 2.97	0.07
Fat thickness, cm[y]	0.78[a] ± 0.10	0.51[b] ± 0.07	< 0.05
APYG[z]	2.77[a] ± 0.04	2.50[b] ± 0.03	< 0.05
Ribeye area, cm^2	33.22 ± 0.97	32.54 ± 1.70	0.51
KPH fat percentage	1.62 ± 0.28	1.69 ± 0.38	0.77
HCW, kg	295.41 ± 17.00	281.71 ± 6.69	0.18

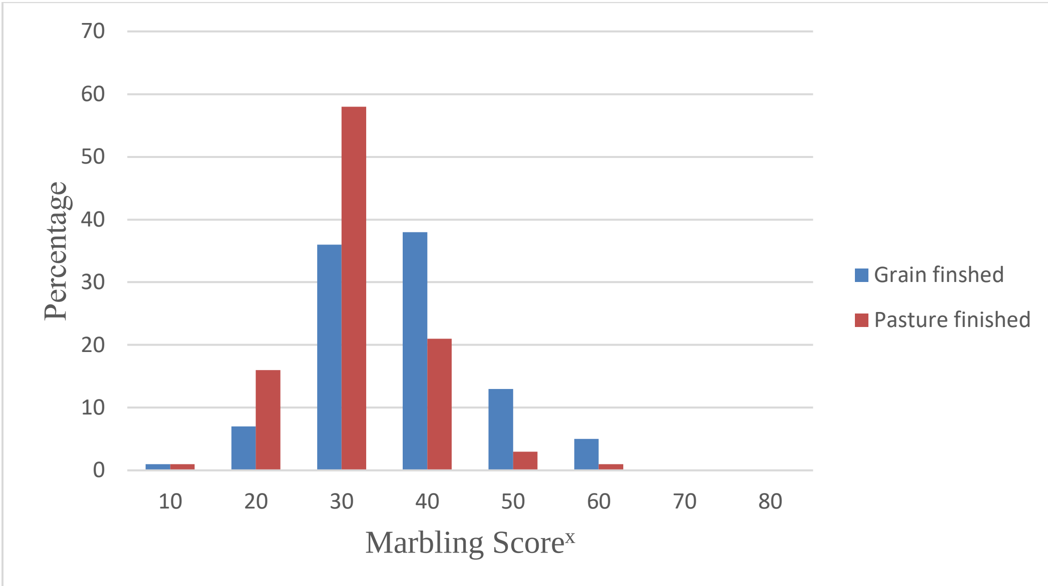
[ab]LS means within a row that do not have common superscript differ ($P < 0.05$)

[x]Marbling Score: 10 = practically devoid; 20 = traces; 30 = slight; 40 = small; 50 = modest; 60 = moderate; 70 = slightly abundant; 80 = moderately abundant

[y]Fat thickness measured at the 12th and 13th rib interface

[z] APYG (Adjusted Preliminary Yield Grade) was measured at the 12th and 13th rib interface and adjusted using fat thickness over the lower rib and entire carcass

Figure 3. 1.. Frequency of marbling score values between finishing systems (n = 445)



[x]Marbling Score: 10 = practically devoid; 20 = traces; 30 = slight; 40 = small; 50 = modest; 60 = moderate; 70 = slightly abundant; 80 = moderately abundant

Table 3.2. LS means ± SEM for Warner-Bratzler shear force comparisons of grain and pasture finished cattle (n = 445)

	Grain finished		Pasture finished	
	14 d	28 d	14 d	28 d
2014	1.95 ± 0.12	2.67 ± 0.09	2.12 ± 0.09	2.62 ± 0.13
2015	2.92 ± 0.08	2.66 ± 0.12	2.70 ± 0.08	2.59 ± 0.09
2016	2.84 ± 0.12	2.61 ± 0.12	2.47 ± 0.08	2.25 ± 0.14
2017	2.45 ± 0.14	2.53 ± 0.14	2.61 ± 0.09	2.71 ± 0.09
Avg	2.48 ± 0.05	2.56 ± 0.04	2.55 ± 0.06	2.61 ± 0.06

Figure 3.2. Frequency of WBS values between finishing systems.

