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Effects of Beef Finishing Diets and Muscle Type on Meat Quality, Fatty Acids and Volatile Compounds

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EFFECTS OF BEEF FINISHING DIETS AND MUSCLE TYPE ON MEAT QUALITY, FATTY ACIDS AND VOLATILE COMPOUNDS

by

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ABSTRACT

Effects of Beef Finishing Diets and Muscle Type on Meat Quality Measures, Fatty Acids and Volatile Compounds

by

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Utah State University, 2015

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Consumer evaluation, proximate data, Warner-Bratzler shear force (WBSF), fatty acid (FA) composition and volatile compounds were analyzed from the *Longissimus thoracis* (LT), *Tricep brachii* (TB) and *Gluteus medius* (GM) muscles finished on conventional feedlot (FL) and forages, including a perennial legume, birdsfoot trefoil (BFT; *Lotus corniculatus*), and a grass, meadow brome (*Bromus riparius Rehmann*, Grass). Representative retail forage (USDA Certified Organic Grass-fed, COGF) and conventional beef (USDA Top Choice, TC) were investigated (n = 6) for LT. Additionally, the effects of diet on *Gluteus medius* (GM) and *Tricep brachii* (TB) muscles were explored. Forage-finished beef scored lower ($P < 0.05$) in most of the affected sensory attributes except BFT which was similar to grain-finished beef. In forage-finished beef GM was more liked and in FL, TB was similar to GM except juiciness where it scored greater. The fat percent was found to be greatest ($P < 0.05$) in

TC followed by BFT and FL. Nutritionally beneficial ratios of FAs were observed in forage-finished diet. Fatty acid concentrations were majorly affected ($P \leq 0.046$) by diet. Few long-chain PUFAs were affected ($P \leq 0.015$) by muscle type. No FA was a effected ($P > 0.05$) by the interaction of muscle and diet. 3-hydroxy-2-butanone, known to evoke a buttery sensation was affected ($P = 0.011$) by diet with greater ($P < 0.05$) concentration in GM across all diets. Strecker degradation products were affected ($P \leq 0.014$) by muscle type being prominent in GM. Meanwhile, 2-ethyl-3,5-dimethyl-pyrazine was greatest ($P < 0.05$) in BFT. All pyrazine compounds were ($P < 0.05$) greater in GM. These results indicate that when consumer evaluated beef of finishing diets, FL beef was rated highly. Additionally, not all forages produce similar beef. There were similar ratings for BFT for all attributes except flavor having lower values compared with FL. The chemical composition of BFT beef was found to be intermediary and similar to both FL and Grass beef in many cases. Diet was found to interact with muscle for sensory and chemical measures. The GM and TB of FL did not differ ($P < 0.05$), while within forage treatments sensory response and chemical composition varied. These results indicate the meat quality of secondary beef muscles is more greatly impacted by forage diets.

(106 pages)

PUBLIC ABSTRACT

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Consumer evaluation, proximate data, Warner-Bratzler shear force (WBSF), fatty acid (FA) composition and volatile compounds were analyzed from the ribeye steaks (LT) finished on conventional feedlot (FL) and forages, including a perennial legume, birdsfoot trefoil (BFT; *Lotus corniculatus*), and a grass, meadow brome *(Bromus riparius Rehmann*, Grass). Representative retail forage (USDA Certified Organic Grass-fed, COGF) and conventional beef (USDA Top Choice, TC) were investigated (n = 6) for LT. Additionally, the effects of diet on round (GM) and chuck (TB) muscles FL, BFT and Grass were explored. Forage-finished beef was less liked in most of the affected attributes except BFT, which was similar to grain-finished beef. Flavor liking of BFT was similar to Grass. In GM and TB, GM was rated superior among forage-finished beef except juiciness and in FL, TB was similar to GM except juiciness where it scored greater. Grain-feeding produced more perceived tenderness meat in LT. The fat percent was found to be greatest in TC beef followed by BFT and FL being similar. A nutritionally beneficial ratio of fat components was observed in forage-finished diet. The volatile compound that evokes a buttery sensation was affected by diet and had a greater concentration in GM across all the diets. One among the compounds contributing to

roasted flavor was impacted by diet among LT steaks and was greatest in BFT. All the roasted flavor compounds differed between TB and GM and were greater in GM. These results indicate that when consumers evaluated finishing diets of beef, conventional feedlot finished beef was rated most highly. However, these results further reveal that not all forages produce similar "grass-finished" beef. The perennial legume, BFT, was rated similar by consumers for all attributes, with the exception being flavor having lower values compared with FL. The chemical composition of BFT beef was found to be intermediary and similar to both FL and Grass beef in many cases. Diet was found to interact with muscle type for sensory and chemical measures. The GM and TB of FL did not differ, while within forage treatments sensory response and chemical composition were varied. These results indicate the meat quality of secondary beef muscles is more greatly impacted by forage diets. Thus more careful selection of muscles from forage finished beef is required in order to ensure quality.

DEDICATION

I dedicate my degree and work to my parents, Dr. Ranen Chail and Mrs. Ratna Chail, who have always put their children's education before their luxuries in life, compromising and sacrificing at every step to make me what I am today. And to you my beloved sister, Anurupa Chail, for being what you are, someone to whom I looked up to. I thank all three of you for inculcating the importance of education in me, I love you.

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CHAPTER 1

INTRODUCTION AND OBJECTIVES

The quality, flavor and composition of beef changes with cattle diet regimen (Muir et al., 1998). Finishing diet is defined as the diet regimen that is given to cattle pre-slaughter after an initial growth period of being raised on pasture lands (Owens et al., 1995). In this study, the effects of varied finishing diets and muscle type were explored for consumer liking of eating attributes, meat quality measures and composition.

Growing interest by consumers has led researchers and producers to explore non-conventional or non-concentrate finishing diets. One of the primary issues with non-concentrate finishing diets, like forages, is that the carbohydrates in forages are in the form of cellulose which is digested more slowly compared with the starches of concentrate diets (Daley et al., 2010; Nuernberg et al., 2005). This difference in carbohydrate type may reduce intake and result in a longer period to reach slaughter weights (Hall and Hunt, 1982). Previous Utah State University (USU) studies with cattle fed birdsfoot trefoil (BFT; *Lotus corniculatus*), a perennial legume that can be grown in the irrigated pastures western intermountain region of the U.S., demonstrated greater average daily gains (ADG) than reported for cattle fed grass pastures (Pitcher, 2015). While improved growth on perennial legumes is encouraging, the impacts of this forage finishing diet on consumer liking and beef chemical composition have not been extensively explored. Preliminary USU studies revealed consumers found no difference between conventional feedlot-finished beef and BFT-finished beef (unpublished data). Therefore, one of the objectives of this study was to more rigorously determine the

effects of a BFT-finishing diet on consumer liking, proximates, WBSF, fatty acids and volatile compounds relative to conventional and other forage finishing diets. In addition to finishing diet, beef muscle type is known to greatly impact eating experience and beef chemical composition (McKeith et al., 1985). Utilization of the entire beef carcass continues to be high priority of beef processors. Therefore, the second objective of this study was to determine what effect pasture finishing diets may have on muscles of the chuck and sirloin.

Hypothesis

Consumer liking and chemical composition of beef is affected by muscle type (*Longissimus thoracis*; LT, *Gluteus medius;* GM, *Tricep brachii*; TB) and finishing diets (feedlot grain-finished, FL; grass-finished, Grass; BFT-finished, USDA Certified Organic grass-finished, COGF; and USDA Top Choice, TC).

Objectives

- **Study 1**. Comparison of consumer liking and the chemical composition of LT steaks of varied finishing diets (Grass, FL and BFT) and retail production claims (COGF, TC).
- **Study 2**. Comparison of consumer liking and the chemical composition of GM and TB steaks of varied finishing diets (FL, Grass and BFT).

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CHAPTER 2

LITERATURE REVIEW

Introduction

Beef palatability is determined by three major factors: tenderness, juiciness and flavor (Reicks et al., 2011; Garmyn and Miller, 2014). Kerth et al. (1995) defined tenderness and inherent beef flavor to be the most important sensory traits for consumer acceptance. Hence the determination of these attributes of eating quality by consumers is of paramount importance for beef to remain competitive in the market (Hocquette et al., 2014).

Uncooked beef has minimal aroma and a blood-like flavor. Thermally-induced reactions like the Maillard reaction and lipid degradation are responsible for the development of cooked beef flavor (Mottram, 1998). Meat is composed primarily of water, protein and lipids, with low percentages of carbohydrates, vitamins and minerals. When heated, these components are hydrolysed into countless flavor contributing compounds. Different flavor compounds have different thresholds for perception, and together contribute to the final palatability (Brewer, 2006). Tenderness has been measured as one of the quality aspects in meeting consumer expectation and product consistency (Klont et al., 1998). Consumers are willing to pay more for tender meat (Xue et al., 2010; Miller et al., 2001). Various factors may be associated with tenderness of beef, namely decline in pH and temperature (Seideman et al., 1987), post-mortem proteolysis by enzymes like cathepsin (Seideman et al., 1987), the amount and solubility of collagen (Sims and Bailey, 1980; Crouse et al., 1991), cold-shortening of muscle myofibrils (Pearson, 1986; Crouse et al., 1991) and intramuscular fat content (Seideman

et al., 1987). There are various health aspects that relate to the chemical composition of beef, more importantly the fatty acid composition (Daley et al., 2010)

The following literature review is provided to highlight the status of this subject area to this point. First, factors of interest (beef finishing diet and muscle) will be defined and their importance will be described. Subsequent sections will follow which explore the effects of beef finishing diet and muscle on measures of beef quality.

Beef Finishing Diet

Feed source is the most important environmental factor that influences the flavor, tenderness and juiciness of beef (Ford and Park, 1980; Carmack et al., 1995). Cattle finishing diets are considered to be forage-based or conventional (grain-finished; GNF). Forage diets are comprised of grass or legume pastures or hay, and silage. Conventional finishing diets are comprised mainly of corn, barley, wheat, or other grains (Muir et al., 1998a). Over the past two decades, food processing by-products from wet and dry milling feed have also been widely used as a part of feedlot finishing diet (Stock et al., 1999). Forage-finished beef is also known as grass finished (Grass) beef, which refers to meat produced from cattle fed forage from weaning to slaughter without using grains at any point of time (Daley et al., 2010). Grain-finished or feedlot-finished beef are commonly raised on pasture land for the initial 12 to 18 months of life and then fed a formulated ration with 70 to 90 percent grain till they are slaughtered (Owens et al., 1995).

The single largest input cost for cattle is the feed (Hamilton, 2010). Profitability of the producers and packers are closely associated with the kind of feed used (Harrison et al., 1978). The main goal of feedlot finishing is to increase cattle average daily gain (ADG) resulting in maximized turnover and profitability (Muir et al., 1998a). On the

other hand, some consumers choose to, and are happy, to pay more for Grass beef due to potential health benefits like higher concentration of n-3 fatty acids and conjugated linoleic acid (CLA) (French et al., 2000; Leheska et al., 2008). Birdsfoot trefoil (BFT) is a forage that can be grown in the northern intermountain west region of the US, and may be used to graze cattle. Recently, BFT was found to provide ADG in a way that approaches feedlot ADG rates (MacAdam and Brain, 2013). Previous studies have reported the presence of condensed tannin in BFT which has been observed to reduce protein losses in ruminants (Douglas et al., 1999)

Beef muscles

Considering the economic perspective of the beef market, a considerable value may be lost for underutilized cuts of the beef carcass. Therefore, to maximize value of the entire beef carcass lower value cuts should be explored (Seggern et al., 2005). Lower quality cuts make up the majority of beef carcasses which have declining values when compared to rib and loin cuts (Cattle, 1998; Rhee et al., 2004). Muscle profiling has increased the value of wholesale cuts of chuck and round resulting in enhancement of the overall value of the beef carcass (Seggern et al., 2005). There has been a considerable amount of work done concluding the differences and similarities of various beef muscles (Breidenstein et al., 1968; Browning et al., 1990; Crouse et al., 1991; Carmack et al., 1995; McKeith et al., 1985; Seggern et al., 2005). Diet and muscle may greatly affect the stability, palatability and acceptability of beef (Srinivasan et al., 1998). Therefore, it is of importance to explore any interacting quality factors impacted by diet and muscle.

Perceived flavor

Flavor greatly impacts consumer acceptability of beef (Dashdorj et al., 2015). Several factors contribute to cooked meat flavor (Mottram, 1998), including cattle finishing diet (French et al., 2001; Calkins and Hodgen, 2007). Additionally, Muscle type has been found to influence consumer flavor liking (Hunt et al., 2014).

Some of the largest difference of meat flavor has been observed between beef from steers slaughtered directly off a grass diet and those finished on a high-concentrate corn diet (Melton, 1990). Through sensory analysis it has been observed that grain diets are considered to produce a more intense and acceptable flavor compared with grass finished beef (Melton, 1990). A preference for GNF meat has been observed among US consumers over Grass beef (Wood et al., 2003). A reduction in flavor desirability in GNF versus hay-fed cattle was reported by Oltjen et al. (1971). An increase in flavor score for barley finished over pasture-finished cattle was detected in a study by Purchas and Davies (1974).

In an investigation by Oltjen et al. (1971) of various forage diets, cattle fed alfalfa hay were more flavorful and tender than cattle finished on a corn-based diet. Meanwhile, a grassy- and bitter-like taste was characteristic of beef from steers grazed on fescue pasture (Hedrick et al., 1980). Beef produced from barley-finished cattle had slightly less desirable flavor when compared to corn-finished beef (Jeremiah et al., 1998; Busboom et al., 2000).

Jeremiah et al. (1998) and Busboom et al. (2000) further reported that barley fed cattle produced a metallic aftertaste, detected by consumers. Consumers in Chicago and Denver preferred the flavor of U.S corn-fed beef in comparison with Canadian barley-fed beef (Sitz et al., 2005). U.S corn-fed beef was also compared to Argentine grass-fed beef

in a beef marketing study in Chicago and San Francisco (Killinger et al., 2004). In this study, U.S corn-fed beef was rated greater for flavor desirability and overall acceptability in both the cities. The effects of canola meal as a diet for bulls has been investigated and reported to cause an off flavor in the meat, the presence of phenolic choline ester being the probable reason (Melton, 1990).

Often sensory panelists use terms like "grassy," "milky," gamey" or "fishy" to define the less desirable grass-fed beef in contrast to "beef-fat" for grain-fed beef (Melton et al., 1982a; Larick and Turner, 1990). In 1987, Larick et al. (1987) found that the "grass" flavor of beef loin steaks were positively correlated to 14 different volatile compounds from the melted subcutaneous fat of forage-fed cattle. The grass-fed flavors like "gamey" or "grassy" or "fishy" develop from high levels of linolenic acid (Wood et al., 2003). Priolo et al. (2001) stated that the products of oxidation of linolenic acid and its derivatives, substantially derived from pasture, had an important part to play in the off-flavors of beef.

The time period of grain feeding before harvest in GNF has been found to be directly proportional to the desirable flavor of cooked beef fat (Harrison et al., 1978). Based on sensory evaluation, it can be noted that there was a decrease in "grassy" flavor with increase in the time of grain feeding (Larick et al., 1987). In ground beef studies by Melton et al. (1982b), it was observed that flavors described as "milky-oily," "sour" and "fishy" decreased and "beef fat" flavor increased with increase in grain feeding period. Researchers have further determined that the desirable beef fat flavor typical of grain-fed beef increases as the time on feed is increased (Melton et al., 1982b; Yeo, 1982; Bolton,

1987). The “grassy” flavor in steaks and ground beef is decreased in pasture-fed cattle provided grain ad libitum (Mcmillin et al., 1991).

There is a considerable amount of work done on the difference in perceived flavor and off-flavors within different selected muscles (McKeith et al., 1985; Johnson et al., 1990; Carmack et al., 1995; Rhee et al., 2004). According to the results from McKeith et al. (1985) muscles having the greatest flavor desirability scores among the thirteen muscles studied were the *Infraspinatus* and the muscles from loin and rib of similar maturity. *Psoas major* and *Supraspinatus* have been reported to have the greatest and lowest flavor desirability, respectively, by trained taste panelists in a study by Carmack et al. (1995). The beef flavor rating was found to be greatest for *Longissimus dorsi* and least for *Psoas major* in addition to off-flavor lowest for *Longissimus dorsi* and greatest for IS by trained sensory panelists (Rhee et al., 2004).

As reported by Stetzer et al. (2008), *Complexus* was rated the highest with beef flavor intensity score by trained panelists, whereas *Rectus femoris* had the lowest score. Furthermore, *Gluteus medius* had the highest livery off-flavor score and *Longissimus dorsi* the lowest (Stetzer et al., 2008). The iron content in meat has been found to be directly proportional to livery flavor and inversely proportional to beef flavor (Calkins and Cuppett, 2006). The *Psoas major* and *Gluteus medius* have been noted to have higher levels of heme iron and thus have a livery flavor (Yancey et al., 2006).

Tenderness

A certain section of consumers is willing to pay a premium price for guaranteed tender beef (Boleman et al., 1997; Lusk et al., 2001; Shackelford et al., 2001). In addition to flavor, tenderness is shown to increase in concentrate-finished beef compared to Grass

beef where yearlings were allowed to graze on grasses for seven months and finished on grain for 0, 56, 84 and 112 days before slaughter (Larick et al., 1987). Dryden and Maechello. (1970), in their study found a correlation between the lipid content and tenderness of meat.

Fatty acids also have an impact on tenderness. The melting points of different fatty acids are different and thus have an effect on the firmness of the meat which in turn determines the tenderness (Wood et al., 2003). Saturation of fatty acids is directly proportional to melting point and the structure of the fatty acid is also important. Straight chain fatty acids have greater melting points when compared to branched chain fatty acids with the same number of carbon atoms, and cis-isomers have lower melting points when compared to the trans-isomers (Enser, 1984). As mentioned above, diet has an impact on fatty acid composition of meat and can in turn impact the tenderness of meat. Crouse et al. (1984) found that sensory panelists determined the tenderness of grass-fed heifers to be similar to GNF heifers. Moreover the Warner Bratzler shear values were also found to be similar between Grass and GNF beef (Crouse et al., 1984).

