EFFECTS OF FORAGE LEVEL IN FEEDLOT FINISHING DIETS ON CARCASS CHARACTERISTICS, SENSORY ATTRIBUTES, AND PALATABILITY OF JERSEY BEEF

Thesis

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ABSTRACT

Jersey cattle are recognized as being slower growing and having more yellow fat compared with other breeds, thus limiting the use of this breed for beef production. Because Jerseys are slower growing, they require additional time on feed to achieve acceptable market weights and yield acceptable hot carcass weights. Although Jerseys face challenges, the resulting product has other quality aspects that exceed the general beef population. Gaps in knowledge exist regarding the optimum forage level in finishing diets on growth performance, carcass characteristics, and beef palatability. The objective of this study was to evaluate the effects of forage level (12 vs. 24% sudangrass:alfalfa hay, DM-basis) in steam-flaked, corn-based finishing diets on carcass characteristics, palatability, and retail color stability of Jersey beef. Seventy-nine Jersey steers were blocked by weight and randomly assigned one of the following treatments for a 385-d trial period: Jersey low- 12% (JL; n = 38) or Jersey high- 24% (JH; n = 39) forage, DM-basis. Forty-eight hours postmortem (PM), strip loins were removed, vacuum-packaged, and aged at 3°C for 18 d PM. Following the aging period, steaks from the longissimus muscle were sliced, vacuum-packaged, and frozen (-20°C) until analyzed. Steers fed the low forage diet had greater ($P < 0.05$) backfat and tended to have greater dressing percent compared to steers fed the high forage diet. Live weight, HCW, LMA, and USDA Yield Grade were not affected ($P > 0.05$) by forage level. Steers fed the low forage diet on
average tended to bring a 6% greater value ($63.73 more per head) compared to steers fed the high forage diet. Objective color \((L^*, a^*, b^*)\) measurements decreased \((P < 0.05)\) over time of display across treatments. There were no differences among treatments for \(L^*\); however, overall during retail display JH had greater \((P < 0.05)\) \(a^*\) and \(b^*\) values than JL. Subjective color scores increased over time of display and were not affected by forage level. Warner-Bratzler shear force (WBSF) values and cooking loss were not affected by forage level. All measured sensory panel ratings were more favorable for JL steaks than JH steaks. These results suggest that forage level had minimal effects on carcass characteristics, color stability, and beef palatability; however, feeding a low forage diet decreases input cost and results in a greater value carcass. Finishing fed Jersey steers in conventional feeding systems can be accomplished meeting beef industry expectations and result in a high quality beef product.

Key words: beef; forage; Jersey; sensory
DEDICATION

Dedicated to my dogs.
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# TABLE OF CONTENTS

Abstract.................................................................................................................................ii

Dedication ...............................................................................................................................iv

Acknowledgements ................................................................................................................v

Vita ........................................................................................................................................vii

List of Tables ..........................................................................................................................xi

List of Figures .........................................................................................................................xii

Chapters:

1. Introduction .........................................................................................................................1

2. Review of Literature ............................................................................................................6

   Factors Limiting the Use of Jersey Genetics for Beef Production ......................................6

   Color of Bovine Subcutaneous Adipose Tissue .................................................................8

   Effects of Time on Feed on:

       Performance ....................................................................................................................12

   Carcass Characteristics ....................................................................................................13

   Lean and Subcutaneous Fat Color ....................................................................................14

   Meat Composition ...........................................................................................................15

   Palatability ..........................................................................................................................15

   Effects of Forage Level in Feedlot Diets on:

       Performance ....................................................................................................................17
3. Effects of forage level in feedlot finishing diets on carcass characteristics, Sensory Attributes, and palatability of Jersey beef ................................................................. 25

Abstract ......................................................................................................................... 25

Introduction ...................................................................................................................... 27

Materials and Methods .................................................................................................. 28

Animals, Diets, and Experimental Design ....................................................................... 29

Carcass Data Collection .................................................................................................. 30

Carcass Value Determination .......................................................................................... 30

Objective Carcass Color ................................................................................................ 31

Strip Loin Transportation and Aging .............................................................................. 31

Strip Loin Processing ....................................................................................................... 31

Proximate Composition .................................................................................................. 32

Retail Display Conditions ............................................................................................... 33

Color Measurements ....................................................................................................... 33

Thawing and Cooking ..................................................................................................... 34
LIST OF TABLES

Table

1. Composition of experimental diets feed to Jersey steers ..........................................................50

2. Effect of two (High = 24% sudangrass hay (50):alfalfa hay (50); Low = 12% sudangrass hay (50):alfalfa hay (50) of the diets, DM basis) forage levels on slaughter weight and carcass characteristics of Jersey steers ...........................................................................51

3. Effect of two (High = 24% sudangrass hay (50):alfalfa hay (50); Low = 12% sudangrass hay (50):alfalfa hay (50) of the diets, DM basis) forage levels on marbling scores, USDA Quality and Yield Grade ..................................................................................52

4. Effect of two (High = 24% sudangrass hay (50):alfalfa hay (50); Low = 12% sudangrass hay (50):alfalfa hay (50) of the diets, DM basis) forage levels on initial carcass objective color and meat quality traits of Jersey steers .................................................................53