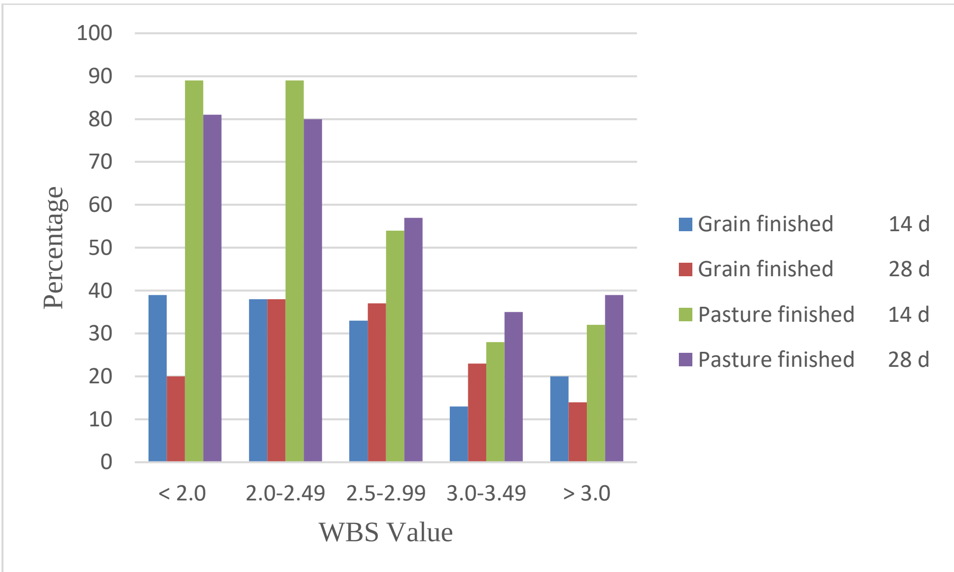


Table 3.3. LS means ± SEM sensory analysis traits stratified by diet and days of age (n = 334)

	Grain finished		Pasture finished	
Item	14 d	28 d	14 d	28 d
Initial juiciness[1]	6.12[b] ± 0.05	6.25[a] ± 0.05	6.28[a] ± 0.04	6.25[a] ± 0.04
Sustained juiciness[1]	5.69[b] ± 0.06	5.81[a] ± 0.05	5.87[a] ± 0.03	5.79[a] ± 0.04
Initial tenderness[2]	6.35 ± 0.06	6.47 ± 0.05	6.41 ± 0.04	6.45 ± 0.04
Overall tenderness[2]	5.98 ± 0.06	6.07 ± 0.05	6.03 ± 0.04	6.04 ± 0.04
Connective tissue[3]	7.66 ± 0.05	7.64 ± 0.05	7.56 ± 0.04	7.61 ± 0.04
Beef flavor[4]	2.21[a] ± 0.04	2.07[b] ± 0.03	2.08[b] ± 0.02	2.07[b] ± 0.05
Grassy flavor[4]	1.34[c] ± 0.04	1.48[ab] ± 0.04	1.41[b] ± 0.02	1.50[a] ± 0.03
Warner-Bratzler shear, kg	2.55 ± 0.06	2.61 ± 0.06	2.48 ± 0.05	2.56 ± 0.04

[abc]LS means within a row that do not have common superscript differ ($P < 0.05$).

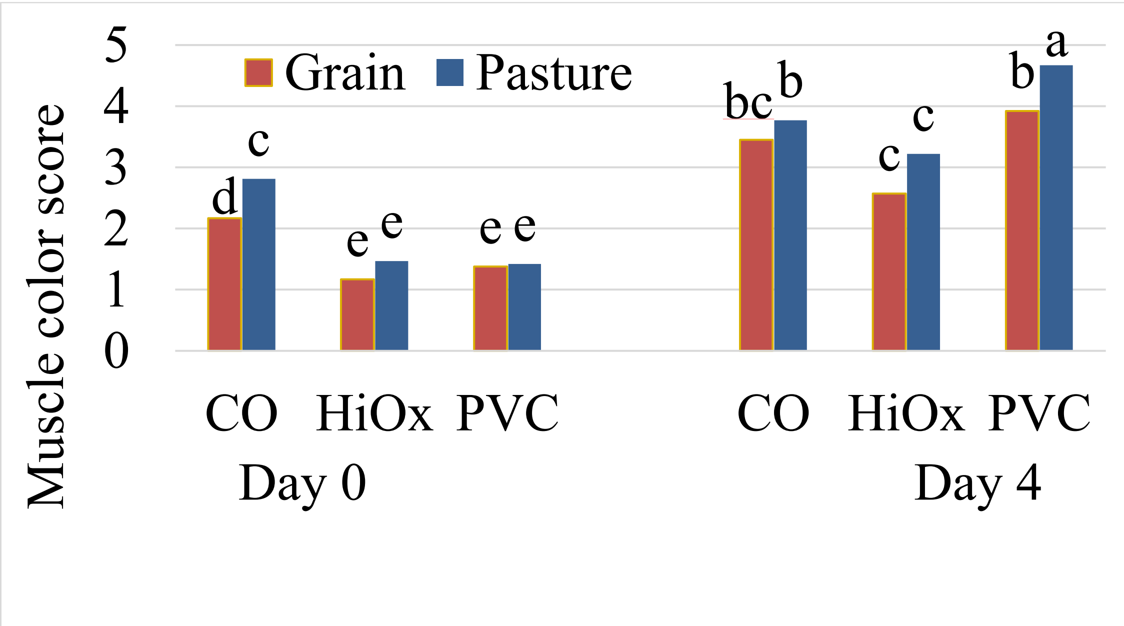
[1]0 = extremely dry; 8 = extremely juicy