The rapid ADG in cattle prior to slaughter which is seen in GNF has been shown to produce more tender meat (Aberle et al., 1981; Fishell et al., 1985). This has been associated with higher concentrations of proteolytic enzymes in rapidly growing cattle during slaughter as a result of increased protein turnover (Muir et al., 1998b). It has also been observed with Grass and GNF cattle, when grown at a similar rate prior to slaughter at the same age and time, there is no difference in Warner Bratzler shear force values or taste panel assessment of beef tenderness (McIntyre and Ryan, 1984).

There is a clear positive correlation between tenderness and carcass fat (Simone et al., 1958; Pearson, 1966; Merkel and Pearson, 1975; Bowling et al., 1978; Miller et al., 1987), which is generally lower in Grass compared with GNF cattle. Hedrick et al. (1983) concluded from his study, however, that cattle finished on silage are equally tender or more than GNF cattle in spite of having a lower fat cover.

The amount and solubility of collagen in the muscle also influences tenderness (Muir et al., 1998a). There is a direct relationship of the pre-slaughter feeding and growth rate with the collagen stability and tenderness (Aberle et al., 1981; Fishell et al., 1985). Aberle et al. (1981) and Fishell et al. (1985) have further stated that high energy diets fed to cattle result in rapid rates of protein synthesis, which further results in a large proportion of newly synthesized and heat labile collagen. Furthermore, Hall and Hunt (1982) conclude from their studies that since GNF cattle reach maturity more quickly, they are likely to contain more soluble collagen and thus would produce more tender meat. Collagen is an animal protein which is considered to be the most abundant protein of animal source, this can be extracted by solubilizing in acid which is thus termed as soluble collagen (Muyonga et al., 2004). Beef from GNF when compared to Grass is expected to produce more tender meat due to a faster growth rate at similar chronological age (Muir et al., 1998a).

Tenderness assessed by Warner-Bratzler shear force (WBSF) has been found to be influenced by the location of muscle (Stolowski et al., 2006). Some of the major beef muscles vary in tenderness because of the considerable variability in the sarcomere length and collagen content (Herring et al., 1965; McKeith et al., 1985; Wheeler et al., 2000). Furthermore, variation in the extent of proteolysis also influences tenderness among

muscles (Wheeler et al., 2000). The sarcomere length is directly proportional to tenderness of meat and the length of the sarcomere is greatly affected by the muscle position during rigor mortis (Calkins and Sullivan, 2007). The amount of connective tissue is inversely proportional to tenderness, the amount of connective tissues are seen to be more in locomotive muscles that are thus less tender (Calkins and Sullivan, 2007).

Based on previous studies, *Psoas major* has been rated the most tender by trained sensory panelists followed by *Infraspinatus, Longissimus dorsi, Tricep brachii, Rectus femoris* and *Gluteus medius*; *Bicep femoris* was rated the least tender muscle (McKeith et al., 1985; Carmack et al., 1995; Shackelford et al., 1995; Rhee et al., 2004). *Psoas major* has also been rated least for amount of connective tissue by trained sensory panels followed by *Longissimus dorsi*, *Infraspinatus* and *Tricep brachii*; whereas *Bicep femoris* received the highest rating for most amount of connective tissue (McKeith et al., 1985; Shackleford et al., 1995). The *Psoas major* has been found to have the lowest shear force value for WBSF studies followed by *Infraspinatus*; whereas *Adductor* and *Supraspinatus* the highest shear force values (McKeith et al., 1985; Brooks et al., 2000).

Proximate composition

Proximate composition varies between Grass and GNF cattle (Srinivasan et al., 1998). Protein content has been found to be greater in GNF compared with Grass. Meanwhile, moisture content was determined to be greater in Grass than GNF. There was no difference between the ash content between Grass and GNF and the lipid content had a higher value in GNF than Grass (Srinivasan et al., 1998). The fat content or the marbling score was determined to be higher in GNF cattle than Grass cattle (Westerling and Hedrick, 1979; Srinivasan et al., 1998). As in the fat content and the marbling score

has been reported to be directly proportional with each other (Seggern et al., 2005). Additionally, fat content has been revealed to be inversely proportional to moisture percentage (Hedrick et al., 1981; Brackebusch et al., 1991; Seggern et al., 2005). Van Elswyk and McNeill (2014) have also observed that feeding grass lowers the total fat content in the meat as compared to meat from GNF cattle.

Previous research states the variation in composition of muscles in a beef carcass (Cecchi et al., 1988; Johnson et al., 1988; Brackebusch et al., 1991). In a study by Stetzer et al. (2008), the *Infraspinatus* and the *Serratus ventralis* contained more than 8% fat whereas *Gluteus medius*, *Rectus femoris* and *Vastus lateralis* contained less than 5% fat. In a study by Brackebusck et al. (1991), the *Tricep brachii* was categorized as one of the muscles which was lower in fat content than the mean of composite muscle mass. The fat percent of *Tricep brachii* was also found to be lower when compared to *Longissimus dorsi* and *Gluteus medius* (Seggern et al., 2005). In addition, it has been reported by McKeith et al. (1985) that major muscles from the round have lower fat content as compared to muscles from chuck and the muscles that are associated with maintenance of posture.

pH

There are previous studies where the ultimate pH was found not to be significantly different between Grass and GNF (Bidner et al., 1981, 1986; Morris et al., 1997). In contrast, McIntyre and Ryan (1984) and Muir et al. (1998a) found significant differences in ultimate pH between Grass and GNF in their studies. The ultimate pH can also have an effect on the tenderness of meat, as the decline in pH from 7.0 (in live

animals) to 5.8 (post-mortem) can increase the autolysis of calpains and consequently reduce post-mortem proteolysis (Muir et al., 1998a).

Post-mortem pH decline has been found to be influenced by muscle (Stolowski et al., 2006). *Tricep brachii* has been reported to have the slowest pH decline and *Gluteus medius* having the fastest pH decline at post-mortem, the reason being the anatomical location of these muscles along with other factors during electrical stimulation (Stolowski et al., 2006).

Variation of pH has been seen among various muscles as well as within a muscle (Gariepy et al., 1990). Proximity with respect to bone has been one of the suggested reasons of variation in pH due to the neutralization of lactic acid by calcium carbonate in the bone which can cause a rise in pH (Callow, 1939). Variation in connective tissue has also been associated with variation in pH among various muscles (Bate-Smith, 1948). Bate-Smith (1948) also stated that with the muscle narrowing towards its tendinous insertion, there is an increase in relative amount of tendon to muscle which decreases the lactic acid produced per gram and thus there is a reduction of fall in pH correspondingly (Bate-Smith, 1948). In a study by Seggern et al. (2005), the *Longissimus costarum* was found to have the highest pH whereas the *Gluteus medius* had the lowest pH.

Fatty acids

The final composition of beef is known to be impacted by diet, specifically the lipid components which are recognized to have consumer dietary implications (Meyer et al., 1960; Melton, 1983; Wood et al., 2003). Fatty acid composition has been reported to be significantly correlated to flavor (Westerling and Hedrick, 1979; Melton, 1983; Larick and Turner, 1990).

Van Elswyk and McNeill (2014) state that meat from Grass cattle have lower levels (g/ 100g) of total saturated fat when compared to GNF beef. A 25% increase in polyunsaturated fatty acids (PUFA) has been associated as the response of grass feeding (Van Elswyk and McNeill, 2014). Grass finished beef have greater percentages of total fatty acid n-3 PUFA while GNF beef has a greater percentages by total fatty acid n-6 PUFA (Enser et al., 1998). Wood et al. (2003) has defined n-6 and n-3 PUFA of grass and grain diets in beef, respectively as the explanation for flavor difference. Furthermore, Van Elswyk and McNeill (2014) have observed small increases in short chain omega-3-fatty acids in Grass beef in comparison to GNF beef. Supplements like palm-oil and whole linseed increase the concentration of α-linolenic acid and eicosapentaenoic acid (EPA) in skeletal muscles of beef, whereas fish oil supplements increases the levels of EPA and docosahexaenoic acid (DHA) (Elmore et al., 2004). Unsaturated fatty acids have the ability to rapidly oxidize and more importantly affect the flavor as the meat is cooked (Wood et al., 2003).

The percentage of monounsaturated fatty acids (MUFA) have been found to be low in Grass beef when compared to GNF beef (Van Elswyk and McNeill, 2014). In addition, major flavor differences were related to greater content of oleic acid and its derivatives in grain-fed beef in contrast to high content of linolenic acid and its derivatives in forage-fed beef (Mandell et al., 1998). Feeding grass to cattle has resulted in a significant increase in the percentage of conjugated linoleic acid (CLA) in total fatty acids than GNF beef (Van Elswyk and McNeill, 2014).

Large difference in fatty acid composition among muscles has been observed by Marchello et al. (1968). In the study by Marchello et al. (1968), *Longissimus dorsi*

muscle was found to contain significantly more palmitic acid and stearic acid when compared to *Tricep brachii* and *Semimembronous* with significantly less C16:1 and C18:2. In addition, *Longissimus dorsi* was reported to have a lower content of oleic acid than the muscle *Semimembranosus* but significantly higher than *Tricep brachii* (Marchello et al., 1968). The weight percentage of PUFA has been found to be least in *Longissimus dorsi* when compared to other muscles like *Supraspinatus* and *Semitendinosus* (Rule et al., 2002). Moreover, *Longissimus dorsi* was noted to contain more saturated fatty acids than *Gluteus medius* and *Tricep brachii* in both Grass and GNF beef (Enser et al., 1998).

Volatile compounds

Various components of meat like amino acids, peptides, nucleotides, sugars, and lipids can contribute to the formation of aroma volatiles (Shahidi et al., 1986). Volatile components differentiate in response to fatty acid variation (Hornstein and Crowe, 1964). Volatile compounds evolve from various pathways which are illustrated in Figure 1, which is adopted from Dahsdorj et al. (2015). Flavor contributing volatile compounds are affected by cattle diet (Larick et al., 1987). According to Muir et al. (1998a), Grass cattle have an altered fatty acid composition and flavor but this flavor effect is not always detected by sensory panelists. It was found that 31 out of 53 volatile compounds identified had differences in from GNF beef fat and Grass beef fat in a study by Larick et al (1987). Fat of Grass beef had greater levels of pentanoic, heptanoic, octanoic, nonanoic, decanoic and dodecanoic acid; heptanal, 2,3-octanedione, 3-hydroxyoctan-2-one, 2-decenal, 2-tridecanone, hexadecane, heptadecane and octodecane (Suzuki and Bailey, 1985). In addition to this, terpenoids were found in greater concentration in Grass

due to rumen-fermented chlorophyll (Suzuki and Bailey, 1985). Fat from grain-finished cattle had greater δ – tetradecalactone and δ – hexadecalactone (Larick et al., 1987). Diterpenoids have also been associated with the off-flavor in beef fat derived from pasture-fed cattle (Larick et al., 1987). Diterpenoids were derived from the breakdown of chlorophyll, phyt-2-ene was found to be closely associated with the "grassy" flavor whereas 2-lactones, δ – tetradecalactone and δ – hexadecalactone were negatively correlated with the "grassy" flavor. Later, it was found that the diterpenoid phyt-1-ene in beef fat was positively associated to the off-flavor termed as "gamey/stale" flavor and negatively correlated to the desirable "roasted" flavor and that the lactones were associated with the "roasted" flavor of grain-fed beef (Maruri and Larick, 1992). The concentration of lactones decreased while low molecular weight alkanols, alkenals and acids, C7 to C10 and various C20 hydrocarbons increased which resulted into "grassy" flavor (Brewer, 2006).

Difference in volatile compounds among muscles have been reported in previous literature (Brewer, 2004; Farmer and Patterson, 1991). In the study by Farmer et al. (1990), the *Infraspinatus* had a higher content of hexanal whereas the *Gluteus medius* and *Teres major* had the least hexanal content. The cardiac muscles are reported to have a high level of bis (2-methyl-3-furyl) disulphide and 2-furfuryl-2-methyl-3-furyl disulphide when compared to *Semimembranosus* and *Psoas major* muscles.

Five volatile compounds were found to differ among muscles studied by Legako et al., (2015) namely 2,3-butanedione, heptane, 3-hydroxy-2-butanone, octane and methyl pyrazine. *Psoas major* was noted to have the highest amount of the above mentioned

alkanes, *Gluteus medius* containing the greatest quantity of above mentioned ketones and *Longissimus lumborum* being abundant in methyl pyrazines (Legako et al., 2015).

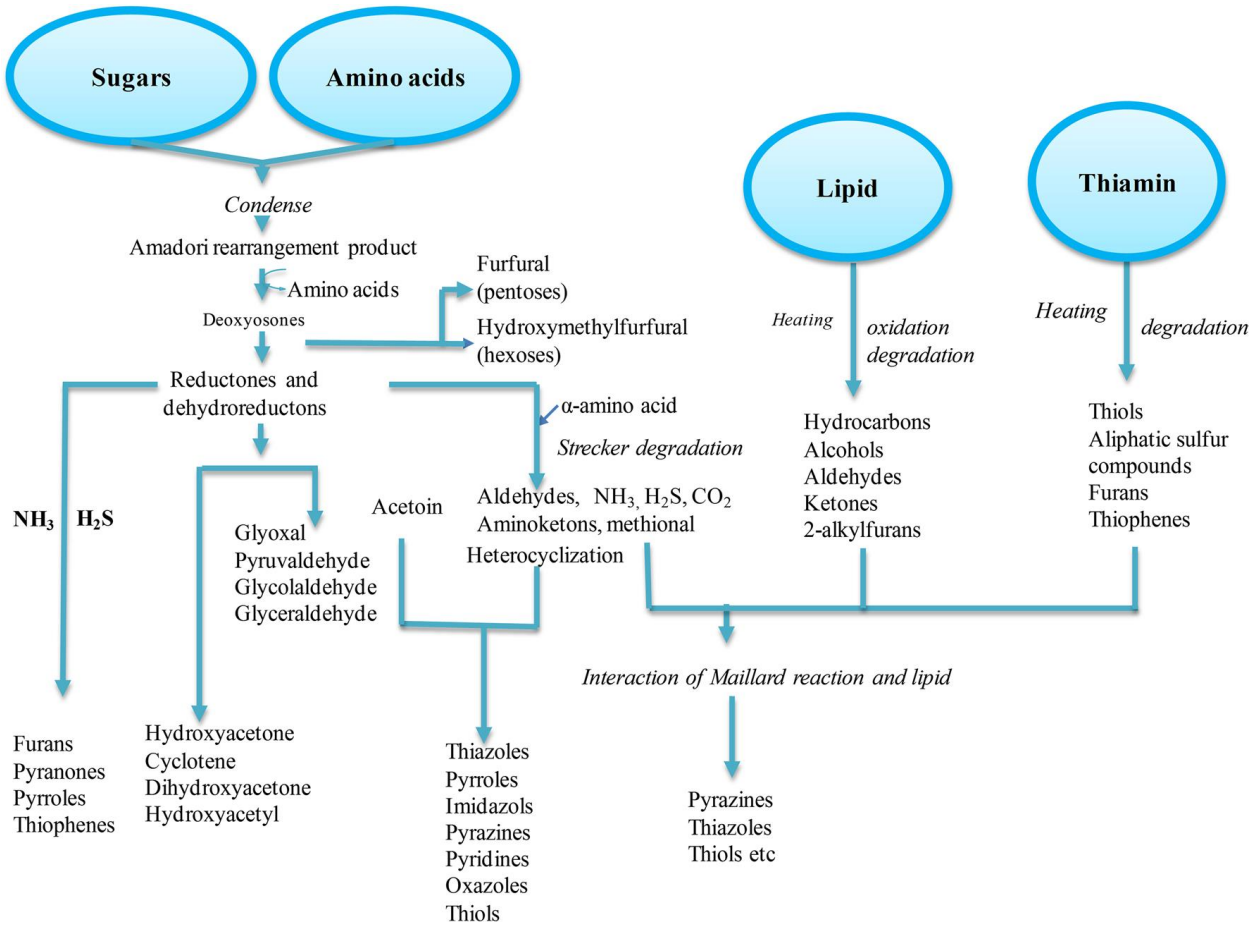

Figure 1: Different pathways producing various volatile compounds adopted from Dashdorj et al. (2015)

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CHAPTER 3

CONSUMER SENSORY EVALUATION AND CHEMICAL COMPOSITION OF BEEF RIBEYE STEAKS FROM CATTLE FINISHED ON FORAGE AND CONCENRATE DIETS

Abstract

Consumer evaluation, proximate data, Warner-Bratzler shear force (WBSF), fatty acid (FA) composition and volatile compounds were analyzed from the *Longissimus thoracis* muscle of ribeye steaks of cattle (n = 6 per diet) finished on conventional feedlot (FL) and forages. Forage diets included a perennial legume, birdsfoot trefoil (BFT; *Lotus corniculatus*) and a grass, meadow brome (*Bromus riparius Rehmann*, Grass). Moreover, representative retail forage (USDA Certified Organic Grass-fed, COGF) and conventional beef (USDA Top Choice, TC) were investigated (n = 6 per retail type). Diet regimens affected ($P \leq 0.009$) all the attributes in consumer evaluation except aroma ($P = 0.120$). Diet type did not affect ($P = 0.880$) WBSF. Proximate composition was impacted ($P \leq 0.009$) by finishing diets. In our studies, forage-finished beef had a greater ($P < 0.001$) PUFA:SFA ratio than grain finished beef. Also, forage-finished beef had a lower ($P < 0.001$) ratio of n-6:n-3 FA, when compared to FL and TC. Sixteen out of thirty nine quantified volatile compounds identified were found to be affected ($P \leq 0.040$) by diet which included aldehydes, ketones, sulfides, furan, carboxylic acids, alcohols, alkanes and pyrazine compounds. Hexanal was the most abundant aldehyde which was greater ($P = 0.002$) in grain-finished beef as compared to Grass and COGF beef with BFT having comparable ($P > 0.05$) concentration with grain-finished beef. None of the aldehydes

evolving from Strecker degradation were impacted ($P > 0.05$) by diet. There was no particular trend observed with the concentration of ketones though TC had the greatest ($P < 0.05$) concentration. Carbon disulfide had the greatest ($P < 0.05$) concentration in COGF followed by TC and FL which were similar and greater than BFT and Grass. Pyrazine compounds which contribute to the roasted flavor were similar ($P > 0.05$) between BFT and FL which were each greater ($P < 0.05$) than Grass, COGF and TC. Several crucial factors of quality and acceptability tested by consumer evaluation and chemical analysis differed due to diet regimes. Though BFT is a forage, several factors were found to be similar to FL and TC which were more preferred by consumers. Moreover, BFT-finished beef had a better FA composition with respect to health and nutrition.