5. Effect of two (High = 24% sudangrass hay (50):alfalfa hay (50); Low = 12% sudangrass hay (50):alfalfa hay (50) of the diets, DM basis) forage levels on chemical composition of the longissimus muscle from Jersey strip loins .................................................................54

6. Effect of two (High = 24% sudangrass hay (50):alfalfa hay (50); Low = 12% sudangrass hay (50):alfalfa hay (50) of the diets, DM basis) forage levels on Warner–Bratzler shear force values and cooking loss of strip loin steaks from Jersey steers ..........60

7. Correlation coefficients for live weight and carcass traits of Jersey steers .................................63

8. Correlation coefficients for meat quality traits of Jersey carcasses ..............................................64

9. Correlation coefficients for consumer and semi-trained sensory panel attributes, Warner–Bratzler shear force value, and marbling score of Jersey steaks ........................................65
LIST OF FIGURES

Figure

1. *Longissimus dorsi* display color scores of steaks from Jersey steers fed two different forage levels during retail display .............................................................55

2. *Longissimus dorsi* discoloration scores of steaks from Jersey steers fed two different forage levels during retail display .................................................................56

3. *Longissimus dorsi* Hunter $L^*$ values of steaks from Jersey steers fed two different forage levels during retail display .................................................................57

4. *Longissimus dorsi* Hunter $a^*$ values of steaks from Jersey steers fed two different forage levels during retail display .................................................................58

5. *Longissimus dorsi* Hunter $b^*$ values of steaks from Jersey steers fed two different forage levels during retail display .................................................................59

6. Consumer sensory evaluation means of steaks from Jersey steers fed two different forage levels ........................................................................................................61

7. Semi-trained sensory evaluation means of steaks from Jersey steers fed two different forage levels ........................................................................................................62
CHAPTER 1

INTRODUCTION

Male Jersey calves are of very little or no value at birth to Jersey producers and most of these calves go into veal production or in some cases euthanized at a day of age. These common systems increase consumer concerns about the welfare of these animals. As a proactive response, Jersey producers are investigating the potential of Jersey steers to be used in beef production. The use of Jersey genetics for beef production has been studied in both grain based and grass-based systems; however, there is a lack of information regarding the optimum forage level in feedlot diets for finishing Jersey steers. Furthermore is it economically feasible to finish Jersey steers in conventional feeding systems for beef production. Increasing the use Jersey steers for beef production requires more information on the effects of higher forage levels on muscle and fat characteristics and beef palatability.

The Jersey breed is small-framed, exhibits little genetic variation, and when compared to eight British cattle breeds, Weiner et al. (2004) reported that the Jersey breed was one of the best defined and most distinctive of the breeds (i.e. greatest measure of breed integrity). This indicates that differences do exist for muscle growth, meat, and fat characteristics of dairy and beef breeds. Jersey cattle are characterized as slower growing compared with Holsteins or other beef breeds (Smith et al., 1976; Barton et al.,
1994; Burke et al., 1998; Albertí et al., 2008). Thus, these animals may need an extended period of time on feed to achieve acceptable market weights. Jersey cattle currently finished in feedlot operations receiving 8 to 12% forage, do not perform well due to poor genetic growth potential, and are often times discounted for yielding light hot carcass weights (Albertí et al., 2008). It has been demonstrated that lower energy diets, those with increased forage content, would improve slaughter weights relative to high energy diets when cattle were fed to a constant composition end point (Crouse et al., 1984). Additionally, feeding high starch diets to these long-term fed cattle might increase the incidence of digestive disorders (i.e. rumen acidosis, rumenitis and bloat); therefore, increasing the forage level in feedlot diets would mitigate these digestive disorders because it stimulates rumination and increases salivary buffering capacity (Owens et al., 1998).

The color of lean and external fat greatly influences consumer purchasing decisions and visual acceptability (Dikeman, 1990; Kropf, 1980), and consumers relate the bright red color to freshness, while discriminating against brown meat (Morrissey et al., 1994). While there are many factors which can impact meat quality and color, the diet fed to the animal is one of the most important production factors (Kerry et al., 2000). Forage-finished cattle have darker lean color (Smith, 1990) and an increased yellow color of subcutaneous fat due to greater amount of β-carotene (Smith, 1990; French et al., 2000; Realini et al., 2004) within the lean. One of the major issues limiting the high demand of Jersey beef in the marketplace is that Jersey carcasses are recognized in the
beef industry as having more yellow fat than other breeds (Morgan and Pickering, 1969; Barton et al., 1994; Pitchford et al., 2002). Fortunately, this can be managed to an extent, as finishing cattle on a grain-based diet results in more white fat compared with pasture-finishing (Pitchford et al., 2002). Although incorporating higher forage levels in feedlot diets may increase carotenoid consumption and result in more yellow fat, it may also increase antioxidant levels (vitamin E) in the lean, which could improve color stability during retail display. One of the primary functions of vitamin E is to maintain and protect biological membranes from oxidative damage (Rice and Kennedy, 1988).