[2]0 = extremely tough; 8 = extremely tender

[3]0 = abundant; 8 = none

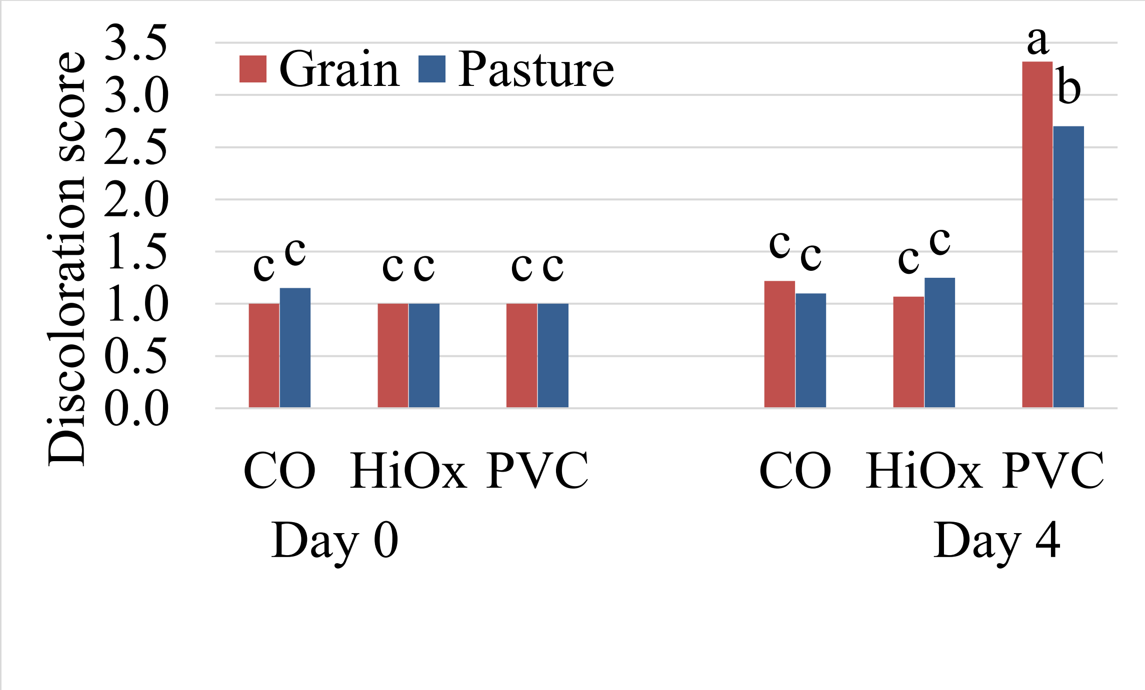
[4]0 = no presence; 3 = strong presence

Figure 3.3. LS means for visual color evaluation for muscle color (packaging x display day x finishing system interaction) of beef steaks displayed 4 d (n = 60)