Introduction

Beef quality is impacted by cattle finishing diet (Reagan et al., 1977; Bidner et al., 1981;1986; McIntyre and Ryan, 1984; Morris et al., 1997; Maughan et al., 2012). The nutrient composition of the feed along with the amount of available feed energy to the animal can modify beef quality (Muir et al., 1998). Specifically, diet influences the eating quality and flavor of beef (Melton, 1990; Tansawat et al., 2013). Additionally, Melton (1990) has also stated that grain-finished beef produces a more acceptable flavor than forage-finished beef. Previously, grain-finished cattle produced more tender and acceptable beef flavor when compared to forage-finished beef (Larick et al., 1987; Medeiros et al., 1987; French et al., 2001; O'Quinn, 2012; Corbin et al., 2015). Volatile compounds and fatty acid composition vary with pre-slaughter diet regimens (Mills et al., 1992; Elmore et al., 1999, 2004; French et al., 2001). Additionally, WBSF and proximate

composition of beef have been revealed to be affected by diet (Reagan et al., 1977; Srinivasan et al., 1998).

Fatty acid composition varies with cattle finishing diet impacting beef nutritional quality (Warren et al., 2008). A greater ratio of PUFA to SFA and a lower ratio of n-6:n-3 may combat coronary artery disease (Warren et al., 2008). Forage-finished beef has improved ratios of n-6:n-3 fatty acids and PUFA:SFA (Enser et al., 1998; Elmore et al., 2004), and has been concluded to have comparatively greater nutritional value (Manner et al., 1984; Muir et al., 1998; Warren et al., 2008). However, stearic acid and some PUFAs have been related with off-flavors, which have been reported to be greater in concentration in grass-finished beef (O'Quinn, 2012). Fat content has been determined to be greater in grain-finished beef (Srinivasan et al., 1998). Feeding grass yields a lower total fat content in beef (Van Elswyk and McNeill, 2014). Flavor compounds like 3-hydroxy-2-butanone and 2,3-butanedione have been positively correlated to overall flavor desirability and reported to increase in concentration with increasing intramuscular fat percentage (O'Quinn, 2012).

Birdsfoot trefoil is a perennial legume that may be grown in the Intermountain West of the US. Previous work indicated BFT-finished animals had greater ADG than Grass but less ADG compared with FL-finished cattle (Pitcher, 2015). Consumer evaluation of two BFT-finished steers with purchased FL-finished beef was found to be similar (unpublished data). The objective of this study was to compare the acceptability and chemical properties of conventionally-finished and forage-finished beef, specifically to explore the quality of BFT-finished beef.

Materials and Methods

Animal care and use

All animal procedures and protocols in this study were approved by the Utah State University (USU) Animal Care and Use committee, IACUC #A1997-10125-0

Cattle finishing, harvest and grading

Eighteen spring-born (March 2012) and fall weaned (2012) Angus steers with similar initial weights (416 – 490 kg) were selected from the USU herd. Prior to the study, from weaning until the end of May 2013, cattle were fed a mixture of corn silage and alfalfa hay. Six grass-finished steers were put on tall fescue for six weeks from 1 June 2013 and then moved onto meadow brome until slaughter. Six of the eighteen steers were put on BFT from the 1 June 2013 until slaughter. The remaining six steers were feedlot finished on a concentrate diet of high starch cereal grain from 1 June 2013 until slaughter. Cattle were harvested at approximately 18 months of age in September 2013. Hot carcass weight was determined.

Carcasses were chilled for 24-48 hours at 2-4 °C and the quality and yield grade were determined based on USDA protocols (USDA, 1997). Lean maturity (A^{00} to A^{100}), skeletal maturity (A^{00} to A^{100}), fat thickness (cm), *Longissimus* muscle (LM) area (cm^2), hot carcass weight (kg) and percentage of kidney, pelvic and heart fat were determined. The carcass marbling scores were identified by comparison of visual marbling of the LM at the 12^{th} and 13^{th} ribs with official USDA marbling photographs (NCBA, Centennial, CO). The results from the analysis of the grading of the carcasses are shown in Table 3.1.

Product collection and fabrication

Paired ribeye rolls (Institutional Meat Purchasing Specification # 112; North American Meat Processors Associatiob, 2010) were collected from each carcass (n=6 per

treatment). In addition to the three experimental treatments, ribeye rolls from retail forage-fed beef (USDA Certified Organic Grass-finished; COGF) were purchased from a retail store in Salt Lake City, UT and feedlot (USDA Certified Angus grain-finished; TC) ribeye rolls were purchased at a local retail store in Logan, UT. Subprimals were wet-aged under vacuum for 14 days at 2-4 °C before producing retail steaks. Ribeye steaks (Institutional Meat Purchasing Specification # 112) were produced by slicing ribeye rolls using a band saw (Butcher boy; American meat equipment, LLC; Model # SA-16; Selmer, TN) into 2.5 cm thick steaks. All steaks were vacuum packaged and stored at -20 °C for further analysis.

Consumer sensory evaluation

Sensory evaluation was conducted at the USU Department of Nutrition, Dietetics, and Food Science as per an approved IRB protocol (IRB # 4760). Prior to consumer evaluation, steaks were thawed for 48 hours at 4°C. Steaks were cooked as described by (Maughan et al., 2011) using Presto Tiltn' Drain electric griddles (Eau Claire, WI; 42096US) to a medium degree of doneness (70°C) determined with a digital thermometer (Atkins Temp tech digital thermometer, Middlefield, Connecticut) equipped with a fast responding microneedle probe. The temperature was read by inserting the probe parallel to the surface of the griddle to the geometric center of the steak. Immediately after cooking all external fat, connective tissues and exterior muscles were removed from the cooked steaks leaving the *Longissimus thoracis* muscle for evaluation. Steaks were cut into 2.5cm X 2.0cm X 2.0cm cubes and served warm to consumers under red light to prevent visual bias.

Each sample was evaluated for smell, flavor, texture/tenderness, juiciness and overall liking on a hedonic scale of 9 with 1 being "dislike extremely" and 9 being "like extremely". A four point hedonic scale was used for quality where 1= unsatisfactory, 2= everyday quality, 3= better than everyday quality and 4= Premium quality. Six replicates comprising the five treatments were conducted with 120 panelists in each replicate. Each replicate occurred on separate days and only one animal replicate of each treatment was represented within each replicate.

Warner-Bratzler shear force

The Warner-Bratzler shear force method was used to determine objective tenderness (AMSA, 1995). Steaks were thawed for 24 hours until an internal temperature of 4-6^{o} C was reached and then cooked as previously described. Cooked steaks were plastic wrapped on metal trays to prevent moisture loss and cooled overnight in the cooler (4-8 ^{o} C). Three hours before coring, samples were thawed at room temperature (24-26 ^{o}C). Six 1.27-cm cores per steak sample were removed parallel to the longitudinal orientation of the muscle fiber of the *Longissimus thoracis* muscle. Each core was sheared once on a TMS-Pro Texture Analyzer (FTC 500N ILC, Food Technology Corporation, Sterling, Virginia) with Warner-Bratzler shear force attachment using 200 mm/min crosshead speed and a 50 Kgf load cell. The instrument calculates the maximum force required to shear through the fiber.

Sample preparation for chemical analysis

Samples were thawed for 24-48 hours at 4-8°C. All exterior muscles, connective tissue and external fat were removed leaving only the *Longissimus thoracis* muscle. Samples were cubed, submerged in liquid nitrogen for rapid freezing, placed in a blender

(VITA-MIX Corp, Cleveland, OH; model # VM0100A) and ground to form beef homogenates. Powdered samples were double packed in VWR sample bags (BPR-4590 VW1, Radnor, Pennsylvania) and stored at -80°C for subsequent analysis (Martin et al., 2012).

Fatty acid analysis

Fatty acid methyl esters (FAME) were prepared by the method described by O'Fallon et al. (2007). One gram of meat homogenate was weighed into a screw cap glass vial along with 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 (Fisherbrand; made in Mexico; 14-962-26G). Vials were placed in a water bath (Precision Scientific, Cat # 67120, Chicago, IL) for incubation at 55 ºC. Hexane was used to extract FAME prior to analysis by gas chromatography (GC).

Separation of FAME was carried out by Shimadzu, GC-2010 (Japan) equipped with a HP-88 capillary column (100m X 0.25 mm X 0.20 µm; Agilent Technologies, Palo Alto, CA) and a flame ionization detector (FID). The GC was operated based on the conditions described 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: 2.47 mL/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

based on the similarity of retention times with the GC reference standards (Nu-chek Prep, Inc., Elysian, MN).

pH analysis

A Thermo Electron Corporation Orion 3 star benchtop pH-meter was used to determine the pH of homogenized samples. Five grams of homogenized samples was weighed in 50 ml (VWR, Radnor, PA) disposable culture tubes. Forty five milliliters of distilled water was added to the culture tube and vortexed until all meat was dispersed. A filter paper (VWR; Radnor, PA; North American Cat # 28320-085) folded in the form of a cone was immersed in the culture tube and then the pH electrode was immersed in the solution. (John et al., 2004).

Proximate analysis

A chloroform:methanol extraction method was used for determination of total fat, similar to Folch et al. (1957). One gram of homogenized sample was weighed in 50 ml centrifuge tubes (VWR; Radnor, PA; North American Cat # 89039-656) along with 3.2 ml of distilled water and vortexed. Eight milliliters each of methanol and chloroform were added to this and vortexed for 2 min. Four milliliters of water was added to the vortexed samples and vortexed again for an additional 30 sec. This mixture was centrifuged at 3500 rpm (rotations per minute) for 10 min. Four milliliter of the chloroform extract was pipetted out in labeled and pre-weighed disposable 50 ml culture tubes. These tubes were placed on heating blocks under the fume hood for 10 min for evaporation. These tubes were further exposed to 101 ºC in the oven to a constant weight. These samples were cooled in a desiccator and weighed. The total fat percentage was

calculated {fat % = [(weight of residue in g) / (weight of homogenized sample in g)] X 2 X 100}.

The AOAC method of oven-drying was used to determine the total moisture (950.46 and 934.01; AOAC, 1995). Percentage of moisture was calculated as {moisture % = [((pre-dry weight of sample) – (post-dry weight of sample)) / (pre-dry weight of sample)] X 100}

The AOAC ash oven method was used to determine the percent ash (923.03; 920.153: AOAC, 1995). Crucibles were kept in a drying oven for 30 min, cooled in a desiccator and then weighed and recorded before use. One gram of the homogenized samples were weighed in the crucibles. These crucibles were placed in the furnace at 550 ºC to 600 ºC for at least 24 hours. Incinerated samples were removed from the furnace and allowed to cool in the desiccator. These crucibles were re-weighed and the weight was recorded. The percentage of ash was calculated as {ash % = (ash weight / initial weight) X 100}

Protein percent was determined by the dye-binding method (AOAC Official method 2011.04; AOAC, 2011). Protein percentage was determined by using CEM Sprint™ Protein Analyzer (Matthews, NC) as described by Moser and Herman (2011) in the "Determination" section.

Volatile compounds

Volatile analysis was carried out similar to Legako et al. (2015). Cooking protocols were the same as those previously described. Immediately after cooking, five 1.27-cm cores were extracted by coring perpendicular to the surface of the steak cut surface. Cores were then minced in a coffee-bean grinder (KRUPS, Medford, MA; Type

#F203). Five grams of the ground sample were weighed out in a 20 ml glass GC vials (Art # 093640-036-00; Gerstel; Linthicum, MD) and closed with a polytetrafluoroethylene septa and screw cap (Art # 093640-092-00; Gerstel; Linthicum, MD). Ten microliters of an internal standard (1, 2-dicholorobenzene; 0.801mg/ ml) was added and the vial was loaded by a Gerstel automated sampler (MPS, Linthicum, MD) for a 5 min incubation period at 65 ºC in the Gerstel agitator (500 rotations per minute) followed by 20 min of extraction where volatile compounds were collected from the headspace of cooked samples by solid phase microextraction (SPME) using an 85-µm film thickness carboxen polydimethylsiloxane fiber (Supelco, Bellefonte, PA). Extracted volatile compounds were injected on a VF-5 ms capillary column (30m × 0.25mm × 1.00µm; Agilent J&W GC Columns, Santa Clara, CA). The electron impact mode was set at 70 eV in the mass spectrometry which detected the ions within the range of 50-500m/z. Selective ion monitoring/scan mode was used to collect the data. External standard comparison was used to validate the volatile compound identity of ion fragmentation patterns. Quantitation was carried out by an internal standard calibration with authentic standards.

Statistical analysis

A generalized linear mixed model using Proc Glimmax procedure of SAS (Version 9.3, Cary. NC) was used for statistical analysis. One-way analysis of variance was used to determine the effects of diet. Carcass served as the experimental unit. For consumer evaluation data, carcass and consumers were treated as random effects in the model. For all other measurements, carcass was treated as the random effect in the model.

Significant differences were considered at $P < 0.05$ and the denominator degree of freedom was calculated by the Kenward-Roger method.

Results and Discussions

Carcass evaluation

The data collected from carcass grading was analyzed and illustrated in Table 3.1. Live weight (Kg), hot carcass weight (Kg), fat thickness (cm), adjacent fat thickness (cm), ribeye area (cm^2), kidney, pelvic and heart (KPH) fat percentage and calculated yield grade (YG) were affected ($P \leq 0.20$) by diet. Feedlot-finished animals had the greatest ($P < 0.001$) live weight followed by BFT-finished beef and then grass-finished beef. Hot carcass weight (HCW) of FL and BFT were similar ($P > 0.05$) and were greater ($P < 0.05$) than Grass. Fat thickness ($P < 0.001$), adjacent fat thickness ($P < 0.001$), KPH % ($P = 0.004$) and calculated YG ($P = 0.020$) followed the same trend as HCW. In the case of ribeye area (cm^2), BFT and Grass had similar ($P > 0.05$) values which were lower ($P = 0.012$) than FL. Marbling and YG had no effect ($P > 0.05$) of dietary treatments.

Table 3. 1: Carcass characteristics of cattle (n=6 per diet) finished on different dietary treatments (Birdsfoot trefoil-finished; BFT, Feedlot-finished; FL and Grass finished; Grass)

	Dietary treatments[1]				
	FL	**BFT**	**Grass**	**SEM[2]**	**P-value**
Live weight, Kg	644.6^{a}	556.8^{b}	511.1^{c}	13.7	< 0.001
HCW, Kg	370.3^{a}	346.0^{a}	291.0^{b}	9.3	< 0.001
Marbling	493.3	438.3	406.7	34.3	0.227
Fat thickness, cm	1.1^{a}	1.0^{a}	0.5^{b}	0.1	< 0.001
ADJ Fat thickness, cm	1.2^{a}	1.1^{a}	0.5^{b}	0.1	< 0.001
Ribeye Area, cm²	83.3^{a}	72.3^{b}	66.7^{b}	3.5	0.012
KPH, %	3.0^{a}	2.6^{a}	1.8^{b}	0.2	0.004
Calculated YG	3.2^{a}	3.4^{a}	2.5^{b}	0.2	0.020
Yield Grade	2.8	2.7	2.0	0.3	0.090

[1]Grass-finished; Grass, conventional feedlot-finished; FL, Birdsfoot trefoil-finished; BFT, USDA Top Choice TC and USDA Certified Organic Grass-fed COGF
[2]Pooled (largest) SE of LS mean
HCW, Hot carcass weight
ADJ, adjacent
KPH, Kidney pelvic and heart
YG, Yield grade

Consumer sensory evaluation and WBSF

The results obtained from consumer evaluation and WBSF are tabulated and presented in Table 3.2. All attributes were affected by diet type *(P* < 0.009*)* except aroma *(P* = 0.120*)*. Grain finished diets (FL and TC) were rated greater *(P* < 0.009) for flavor, tenderness, fattiness, juiciness, overall and quality when compared with Grass and COGF. Scores of BFT-finished beef for tenderness, fattiness, juiciness, overall liking and quality were comparable (*P* > 0.05) to the grain-finished beef. Specifically, flavor liking was observed to be greatest (*P* = 0.005) in FL followed by TC and BFT where BFT was similar to both TC and Grass. Grass finished and COGF were rated lowest (*P* = 0.005) for flavor liking. Tenderness was found to be greatest (*P* = 0.001) in FL and BFT. A

similar trend was seen in juiciness ($P = 0.005$), overall liking ($P = 0.001$), quality rating ($P = 0.002$) and fattiness ($P = 0.009$).