Consumers indicated that beef tenderness is an important attribute (Huffman et al., 1996), and they are willing to pay more for tender beef products (Boleman et al., 1997; Miller et al., 1998). Because Jersey cattle are slower growing (Smith et al., 1976; Barton et al., 1994; Burke et al., 1998; Albertí et al., 2008), they might require an extended period of time on feed to reach acceptable harvest weights, thus resulting in increased maturity compared to their counterparts. Animal age is positively associated with shear force and negatively associated with sensory tenderness scores (Shorthose et al., 1990), even in studies with a narrow age range (15 to 18 mo of age; Wulf et al., 1996). There has been research indicating beef from Jersey steers under pastoral conditions were superior in tenderness compared to other breeds (Purchas and Barton, 1976); however, there is limited information regarding Jersey beef palatability under feedlot conditions receiving altered forage levels.
Intramuscular fat, has been reported to be highly correlated to sensory tenderness ratings (Seideman et al., 1998), juiciness, and beef flavor (Platter et al., 2003), and is currently an important determinant of carcass value for markets which desire meat with a high degree of marbling (Baud et al., 1998). Although other studies have found stronger relationships, that the degree of marbling accounted for 5 to 10% of the variation in tenderness (Blumer, 1963; Pearson, 1966; Parrish, 1974; Jeremiah, 1978). Jersey cattle demonstrate the potential to produce a highly-marbled product (Alberti et al., 2008), thus may create the opportunity for a niche market. Pitchford et al. (2002) reported that Jersey beef had similar levels of intramuscular fat as Wagyu with a lower melting point compared to other breeds such as Angus. Beef from cattle finished on low levels of forage was more tender and juicer when compared to beef from cattle finished on higher levels of forage (Jenschke et al., 2008); however, there is limited information evaluating the impacts of increasing forage in feedlot diets on Jersey beef quality and the effects on sensory attributes.

Although the Jersey breed demonstrates challenges in terms of beef production, gaps in knowledge exist about the use of Jersey genetics for beef production under feedlot conditions. The objective of this study was to evaluate the effects of forage level (12 vs. 24% sudangrass:alfalfa hay, DM-basis) in steam-flaked, corn-based finishing diets on carcass characteristics, palatability, and retail color stability of Jersey beef. We hypothesized that (1) variations in forage level will affect carcass characteristics and sensory attributes of Jersey beef and (1) feeding high forage would increase carcasses
with yellow carcass color (3) steaks from Jersey steers receiving the high forage diet (24% forage, DM-basis) will maintain color stability better than steaks from Jersey steers receiving the low forage (12% forage, DM-basis).
CHAPTER 2

REVIEW OF LITERATURE

Factors limiting the use of Jersey genetics for beef production

The use of Jersey genetics for beef production is limited by several factors (1) growth performance, (2) carcass weight, and (3) carcass fat color. Finished on forage based systems, Jersey or Jersey-sired calves have demonstrated slower rates of gain compared with Holsteins, Friesians or beef breeds (Barton et al., 1994; Burke et al., 1998; Lehmkuhler et al., 2008). Additionally, in recent years, Albertí et al. (2008) reported Jerseys were one of the slowest growing (ADG, ~1.08 kg/day) compared with 15 European breeds under feedlot conditions. This slow rate of gain observed in Jersey cattle greatly impacts feed costs, operation profitability, and an animal’s end, or market weight. In addition, because producers are paid by the pounds of carcass hanging on the rail, lightweight carcasses (< 273 kg) do not fit the processor’s specifications, and are severely discounted. The 2000 National Beef Quality Audit outlined a range of acceptable carcass weights (~295 to 386 kg) as the target weight for the industry (NCBA, 2000). In a recent study completed by Lehmkuhler et al. (2008), comparing dairy beef genetics on a high- and low- roughage diet, Holsteins had heavier hot carcass weights; 333 vs. 208 kg Holstein and Jersey, respectively), greater dressing percentages, and larger longissimus muscle area when compared to Jersey cattle, although Jerseys tended to have less backfat;
whereas marbling scores and yield grades did not differ between Jerseys and Holsteins ($P > 0.05$). Albertí et al. (2008) reported the Jersey breed had the lightest hot carcass weight (189.7 kg), the lowest dressing percentage (50.1%), and the smallest muscle area (24.9 cm$^2$) of 15 European breeds. The color of lean and external fat greatly influences consumer purchasing decisions and visual acceptability (Dikeman, 1990; Kropf, 1980). Jersey carcasses are recognized in the beef industry as having more yellow fat than other breeds, which has been demonstrated under both pastoral (Morgan and Pickering, 1969; Barton et al., 1994) and feedlot conditions (Pitchford et al., 2002). Factors affecting carcass fat color, and specifically why Jerseys have more yellow carcass fat color than other breeds, will be explained later.

Although, Jersey cattle face challenges for high demand for beef production they do have potential to produce a high quality, tender beef product. Killinger et al. (2004) observed that consumers are willing to pay a premium for beef with Moderate (USDA Choice$^+$) or Modest (USDA Choice$^o$) marbling compared with Slight (USDA Select$^-$/+) marbling. Under a grain based feeding system, Jersey carcasses had similar levels of intramuscular fat (IMF) as the highly-prized Wagyu and Angus. Also, Jersey and Wagyu had similar softer fat, with a 6% lower melting point compared with other breeds (Pitchford et al., 2002); however, a gap in knowledge exits for the effects altered forage levels and long feeding time on Jersey beef palatability.
Color of bovine subcutaneous adipose tissue

The color of bovine subcutaneous adipose tissue (carcass fat) is an important determinant of carcass quality and also beef grading systems in the United States, Canada, Japan and Australia (Walker et al., 1990; Price, 1995; UNECE, 2004). Crouse et al. (1984) reported in the United States, that lean and fat color are increasing important in quality grading. Beef carcasses with excessive yellowness are often discounted and less desirable (Walker et al., 1990; Yang et al., 1992). There are negative perceptions related to yellow fat in which consumer purchasing decisions are impacted, with the belief that carcasses with yellow fat come from older animals, thus a less tender product or an animal was in a diseased state at the time of harvest (Anonymous, 1993). In a recent survey of 900 individuals from Japan, Korea, Taiwan, Hong Kong and Mexico, it was reported that 80% of the participants favored beef with white fat or light amber colored fat (Anonymous, 2007).