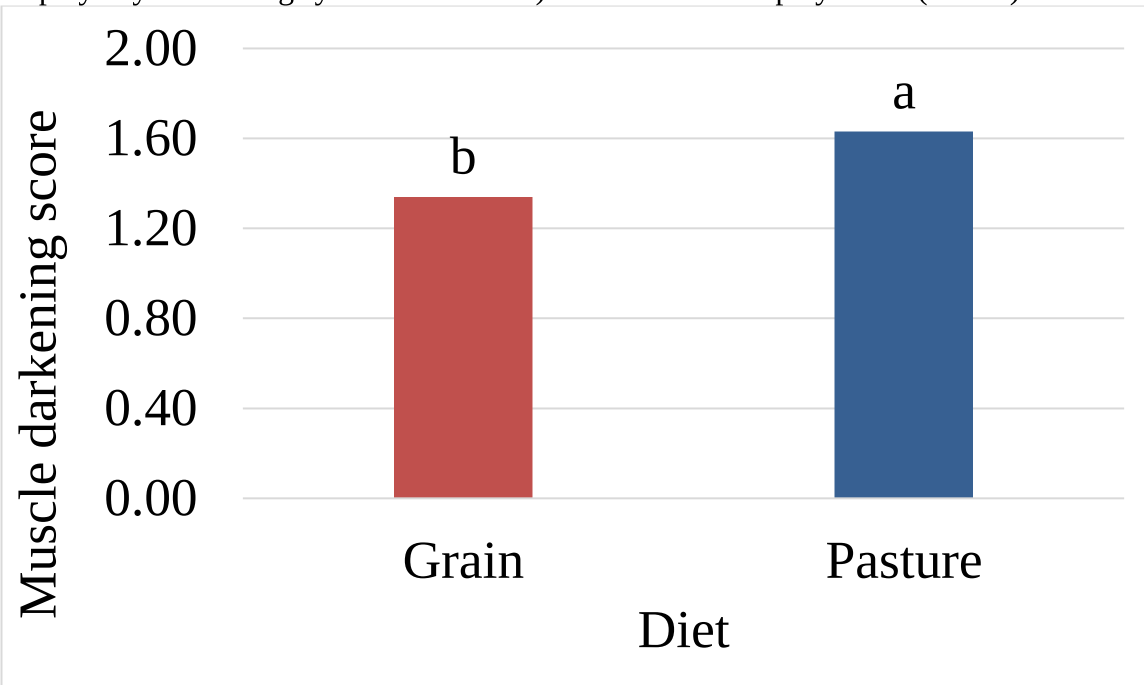
[1]Muscle color: 1 = extremely bright cherry red, 7 = extremely dark red
[a-e] Interaction for (packaging x finished system x display day) means without common superscript differ ($P < 0.05$)

Figure 3.4. LS means for visual color evaluation for surface discoloration (packaging x display day x finishing system interaction) of beef steaks displayed 4 d (n = 60)



[1]Surface discoloration: 1= no discoloration (0%), 7 = extensive discoloration (81-100%)
[a-c] Interaction for (packaging x finished system x display day) means without common superscript differ ($P < 0.05$)

Figure 3.5. LS means for visual color evaluation for muscle darkening (packaging x display day x finishing system interaction) of beef steaks displayed 4 d (n = 60)



1Muscle darkening: 1 = no darkening, 7 = very dark

[a-c] Interaction for (packaging x finished system) means without common superscript differ ($P < 0.05$)

CHAPTER IV

FATTY ACID ATTRIBUTES OF PASTURE VERSUS GRAIN FINISHED CATTLE AGED 14 DAYS

Abstract

The objective of this study was to evaluate the effects of two feeding types, grain and pasture finished, on the fatty acid profiles over 4 y period. All cattle were on a forage diet during the stocker period. They were randomly assigned to either a conventional grain based or alfalfa pasture-based finishing diet. Conventionally finished cattle were fed for 94 d, and alfalfa cattle were on pasture for either 88 or 130 d. Average age of cattle at slaughter was 18.2 mo for concentrate finished and 18.9 mo for alfalfa finished. Strip loins (n = 445) were cut into 2.54 cm thick steaks and vacuum packaged. The face steak was utilized for proximate analysis to determine protein, fat, moisture, and collagen. Composite samples, patties, were made each year for both finishing systems, and then half were cooked, and half remained raw for chemical analysis to determine fatty acid profiles. Steaks from grain finished cattle had a higher ($P < 0.05$) percentage fat than pasture finished, but similar ($P > 0.05$) protein, moisture, and collagen percentage. The fatty acid chemical analysis found raw and cooked patties from grass finished cattle to have a higher percentage ($P > 0.05$) of polyunsaturated omega 3 6:omega 3 ratio. No differences ($P > 0.05$) were found for saturated fatty acids,

polyunsaturated fatty acids, vaccenic acids, or other trans fatty acids between raw or cooked patties from either finishing system.

Introduction

According to Forbes Magazine (2015), the progressive health and wellness consumer is increasingly influential in redefining the food culture. Consumers have shifted from only worrying about their health to lower cholesterol, blood pressure, or weight and now focus on finding quality foods that are fresh, less processed and have a positive impact on their nutrition (Forbes, 2015). These consumers are also concerned with what makes up their food products. The simple idea that meat is healthy for you is not enough, they want to know what is in the meat they are consuming. Dr. Gary Smith (2015) suggested the same idea, "there is a growing public interest globally in when, where, how and by whom animals that ultimately yield or generate meat are raised and sustained during their productive lives."