Table 3. 2: The effects of dietary treatments on the evaluation of samples rated by consumers (n=120) for aroma, flavor, tenderness, fattiness, juiciness, overall and quality and Warner Bratzler Shear Force (WBSF) of *Longissimus thoracis* muscles

	Dietary treatments[1]						
Attributes	**FL**	**TC**	**BFT**	**Grass**	**COGF**	**SEM[4]**	**P value**
Aroma[2]	6.53	6.41	6.32	6.35	6.33	0.08	0.120
Flavor[2]	6.50^{a}	6.23^{ab}	6.15^{bc}	6.10^{bc}	6.01^{c}	0.11	0.005
Tenderness[2]	6.56^{a}	6.39^{ab}	6.58^{a}	6.12^{bc}	6.08^{c}	0.12	0.001
Fattiness[2]	6.35^{a}	6.18^{abc}	6.26^{ab}	5.93^{c}	6.01^{bc}	0.12	0.009
Juiciness[2]	6.28^{a}	5.88^{b}	6.20^{a}	5.81^{b}	5.75^{b}	0.12	0.005
Overall liking[2]	6.45^{a}	6.20^{ab}	6.24^{a}	5.93^{bc}	5.92^{c}	0.11	0.001
Quality rating[3]	2.46^{a}	2.35^{ab}	2.36^{a}	2.21^{bc}	2.21^{c}	0.06	0.002
WBSF (Kgf)	2.91	2.99	2.74	3.02	3.03	0.22	0.880

[1]Grass-finished; Grass, conventional feedlot-finished; FL, Birdsfoot trefoil-finished; BFT, USDA Top Choice TC and USDA Certified Organic Grass-fed COGF
[2]Evaluated on a nine point hedonic scale (1 = dislike extremely and 9 = like extremely)
[3]Evaluated on a four point hedonic scale (1= unsatisfactory, 2= everyday quality, 3= better than everyday quality and 4= Premium quality
[4]Pooled (largest) SE of LS mean
[abc]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet.

Melton (1983), in his review, concluded that the largest flavor differences were observed between beef finished on grass and beef finished on concentrates. In a study by Maughan et al., (2012) where a descriptive panel and consumer evaluation were conducted with *Longissimus dorsi* muscles from grain-finished and forage-finished cattle, the descriptive panel evaluated grain-finished beef to be juicier and consumer evaluation results stated that grain-finished beef was more liked when compared to forage-finished beef. Font i Furnols et al. (2009) revealed that meat from lamb fed BFT were rated similar to concentrate-finished meat with respect to overall acceptability, tenderness

acceptability and flavor acceptability by consumers in France and Germany. Juiciness is associated with marbling (Blumer, 1963; Pearson, 1966). In this study marbling was not statistically different ($P = 0.227$). However, numerical differences were apparent and fat percent (Table 3.3) was affected by diet ($P < 0.001$). Looking at our experimental treatment data for BFT, FL and Grass, perceived juiciness ($P = 0.005$) is in line with fat percent ($P < 0.001$) differences by diet treatments.

Dietary treatment had no effect ($P = 0.880$) on WBSF. Though Grass and COGF had greater numerical values of WBSF, there was no significant difference ($P = 0.880$) among treatments. In our research, the cattle were slaughtered at the same chronological age. Shimokomaki et al. (1972) stated that the tenderness of meat is more closely related to rate of growth pre-slaughter than the chronological age, but that was not what we found. In research conducted by Hall and Hunt (1982), it was noted that WBSF was not effected by control group and concentrate fed groups where control groups were finished on grass.

The demographic data is presented in Table 3.3 for ribeye steaks. The age and gender percentages were very similar to previous USU studies (Lance et al., 2011). The most probable reason for the percentage of consumers between 18 to 29 years being high would be because the tests were conducted in the university.

Table 3. 3: Data from consumer demographic, most important palatability trait, meat origin and type of meat.

Categories	Options	Percentages
Age	18-29	69.31
	30-39	13.33
	40-49	8.19
	50-60	5.69
	over 60	3.47
Gender	Male	56.53
	Female	43.47
Ethnic origin	African-American	0.42
	Asian	13.47
	Caucasian/White	81.39
	Hispanic	2.78
	Native American	0.14
	Other	1.81
Income	Under $25,000	49.31
	$25,000 - $34,999	13.89
	$35,000 - $49,999	10.28
	$50,000 - $74,999	12.50
	$75,000 - $100,000	8.89
	More than $100,000	5.14
Education level	Non-high school graduate	0.14
	High school graduate	3.19
	Some College/Technical School	17.64
	College Bachelor	39.58
	Master Degree	22.36
	Professional Degree (e.g. MD, JD)	2.50
	Doctorate	14.58
Frequency of consumption of beef	Less often than once a year	0.14
	Once or twice a year	1.39
	Once every 4-6 months	2.78
	Once every 2-3 months	5.69
	Once a month/every 4 weeks	10.14
	Once every 2-3 weeks	31.25
	Once a week or more often	48.61
Most important palatability trait	Flavor	55.28
	Tenderness	32.08
	Juiciness	12.64
Type of beef	Grain-Fed	17.08
	Grass-Fed	20.42
	Doesn`t Matter	62.50

meat product	Beef	41.25
	Chicken	16.53
	Fish	6.94
	Lamb	9.86
	Pork	14.31
	Shellfish	2.78
	Turkey	4.17
	Veal	1.25
	Venison (Deer)	2.92

The data collected from consumer regarding the importance of factors like Brand, Country of Origin, Natural or Organic claims, Price and USDA grade of the meat is presented in Table 3.4. According to the data, price was rated the most important ($P < 0.001$) factor and brand of the product was rated the least important ($P < 0.001$) factor while buying meat.

Table 3. 4: Consumer rating on importance of various factors while buying meat.

Factors	**Importance**
Brand of meat	3.56^{e}
Country Of Origin	4.65^{c}
Natural or Organic claims	4.02^{d}
Price	7.58^{a}
USDA grade	6.37^{b}
SEM[1]	0.10
P-value	< 0.001

[1]Pooled (largest) SE of LS mean

Proximate analysis and pH

Moisture, ash, intramuscular fat (IMF) and protein percentage were affected by diet ($P \leq 0.009$; Table 3.3), with percent moisture and IMF being inversely related. The greatest ($P < 0.05$) value of moisture was in COGF which had the lowest ($P < 0.05$) IMF percentage. Similarly, TC had the greatest ($P < 0.05$) IMF percentage but the lowest ($P <$

0.05) value of moisture percent. This inversely proportional trend has also been observed in the study done by Reagan et al. (1977) with beef ribs obtained from grain-finished and forage-finished cattle. In this study, protein percentage was also affected ($P = 0.008$) by diet where TC and COGF had greater ($P < 0.05$) values than BFT, FL and Grass which were similar ($P > 0.05$) to each other. This is similar to studies conducted by Reagan et al. (1977) and French et al. (2001) where protein percentage was not affected by dietary treatment. In the present study, BFT, FL and Grass steaks came from genetically similar cattle, whereas the origin of purchased ribeye rolls was unknown, although the TC steaks were labeled "Certified Angus." The retail cuts had a greater ($P = 0.008$) protein percentage than the experimental diet regimes from our study. Ash percent had a greater value ($P = 0.009$) in forage finished beef with the exception of BFT which shows comparable ($P > 0.05$) values to FL. In previous study by Srinivasan et al., (1998), mineral content did not differ between diet types in *Semimembranosus* muscle.

Dietary regimen had no significant effect (P = 0.080) on pH. These results are found to be similar with Bidner et al. (1981, 1986) and Morris et al. (1997) studies where the comparison of pH from forage-finished beef and grain-finished beef did not have a significant effect.

Table 3. 5: The effects of dietary treatments on the least square means for percentage of moisture, ash, chemical intramuscular fat (IMF), protein and pH of raw samples (n= 30)

	Dietary treatments[1]						
Measurements	**FL**	**TC**	**BFT**	**Grass**	**COGF**	**SEM[2]**	**P-value**
Moisture, %	71.87^{b}	69.98^{c}	73.33^{ab}	74.91^{a}	74.69^{a}	0.57	<0.001
Ash, %	1.02^{bc}	0.99^{c}	1.01^{bc}	1.04^{ab}	1.06^{a}	0.01	0.009
IMF, %	5.84^{b}	7.94^{a}	4.43^{bc}	2.91^{cd}	2.21^{d}	0.67	<0.001
Protein, %	22.68^{b}	23.95^{a}	22.93^{b}	22.84^{b}	24.01^{a}	0.31	0.008
pH	5.71	5.72	5.78	5.91	5.87	0.06	0.080

[1]Grass-finished; Grass, Feedlot-finished; FL, Birdsfoot trefoil-finished; BFT, USDA Top Choice; TC and Certified Organic Grass-fed; COGF
[2]Pooled (largest) SE of LS mean
[a-d]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet.

Fatty acids

The fatty acid (FA) composition of beef samples was tabulated in Table 3.4. Additionally, the percentage of individual FAs were calculated on total FA concentration and are illustrated in Table 3.5. The concentration of all fatty acids was effected ($P \leq 0.004$) by diet except ($P = 0.398$) docosanoic acid (C22:0). Muir et al. (1998) determined that the fatty acid composition is altered with diet. The SFA, MUFA and PUFA concentrations were greatest ($P < 0.05$) in TC and least ($P < 0.05$) in COGF. Fat content is the primary determining factor of fatty acid concentration and composition (Scollan et al., 2006). The concentrations of SFA, MUFA and PUFA increases with increased intramuscular fat percentage (Table 3.3).

Table 3. 6: The effects of dietary treatment on concentration (mg/g homogenized samples) of individual fatty acids (FA). FA categories (Saturated fatty acids, SFA; monounsaturated fatty acids, MUFA; and polyunsaturated fatty acids, PUFA) from raw *Longissimus thoracis* steaks.

	Dietary treatments[1]						
Fatty acids (mg/g of homogenized samples)	**FL**	**TC**	**BFT**	**Grass**	**COGF**	**SEM[2]**	**P-value**
SFA	27.32^{ab}	37.41^{a}	21.42^{bc}	14.66^{cd}	8.14^{d}	3.81	< 0.001
C10:0	0.03^{b}	0.04^{a}	0.03^{cb}	0.02^{cd}	0.01^{d}	< 0.01	< 0.001
C12:0	0.03^{b}	0.05^{a}	0.03^{b}	0.02^{cb}	0.01^{c}	0.01	0.002
C14:0	1.46^{b}	2.34^{a}	1.21^{bc}	0.81^{cd}	0.40^{d}	0.25	< 0.001
C15:0	0.23^{b}	0.38^{a}	0.23^{b}	0.17^{bc}	0.11^{c}	0.03	< 0.001
C16:0	16.77^{ab}	21.33^{a}	12.45^{bc}	8.31^{cd}	4.27^{d}	2.38	0.001
C17:0	0.63^{b}	0.94^{a}	0.48^{bc}	0.32^{cd}	0.22^{d}	0.07	< 0.001
C18:0	8.02^{b}	12.03^{a}	6.82^{bc}	4.89^{cd}	3.02^{d}	1.14	< 0.001
C19:0	0.07^{c}	0.21^{a}	0.11^{b}	0.07^{cb}	0.06^{c}	0.01	< 0.001
C20:0	0.06^{b}	0.08^{a}	0.06^{ab}	0.04^{bc}	0.03^{c}	0.01	0.004
C22:0	0.01	0.01	0.02	0.01	0.01	< 0.01	0.398
MUFA	28.24^{ab}	35.59^{a}	18.35^{bc}	12.07^{cd}	6.65^{d}	4.04	< 0.001
C14:1 c9	0.32^{b}	0.48^{a}	0.21^{bc}	0.15^{c}	0.07^{c}	0.06	< 0.001
C16:1 t9	0.17^{b}	0.35^{a}	0.18^{b}	0.14^{b}	0.11^{b}	0.04	0.002
C16:1 c9	2.15^{ab}	2.55^{a}	1.45^{bc}	1.00^{cd}	0.52^{d}	0.30	< 0.001
C18:1t11	0.29^{b}	3.18^{a}	0.82^{b}	0.53^{b}	0.44^{b}	0.51	< 0.001
C18:1n9	24.45^{a}	28.15^{a}	15.21^{b}	9.89^{bc}	5.30^{c}	3.29	< 0.001
C18:1n7	0.88^{a}	0.89^{a}	0.47^{b}	0.36^{b}	0.21^{b}	0.10	< 0.001
PUFA	2.04^{b}	4.05^{a}	2.25^{b}	1.67^{b}	1.41^{b}	0.39	< 0.001
C18:2n6	1.22^{b}	3.06^{a}	1.06^{b}	0.84^{b}	0.63^{b}	0.32	< 0.001
C18:3 n6	0.02^{a}	0.02^{a}	0.01^{b}	0.01^{c}	0.01^{c}	< 0.01	< 0.001
C18:3 n3	0.23^{b}	0.20^{b}	0.52^{a}	0.27^{b}	0.26^{b}	0.04	< 0.001
C20:2 n6	0.03^{b}	0.06^{a}	0.03^{b}	0.02^{b}	0.01^{b}	0.01	< 0.001
C20:3n6	< 0.01^{b}	< 0.01^{b}	0.03^{a}	0.01^{b}	0.01^{b}	< 0.01	< 0.001
C20:4 n6	0.38^{ab}	0.40^{a}	0.34^{c}	0.35^{bc}	0.29^{d}	0.01	< 0.001
C20:5 n3	0.04^{d}	0.02^{e}	0.09^{b}	0.07^{c}	0.12^{a}	< 0.01	< 0.001
C22:6n3	0.02^{a}	0.01^{b}	0.02^{a}	0.02^{a}	0.02^{a}	< 0.01	< 0.001
CLA 9-11	0.08^{b}	0.28^{a}	0.16^{b}	0.08^{b}	0.06^{b}	0.03	< 0.001

TOTAL UNK	2.05[b]	3.14[a]	1.85[bc]	1.42[cd]	1.12[d]	0.23	< 0.001
PUFA:SFA	0.08[c]	0.10[b]	0.11[b]	0.12[b]	0.19[a]	0.01	< 0.001
n-6:n-3	5.74[b]	15.21[a]	2.41[c]	3.44[c]	2.33[c]	0.46	< 0.001

[1]Grass-finished; Grass, Feedlot-finished; FL, Birdsfoot trefoil-finished; BFT, USDA Top Choice; TC and Certified Organic Grass-fed; COGF
[2]Pooled (largest) SE of LS mean
[a-e]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet
UNK: Unknown

Palmitic acid (C16:0) and stearic acid (C18:0) were the major contributors to the overall concentration of SFA, each of which were greater ($P < 0.001$) in concentrate based diets (FL:16.77 and 8.02; TC:21.33 and 12.03) compared with Grass (8.31 and 4.81) and COGF (4.21 and 3.02). Meanwhile, the concentration in BFT of C16:0 (12.45) and C18:0 (6.82) was intermediate and similar ($P > 0.05$) to FL and Grass, but lower ($P < 0.05$) than TC and greater ($P < 0.05$) than COGF. Genetically similar, 18-month old steers resulted in meat that was more similar, while retail sources were distinctly higher (TC) or lower (COGF) in SFA than meat from BFT-finished steers. Interestingly, the percentages of stearic acid (Table 3.5) were found to be greater ($P < 0.05$) in forage-finished diet than grain-finished diet with BFT having intermediate percentage. O'Quinn, (2012) found increased percentages of stearic acid in Grass beef to be associated with increased off-flavors. Concentrations of C16:0 has been analyzed to have a positive correlation with desirable beef flavors (Baublits et al., 2009) which was found to be greater ($P = 0.001$) in grain-finished beef in this study closely followed by BFT. In the current study, grain-finished beef was more-liked ($P < 0.05$) than grass-finished beef with BFT having an intermediary score.

Table 3. 7: The effects of dietary treatments on percentages (mg/g homogenized samples) of individual fatty acids (FA) on overall FA, FA categories (Saturated fatty acids, SFA; monounsaturated fatty acids, MUFA; polyunsaturated fatty acids, PUFA; and total unknown FA, UNK) from raw *Longissimus thoracis* steaks.

	Dietary treatments[1]						
Fatty acid percentages	**FL**	**TC**	**BFT**	**Grass**	**COGF**	**SEM[2]**	**P-value**
SFA	47.65^{c}	48.92^{bc}	50.56^{ab}	51.21^{a}	50.41^{ab}	0.79	0.010
C10:0	0.05^{b}	0.06^{ab}	0.06^{a}	0.06^{ab}	0.06^{ab}	< 0.01	0.298
C12:0	0.05^{b}	0.07^{a}	0.07^{a}	0.08^{a}	0.07^{a}	< 0.01	0.009
C14:0	2.50^{b}	3.09^{a}	2.81^{ab}	2.73^{ab}	2.46^{b}	0.18	0.081
C15:0	0.41^{c}	0.53^{b}	0.55^{b}	0.60^{ab}	0.69^{a}	0.04	0.001
C16:0	28.91^{ab}	27.81^{b}	29.38^{a}	28.88^{ab}	26.02^{c}	0.58	0.002
C17:0	1.12	1.33	1.16	1.14	1.36	0.11	0.294
C18:0	14.37^{c}	15.63^{bc}	16.11^{bc}	17.27^{ab}	19.10^{a}	0.67	< 0.001
C19:0	0.12^{c}	0.28^{b}	0.25^{b}	0.26^{b}	0.36^{a}	0.02	< 0.001
C20:0	0.10^{c}	0.10^{c}	0.13^{b}	0.16^{b}	0.21^{a}	0.01	< 0.001
C22:0	0.02^{c}	0.02^{c}	0.04^{b}	0.05^{b}	0.08^{a}	0.01	< 0.001
MUFA	48.44^{a}	46.00^{b}	43.87^{bc}	42.67^{c}	40.16^{d}	0.89	< 0.001
C14:1 c9	0.52	0.65	0.51	0.49	0.41	0.06	0.111
C16:1 t9	0.30^{c}	0.44^{b}	0.44^{b}	0.51^{b}	0.72^{a}	0.03	< 0.001
C16:1 c9	3.64	3.44	3.45	3.44	3.08	0.21	0.452
C18:1t11	0.54^{c}	3.55^{a}	1.92^{bc}	1.89^{bc}	2.72^{ab}	0.52	0.003
C18:1n9	41.92^{a}	36.70^{b}	36.40^{b}	35.04^{b}	31.96^{c}	0.89	< 0.001
C18:1n7	1.51	1.23	1.15	1.31	1.27	0.10	0.078
PUFA	3.91^{c}	5.08^{bc}	5.57^{bc}	6.12^{b}	9.43^{a}	0.63	< 0.001
C18:2n6	2.36^{c}	3.78^{ab}	2.65^{c}	3.09^{bc}	4.18^{a}	0.37	0.006
C18:3 n6	0.04	0.03	0.03	0.03	0.05	0.01	0.106
C18:3 n3	0.42^{d}	0.25^{d}	1.25^{b}	0.97^{c}	1.68^{a}	0.07	< 0.001
C20:2 n6	0.06	0.07	0.06	0.06	0.08	0.01	0.057
C20:3n6	0.01^{c}	0.01^{c}	0.07^{a}	0.04^{b}	0.04^{b}	0.01	< 0.001
C20:4 n6	0.75^{c}	0.56^{c}	0.86^{bc}	1.30^{b}	1.99^{a}	0.17	< 0.001
C20:5n3	0.08^{cd}	0.03^{d}	0.21^{bc}	0.27^{b}	0.87^{a}	0.07	< 0.001
C22:6n3	0.04^{bc}	0.01^{c}	0.05^{b}	0.07^{b}	0.16^{a}	0.01	<0.001
CLA 9-11	0.15^{c}	0.34^{ab}	0.37^{a}	0.29^{b}	0.38^{a}	0.03	<0.001
TOTAL UNK	3.65^{c}	4.33^{bc}	4.49^{bc}	5.10^{b}	7.22^{a}	0.38	<0.001

[1]Grass-finished; Grass, Feedlot-finished; FL, Birdsfoot trefoil-finished; BFT, USDA Top Choice; TC and Certified Organic Grass-fed; COGF

[2]Pooled (largest) SE of LS mean
[a-d]Within a row, least squares means without a common superscript differ (*P<0.05*) due to diet
UNK: Unknown

Oleic acid (C18:1n9) had a considerable concentration among the MUFAs and was greater ($P < 0.001$) in concentration in grain-based diets when compared to forage-based diets. Oleic acid has been determined to be related with beef flavor desirability (Dryden and Maechello, 1970). Percentages of oleic acid were greatest ($P < 0.05$) in FL followed by TC, BFT and Grass which were similar ($P > 0.05$) and greater than COGF. O'Quinn (2012) revealed that percentages of oleic acid had the strongest positive correlation with desirable flavors in comparison with other MUFA. Percentage of hexadecenoic acid (C16:1n9) has been found to have a positive correlation with flavor desirability (O'Quinn, 2012). The percentage of hexedecenoic acid was not affected ($P = 0.0452$) by the diet but concentrations were affected ($P < 0.001$) and were found to be greater in grain-finished than forage-finished with BFT having intermediate concentrations. In the case of PUFA, TC had a significantly greater ($P < 0.001$) concentration than any other diets.