Carotenoids are present in photosynthetic organisms and higher plants although their presence is often masked by chlorophyll. Forages are a rich source of carotenoids. These chemical compounds posses a variety of distinctive yellow and orange color and cause yellow color to develop in the fat of bovine when forages are consumed regularly. The principal carotenoid associated with yellow fat coloration is β-carotene (Morgan and Everitt, 1969; Strachan et al., 1993; Zhou et al., 1993), because the main storage sites for β-carotene is the adipose tissue of mammals (Kaplan et al., 1990). Although carotenoids
are not essential in animal nutrition, β-carotene is highly important because it has pro-vitamin A activity and is recognized as a physiological antioxidant (Lejeune et al., 2000).

Numerous factors affect carotene concentrations including species and cultivar, stage of growth, fertilizer treatments, pesticides and intensity of solar radiation (Lee, 1988). The carotene concentration in forages is most often greater in fresh pasture, and decreases following harvesting and conservation (Bernstein and Thompson, 1947; Walsh and Hauge, 1953; Nehring and Hoffmann, 1967). Most green leafy forage will contain between 200 to 700 mg carotene/kg DM (Coultate, 1996) and alfalfa hay will contain 77 to 88 mg carotene/kg DM (McDowell et al., 2000).

The absorption of β-carotene via the small intestine is dependent on three steps: (1) absorption of the enterocyte brush borders membrane level, partially via the cholesterol transporters SR-BI and CD36 (During et al., 2005; Felipe et al., 2005), but also via passive diffusion (Yonekura et al., 2007); (2) enzymatic conversion of β-carotene in a centric or eccentric fashion by the β-carotene 15,15′-monooxygenase BCMO1 (releasing retinol) or by the β-carotene 9′,10′dioxygenase, BCDO2 (releasing β-apo-10′carotenal and β-ionone), respectively (von Lintig et al., 2005); lastly, (3) secretion of chylomicron into the lymph (Harrison, 2005). Recent research has looked at the association between fat color in bovine adipose tissue color and genetic variation in the β-carotene 9′, 10′dioxygenase gene (Tian et al., 2009) to determine if β-carotene 9′, 10′dioxygenase (BCO2) is involved in the control of adipose tissue in cattle.
The color of bovine subcutaneous adipose tissue (carcass fat) is influenced by intrinsic factors which include cattle age, gender, and breed. Shemeis et al. (1994) reported that older cull cows had more yellow carcass fat. Buchanan-Smith and Mandell (1994) reported that no yellow fat was observed in young cattle, less than 2 years of age, fed forages. Walker et al. (1990) conducted a comprehensive study of beef carcass and reported that females had more yellow subcutaneous fat than steers. Generally, dairy breeds are recognized as having more yellow fat than beef breeds. Kruk et al. (1998) and Siebert et al. (2003) found that pure Jerseys had higher β-carotene concentrations in their subcutaneous fat than Limousin and as result produced more yellow fat. Barton and Pleasants (1993) compared different breeds of steers finished on pasture, and harvested at 30 mo of age, and reported that beef breeds had significantly more carcasses with white fat than dairy breeds and the Jersey breed had more carcasses with yellow fat than any other breed. Pitchford et al. (2002) compared genetic variation of fat from crossbred cattle finished in the feedlot, and reported that Jersey crosses had higher fat color scores (more yellow) than other breeds.

Diet is the most important extrinsic factor which affects carcass fat color, but the extent of its influence depends on the duration of feeding. Traditional grass-based beef operations are positively associated with yellow fat (Wood and Fisher, 1997). Grazing cattle consume leafy green forages and accumulate carotenoids (β-carotene) in their adipose tissue which results in yellow color (Strachan et al., 1993; French et al., 2000; Realini et al., 2004). Management strategies to mitigate carotenoid concentrations
(resulting in yellow fat) include grain-finishing, because high grain diets are a poorer source of β-carotene. Shaake et al. (1993) reported that finishing cattle on grain-based diets resulted in more white fat compared with pasture-finishing. Pitchford et al. (2002) discovered that β-carotene concentrations were diluted, and fat color scores were improved, by grain-finishing for a short period of time (around 70 d), and Strachan et al. (1993) found the fat color scores were decreased after 35 d of grain feeding period of time (around 70 d) and a trend of further reduction in fat color scores with longer feeding times. Dunne et al. (2006) found that the effect of diet on fat color was dependent on the duration of feeding; and thus, although grass-fed heifers tended to have the most yellow fat compared with silage- and concentrate-fed heifers, the differences observed between grass- and silage-fed heifers decreased over time.