Red meat is a nutrient dense food that provides essential amino acids such as vitamins A, B_6, B_{12}, E and minerals such as iron, zinc and selenium (Daley et al., 2010). Furthermore, a serving of lean beef provides 10 essential nutrients, including a high percentage of protein, that can often be difficult to obtain in adequate quantities from plant-based food sources alone (USDA, 2018 and Andreini, 2019). However, beef fat is comprised of a high percentage of monounsaturated fatty acids (MUFA) and saturated fatty acids (SFA); (Leheska et al., 2008). Furthermore, a focus has been placed on omega-3 (n-3) fatty acids, as well as conjugated linoleic acid (CLA) and *trans* vaccenic acid (VA) as they are believed to have positive health benefits especially in regard to heart health. Beef is noted to be an excellent source of these components (Groff and Gropper, 1999).

The effect finishing diet of cattle, grass or pasture, has on the fatty acid profile of beef has resulted in conflicting findings. Some studies have found pasture finished beef to have higher levels of n-3 fatty acids and SFA concentration, while having lower MUFA levels and total lipid amounts (Leheska et al., 2008, Ponnampalam et al., 2006, and Nuernberg et al., 2005). Other studies found grain finished beef to have higher MUFA levels and lower SFA concentration (Melton et al., 1982, Leheska et al., 2008). Finally, one study found grass-fed beef to have a lower concentration of SFA and a greater level of MUFA (French et al., 2000). Ultimately, there are conflicting findings between the finishing types and the variation in their fatty acid profile. Therefore, the objective of this study was to determine the nutrient composition that exists, in both raw and cooked patties from pasture and grain finished beef.

Materials and Methods

Cattle Management and Feed Rations

All procedures involving animals throughout the study were approved by the Institutional Animal Care and Use Committee (GRL-2015-6-19-2). All animals were handled in accordance with the standards set by the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010).

Cattle utilized in this study were finished in El Reno, OK at the USDA research station. During the stocker period cattle were on a complete forage diet. For finishing, cattle were randomly split and assigned to either a conventional grain based or an alfalfa pasture diet. The conventional grain diet (% DM basis) included 82.4% corn, 8.85% alfalfa hay, 3.0% cottonseed meal, 5.0% cane molasses, and 0.75% calcium carbonate. Pasture finished cattle grazed regrowth alfalfa (after the first cutting), as well as, regrowth of other subsequently hayed or grazed alfalfa areas. Conventional cattle were fed for 94 d, and pasture cattle were on alfalfa pasture for either 88 or 130 d. Over the 4 y trial, cattle were comprised of multiple breed types. The breeds were comprised of Angus dam with an Angus sire, Angus dam with a Red Angus sire, high percentage Angus dam with an Angus sire, F1 dam to Charolais sire, Red Angus dam to Red Angus sire, or old, large framed cows sired by Charolais or Angus bulls. Steers and heifers were utilized in the study, and they were 17 - 20 mo of age at slaughter, and an average age of 18.2 mo for concentrate finished and 18.9 mo for alfalfa finished.

Processing and Product Preparation

Each year (4 y) the cattle were shipped to slaughter in two groups. The first group consisted of 88 d alfalfa finished cattle and all conventional finished cattle fed 94 d. The second group consisted of 130 d alfalfa finished cattle. The cattle were slaughtered at a commercial beef processing facility in Amarillo, TX. West Texas A&M University collected carcass data: hot carcass weight (HCW), marbling score, quality grade, preliminary yield grade (PYG), fat thickness, ribeye area (REA), kidney/pelvic/heart fat (KPH), and yield grade. One strip loin (n = 445) from each animal was collected by West Texas A&M University. Strip loins were held postmortem in Canyon, TX for 7 to 10 d postmortem and then transported on ice to the Robert M. Kerr Food and Agricultural Products Center at Oklahoma State University (FAPC, OSU). Upon arrival to OSU, 11 d, strip loins were cut into 6, 2.54 cm thick steaks using a gravity slicer (model SE-12, Bizerba USA, In., Sandston, VA). All steaks were vacuum packaged in 3-mil high barrier Cryovac vacuum bags (Sealed Air-Cryovac, St. Louis, MO) using a Multivac C500 vacuum packager (MultiVac, Wolfertschwenden, Germany). Each face steak was individually vacuum packaged, frozen 14 d postmortem, and then used to determine the fatty acid profile, and one other steak was assigned to 14 d proximate analysis; then vacuum packaged individually. The steaks were aged in their individual vacuum packages at 4ºC, for the specified aging time. All steaks were frozen at the end of their aging time at -20ºC. All steaks included only the *Longissimus dorsi* muscle.