The ratio of PUFA: SFA has nutritional value with respect to coronary artery disease and cancer (Simopoulos, 2004; Williams, 2000). A ratio of PUFA:SFA above 4.5 is considered to combat disease (Warren et al., 2008). In our study, the ratio was not found to be above 4.5 but the ratios are greater ($P < 0.001$) in forage-finished beef than grain-finished beef. It has also been mentioned by Warren et al. (2008) that the ratio of n-6:n-3 FA should be below 4.0 to decrease chances of coronary diseases and cancer. According to our results, diet had an effect ($P < 0.001$) on the ratio of n-6:n-3 in beef.

Ratios in the forage-finished beef were less than 4.0 whereas the grain-finished beef had greater ratios ($P < 0.05$). Ecosapentanoic acid (EPA), is thought to have positive health impacts (Warren et al., 2008) and can have a negative impact on the flavor desirability of beef (O'Quinn, 2012). Every treatment in our study was different from each other with the concentration of EPA; however, forage-finished beef had a greater ($P < 0.001$) concentration of EPA than grain-finished beef. Omega-3 FAs have a negative impact toward desirable beef flavors which increases with feeding forage to cattle but also elevates undesirable and off-flavors in beef (French et al., 2000; Wood et al., 2004)

The ratio of PUFA:SFA (Table 3.4) in ribeye roll meat was greater for the grass-finished steers than for steers from the other treatments ($P < 0.01$). This is similar to work conducted by Warren et al., (2008) where these percentages were found to be greater ($P < 0.05$) in forage-finished beef. As per the Dietary Guideline Advisory Committee (2010), SFA having carbon chain lengths from C12 to C16 are classified as "cholesterol raising fatty acids." When reported as the percentage over total fatty acids, SFA has been repeatedly found to be higher in forage-finished when compared to grain-finished beef (Duckett et al., 2009, 2013; Leheska et al., 2008; Lorenzen et al., 2007). However, the total fat content averaged 2.5 percent (Table 3.3) in grass-based diets, so SFA consumption is less in case of forage finished beef. It can be indicated that the percentages of long chain saturated fatty acids (C18:0, C19:0, C20:0 and C22:0) were all found to be greatest ($P < 0.001$) in forage-based (BFT, Grass and COGF) diets. Linoleic acid (C18:2n6) was the most abundant PUFA in both grass-finished and grain-finished beef. Polyunsaturated fatty acids have been reported to increase up to 25% as a response to grass-feeding (Daley et al., 2010). As previously studied, linolenic acid (C18:3n3) has

been found to be elevated in grass based diets (Warren et al., 2008). Even in case of CLA 9-11, COGF had the greatest ($P < 0.001$) values followed by other grass based diets, which is in agreement with the study of fatty acids between diets by Dannenberger et al. (2005).

Volatile compounds

Volatile compound results are summarized in Table 3.6. Sixteen out of 39 volatile compounds were affected ($P \leq 0.044$) by diet. The primary mechanism for formation of the measured volatile compounds were the Maillard reaction or degradation of lipids during cooking (Dashdorj et al., 2015) Aldehydes are formed as a result of thermal oxidation of FA like oleic acid, linoleic acid, and linolenic acid (Cerny, 2007). While aldehyde odor threshold is low, they contribute to flavor (Elmore et al., 1999). Specifically, hexanal is formed via the oxidation of linoleic acid (Grosch, 1987). Hexanal was the most numerically abundant aldehyde across all the diets in our study and was found to be greatest ($P < 0.05$) in TC followed by FL which was greater but similar to BFT; COGF and Grass had the least values of hexanal. In this study, the concentration of hexanal did not have any meaningful increase or decerease with increase or decrease of the concentration of oleic acid, linolenic acid and linoleic acid though TC had the highest concentration of C18:1n9 and hexanal. It has also been explained by Elmore et al. (1999) that highly unsaturated FAs enter free radical reactions which break down to form smaller chain FA which in turn leads to the formation of flavor contributing volatile compounds. Concentration of hexanal increased with the increasing concentration of total PUFA. Though the concentration of decanal was low among the aldehydes, it was found to be affected ($P < 0.029$) by diet. Top choice had a significantly greater ($P < 0.05$)

concentration of decanal than all the other diet types. Strecker degradation of amino acids entering the Maillard reaction results in the formation of strecker aldehydes (Cerny and Grosch, 1992), none of the strecker aldehydes were found to be affected by the diet regimens.

Table 3. 8: The effects of dietary treatments on concentrations (ng/g of sample) of volatile compounds of cooked *Longissimus thoracis* steaks to medium degree of doneness (70 °C).

	Dietary treatments[1]						
Volatiles	**FL**	**TC**	**BFT**	**Grass**	**COGF**	**SEM[2]**	**P-value**
n-aldehydes							
Acetaldehyde	10.36	8.99	9.13	8.09	7.54	1.11	0.457
2-methyl- Propanal	4.06	3.26	3.52	3.22	3.99	0.47	0.588
Hexanal	27.88^{b}	42.58^{a}	29.53^{ab}	13.49^{c}	16.23^{bc}	4.85	0.002
Heptanal	2.37	3.01	2.45	1.90	1.84	0.48	0.445
Octanal	2.77	3.36	2.36	2.73	2.17	0.58	0.654
Nonanal	3.18	3.22	2.61	2.92	2.14	0.66	0.760
Decanal	0.10^{b}	0.44^{a}	0.08^{b}	0.14^{b}	0.10^{b}	0.10	0.028
Strecker aldehydes							
3-methyl- Butanal	11.92	8.75	11.78	10.29	9.70	1.42	0.467
2-methyl- Butanal	4.05	2.83	4.54	3.69	3.53	0.72	0.548
Benzaldehyde	2.04	1.82	2.32	1.84	2.32	0.17	0.118
Benzeneacetaldehyde	0.48	0.46	0.49	0.40	0.43	0.02	0.056
Ketones							
Acetoin	234.26^{abc}	368.78^{a}	82.07^{c}	135.26^{bc}	249.95^{ab}	54.96	0.011
2-Propanone	15.85^{ab}	19.72^{a}	9.85^{c}	10.21^{c}	13.47^{bc}	1.92	0.007
2,3-Butanedione	9.63^{ab}	14.51^{a}	4.47^{b}	11.49^{a}	9.79^{ab}	2.16	0.044
2-Butanone	11.55	10.23	9.75	8.43	11.01	1.22	0.438
2-Pentanone	1.18	1.17	1.02	0.83	0.97	0.09	0.064
2-Heptanone	3.51^{a}	2.22^{b}	1.86^{bc}	1.20^{c}	1.37^{bc}	0.30	<0.001
Sulfides							
Dimethyl sulfide	2.10	2.10	2.03	1.66	2.05	0.24	0.654
Disulfide, dimethyl	0.42	0.41	0.36	0.34	0.39	0.03	0.297
Carbon disulfide	6.60^{ab}	6.17^{ab}	3.17^{b}	3.45^{b}	9.63^{a}	1.36	0.016
Thiols							
Methional	1.55	1.43	1.65	1.21	1.44	0.13	0.179
Furans							
2-pentyl- Furan	1.22^{a}	1.17^{ab}	1.12^{bc}	1.04^{c}	1.05^{c}	0.03	0.003
Carboxylic acids							
Butanoic acid	3.85	5.23	4.26	3.20	1.99	0.89	0.150
Pentanoic acid	1.07^{a}	1.12^{a}	1.07^{a}	0.95^{b}	0.94^{b}	0.04	0.012
Hexanoic acid	1.56^{a}	1.43^{a}	1.22^{ab}	0.81^{bc}	0.74^{bc}	0.14	0.001

Heptanoic acid	0.59	0.61	0.58	0.57	0.58	0.01	0.146
Octanoic acid	0.32[b]	0.39[a]	0.39[a]	0.34[b]	0.34[b]	0.02	0.007
Alkanes							
Octane	1.47[a]	1.57[a]	0.74[b]	0.56[b]	0.86[b]	0.20	0.003
Pyrazines							
Methyl-Pyrazine	0.38	0.35	0.37	0.35	0.34	0.01	0.208
2,5-dimethyl- Pyrazine	0.51	0.44	0.50	0.46	0.44	0.02	0.051
Trimethyl-Pyrazine	0.42	0.38	0.42	0.39	0.39	0.01	0.087
2-ethyl-3,5-dimethyl-Pyrazine	1.21[ab]	1.14[c]	1.22[a]	1.15[bc]	1.16[bc]	0.02	0.036
Esters							
Acetic acid, methyl ester	2.04	1.59	3.27	4.94	3.91	1.54	0.543
Butanoic acid, methyl ester	1.31	1.46	1.66	1.25	1.23	0.18	0.406
Octanoic acid, methyl ester	0.23	0.26	0.37	0.33	0.26	0.05	0.326
Alcohols							
1-Hexanol	0.64[a]	0.55[a]	0.52[ab]	0.38[b]	0.38[b]	0.05	0.006
1-Heptanol	0.82[ab]	0.89[a]	0.75[bc]	0.65[c]	0.67[c]	0.05	0.003
1-Octen-3-ol	1.93[a]	1.02[b]	1.11[b]	0.69[b]	0.67[b]	0.18	<0.001
Alkenes							
2-methyl-1-Pentene	5.38	9.55	4.52	7.00	6.64	1.56	0.233

[1]Grass-finished; Grass, Feedlot-finished; FL, Birdsfoot trefoil-finished; BFT, USDA Top Choice; TC and Certified Organic Grass-fed; COGF
[2]Pooled (largest) SE of LS mean
[a-c]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet

There was no particular pattern found in the concentration of ketones among the forage-finished and grain-finished beef but 3-hydroxy-2-butanone, 2-propanone, 2,3-butanedione and 2-heptanone were found to be effected ($P \leq 0.044$) by diet regimens. These can be formed by the thermal oxidation of FA (Mottram, 1998) or simple sugar degradation (Elmore et al., 2005). Additionally, acetoin (3-hydroxy-2-butanone) is also an intermediate product of Maillard reaction (Dashdorj et al., 2015). 3-hydroxy-2-butanone and 2,3-Butanedione have been previously reported to have a positive correlation with flavor desirability (O'Quinn, 2012). Top choice, COGF and FL had

similar ($P > 0.05$) concentrations of 3-hydroxy-2-butanone which were greater ($P < 0.05$) than BFT and Grass. In the case of 2,3-butanedione, Grass and TC had similar ($P > 0.05$) concentrations which were greater ($P < 0.05$) than COGF, FL and BFT. A deterioration in beef odor has been associated with the concentration of 2-propanone (Insausti et al., 2002). Moreover, it has been associated with sour flavor and bitterness (O'Quinn, 2012). In our study, however, the concentration of 2-propanone was greater ($P < 0.05$) in grain-finished beef, which scored higher for flavor liking than forage-finished.

Volatile sulfur compounds may be derived from sulfur containing amino acids (Boylston et al., 2012). Carbon disulfide has been reported to be responsible for off-flavors in pork (Nam and Ahn, 2003). In the current study, carbon disulfide had the greatest ($P < 0.05$) concentration in COGF, the values of TC and FL were comparable which were greater ($P < 0.05$) than BFT and Grass.

Alcohols like 1-octen-3-ol, 1-hexanol, 1-heptanol along with 2-pentyl-furan have been all determined to be a result of oxidation of unsaturated FA (Back, 2007), specifically linoleic acid (Grosch, 1987), and have been reported to be higher in the grain-finished diets (Elmore et al., 2004). 2-Pentyl furan, hexanol and heptanol were observed to be greater ($P < 0.05$) in grain-based beef when compared to forage-finished beef, with BFT having an intermediate concentration which was in line with the concentration of linoleic acid. With the exception of BFT, which had the greatest ($P < 0.05$) concentration of 1-octene-3-ol, grain-finished beef had greater concentrations when compared to forage-finished beef.

Among the carboxylic acids, the concentrations of pentanoic acid, octanoic acid and hexanoic acid were impacted ($P \leq 0.009$) by diet. Pentanoic acid was found to be

lower ($P < 0.05$) in forage-finished beef with the exception of BFT, which had a greater pentanoic acid ($P < 0.005$), comparable to that of grain-finished beef. The concentration of hexanoic acid was significantly greater ($P < 0.05$) in FL and TC, while lower in Grass and COGF, with BFT having intermediate concentration. Octanoic acid had the greatest ($P < 0.05$) concentration in TC followed by BFT. Grass, COGF and FL had similar ($P > 0.05$) concentration of octanoic acid. Octane was noted to have a greater ($P < 0.05$) concentration in grain-finished beef when compared with forage-finished beef.

Strecker degradation of amino acids leads to the formation of alkylpyrazines (Mottram, 1998). It has also been stated that pyrazines are one among the compounds which are solely formed by the Maillard reaction (Elmore et al., 1999). Pyrazines are one of the major classes of nitrogen-containing volatiles, which form the end products of Maillard reaction (Back, 2007). These contribute to the roasted flavor of meat and have lower odor thresholds (Buttery and Ling, 1997). In our study, only 2-ethyl-3,5-dimethyl pyrazine was found to be affected ($P < 0.04$) by diet. The concentration of this particular pyrazine compound was found to be greatest ($P = 0.036$) in BFT followed by FL, Grass and COGF had intermediary values and TC had the lowest concentration.

Conclusion

From the results of this study we can conclude that finishing diet has an effect on some of the key components of acceptability and palatability. Although, in flavor liking BFT was rated similar to Grass, it was found to be similar to FL in tenderness, fattiness, juiciness, overall liking and quality rating, and was highly rated by consumers. The concentration of individual fatty acids of BFT-finished beef were intermediary to forage-finished beef and grain-finished beef, and often more similar to grain- than to grass-

finished meat. In contrast, BFT had similar ratios of PUFA:SFA and n-6:n-3 to those of Grass and COGF beef. In general, volatile compounds had an intermediate concentration in BFT as compared with forage-finished and grain-finished beef. Thus, it can be concluded that feeding different forages can result in differences in beef characteristics. In our case, BFT was more or less similar to FL and differed from "grass-finished" beef.

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CHAPTER 4

CONSUMER SENSORY EVALUATION AND CHEMICAL COMPOSITION OF BEEF FROM *GLUTEUS MEDIUS AND TRICEP BRACHII* STEAKS FROM CATTLE FINISHED ON FORAGE AND CONCENRATE DIETS

Abstract

Consumer evaluation, proximate data, Warner-Bratzler shear force (WBSF), fatty acid (FA) composition and volatile compounds were analyzed from the *Gluteus medius* (GM) and *Tricep brachii* (TB) muscles of cattle (n = 6) finished on conventional feedlot (FL) and forages including two treatments, a perennial legume, birdsfoot trefoil (BFT; *Lotus corniculatus*) and a grass, meadow brome (*Bromus riparius*, Grass). Diet had an effect on all attributes except ($P > 0.05$) aroma and flavor. In forage-finished beef, GM was more liked than TB ($P < 0.05$) in all attributes except juiciness, where they were similar ($P > 0.05$). Whereas in FL, both muscles were rated similar ($P > 0.05$) except in juiciness, where TB was more liked. As per the WBSF, GM was found to be more tender ($P < 0.05$) than forage-finished beef whereas TB was more tender ($P < 0.05$) in FL finished beef. All except fat percent was affected by the muscle type ($P = 0.092$). Except protein percent ($P = 0.267$), all other measured proximates of GM and TB were affected by the dietary treatment ($P \leq 0.034$). Moisture and ash percent were greater ($P < 0.05$) in forage finished beef whereas fat percent was greater ($P < 0.05$) in FL. The pH was effected ($P < 0.001$) by muscle type and TB was found to be greater ($P < 0.05$) than GM across all diets. The total concentrations of SFA, MUFA and PUFA were affected ($P \leq 0.032$) by diet. The concentration of SFA was greatest ($P < 0.05$) in FL and least in

Grass, with BFT having intermediate values. Forage-finished beef had lower ($P < 0.05$) values of MUFA than FL. In the case of PUFA, BFT had the greatest ($P < 0.05$) concentration and was similar ($P > 0.05$) to FL. The ratio of PUFA:SFA was significantly different ($P = 0.039$) between diets there was an interaction effect of diet and muscle on n-6:n-3 ($P = 0.016$). Forage-finished beef had lower ($P < 0.05$) values of PUFA:SFA when compared to FL. The ratio of n-6:n-3 was found to be greatest ($P < 0.05$) in TB of FL followed by GM of FL, GM had greater ($P < 0.05$) values than TB in forage-finished beef. 3-Hydroxy-2-butanone was the only volatile that differed due to the interaction effect ($P \leq 0.011$) where GM from BFT had the greatest ($P < 0.05$) concentration and TB from BFT and Grass had least concentration. Strecker aldehydes, ketones, pyrazines and methional were effected ($P \leq 0.036$) by muscle and found to have a greater concentration in GM than TB. Thus, GM and TB did not differ much in FL but there was a variation in sensory attributes and chemical composition among muscles within forage-finished beef.