Although diet is the major contributor of yellow fat color, there are breed genetic differences in the control of β-carotene (Kruk et al., 1998), thus different breeds require various lengths of time on grain diets to reduce the yellow fat color and some breeds may not have any reduction in yellowness (i.e. Jersey). Dairy breeds are generally recognized as having more subcutaneous yellow colored fat than British breeds. Kruk et al. (1998) discovered that pure Jersey cows had higher β-carotene concentrations in their subcutaneous fat and more yellow fat color than either Jersey-Limousin or pure Limousin cows. One of the major issues limiting the high demand of Jersey beef in the marketplace is that Jersey carcasses are recognized in the beef industry as having more yellow fat than other breeds (Morgan and Pickering, 1969; Barton et al., 1994; Pitchford et al., 2002).
Recently, Tian et al. (2009) evaluated genetic variation in the β-carotene 9′,10′-dioxygenase (*BCO2*) gene and its association with adipose tissue and milk color. The breeds of cattle evaluated in the study were Jersey and Limousin. The researchers sequenced the *BCO2* gene and observed that a single nucleotide base change caused a substitution of a pre-mature stop codon (encoded by the A allele) for tryptophan (encoded by the G allele). This mutation resulted in an altered genotype and *BCO2* activity. They discovered that cattle with the *BCO2* AA genotype had more yellow beef fat and higher β-carotene concentrations within the fat samples than cattle with the *BCO2* GA or GG genotype. They also determined that this nonsense mutation was only present in the Jersey breed because no Limousin backcross cattle were homozygous AA. Because the *BCO2* genotype was altered, enzymatic activity was lost and β-carotene accumulated within the fat which caused an undesirable yellow carcass fat to develop; thus, explaining why the Jersey breed is recognized as having more yellow fat color than other breeds.

**Effects of time on feed on:**

*Performance*

As cattle are fed longer, performance is impacted. Van Koevering et al. (1995) reported daily gains (carcass weight-adjusted basis) increased in a quadratic manner, whereas feed intake tended to increase linearly, as cattle were fed longer (147 d vs. 119 d), and feed efficiency (carcass weight adjusted basis) decreased. In contrast, Sami et al.
(2004) evaluated the effect of time on feed (100 vs. 138 d) on performance of Simmental bulls, and reported that performance was not affected by time on feed. There is a gap in knowledge of the effects on performance of cattle fed for more than 300 d. Because Jerseys are slower growing than other breeds, Jersey cattle require a much longer time on feed to produce carcasses with acceptable carcass weights; however, longer time on feed is associated with decreased tenderness (described below) which has yet been determined for Jersey cattle.

**Carcass characteristics**

Longer feeding times for cattle of a given starting weight typically increased final live weight, hot carcass weight, *longissimus* muscle area, subcutaneous fat thickness, kidney, pelvic and heart fat, overall carcass maturity, resulted in less desirable yield grades and improved quality grade (Zinn et al., 1970a; Tatum et al., 1980; Dolezal et al., 1982; Van Koevering et al., 1995; Camfield et al., 1997). As cattle are fed for longer periods prior to slaughter, there are increases in marbling scores and quality grades (Wellington et al., 1968; Zinn et al., 1970a; Champion et al., 1975), subcutaneous fat (Champion et al., 1975) and tenderness (Epley et al., 1968; Zinn et al., 1970b). Longer feeding periods for Jersey beef production may contribute to their desirable carcass characteristics.
**Lean and subcutaneous fat color**

Information in the literature is available on the effects of increased time on feed on lean color under forage-based feeding systems; however, there is limited information about this topic for cattle finished in feedlots for extended periods of time. While there are many factors that can influence meat quality and color, the diet fed to the animal is one of the most important production factors (Kerry et al., 2000). Binder et al. (1981) reported that lean color was darker for forage-fed cattle than grain-fed cattle; in addition, these same forage-fed cattle required an additional 160 d to reach acceptable harvest weight compared to their grain-fed counterparts. Binder et al. (1981) concluded that darker lean color was attributed to increased animal age, due to a longer time on feed. Subjective lean and fat color did not differ between carcasses from cattle finished on grass silage only and grass silage plus concentrates in the feedlot; although, cattle feed diets containing concentrate required 30 d less on feed to reach harvest weights (Berthiaume et al., 2006). Additionally, Shemeis et al. (1994) reported as animal age increased the carcass lean and fat color tended to become darker red and more yellow, respectively. Sami et al. (2004) reported that \( L^* \) and \( b^* \) were not affected by increasing time on feed (100 vs. 138 d); however, bulls fed longer (138 vs. 100 d) elevated \( a^* \) values) meat redness.
**Meat composition**

As cattle are fed for longer periods of time, the ability of the animal to deposit fat is altered. Recently, Chung et al. (2007) reported long-fed (16 mo) Angus and Wagyu cattle receiving a corn-based diet had a 60 to 90% lower lipogenesis in intramuscular and subcutaneous adipose tissues than in short-fed (8 mo) cattle fed corn-based diet. Lipogenesis in subcutaneous adipose tissue declined in British-cross cattle after 19 mo of age (Smith et al., 1984). The importance of marbling, intramuscular fat, is that it is reported to be highly correlated to sensory tenderness ratings (Seideman et al., 1998), juiciness and beef flavor (Platter et al., 2003), and is currently an important determinant of carcass value for markets which desire meat with a high degree of marbling (Baud et al., 1998). Jersey influenced carcasses have demonstrated the potential to produce highly-marbled meat (Pitchford et al., 2002); however there is limited information on these characteristics when Jersey steers are fed for greater than 300 d.