Proximate Analysis

Proximate analyses were conducted to determine the chemical percentages of protein, fat, moisture, and collagen of one steak from each strip loin. The steaks utilized were aged 14 d. They were thawed at 4ºC for 24 h. All subcutaneous fat and connective tissue were removed before analysis. Each sample was ground, utilizing a table top grinder (Big Bite Grinder, 4.5 mm, fine grind, LEM). The ground samples were tightly packed in a 140-mm sample cup and analyzed using the NIR. Proximate analyses were conducted using an AOAC approved near infrared spectrophotometer (FoodScan Lab Analyzer, Serial No. 91753206, Foss, NIRsystem Inc., Slangerupgade, Denmark, 2014).

Strip Steak Sample Preparation

Packages of strip steaks were placed in a cooler at 4ºC for 24 h to thaw before sample preparation. After thawing, strip steaks were grouped by finishing type. Lean was separated from subcutaneous fat and connective tissue. Lean was ground using a Biro

Mixer Grinder (Model AFMG-24, Biro Manufacturing Company, Marblehead, Ohio) to make composite samples of both pasture finished and grain finished steaks from each year. This was replicated four times. After grinding samples were made into 0.22 kg patties (adjust-a-burger patty press). Two patties of each finishing type were sealed and frozen, to later be thawed for raw analysis. Two patties from each finishing type were cooked utilizing an XLT Impingement Oven (model 3240-TX, BOFI Inc., Wichita, KS). They were cooked at 200ºC to an internal temperature of 71ºC. If the patty had not reached 71ºC, it was returned to the conveyor until they reach the optimum temperature. After cooling, patties were sealed and then frozen for further chemical analysis.

Ground Beef Samples and Chemical Analysis

Frozen patties were placed in a cooler at 4ºC for 24h to thaw before sample preparation. Thawed ground beef samples were frozen in liquid nitrogen then homogenized in a Blixer food processor (Model 10; Robot Coupe U.S.A., Inc. Jackson, MS) at 1,500 rpm for 10 s and then at 3,500 rpm for 30 s. Once homogenized, samples were utilized for chemical analysis. Fatty acid methyl esters (FAME) were prepared by the O'Fallon et al. (2007) method and were conducted at the Food and Agricultural Products Center Analytical Laboratory at Oklahoma State University. One gram of homogenate was weighed into a screw cap glass vial containing an internal standard solution of tridecanoic acid (0.5 mg/ml in methanol; Nu-chek; T-135; Elysian, MN) and sealed with a polypropylene lined cap. Vials were placed in a water bath for incubation at 55°C. Hexane was used to extract FAME prior to analysis by gas chromatography (GC).

Separation of FAME was carried out using an Agilent gas chromatograph coupled with a mass spectrometer (Agilent 6890 GC, Agilent 5973N MS; Agilent Technologies, Palo Alto, CA) equipped with a HP-88 capillary column (100m X 0.25 mm X 0.20 μm; Agilent Technologies, Palo Alto, CA). The GC was operated based on conditions descried by Tansawat et al. (2013). The injector was held at 250°C fitted with sitlek deactivated split/splitless liner packed with glass wool (Restek, Bellefonte, PA). The column head pressure was 195.6 kPa and a total flow rate of 129.1 mL/min (Column flow: 2.47mL/min and Purge flow: 3.0 mL/min). One microliter of sample was injected with a split ratio of 50:1. The oven method was as follows: 35°C held for 2 min, increased to a temperature of 170°C at the rate of 4°C/min held for 4 min, then increased to a temperature of 240°C at the rate of 3.5°C/min, held for 7 min. Hydrogen was used as the carrier gas. The FID was operated at 250°C. Fatty acids were identified on the similarity of retention times with the GC reference standards. Samples were evaluated for saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acid omega-6 (PUFA n-6), vaccenic acid (VA), and other trans (OT) fatty acids, omega-3 (PUFA n-3), omega-6:3 ratio (PUFA n-6:3), and conjugated linoleic acid (CLA).