Introduction

To increase availability and demand for beef, the beef industry has made an effort to utilize muscles from throughout the beef carcass (Philip, 2011). Various beef muscles have been reported to differ in flavor (Adhikari and Chambers, 2010), concentration of volatile compounds (Legako et al., 2015), consumer evaluated tenderness and WBSF (Hunt et al., 2014). Early studies have reported that round and chuck muscles are less tender when compared with muscle from the loin (McKeith et al., 1985). In a study by Stetzer et al. (2008), the muscles from chuck had greater percent fat than muscles from the round. Steaks from top sirloin (*Gluteus medius)* have been revealed to have more beef flavor identity than top blade (*Infraspinatus*) steaks (Yancey

et al., 2003). Additionally, top sirloin was found to have a greater sour flavor intensity than top blade (Yancey et al., 2003) Muscle type has been reported to effect perceived tenderness by consumer evaluation (Hunt et al., 2014).

Moreover, the effect of diet on the acceptability, palatability and chemical composition of meat has been studied extensively (Larick et al., 1987; Melton, 1990; Mandell et al., 1998; Warren et al., 2008; Corbin et al., 2015). Grain-feeding produces more acceptable flavor as compared to grass-finished beef (Melton, 1990). Although the FA composition of forage finished beef may positively impact health (Warren et al., 2008), PUFA and stearic acid percentages, high in grass-finished beef, have been reported to be positively correlated to off-flavors (O'Quinn, 2012). Previous study states that grain-finished beef has a higher fat content than forage-finished beef (Srinivasan et al., 1998). Volatile compounds that contribute to desirable flavor in beef like 3-hydroxy-2-butanone and 2,3-Butanedione have been reported to be elevated with increasing fat percentage (O'Quinn, 2012).

Birdsfoot trefoil, is a perennial legume that may be grown in the Intermountain West of the U.S. and can be used to graze cattle. Previous work indicated BFT-finished animals had greater ADG than forage legume but comparatively less than FL-finished cattle (Pitcher, 2015). Preliminary studies revealed that consumer evaluation for BFT-finished beef and FL-finished beef were similar (unpublished data). Little information is available about the effects of muscle type and different dietary treatments on the palatability and chemical properties of beef. This study concentrates on the effects of muscle type, diet regimen and the interaction of diet and muscle type on the acceptability

and chemical composition of beef from GM and TB muscles from cattle finished on FL, BFT and Grass.

Materials and Methods

Animal care and use

All animal procedures and protocols in this study were approved by the Utah State University (USU) Animal Care and Use committee, IACUC #A1997-10125-0.

Cattle finishing, harvest and grading

Eighteen spring-born (March 2012) and fall weaned (2012) Angus steers with similar initial weights (416 – 490 kg) were selected from the USU herd. Prior to the study, from weaning until the end of May 2013, cattle were fed a mixture of corn silage and alfalfa hay. Six grass-finished steers were put on tall fescue for 6 weeks from 1 June 2013 and then moved onto meadow brome until slaughter. Six of the 18 steers were put on BFT from the 1 June 2013 until slaughter. The remaining 6 steers were feedlot finished on a concentrate diet of high starch cereal grain from 1 June 2013 until slaughter. Cattle were harvested at approximately 18 months of age in September 2013. Hot carcass weight was determined.

Carcasses were chilled for 24-48 h at 2-4 °C and the quality and yield grade were determined based on USDA protocols (USDA, 1997). Lean maturity (A^{00} to A^{100}), skeletal maturity (A^{00} to A^{100}), fat thickness (cm), *Longissimus* muscle (LM) area (cm^2), hot carcass weight (kg) and percentage of kidney, pelvic and heart fat were determined. The carcass marbling scores were identified by comparison of visual marbling of the LM at the 12^{th} and 13^{th} ribs with official USDA marbling photographs (NCBA, Centennial, CO). The results from the analysis of the grading of the carcasses are shown in table 4.1.

Product collection and fabrication

Two different boneless subprimals; top sirloin butt (Institutional meat purchase apecification # 184; North American Meat Processors Association, 2010) and shoulder clod (Institutional meat purchase specification # 114; North American Meat Processors Association, 2010) were collected from each carcass (n=6 per treatment). Subprimals were wet-aged under vacuum for 14 d at 2-4 °C before producing retail steaks. Top sirloin steaks of 2.5 cm thickness were prepared following the removal of the *Biceps femoris, Gluteus accessorius* and *Gluteus profundus*, leaving only the GM muscle. *Infraspinatus* and *Teres major* muscles were removed from the aged shoulder clod and 2.5 cm thick beef arm steaks were produced from the *Triceps brachii* muscle only. All steaks were vacuum packaged and stored at -20 °C for further analysis.

Consumer Sensory evaluation

Sensory evaluation was conducted at the USU Department of Nutrition, Dietetics, and Food science as per an approved IRB protocol (IRB # 4760). Prior to consumer evaluation, steaks were thawed for 48 h at 4°C. Steaks were cooked as described by (Maughan, 2011) using Presto Tiltn' Drain electric griddles (Eau Claire, WI; 42096US) to a medium degree of doneness (70°C) determined with a digital thermometer (Atkins Temp tech digital thermometer, Middlefield, CT) equipped with a fast responding microneedle probe. The temperature was read by inserting the probe parallel to the surface of the griddle to the geometric center of the steak. Immediately after cooking all external fat, connective tissues and exterior muscles were removed from the cooked steaks leaving the *Longissimus thoracis* muscle for evaluation. Steaks were cut into 2.5 cm^3 cubes and served warm to consumers under red light to prevent visual bias.

Each sample was evaluated for smell, flavor, texture/tenderness, juiciness and overall liking on a hedonic scale of 9 with 1 being "dislike extremely" and 9 being "like extremely". A four point hedonic scale was used for quality where 1= unsatisfactory, 2= everyday quality, 3= better than everyday quality and 4= Premium quality. Six replicates comprising the five treatments were conducted with 120 panelists in each replicate. Each replicate occurred on separate days and only one animal replicate of each treatment was represented within each replicate.

Warner-Bratzler shear force

The Warner-Bratzler shear force method was used to determine objective tenderness (AMSA, 1995). Steaks were thawed for 24 h until an internal temperature of 4-6^{o} C was reached and then cooked as previously described. Cooked steaks were plastic wrapped on metal trays to prevent moisture loss and cooled overnight in the cooler (4-8 ^{o} C). Three hours before coring, samples were thawed at room temperature (24-26 ^{o}C). Six 1.27-cm cores per steak sample were removed parallel to the longitudinal orientation of the muscle fiber of the *Longissimus thoracis* muscle. Each core was sheared once on a TMS-Pro Texture Analyzer (FTC 500N ILC, Food Technology Corporation, Sterling, VA) with Warner-Bratzler shear force attachment using 200 mm/min crosshead speed and a 50 Kgf load cell. The instrument calculates the maximum force required to shear through the fiber.

Sample preparation for chemical analysis

Samples were thawed for 24-48 h at 4-8°C. All exterior muscles, connective tissue and external fat were removed leaving only the *Longissimus thoracis* muscle. Samples were cubed, submerged in liquid nitrogen for rapid freezing, placed in a blender

(VITA-MIX Corp, Cleveland, OH; model # VM0100A) and ground to form beef homogenates. Powdered samples were double packed in VWR sample bags (BPR-4590 VW1, Radnor, PA) and stored at -80°C for subsequent analysis (Martin et al., 2012).

Fatty acid analysis

Fatty acid methyl esters (FAME) were prepared by the method described by O'Fallon et al. (2007). Half a gram of meat homogenate was weighed into a screw cap glass vial along with 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 (Fisherbrand; made in Mexico; 14-962-26G). Vials were placed in a water bath (Precision Scientific, Cat # 67120, Chicago, IL) for incubation at 55 ºC. Hexane was used to extract FAME prior to analysis by gas chromatography (GC).

Separation of FAME was carried out by Shimadzu, GC-2010 (Japan) equipped with a HP-88 capillary column (100m X 0.25 mm X 0.20 µm; Agilent Technologies, Palo Alto, CA) and a flame ionization detector (FID). The GC was operated based on the conditions described 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: 2.47 mL/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

based on the similarity of retention times with the GC reference standards (Nu-chek Prep, Inc., Elysian, MN).

pH analysis

A Thermo Electron Corporation Orion 3 star benchtop pH-meter was used to determine the pH of homogenized samples. Five grams of homogenized samples was weighed in 50 ml (VWR, Radnor, PA) disposable culture tubes. Forty five milliliters of distilled water was added to the culture tube and vortexed until all meat was dispersed. A filter paper (VWR; Radnor, PA; North American Cat # 28320-085) folded in the form of a cone was immersed in the culture tube and then the pH electrode was immersed in the solution. (John et al., 2004).

Proximate analysis

A chloroform:methanol extraction method was used for determination of total fat, similar to Folch et al. (1957). One gram of homogenized sample was weighed in 50 ml centrifuge tubes (VWR; Radnor, PA; North American Cat # 89039-656) along with 3.2 ml of distilled water and vortexed. Eight milliliters each of methanol and chloroform were added to this and vortexed for 2 min. Four milliliters of water was added to the vortexed samples and vortexed again for an additional 30 sec. This mixture was centrifuged at 3500 rpm (rotations per minute) for 10 min. Four milliliter of the chloroform extract was pipetted out in labeled and pre-weighed disposable 50 ml culture tubes. These tubes were placed on heating blocks under the fume hood for 10 min for evaporation. These tubes were further exposed to 101 ºC in the oven to a constant weight. These samples were cooled in a desiccator and weighed. The total fat percentage was

calculated {fat % = [(weight of residue in g) / (weight of homogenized sample in g)] X 2 X 100}.

The AOAC method of oven-drying was used to determine the total moisture (950.46 and 934.01; AOAC, 1995). Percentage of moisture was calculated as {moisture % = [((pre-dry weight of sample) – (post-dry weight of sample)) / (pre-dry weight of sample)] X 100}

The AOAC ash oven method was used to determine the percent ash (923.03; 920.153: AOAC, 1995). Crucibles were kept in a drying oven for 30 min, cooled in a desiccator and then weighed and recorded before use. One gram of the homogenized samples were weighed in the crucibles. These crucibles were placed in the furnace at 550 ºC to 600 ºC for at least 24 hours. Incinerated samples were removed from the furnace and allowed to cool in the desiccator. These crucibles were re-weighed and the weight was recorded. The percentage of ash was calculated as {ash % = (ash weight / initial weight) X 100}

Protein percent was determined by the dye-binding method (AOAC Official method 2011.04; AOAC, 2011). Protein percentage was determined by using CEM Sprint™ Protein Analyzer (Matthews, NC) as described by Moser and Herman, (2011) in the "Determination" section.

Volatile compounds

Volatile analysis was carried out similar to Legako et al. (2015). Cooking protocols were the same as those previously described. Immediately after cooking, five 1.27-cm cores were extracted by coring perpendicular to the surface of the steak cut surface. Cores were then minced in a coffee-bean grinder (KRUPS, Medford, MA; Type

#F203). Five grams of the ground sample were weighed out in a 20 ml glass GC vials (Art # 093640-036-00; Gerstel; Linthicum, MD) and closed with a polytetrafluoroethylene septa and screw cap (Art # 093640-092-00; Gerstel; Linthicum, MD). Ten microliters of an internal standard (1, 2-dicholorobenzene; 0.801mg/ ml) was added and the vial was loaded by a Gerstel automated sampler (MPS, Linthicum, MD) for a 5 min incubation period at 65 ºC in the Gerstel agitator (500 rotations per minute) followed by 20 min of extraction where volatile compounds were collected from the headspace of cooked samples by solid phase microextraction (SPME) using an 85-µm film thickness carboxen polydimethylsiloxane fiber (Supelco, Bellefonte, PA). Extracted volatile compounds were injected on a VF-5 ms capillary column (30m × 0.25mm × 1.00µm; Agilent J&W GC Columns, Santa Clara, CA). The electron impact mode was set at 70 eV in the mass spectrometry which detected the ions within the range of 50-500m/z. Selective ion monitoring/scan mode was used to collect the data. External standard comparison was used to validate the volatile compound identity of ion fragmentation patterns. Quantitation was carried out by an internal standard calibration with authentic standards.

Statistical analysis

A generalized linear mixed model using Proc Glimmax procedure of SAS (Version 9.3, Cary. NC) was used for statistical analysis. Two-way analysis of variance was used to determine the effects of diet and muscle type. Carcass served as the experimental unit. For consumer evaluation data carcass and consumers were treated as random effects in the model. For all other measurements, carcass was treated as the

random effect in the model. Significant differences were considered at $P < 0.05$ and the denominator degree of freedom was calculated by the Kenward-Roger method.

Results and Discussion

Carcass evaluation

The data collected from carcass grading was analyzed and illustrated in Table 4.1. Live weight (kg), hot carcass weight (kg), fat thickness (cm), adjacent fat thickness (cm), ribeye area (cm^2), kidney, pelvic and heart (KPH) fat percentage and calculated yield grade (YG) were affected ($P \leq 0.20$) by diet. Feedlot-finished animals had the greatest ($P < 0.001$) live weight followed by BFT-finished beef and then grass-finished beef. Hot carcass weight (HCW) of FL and BFT were similar ($P > 0.05$) and were greater ($P < 0.05$) than Grass. Fat thickness ($P < 0.001$), adjacent fat thickness ($P < 0.001$), KPH % ($P = 0.004$) and calculated YG ($P = 0.020$) followed the same trend as HCW. In the case of ribeye area (cm^2), BFT and Grass had similar ($P > 0.05$) values which were lower ($P = 0.012$) than FL. Marbling and YG had no effect ($P > 0.05$) of dietary treatments.

Table 4. 1: Carcass characteristics of cattle (n=6 per diet) finished on different dietary treatments

	Dietary treatments[1]				
	FL	**BFT**	**Grass**	**SEM[2]**	**P-value**
Live weight, Kg	644.6[a]	556.8[b]	511.1[c]	13.7	< 0.001
HCW, Kg	370.3[a]	346.0[a]	291.0[b]	9.3	< 0.001
Marbling	493.3	438.3	406.7	34.3	0.227
Fat thickness, cm	1.1[a]	1.0[a]	0.5[b]	0.1	< 0.001
ADJ Fat thickness, cm	1.2[a]	1.1[a]	0.5[b]	0.1	< 0.001
Ribeye Area, cm²	83.3[a]	72.3[b]	66.7[b]	3.5	0.012
KPH, %	3.0[a]	2.6[a]	1.8[b]	0.2	0.004
Calculated YG	3.2[a]	3.4[a]	2.5[b]	0.2	0.020
Yield Grade	2.8	2.7	2.0	0.3	0.090

[1]Grass-finished; Grass, conventional feedlot-finished; FL, Birdsfoot trefoil-finished; BFT, USDA Top Choice TC and USDA Certified Organic Grass-fed COGF
[2]Pooled (largest) SE of LS mean
HCW, Hot carcass weight
ADJ, adjacent
KPH, Kidney pelvic and heart
YG, Yield grade

Consumer sensory evaluation and WBSF

The results obtained from the consumer evaluation and WBSF were tabulated and presented as Grass, Feedlot (FL), Birdsfoot trefoil (BFT) for diet types and *Gluteus medius* (GM) and *Tricep brachii* (TB) for muscle types in Table 4.2. Tenderness, fattiness, juiciness, overall liking and quality were affected ($P \leq 0.002$) by the diet and muscle interaction. None of the attributes were affected ($P > 0.05$) by the diet type in GM and TB except ($P = 0.018$) aroma. Flavor liking was not impacted ($P < 0.001$) by the muscle type. Muscle type affected ($P < 0.001$) all attributes except ($P > 0.05$) juiciness.