**Palatability**

Feeding cattle for longer time resulted in increased overall carcass maturity (Zinn et al., 1970a; Dolezal et al., 1982; Van Koevering et al., 1995). It is known that animal age is negatively correlated with sensory panel tenderness scores (Wulf et al., 1996) attributed to more collagen cross-linking. It is also known that solubility of intramuscular collagen decreases with increasing maturity (Hill, 1966), and Dikeman and Tuma (1971) concluded that collagen solubility was highly related to Warner-Bratzler shear force.
values and sensory panel tenderness of beef steaks. Although, Sami et al. (2004) reported that shear force, collagen content, sarcomere length, juiciness, and flavor were not affected by increasing time on feed (100 vs. 138 d). Tenderness increased with time on feed up to some point (139 d, Epley et al., 1968; 150 to 180 d, Zinn et al., 1970b), after which maturity had a greater influence, resulting in reduced tenderness. Dolezal et al., (1982) reported that steers feed for >100 d produced more tender steaks with higher overall palatability rating and lower shear force than steers fed for 90 d or less.

Additionally, detectable connective tissue increased with increasing time on feed (Camfield et al., 1997).

Beef flavor is also an important sensory attribute. Rib steaks from steers fed longer had higher cooking losses; however, they had higher beef flavor intensity than steaks from steers fed for shorter periods of time (Camfield et al., 1997), due to the relationship between intramuscular fat and flavor intensity (Harrison et al., 1978; Camfield et al., 1997), as flavor from fat becomes more desirable as feeding period increases (Harrison et al., 1978). These differences in fat flavor are due to differences in fatty acid composition. As time on fed increased, pentadecyclic (15:0), stearic (18:0), linolenic [18:2 (n-6)] and cis-11-eicosenoic acids [20:2 (n-6)] decreased ($P < 0.05$), whereas, oleic acid [18:1(n-9)] increased ($P < 0.05$), (Camfield et al., 1997).
Effects of forage level in feedlot diets on:

Performance

Cereal grains are a common source of energy in diets fed to feedlot cattle in North America. The use of grain-based finishing diets is preferred over forage-based diets because of reasons such as greater energy density, ease of transport, storage, and blending of grains relative forages. Adding forage to high concentrate diets dilutes the energy density of the diet and can negatively impact performance, carcass traits, and meat composition.

Limiting forage from finishing diets containing whole corn decreased DMI and tended to decrease ADG, however, improved FE (Turgeon et al., 2010). Zinn et al. (1994) reported, decreasing the forage (alfalfa hay:sudangrass hay mixture) in the diet from 20 to 10% increased ADG (10.8%), feed efficiency (11.6%) and diet NE, (11.3%). Reducing forage (sudangrass hay) level within the diet from 16 to 8% did not affect DMI, increased (17%) ADG, improved FE (23%), and increased dietary NE\textsubscript{m} and NE\textsubscript{g} (17% and 22%, respectively; Calderon-Cortes and Zinn, 1996). Whereas Sackmann et al. (2003), reported DMI showed a quadratic response, as forage level increased from 12 to 24% followed by a decrease in DMI when 36% forage was fed, suggesting animals fed the high forage (36% grass hay, DM-basis) became satiated sooner than those fed the 12 and 24% forage level – there was no other performance data reported for this study.
The use of Jersey genetics by feedlot producers is often limited because they are slower growing compared with other breeds (Smith et al., 1976). In recent years, a comparison of dairy genetics receiving diets differing in energy density was performed by Lehmkuhler et al. (2008). The two breeds compared were Holsteins and Jersey. Breed differences were reported in that Holsteins had a higher DMI and greater ADG compared with Jerseys. However, Jerseys had a slightly better feed efficiency from d 0 to 90 (period 1) and during the finishing period (d 169 to 343) of the feeding trial (Lehmkuhler et al., 2008). Additionally, steers (regardless of breed) fed lower forage diets (25% forage DM basis) had greater feed efficiencies compared with steers fed high forage diets (55% forage DM basis) during period 1 (d 0 to 90) of the feeding trial. Although not statistically different, DMI was numerically greater for low forage fed steers than high forage fed steers. Similar results were reported for non-diary cattle. Cattle fed low forage diets had an increased ADG compared to high forage fed cattle (Calderon-Cortes et al., 1996; Gorocica-Buenfil et al., 2005), although cattle fed high forage diets had a greater DMI. Overall, FE was improved for low forage fed cattle compared with high forage fed cattle (Calderon-Cortes et al., 1996; Gorocica-Buenfil et al., 2005). The improved FE observed in low forage fed cattle can be attributed to a more energy concentrated diet with decreased forage. Increasing the level of forage in the diet above 20% in sorghum and corn diets often depressed growth rate due to decreased diet digestibility (Bartle et al., 1994; Zinn et al., 1994).


Carcass characteristics

Increasing or decreasing the forage level can increase, or reduce, the energy density of the diet and thus increase, or limit, the available energy for gain to alter carcass traits.