Statistical Analysis

For proximate analysis, least square means and SE were generated using the MIXED procedure of SAS (SAS 9.4; SAS Inst., Cary, NC). For proximate analysis, the carcass served as the random effect. Year xfinishing system interaction was evaluated and not significant ($P > 0.05$), therefore main effect of treatment was evaluated across all years. For fatty acid percentages, a generalized linear mixed model using Proc Glimmax procedure of SAS (SAS 9.4; SAS Inst., Cary, NC). One-way analysis of variance was used to determine the effect of diet. For all analyses, when a significant F-test was identified ($P < 0.05$), least square means were separated using a pairwise t-test (PDIFF option).

Results and Discussion

Carcass Characteristics

Results for carcass characteristics are presented in Table 4.1. Carcasses from cattle finished on a grain diet were fatter ($P < 0.05$) than those finished on a pasture diet. They had both a higher ($P < 0.05$) fat thickness and APYG. This result agrees with previous findings where grain finished cattle were also noted to be fatter than those finished on grass (Larick et al., 1987). The other carcass characteristics: yield grade, marbling score, REA, KPH fat percentage, and HCW had no variagion ($P > 0.05$) between finishing type. Similar results were found by Maughan et al. (2012) and Miller et al. (1996), where they recorded no differences in HCW, REA, KPH percentage or final yield grade between the finishing systems.

Although, not statically different the cattle finished on grain did have a numerically higher marbling score. Realini et al. (2004), Larick et al. (1987), and Garmyn et al. (2010) all found grain fed cattle to have more marbling.

Cattle in this study were conventionally fed for 94 d, which is far less than what is typical in the U.S. Conventionally finished cattle are typically in the feedlot for 100 to 200 d, or 3 to 6 mo, before slaughter (Umberger et al., 2002). Finishing cattle longer allows for more intramuscular fat to deposit in the meat. If finished similar length to industry grain finished cattle in this study may have had a higher marbling score.

Proximate Analysis

Results of the treatment effect on proximate composition are displayed in Table 4.2. Protein, moisture and collagen percentages were not different ($P > 0.05$) between treatments. Many other studies also found no differences for protein content between pasture and grain finished cattle (Duckett et al., 2013 and Leheska et al., 2008). However, fat percentages were different ($P < 0.05$) between finishing systems; grain finished beef had more fat than pasture finished. This is similar to the trends in marbling score in Table 4.1. O'Quinn et al. (2012) found as the USDA quality grades decreased, the fat level would also decrease. Furthermore, Van Elswyk and McNeill (2014) found that pasture finished cattle had significantly lower total fat compared to grain finished cattle.

Fatty Acids

The percentages of individual fatty acids (FA) were calculated on total FA concentration and are illustrated in Table 4.3. PUFA n-3 was affected ($P < 0.05$) by finishing type. with both raw and cooked pasture finished having a higher percentage ($P < 0.05$) than raw and cooked grain finished. This is similar to the findings of Van Elswyk and McNeill (2014), where they found n-3 fatty acid percentage to be higher in various lean cuts from grass/forage fed cattle versus U.S. grain finished beef. The importance of n-3 is strongly tied to cardiovascular health and is evidenced to have a positive correlation on prevention of heart disease (Food and Agriculture Organization of the United Nations, 2010). Furthermore, there was a difference in the n-6:n-3 ratio ($P < 0.05$)

with both raw and cooked pasture finished having a lower ratio. The ideal ratio is between these is 2:1 to 4:1 (Cooley, 2018), both finishing systems were within this range. It is important to have a proper ratio and not too high of a percentage of n-6 as they cause inflammation (Cooley, 2018). Additionally, omega-6 fatty acids are the primary PUFA in both U.S. grass/forage-fed and grain-finished beef, providing 60-85% of total PUFA (Van Elswyk and McNeill, 2014). Therefore, it is important that the ratio is between the recommended levels.

There was also a significant difference ($P < 0.05$) between the level of CLA, with both raw and cooked pasture finished being higher ($P < 0.05$) than raw and cooked grain finished. CLA is a metabolic end product of the rumen biohydrogenation of linoleic acid and thus accumulates in the fat and muscle of ruminant animals (Van Elswyk and McNeill, 2014). Many studies have found that grass feeding significantly increases the percent of CLA, up to twice that of grain-finished beef (Daley et al., 2010 and Duckett et al., 2013). CLA has been demonstrated to reduce carcinogenesis, atherosclerosis, onset of diabetes, fat loss, and weight maintenance (Daley et al., 2010).