Table 4. 2: The effects of dietary treatments on the evaluation of samples rated by consumers (n=120) for smell, flavor, tenderness, fattiness, juiciness, overall and quality and Warner Bratzler Shear Force (WBSF) of Gluteus medius (GM) and Tricep brachii (TB) muscles

	Dietary treatments[1]									
	FL		BFT		Grass			P-value[5]		
	GM	TB	GM	TB	GM	TB	SEM[4]	Diet	Muscle	D × M
Aroma[2]	6.53^{x}	6.32^{x}	6.39^{y}	6.19^{y}	6.34^{y}	6.10^{y}	0.90	0.018	< 0.001	0.932
Flavor[2]	6.36	6.22	6.33	5.95	6.25	5.88	0.11	0.199	< 0.001	0.078
Tenderness[2]	6.22^{ab}	6.35^{a}	6.53^{a}	5.99^{bc}	6.28^{ab}	5.77^{c}	0.15	0.215	< 0.001	< 0.001
Fattiness[2]	6.11^{ab}	6.12^{ab}	6.18^{a}	5.92^{bc}	6.15^{ab}	5.72^{c}	0.13	0.362	< 0.001	0.002
Juiciness[2]	5.96^{b}	6.36^{a}	6.05^{ab}	6.04^{ab}	6.22^{b}	6.0^{ab}	0.18	0.800	0.256	< 0.001
Overall[2]	6.25^{a}	6.25^{a}	6.24^{a}	5.86^{b}	6.24^{a}	5.71^{b}	0.15	0.254	< 0.001	< 0.001
Quality[3]	2.35^{ab}	2.36^{ab}	2.39^{a}	2.19^{bc}	2.34^{ab}	2.09^{c}	0.07	0.208	< 0.001	< 0.001
WBSF (Kgf)	2.72^{bc}	2.58^{cd}	2.13^{d}	3.21^{ab}	2.66^{c}	3.65^{a}	0.20	0.008	< 0.001	0.003

[1]Grass-finished; Grass, conventional feedlot-finished; FL, Birdsfoot trefoil-finished; BFT, USDA Top Choice TC and USDA Certified Organic Grass-fed COGF
[2]Evaluated on a nine point hedonic scale (1 = dislike extremely and 9 = like extremely)
[3]Evaluated on a four point hedonic scale (1= unsatisfactory, 2= everyday quality, 3= better than everyday quality and 4= Premium quality
[4]Pooled (largest) SE of Least square means
[5]Observed significance levels for main effects of Muscle (M), Diet (D) and D X M interaction
[xy]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet
[abc]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to D X M interaction.

Flavor was impacted by muscle type ($P < 0.001$), where GM was consistently rated greater ($P < 0.05$) in flavor liking than TB across all diets. These results are similar to Carmack et al. (1995), where GM was found to have a more intense beef-flavor than TB as evaluated by a trained sensory panel from grain-finished beef. Previously, GM and TB were reported to have no flavor-desirability differences when evaluated by sensory panelist (McKeith et al., 1985).

Tenderness was found to interact ($P < 0.001$) between diet and muscle type. In our study, GM was observed to be rated more tender ($P < 0.05$) in forage-finished beef. While TB was scored to be more tender ($P < 0.05$) in grain-finished beef. These results are in contradiction to the Carmack et al. (1995) and McKeith et al. (1985) studies where GM and TB were found to be equally tender and did not have any significant differences as perceived by a trained panelist from grain-finished beef. However, in the palatability comparison between eleven muscles done by Rhee et al., (2004), TB was determined to be more tender than GM by trained sensory panelists.

Juiciness was determined to interact between diet and muscle type ($P < 0.001$). Under BFT, GM and TB were scored similarly ($P > 0.05$) to each other. In the case of FL, TB was rated juicier ($P < 0.05$) than GM, whereas in grass, GM was rated more juicy ($P < 0.05$) than TB. Similarly, a study by Carmack et al., (1995) regarding grain-finished beef found TB to be scored juicier than GM by trained panelists, and Mckeith et al. (1985) determined TB to be much juicier than GM from concentrate fed beef as evaluated by experienced sensory panelists (Blumer, 1963; Pearson, 1966).

Warner-Bratzler shearforce (WBSF) was affected by the interaction between diet and muscle type ($P = 0.003$). *Gluteus medius* from BFT-finished beef was found to be the most tender ($P < 0.05$), whereas TB from grass was observed to be the least tender ($P < 0.05$) muscle. Just as tenderness was perceived by consumers, GM was found to be more tender in the case of forage-finished beef and TB was noted to be more tender in FL beef. In our experiment, the result from the consumer evaluation for tenderness was aligned with the results from WBSF. In a study by Belew et al. (2003) of WBSF, GM was found to be more tender than TB were diet was not specified.

The consumer demographic data is presented in Table 4.3. The age and gender percentages were very similar to previous USU consumer tests (Lance, 2011). Also, the reason for a high percentage of people in the age from 18 to 29 years could be because the tests were conducted in the university.

Table 4. 3: Data on consumer demographic, most important palatability traits, type of beef and type of meat product

Categories	**Options**	**Percentages**
Age	18-29	72.83
	30-39	12.40
	40-49	7.10
	50-60	5.16
	over 60	2.51
Gender	Male	56.42
	Female	43.58
Ethnic origin	African-American	0.69
	Asian	11.43
	Caucasian/White	83.83
	Hispanic	3.62
	Native American	0.00
	Other	0.42
Income	Under $25,000	54.59
	$25,000 - $34,999	9.61
	$35,000 - $49,999	7.93
	$50,000 - $74,999	13.51
	$75,000 - $100,000	7.95
	More than $100,000	6.41
Education level	Non-high school graduate	0.42
	High school graduate	2.93
	Some College/Technical School	24.23
	College Bachelor	41.62
	Master Degree	17.00
	Professional Degree (e.g. MD, JD)	2.79
	Doctorate	11.02
Frequency of consumption of beef	Less often than once a year	0.42
	Once or twice a year	1.95
	Once every 4-6 months	3.35
	Once every 2-3 months	5.42
	Once a month/every 4 weeks	10.73

	Once every 2-3 weeks	29.66
	Once a week or more often	48.47
Most important palatability trait	Flavor	53.75
	Tenderness	37.05
	Juiciness	9.21
Type of beef	Grain-Fed	14.21
	Grass-Fed	18.66
	Doesn`t Matter	67.12
meat product	Beef	43.71
	Chicken	22.84
	Fish	6.82
	Lamb	8.09
	Pork	13.80
	Shellfish	0.70
	Turkey	2.09
	Veal	0.84
	Venison (Deer)	1.12

The data collected from consumer regarding the importance of factors like Brand, Country of Origin, Natural or Organic claims, Price and USDA grade of the meat is presented in Table 4.4. According to the data, price was rated the most important ($P < 0.001$) factor and brand of the product was rated the least important ($P < 0.001$) factor while buying meat.

Table 4. 4: Consumer rating on importance of various factors while buying meat.

Factors	**Importance**
Brand of meat	3.79^{e}
Country Of Origin	4.94^{c}
Natural or Organic claims	4.36^{d}
Price	7.70^{a}
USDA grade	6.67^{b}
SEM[1]	0.10
P-value	< 0.001

[1]Pooled (largest) SE of LS mean

Proximate analysis and pH

Moisture percentage, ash percentage, intramuscular fat (IMF) percentage and protein percentage were determined as a part of proximate analysis which are tabulated in Table 4.4 along with pH values. None of the factors were affected ($P > 0.05$) by the interaction of diet and muscle type but all the factors except IMF percent were affected ($P \leq 0.003$) by the muscle type. Only moisture percent, ash percent and IMF percent had an effect ($P \leq 0.034$) of diet.

Table 4. 5: The effects of dietary treatments on the least square means for percentage of moisture, ash, chemical intramuscular fat (IMF), protein and pH of raw samples (n= 18)

	Dietary treatments[1]									
	FL		**BFT**		**Grass**			**P-value[3]**		
	GM	**TB**	**GM**	**TB**	**GM**	**TB**	**SEM[2]**	**Diet**	**Muscle**	**D X M**
Moisture, %	73.23^{y}	74.32^{y}	74.23^{xy}	74.89^{xy}	75.03^{x}	75.91^{x}	0.38	0.007	0.003	0.770
Ash, %	1.05^{y}	1.02^{y}	1.11^{x}	1.07^{x}	1.11^{x}	1.05^{x}	0.01	0.004	< 0.001	0.400
IMF, %	3.99^{x}	4.32^{x}	2.92^{xy}	3.31^{xy}	2.60^{y}	2.80^{y}	0.39	0.034	0.092	0.900
Protein, %	22.64	21.48	22.83	22.16	22.43	21.54	0.27	0.267	< 0.001	0.520
pH	5.59	5.77	5.63	5.77	5.64	5.98	0.06	0.075	< 0.001	0.220

[1]Grass-finished; Grass, conventional feedlot-finished; FL, Birdsfoot trefoil-finished; BFT
[2]Pooled (largest) SE of LS mean
[3]Observed significance levels for main effects of diet (D), muscle (M) and diet X muscle interaction
[xy]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet

Moisture percentage was greatest ($P < 0.05$) in Grass and lowest in FL. Birdsfoot trefoil-finished beef had an intermediate moisture percentage. *Tricep brachii* was consistently found to have a greater ($P < 0.05$) percentage of moisture than GM across all the diet types. This is similar to results found in a study by Seggern et al. (2005) where TB had a higher value of percentage of moisture than GM.

Ash percentage was noted to be greater ($P < 0.05$) in forage-finished beef when compared to FL beef. Also, GM was repeatedly found to have a greater ($P < 0.05$) percentage of ash than TB. This is not in agreement with Seggern et al. (2005) study, where TB had a higher value of ash percentage than GM.

Moisture and marbling (IMF) have been observed to have an inverse relationship in several studies (Hedrick et al., 1981; Brackebusch et al., 1991; Seggern et al., 2005). Just as moisture percentage decreases, IMF percent increases. Intramuscular fat percentage was affected ($P = 0.034$) by diet type only. Grass-finished beef had the lowest ($P < 0.05$) fat percent and greatest moisture percent whereas FL had the greatest ($P < 0.05$) IMF percent but lowest moisture percent with BFT finished beef having an intermediate values for both. Protein percent and pH were effected ($P < 0.001$) by muscle type only. Protein percentage was found to be greater in GM as compared with TB whereas pH was noted to be lower ($P < 0.001$) in GM than TB.

Fatty acids

The fatty acid composition of beef muscles GM and TB from BFT, Grass and FL finished cattle are illustrated in Table 4.4. None of the FA were affected ($P > 0.05$) by diet and muscle interaction except ($P \leq 0.035$) arachidic acid (C20:0) and behenic acid (C22:0). The majority of MUFA and PUFA concentrations were affected ($P \leq 0.47$) by diet conditions pre-slaughter except ($P > 0.05$) some of the long chain FA like docosahexaenoic acid (DHA; C22:6n3) and palmitelaidic acid (C16:1t9). The total concentration of SFA had an effect ($P = 0.032$) of diet but individually only palmitic acid (C16:0) and margaric acid (C17:0) concentrations were affected ($P \leq 0.019$) by diet regimens. Only a handful of FA were affected ($P \leq 0.020$) by the muscle type namely

myristoleic acid (C14:1c9), trans-vaccenic acid (C18:1t11), eicosatrienoic acid (C20:3n6), arachidonic acid (C20:4 n6), ecosapentanoic acid (EPA; C20:5 n3) and conjugated linoleic acid (CLA 9-11). The intramuscular fat (IMF) percent is affected (P = 0.034) by diet and so are the total concentration of SFA, MUFA and PUFA. An increasing concentrations of SFA and MUFA aligns with increasing IMF percent. In PUFA, BFT has a greatest ($P < 0.05$) concentration followed by FL and least in Grass.

Table 4. 6: The effects of dietary treatment on concentration (mg/g homogenized meat samples) of individual fatty acids (FA), FA categories (saturated fatty acids, SFA; monounsaturated fatty acids, MUFA; and polyunsaturated fatty acids, PUFA) from raw *Gluteus medius* (GM) and *Tricep brachii* (TB) steaks.

Fatty acids (mg/g of homogenised samples)	**Dietary treatments[1]**									
	FL		**BFT**		**Grass**			**P-value[3]**		
	GM	**TB**	**GM**	**TB**	**GM**	**TB**	**SEM[2]**	**Diet**	**Muscle**	**D X M**
SFA	20.45^{x}	16.93^{x}	12.19^{xy}	14.13^{xy}	10.57^{y}	11.95^{y}	2.13	0.032	0.957	0.167
C10:0	0.02	0.02	0.01	0.02	0.01	0.02	0.00	1.060	3.950	0.730
C12:0	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.675	0.087	0.458
C14:0	1.00	0.93	0.64	0.83	0.57	0.71	0.13	0.179	0.239	0.325
C15:0	0.18	0.17	0.14	0.18	0.13	0.17	0.02	0.627	0.057	0.192
C16:0	12.58^{x}	10.63^{x}	7.16^{y}	8.26^{y}	6.06^{y}	6.78^{y}	1.36	0.019	0.955	0.241
C17:0	0.51^{x}	0.42^{x}	0.29^{y}	0.34^{y}	0.24^{y}	0.29^{y}	0.05	0.011	0.891	0.150
C18:0	6.04	4.66	3.84	4.35	3.45	3.85	0.58	0.070	0.646	0.066
C19:0	0.05	0.04	0.05	0.07	0.05	0.07	0.01	0.239	0.055	0.058
C20:0	0.04^{a}	0.03^{a}	0.03^{a}	0.04^{a}	0.03^{a}	0.04^{a}	<0.01	0.900	0.576	0.035
C22:0	0.01^{ab}	0.01^{b}	0.01^{ab}	0.01^{a}	0.01^{ab}	0.01^{a}	<0.01	0.665	0.069	0.006
MUFA	18.84^{x}	20.19^{x}	11.65^{y}	14.22^{y}	9.66^{y}	11.45^{y}	2.26	0.001	0.311	0.964
C14:1 c9	0.22^{x}	0.26^{x}	0.13^{xy}	0.19^{xy}	0.12^{y}	0.16^{y}	0.03	0.047	0.020	0.820
C16:1 t9	0.13	0.12	0.12	0.15	0.12	0.14	0.01	0.898	0.127	0.155
C16:1 c9	1.64^{x}	1.68^{x}	0.91^{y}	1.25^{y}	0.79^{y}	1.02^{y}	0.19	0.014	0.082	0.532
C18:1t11	0.21^{y}	0.18^{y}	0.39^{x}	0.56^{x}	0.35^{x}	0.48^{x}	0.05	0.002	0.017	0.051
C18:1n9	15.81^{x}	17.17^{x}	9.73^{y}	11.59^{y}	7.94^{y}	9.24^{y}	2.04	0.002	0.374	0.989
C18:1n7	0.82^{x}	0.78^{x}	0.38^{y}	0.47^{y}	0.34^{y}	0.41^{y}	0.07	<0.001	0.384	0.448
PUFA	2.24^{x}	2.04^{x}	2.25^{x}	2.33^{x}	1.87^{y}	1.91^{y}	0.09	0.005	0.706	0.200
C18:2n6	1.28^{x}	1.19^{x}	1.08^{y}	1.11^{y}	0.91^{z}	0.93^{z}	0.05	<0.001	0.685	0.263
C18:3 n6	0.02^{x}	0.02^{x}	0.01^{y}	0.01^{y}	0.01^{z}	0.01^{z}	0.00	<0.001	0.587	0.302

C18:3 n3	0.21^{z}	0.18^{z}	0.40^{x}	0.46^{x}	0.26^{y}	0.29^{y}	0.03	<0.001	0.202	0.068
C20:2 n6	0.03^{x}	0.03^{x}	0.02^{y}	0.02^{y}	0.01^{z}	0.02^{z}	0.00	0.001	0.345	0.259
C20:3n6	0.00^{z}	0.00^{z}	0.02^{x}	0.02^{x}	0.01^{y}	0.01^{y}	0.00	<0.001	0.015	0.085
C20:4 n6	0.53^{x}	0.48^{x}	0.48^{y}	0.42^{y}	0.47^{y}	0.44^{y}	0.02	0.046	0.002	0.803
C20:5 n3	0.07^{z}	0.05^{z}	0.12^{x}	0.11^{x}	0.11^{y}	0.10^{y}	<0.01	<0.001	<0.001	0.909
C22:6n3	0.02	0.03	0.03	0.03	0.02	0.03	<0.01	0.420	0.118	0.587
CLA 9-11	0.08^{y}	0.07^{y}	0.09^{x}	0.14^{x}	0.07^{xy}	0.10^{xy}	0.01	0.029	0.008	0.051
UNK	1.89^{x}	1.86^{x}	1.43^{xy}	1.74^{xy}	1.31^{y}	1.51^{y}	0.14	0.042	0.105	0.317
PUFA:SFA	0.12^{y}	0.13^{y}	0.20^{x}	0.19^{x}	0.19^{xy}	0.17^{xy}	0.02	0.039	0.267	0.348
n-6:n-3	6.30^{b}	6.72^{a}	2.91^{cd}	2.71^{d}	3.67^{c}	3.51^{cd}	0.28	<0.001	0.807	0.016

[1]Grass-finished; Grass, Feedlot-finished; FL, Birdsfoot trefoil-finished; BFT
[2]Pooled (largest) SE of LS mean
[3]Observed significance levels for main effects of diet (D), muscle (M) and diet X muscle interaction
[ab]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to DXM interaction
[xy]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet
UNK: Total Unknown FA
n-6:n-3: ratio of omega-6 FAs and omega-3 FAs

Finishing diet has an impact on the fatty acid composition of beef (Muir et al., 1998) which is reflected in the our results as well. Total SFA was found to be greatest ($P < 0.05$) in FL, lowest in Grass and intermediate in BFT-finished beef. The total MUFA was noted to be greater ($P < 0.05$) in FL when compared with forage-finished diet. There was no significant difference between the total MUFA concentration from BFT-finished and grass-finished beef. Total PUFA concentration of BFT-finished beef was similar to FL-finished beef which were greater ($P < 0.05$) than grass-finished beef. Palmitic acid (C16:0) and stearic acid (C18:0) were numerically the most abundant SFAs but only palmitic acid was affected by the diet type ($P = 0.019$). Palmitic acid was noted be greater ($P < 0.05$) in FL as compared with forage-finished beef just as reported by O'Quinn (2012). Also, it has been positively correlated to desirable beef flavors (Baublits et al.,

2009). Margaric acid (C17:0), previously correlated with off-flavors in beef (Baublits et al., 2009), was found to be greater in FL than BFT and Grass in this study. Oleic acid (C18:1n9), which had a considerable concentration contributing to the total MUFA, was observed be affected ($P = 0.002$) by diet regimens and found to be greater ($P < 0.05$) in FL than forage-finished diets. It has further been stated that oleic acid has the strongest correlation with flavor desirability in beef among MUFA (O'Quinn, 2012) and also the most advantageous MUFA that contributes to positive beef flavor.