Dairy steers fed lower forage (25% forage), DM-basis diets (DM basis) had greater longissimus muscle area compared with steers fed higher forage diets (55% forage DM basis), but other measured carcass traits (HCW, Dressing %, backfat thickness, marbling score or yield grade) did not differ between the two forage levels (Lehmkuhler et al., 2008). Although, breed had significant effects on some measured carcass traits, Jerseys yielded lighter HCW, had lower dressing percentages, smaller longissimus muscle area, and tended to have less backfat thickness compared to Holsteins, but did differ in marbling score or USDA Yield Grade (Lehmkuhler et al., 2008).

Low forage (5.2% corn silage DM basis) fed beef cattle yielded heavier carcasses, had greater back fat depth, and greater dressing percentages compared with high forage fed (18.2% corn silage DM basis) beef cattle (Gorocica-Buenfil et al., 2005); however, marbling score, kidney, pelvic and heart fat, longissimus muscle area did not differ (Gorocica-Buenfil et al., 2005).

Meat color stability

Color is a very important aspect of appearance of fresh beef sold at retail, and can impact consumers purchasing decisions (Kropf, 1980; Dikeman, 1990). Among the red
meats, consumers relate the bright-red color to freshness, and discriminate against meat which is discolored (Morrissey et al., 1994). The diet fed to the animal can impact meat color and quality (O’Sullivan et al., 2002, 2003), and flavor and lipid oxidation (Gray et al., 1994). Although incorporating higher forage levels in feedlot diets may increase carotenoid consumption and result in more yellow fat, it might also increase antioxidant levels (vitamin E) within the lean, and could improve color stability during retail display. One of the primary functions of vitamin E is to maintain and protect biological membranes from oxidative damage (Rice and Kennedy, 1988). Studies have demonstrated that beef from forage-finished animals had greater color and lipid stability than beef from concentrate-fed steers (O’Sullivan et al, 2002, 2003, 2004) and higher levels of vitamin E caused increased color stability (O’Sullivan et al., 2004).

Metmyoglobin formation and lipid oxidation are the most important issues to control to maintain meat retail display stability. Sherbeck et al. (1994) reported that discoloration of retail meat cuts may be due to the combined interaction of muscle pigment oxidation and lipid oxidation within the membrane phospholipids. The formation of metmyoglobin from oxymyoglobin was positively correlated to lipid oxidation, and also seemed to be dependent on the antioxidant status (Yin and Faustman, 1993).

There are several studies which demonstrated that dietary supplemental vitamin E caused α-tocopherol accumulation within the muscle tissue, which delayed oxymyoglobin and lipid oxidation, thus extending the color stability of beef (Arnold et al., 1992, 1993; Sherbeck et al., 1994; Liu et al., 1996; O’Sullivan et al., 2004). Forages
are a rich source of vitamin E, however, vitamin E in forage can be variable and affected by numerous factors including, extent of processing, stage of maturity, chemical composition at harvest, and dehydration time (Kerry et al., 2000).

**Effects of forage level in feedlot diets for long-fed cattle on:**

*Rumen health*

Cattle fed all-concentrate diets for extended periods suffer from problems such as rumenitis, parakeratosis, and liver abscesses (Huntington, 1988). Ruminal disorders such as chronic and acute acidosis and bloat occur in feedlot cattle fed high concentrate diets when ruminal pH falls to low levels for extended periods of time. Cattle fed all-concentrate diets that suffered from these disorders, had reduced growth rates than those fed diets containing small amounts of roughage (Stock et al., 1990). Forage is included in feedlot diets to alleviate the problems associated with digestive disorders (Owens, 1998), because adding forage in the diet increases rumination, provides physical stimulation of the rumen wall, and increases ruminal pH (Kucuk et al., 2001). Because Jerseys are slower growing than most other breeds, they may have increased incidence of digestive disorders due to the longer feeding period. Vogel and Parrott (1994) reported that feedlot bloat was higher in Holstein cattle than beef cattle; perhaps due to increased feed intake or increased time on feed to finish. Jersey steers fed in the feedlot might take up to 400 d to achieve acceptable market weights because of their relatively slow growth rate;
however, to our knowledge there is no available information about the requirements for dietary forage in long-fed dairy cattle.

Traxler et al. (1995) completed a study on long-fed Holstein steers over a 2 yr period and the length of the experiments ranged from 262 d for the first slaughter group in yr 1 to 302 d for the second slaughter group of yr 2. Joint injuries and bloat were reported, but not attributed to any particular dietary treatment, and required 11 steers (7 and 4 steers in yr 1 and 2, respectively) be removed from the study. The bloat problems, regardless of treatment or roughage level, observed during the growing period were attributed to exceedingly high intakes at the end of the growing phase. These bloat problems were mitigated when the steers were switched to the finishing diet.

Performance and carcass characteristics

The effects of feeding dairy cattle for an extended period of time are not well understood. It is not well understood about the effects on performance of cattle fed for an extended period of time. Traxler et al. (1995) evaluated the effects of roughage source in high concentrate diets on feedlot performance long-fed Holstein steers (2 yr feeding period). Roughage sources included a built-in-roughage (BIR) pellet supplying 15 and 6% roughage (% DM) or hay crop silage (HCS) supplying 7 and 10% roughage (% DM) for the growing and finishing periods, respectively. Dietary treatments fed to the steers included: continuous whole corn and pellet (no added roughage; WSCPEL) ; whole corn and pellet fed during the growing period followed by cracked corn and a roughage pellet
(built-in-roughage; BIR) fed during the finishing period (BIR-F); cracked corn and BIR fed during the growing period followed by whole corn and pellet during the finishing period (BIR-G); cracked corn and BIR fed during both feeding periods (BIRCONT); and two hay crop silage (HCS) treatments in which the corn was fed either whole or cracked (HCS-WSC and HCS-CSC, respectively) for the entire feeding period.