There were no statistical differences ($P > 0.05$) found for SFA, MUFA, PUFA n-6, VA, and OT fatty acids. Other studies found that breed type influences fatty acid profile (Itoh et al., 1999), and this study had a great variety of breed type in both finishing systems. Also, the similarity in fatty acid profiles between the finishing systems could be due to the similarity in marbling score (Table 4.1). Jiang et al. (2010) found that fatty acid composition can vary depending on fat type and location, i.e. marbling. There was a numerical difference for MUFA with pasture finished having a lower percentage. Van Elswyk and McNeill (2014) noted grass finished cattle had 30-70% less MUFA than grain finished cattle. This is an important difference to note as the association between increased MUFA and increased high-density lipoprotein (HDL) has been strongly supported, and it has been noted to improve markers of glucose tolerance and diabetic control; this has not been seen in consumers eating exclusively grass finished beef (Food and Agriculture Organization of the United Nations, 2010).

Finally, there were no differences ($P > 0.05$) found between the raw and cooked samples. This comparison is important to analyze as the products are consumed cooked, therefore, we wanted to quantify if any differences existed between cooked and raw fatty acid profiles for the same product.

Conclusion

As expected, cattle finished on pasture had less fat than those finished on a grain based diet. Also, there were no differences found between protein, moisture and collagen in the two finishing systems. The fatty acid profiles appear to be comparable with other studies where the main differences were in the PUFA n-3, CLA and n-6:n-3. Many studies, including this one, support that both finishing systems provide a product to consumers that contributes a wide variety of important nutrients. Consuming beef is important for providing protein and other essential nutrients like zinc, iron, and B-complex vitamins.

Table 4.1. LS means ± SEM for carcass characteristic comparisons of grain and pasture finished cattle (n = 473)

Item	Grain finished	Pasture finished	*P*-value
Yield grade	1.89 ± 0.23	1.60 ± 0.38	0.23
Marbling scorex	41.76 ± 4.36	35.96 ± 2.97	0.07
Fat thickness, cm[y]	0.78^{a} ± 0.10	0.51^{b} ± 0.07	< 0.05
APYG[z]	2.77^{a} ± 0.04	2.50^{b} ± 0.03	< 0.05
Ribeye area, cm^2	33.22 ± 0.97	32.54 ± 1.70	0.51
KPH fat percentage	1.62 ± 0.28	1.69 ± 0.38	0.77
HCW, kg	295.41 ± 17.00	281.71 ± 6.69	0.18

[ab]LS means within a row that do not have common superscript differ ($P < 0.05$)
[x]Marbling Score- 10 = practically devoid; 20 = traces; 30 = slight; 40 = small; 50 = modest; 60 = moderate; 70 = slightly abundant; 80 = moderately abundant
[y]Fat thickness measured between the 12^{th} and 13^{th} ribs
[z] APYG (Adjusted Preliminary Yield Grade) was measured between the 12^{th} and 13^{th} rib and adjusted using fat thickness over the lower rib and entire carcass

Table 4.2. LS means ± SEM for proximate composition of grain fed and pasture fed beef (n = 445)

Trait	Grain finished	Pasture finished	*P*-value
Protein, %	22.52 ± 0.06	22.54 ± 0.04	0.78
Fat, %	4.73[a] ± 0.16	3.77[b] ± 0.11	< 0.05
Moisture, %	70.80 ± 0.37	71.41 ± 0.27	0.19
Collagen, %	1.84 ± 0.06	1.78 ± 0.02	0.06

[ab]LS means within a row that do not have common superscript differ ($P < 0.05$).

Table 4.3. Pasture finished and grain finished raw and cooked ground beef patty acid profile as a percentage of total fatty acids (n = 32)

	Raw		Cooked	
Item	Grain	Pasture	Grain	Pasture
SFA[1]	44.48	44.46	43.98	44.13
MUFA[2]	40.79	37.57	39.62	37.54
PUFA n-6	3.13	3.43	3.89	3.76
PUFA n-3	0.99[a]	1.44[b]	1.21[a]	1.69[b]
Total CLA	0.66[a]	0.84[b]	0.60[a]	0.82[b]
VA	1.49	2.35	1.67	2.30
OT	0.38	0.42	0.33	0.36
n-6:n-3	3.43[a]	2.24[b]	3.51[a]	2.26[b]

[ab]LS means within a row that do not have common superscript differ ($P < 0.05$).

[1] Total saturated fatty acid = ∑ 8:0, 10.0, 12.0, 14.0, 15.0, 16.0, 17.0, 18.0, 20.0

[2] Total monounsaturated fatty acid = ∑ 9c 14:1, 14 c 15:1, 9c 16:1, 10c 17:1, 11c 20:1, 13c 22:1, 9c 18:1, 11c 18:1, 12c 18:1, 13c 18:1, 14c 18:1, 15c 18:1

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