Among the omega-3 PUFAs, linolenic acid (C18:3n3) was affected by diet ($P < 0.001$) and ecosapentanoic acid (C20: 5n3) was effected both by diet type ($P < 0.001$) and muscle type ($P < 0.001$). These PUFAs were found in greater concentration in the forage-finished beef than FL. These have been associated with undesirable and off-flavors in beef (French et al., 2000; Wood et al., 2004). The concentration of EPA was consistently noted to be higher in GM than TB.

A ratio higher than 4.5 of PUFA:SFA and lower than 4.0 for n-6:n-3 are recommended for health benefits against coronary artery diseases (Warren et al., 2008). The ratio of PUFA:SFA was found to be affected ($P = 0.039$) by diet treatments and n-6:n-3 ratio was affected ($P = 0.016$) by diet treatments and the interaction of diet type and muscle type. In our study, the ratio of PUFA:SFA was found to be greatest ($P = 0.039$) in BFT, followed by grass and least in FL. In case of n-6:n-3 ratio, the highest ($P = 0.016$) values were noted to be in TB from FL, closely followed by GM from FL. With respect to diet, n-6:n-3 ratios were greater in FL than forage-finished beef. In the case of FL, TB had a greater ratio whereas GM had a greater ratio in the forage-based finishing diets.

Fatty acid composition is reported as percent of total FA concentration in Table 4.5.When the percentages of FA were analyzed and compared, MUFA was found to be affected ($P = 0.044$) by muscle type and PUFA was affected ($P = 0.043$) by diet type and muscle type. Furthermore, the percentage of PUFA was found to be greater ($P < 0.05$) in forage-finished then FL diets. Also, GM repeatedly had a greater ($P < 0.05$) percentage of PUFA than TB across all the diets. The percentage of both DHA and EPA were observed to be greater ($P < 0.05$) and similar in forage-finished diets when compared to FL. Saturated fatty acids had no effects ($P > 0.05$) of dietary treatments, muscle type or interaction between diet and muscle type with respect to GM and TB muscles.

Table 4. 7: The effects of dietary treatments on individual fatty acids (FA) as a percentage of total FA concentration and FA categories (saturated fatty acids, SFA; monounsaturated fatty acids, MUFA; and polyunsaturated fatty acids, PUFA) of raw *Gluteus medius* (GM) and *Tricep brachii* (TB) steaks.

	Dietary treatments[1]									
	FL		**BFT**		**Grass**			**P-value[3]**		
Fatty acids, %	**GM**	**TB**	**GM**	**TB**	**GM**	**TB**	**SEM[2]**	**Diet**	**Muscle**	**D X M**
SFA	49.34	43.17	46.41	45.17	47.39	46.92	2.07	0.819	0.121	0.315
C10:0	0.05	0.05	0.06	0.06	0.05	0.06	0.00	0.095	0.040	0.678
C12:0	0.05^{y}	0.06^{y}	0.07^{x}	0.07^{x}	0.07^{x}	0.08^{x}	0.00	0.010	0.092	0.790
C14:0	2.40	2.34	2.42	2.57	2.48	2.78	0.17	0.478	0.177	0.287
C15:0	0.44^{z}	0.43^{z}	0.53^{y}	0.58^{y}	0.60^{x}	0.68^{x}	0.03	<0.001	0.015	0.111
C16:0	30.15	26.90	27.19	26.48	27.14	26.66	1.38	0.482	0.152	0.459
C17:0	1.23	1.07	1.12	1.11	1.11	1.12	0.07	0.877	0.262	0.274
C18:0	14.76^{z}	12.10^{z}	14.67^{xy}	13.89^{xy}	15.53^{x}	15.09^{x}	0.61	0.016	0.015	0.162
C19:0	0.13^{d}	0.12^{d}	0.21^{c}	0.24^{ab}	0.22^{bc}	0.26^{a}	0.01	<0.001	0.010	0.007
C20:0	0.10^{z}	0.08^{z}	0.12^{y}	0.12^{y}	0.14^{x}	0.15^{x}	0.01	<0.001	0.410	0.057
C22:0	0.03^{y}	0.03^{y}	0.04^{x}	0.04^{x}	0.05^{x}	0.05^{x}	<0.01	0.001	0.771	0.370
MUFA	44.81	51.27	44.58	46.63	43.79	45.38	1.96	0.210	0.044	0.402
C14:1 c9	0.52	0.64	0.49	0.64	0.51	0.64	0.04	0.960	<0.001	0.849
C16:1 t9	0.33^{c}	0.32^{c}	0.46^{b}	0.50^{b}	0.53^{a}	0.54^{a}	0.02	<0.001	0.262	0.286
C16:1 c9	3.90	4.23	3.46	4.11	3.54	4.05	0.22	0.484	0.005	0.692
C18:1t11	0.55^{d}	0.48^{d}	1.49^{c}	1.78^{ab}	1.58^{bc}	1.86^{a}	0.09	<0.001	<0.001	0.001
C18:1n9	37.53	43.60	37.19	37.98	36.06	36.66	2.22	0.166	0.180	0.387
C18:1n7	1.99^{a}	2.00^{a}	1.49^{b}	1.62^{b}	1.57^{b}	1.62^{b}	0.11	0.005	0.410	0.843

PUFA	5.85^{y}	5.55^{y}	9.01^{x}	8.21^{x}	8.82^{x}	7.70^{x}	0.68	0.008	0.043	0.609
C18:2n6	3.37	3.24	4.33	3.96	4.29	3.77	0.39	0.222	0.074	0.662
C18:3 n6	0.05	0.05	0.05	0.05	0.04	0.04	0.01	0.359	0.167	0.948
C18:3 n3	0.52^{z}	0.47^{z}	1.60^{x}	1.58^{x}	1.19^{y}	1.14^{y}	0.08	<0.001	0.176	0.866
C20:2 n6	0.07	0.07	0.08	0.08	0.06	0.06	0.01	0.286	0.948	0.975
C20:3n6	<0.01^{z}	<0.01^{z}	0.06^{x}	0.06^{x}	0.03^{y}	0.03^{y}	0.01	<0.001	0.118	0.434
C20:4 n6	1.40	1.32	1.92	1.54	2.25	1.78	0.19	0.038	0.009	0.320
C20:5 n3	0.18^{y}	0.15^{y}	0.51^{x}	0.39^{x}	0.52^{x}	0.38^{x}	0.04	<0.001	<0.001	0.143
C22:6n3	0.06^{y}	0.07^{y}	0.11^{x}	0.10^{x}	0.11^{x}	0.10^{x}	0.01	0.007	0.725	0.536
CLA 9-11	0.19^{d}	0.19^{d}	0.36^{bc}	0.45^{a}	0.32^{c}	0.39^{b}	0.02	<0.001	<0.001	0.002
UNK	4.70^{y}	4.84^{y}	5.62^{x}	5.91^{x}	6.05^{x}	6.01^{x}	0.28	0.003	0.473	0.748

[1]Grass-finished; Grass, Feedlot-finished; FL, Birdsfoot trefoil-finished; BFT
[2]Pooled (largest) SE of LS mean
[3]Observed significance levels for main effects of diet (D), muscle (M) and diet X muscle interaction
[a-d]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to DXM interaction
[xyz]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet

Volatile compounds

Thirty-nine volatile compounds were identified and analyzed from cooked GM and TB muscles. The results are summarized in Table 4.6. None of the aldehydes were affected ($P > 0.05$) by the diet type, muscle type or the interaction of both. The products of strecker degradation of amino acids that enter the Maillard reaction result in the formation of strecker aldehydes (Cerny and Grosch, 1992) specifically the breakdown of leucine and iso-leucine lead to the formation of 2-methyl butanal and 3-methyl butanal in meat (Elmore et al., 1999). These two compounds were effected ($P \leq 0.014$) by muscle type. The concentrations were consistently greater ($P < 0.05$) in GM in all the treatments which was more liked by the consumers for flavor and aroma (Table 4.2). These compounds have been reported to be positively associated with desirable beef flavors (O'Quinn, 2012) and roasted and appealing aromas (Zehentbauer and Grosch, 1997). The product of strecker degradation of phenylalanine is phenylacetaldehyde (Gasser and

Grosch, 1988). The concentration of phenylacetaldehyde was effected ($P = 0.001$) by muscle type and was greater ($P < 0.05$) in GM. This has previously been associated with earthy flavors in beef (O'Quinn, 2012).

Table 4. 8: The effects dietary treatments on concentrations (ng/g of sample) of volatile compounds (ng/g of sample) from cooked *Gluteus medius* (GM) and *Tricep brachii* (TB) steaks to medium degree of doneness (70°C).

	Dietary treatments[1]									
	FL		BFT		Grass			P-values[3]		
Volatiles	**GM**	**TB**	**GM**	**TB**	**GM**	**TB**	**SEM[2]**	**Diet**	**Muscle**	**DXM**
n-aldehydes										
Acetaldehyde	8.82	9.28	10.64	7.04	9.16	7.09	1.15	0.663	0.055	0.182
2-methyl- Propanal	3.62	4.64	5.14	3.36	4.53	3.08	0.64	0.733	0.137	0.053
Hexanal	20.80	19.09	22.57	13.52	14.49	16.13	3.21	0.313	0.222	0.194
Heptanal	1.76	1.33	2.77	1.51	1.61	2.63	0.49	0.351	0.555	0.050
Octanal	2.67	1.89	3.44	2.27	2.34	3.99	0.67	0.370	0.840	0.058
Nonanal	3.15	2.12	3.92	2.56	2.87	4.92	0.82	0.311	0.853	0.059
Decanal	0.14	0.11	0.14	0.14	0.12	0.12	0.01	0.108	0.241	0.325
Strecker aldehydes										
2-methyl-Butanal	7.39	6.88	8.48	5.23	8.11	3.61	1.39	0.622	0.014	0.279
3-methyl-Butanal	13.76	13.16	18.46	11.69	16.25	9.26	2.19	0.539	0.007	0.204
Benzaldehyde	2.44	2.74	3.31	2.37	3.07	2.32	0.32	0.697	0.064	0.103
Benzeneacetaldehyde	0.49	0.44	0.50	0.43	0.49	0.40	0.02	0.476	0.001	0.687
Ketones										
3-hydroxy-2-butanone	386.36^{b}	269.51^{bc}	674.33^{a}	185.79^{c}	282.50^{bc}	162.05^{c}	71.24	0.013	<0.001	0.011
2-Propanone	14.66	15.81	23.09	13.62	17.36	11.39	3.11	0.432	0.035	0.143
2,3-Butanedione	22.96	14.85	32.36	12.48	19.43	8.95	3.66	0.076	<0.001	0.206
2-Butanone	9.48	11.34	13.32	8.29	11.03	7.91	1.58	0.640	0.089	0.073
2-Pentanone	1.09	0.74	1.29	1.06	0.94	0.95	0.12	0.099	0.028	0.188
2-Heptanone	2.40	3.78	2.00	1.75	1.54	1.49	0.65	0.128	0.331	0.179
Sulfides										
Dimethyl sulfide	3.14	2.82	3.89	3.11	3.57	2.82	0.52	0.574	0.134	0.873
Dimethyl disulfide	0.47	0.52	0.52	0.49	0.40	0.37	0.07	0.123	0.995	0.756
Carbon disulfide	4.51	5.35	8.05	3.63	5.72	5.90	1.43	0.768	0.279	0.098
Thiols										
Methional	1.49	1.24	1.60	1.17	1.55	1.08	0.10	0.711	<0.001	0.500
Furans										
2-pentyl-furan	1.13	1.21	1.11	1.07	1.06	1.05	0.05	0.134	0.699	0.295
Carboxylic acids										
Butanoic acid	6.07^{b}	5.98^{b}	16.50^{a}	10.32^{a}	9.15^{b}	5.92^{b}	1.85	0.002	0.032	0.215
Pentanoic acid	1.20^{ab}	1.04^{ab}	1.39^{a}	1.16^{a}	1.13^{b}	1.01^{b}	0.06	0.044	<0.001	0.334
Hexanoic acid	1.64	1.81	2.15	1.74	1.39	1.24	0.27	0.126	0.423	0.371
Heptanoic acid	0.61	0.63	0.65	0.60	0.61	0.59	0.02	0.179	0.157	0.160
Octanoic acid	0.41^{b}	0.37^{b}	0.48^{a}	0.43^{a}	0.43^{ab}	0.43^{ab}	0.02	0.005	0.033	0.313
Alkanes										
Octane	0.89	1.55	1.24	1.08	0.90	1.45	0.25	0.964	0.077	0.179
Pyrazines										
Methyl-Pyrazine	0.53	0.49	0.51	0.41	0.43	0.36	0.04	0.062	0.029	0.706
2,5-dimethyl-Pyrazine	0.78	0.68	0.71	0.57	0.60	0.47	0.07	0.058	0.037	0.954

Trimethyl-Pyrazine	0.53	0.48	0.51	0.44	0.47	0.40	0.04	0.213	0.028	0.915
2-ethyl-3,5-dimethyl-Pyrazine	1.37	1.31	1.36	1.21	1.27	1.17	0.06	0.175	0.021	0.669
Esters										
Acetic acid, methyl ester	2.33	2.32	2.37	1.88	4.81	3.00	1.38	0.318	0.466	0.768
Butanoic acid, methyl ester	1.89	1.26	1.99	1.33	3.65	1.34	0.72	0.324	0.036	0.364
Octanoic acid, methyl ester	0.33[b]	0.28[b]	0.44[ab]	0.37[ab]	0.62[a]	0.37[a]	0.07	0.035	0.032	0.288
Alcohols										
1-Hexanol	0.39	0.51	0.42	0.36	0.37	0.40	0.06	0.412	0.442	0.229
1-Heptanol	0.76	0.87	0.86	0.78	0.74	0.72	0.05	0.164	0.945	0.198
1-Octen-3-ol	1.03	1.78	0.87	0.85	0.73	0.71	0.27	0.093	0.168	0.127
Alkenes										
2-methyl-1-Pentene	14.62	10.10	18.63	8.05	11.08	7.07	2.92	0.342	0.005	0.326

[1]Grass-finished; Grass, Feedlot-finished; FL, Birdsfoot trefoil-finished; BFT
[2]Pooled (largest) SE of LS mean
[3]Observed significance levels for main effects of diet (D), muscle (M) and diet X muscle interaction
[a-d]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to DXM interaction
[xyz]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet

Among all the ketones identified, only 3-hydroxy-2-butanone was found to have an affect ($P = 0.11$) of diet and muscle interaction. It was consistently found to be greater ($P < 0.001$) in concentration in the headspace of GM when compared to TB across all the diets. In case of GM, BFT had the greatest ($P = 0.011$) concentration of 3-hydroxy-2-butanone followed by FL and then Grass. Whereas, in case of TB, BFT and Grass had similar values which were lower ($P = 0.011$) than FL. 3-hydroxy-2-butanone and 2,3-butanedione is formed by the thermal oxidation of FAs (Mottram, 1998), simple sugar degradation (Elmore et al., 2005) or an intermediary product of Maillard reaction (Dashsorj et al., 2015). These two compounds have been positively correlated to desirable flavors in beef (O'Quinn, 2012). 2,3-butanedione in our study have been affected ($P < 0.001$) by muscle type only. The concentration in GM was repeatedly found greater ($P < 0.05$) than TB in all the diet types. 2-propanone has been reported to

positively correlate with bitter flavor (O'Quinn, 2012) and have been found to be responsible for off-odors in beef (Insausti et al., 2002). In our study, it was effected (P = 0.035) by muscle type only and was observed to have greater concentration in GM in forage-finished beef.

Sulfur-containing compounds like thiols are formed from the degradation of sulfur-containing amino acids. Methional was the only thiol identified in this study which was affected (P <0.001) and was greater in concentration in GM than TB. This has been previously identified in cooked beef (Shahidi et al., 1986). Also as stated by Gasser and Grosch, (1988) and Mottram, (1998), sulfur containing compounds have low threshold for odor and thus contribute greatly to flavor.

Alkylpyrazines are formed by the Strecker degradation of amino acids (Mottram, 1998) and also been identified as the compounds which are predominantly formed from Maillard reaction (Elmore et al., 1999). All the pyrazine compounds were affected ($P \leq$ 0.037) by the muscle type and were all found in greater concentration in GM as compared with TB in all the dietary treatments. Just like sulfur containing compounds they also have lower odor thresholds and also contribute to the roasted beef flavor (Buttery and Ling, 1997)

Conclusion

From the results of this study, it can be concluded that diet type and muscle type influences the acceptability and palatability of beef. Finishing diet interacted with muscle in sensory responses and chemical measurements. For the two forage-finishing diets, GM was rated superior for most characteristics; whereas in FL, both the muscles were similar for most attributes. Most of the volatile compounds that contribute desirable flavor in

beef were found to be greater in GM than TB across all the diets. Fatty acid compositions were greatly affected by diet regimens in GM and TB. Thus, it can be concluded that grain-feeding can mask the differences in these two muscles even though the chemical composition varies slightly. On the other hand, differences identified by consumers in samples of forage-finished beef were also reflected in the chemical composition. Consumers are more likely to perceive differences between these two cuts when they prepare or are served beef finished on forage diets.

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CHAPTER 5

CONCLUSION

It can be concluded from the consumer evaluation tests of ribeye steaks that beef finished on conventional feedlot was rated most highly. It can also be stated that not all forages produce similar and typically termed as “grass-finished” beef. The perennial legume, BFT, was rated similar to FL by consumers for all attributes, with the exception of flavor having lower values as compared with FL. The chemical composition measurements of BFT finished beef was found to be intermediary and similar to both FL and Grass beef in many cases.

For the GM and TB steaks, diet was found to interact with muscle type for both sensory and chemical measures. The GM and TB of FL did not differ much and were found to be similar in most measurements. Whereas, within forage treatments sensory response and chemical composition varied between the two muscles. These results also indicate that the meat quality of secondary beef muscles is more greatly impacted by forage diets. Thus, a more careful selection of muscles from forage finished beef is required in order to ensure quality.