The researchers reported that ADG was improved by feeding HCS-WSC vs. HCS-WSC and BIR-G vs. BIF-F; DMI was increased by feeding WSC-PEL vs. BIR-F and HCS-WSC vs. HCS-CSC; FE was improved by feeding WSC-PEL vs. BIR-F.

For all measured carcass traits, there were no differences due to dietary treatment. Although, steers fed the BIR-G and BIR-CONT diets had numerically higher USDA Yield Grades than steers fed the HCS-WSC and HCS-CSC diets. This is attributed to on average steers fed the BIR-G and BIR-CONT diets had heavier HCW, greater backfat thickness, and similar LMA and %KPH compared to steers fed the HCS-WSC and HCS-CSC diets.

Although the objective the previous study was to look at the effects of source and timing of roughage inclusion and of corn processing on feedlot performance and economic efficiency of Holstein steers fed a high-concentrate diet for a long period of time, this is the only available information for long-fed dairy cattle fed high-concentrate diets in the feedlot. Thus, suggesting a gap in knowledge exists about the optimal forage level for long-fed feedlot cattle on performance and carcass characteristics and proposing an important part of the current research.
SUMMARY

Feeding and management practices that effectively increase hot carcass weights without impacting backfat, USDA Quality Grade, palatability, and adversely affecting USDA Yield Grade are desirable for Jersey beef production. It is well known that Jerseys face challenges in terms of beef production; however, discovering the optimal feeding regimen for finishing Jersey steers to overcome these challenges is much needed. Jerseys produce a high quality product that lends an opportunity for a niche market. The objective of this study was to evaluate the effects of forage level (12 vs. 24% sudangrass:alfalfa hay, DM-basis) in steam-flaked, corn-based finishing diets on carcass characteristics, palatability, and retail color stability of Jersey beef.
CHAPTER 3

EFFECTS OF FORAGE LEVEL IN FEEDLOT FINISHING DIETS ON CARCASS CHARACTERISTICS, SENSORY ATTRIBUTES, AND PALATABILITY OF JERSEY BEEF

ABSTRACT

Jersey cattle are recognized as being slower growing and having more yellow fat compared with other breeds, thus limiting the use of this breed for beef production. Because Jerseys are slower growing, they require additional time on feed to achieve acceptable market weights and yield acceptable hot carcass weights. Although Jerseys face challenges, the resulting product has other quality aspects that exceed the general beef population. Gaps in knowledge exist regarding the optimum forage level in finishing diets on growth performance, carcass characteristics, and beef palatability. The objective of this study was to evaluate the effects of forage level (12 vs. 24% sudangrass:alfalfa hay, DM-basis) in steam-flaked, corn-based finishing diets on carcass characteristics, palatability, and retail color stability of Jersey beef. Seventy-nine Jersey steers were blocked by weight and randomly assigned one of the following treatments for a 385-d trial period: Jersey low- 12% (JL; n = 38) or Jersey high- 24% (JH; n = 39) forage, DM-basis. Forty-eight hours postmortem (PM), strip loins were removed, vacuum-packaged, and aged at 3°C for 18 d PM. Following the aging period, steaks from the longissimus dorsi...
muscle were sliced, vacuum-packaged, and frozen (-20°C) until analyzed. Steers fed the low forage diet had greater \((P < 0.05)\) backfat and tended to have greater dressing percent compared to steers fed the high forage diet. Live weight, HCW, LMA, and USDA Yield Grade were not affected \((P > 0.05)\) by forage level. Steers fed the low forage diet on average tended to bring a 6\% greater value ($63.73 more per head) compared to steers fed the high forage diet. Objective color \((L^*, a^*, b^*)\) measurements decreased \((P < 0.05)\) over time of display across treatments. There were no differences among treatments for \(L^*\); however, overall during retail display JH had greater \((P < 0.05)\) \(a^*\) and \(b^*\) values than JL. Subjective color scores increased over time of display and were not affected by forage level. Warner-Bratzler shear force (WBSF) values and cooking loss were not affected by forage level. All measured sensory panel ratings were more favorable for JL steaks than JH steaks. These results suggest that forage level had minimal effects on carcass characteristics, color stability, and beef palatability; however, feeding a low forage diet decreases input cost and results in a greater value carcass. Finishing fed Jersey steers in conventional feeding systems can be accomplished meeting beef industry expectations and result in a high quality beef product.
INTRODUCTION

Cattle that produce high quality milk and meat are highly valuable. Today, more than ever, consumer demands for branded programs which require products with certain quality attributes are on the rise. Traditionally, Jersey cows are recognized as producing quality milk with more solids and a higher fat content; however, Jersey steers are of little value in the marketplace.

Consumers indicated that beef tenderness is an important quality attribute (Huffman et al., 1996), and they are willing to pay more for beef products known to be tender (Boleman et al., 1997; Miller et al., 1998). Purchas and Barton (1976) reported beef from Jersey steers was superior in tenderness compared to other breeds. Marbling, or intramuscular fat, has been highly correlated to sensory tenderness ratings (Seideman et al., 1998), juiciness and beef flavor (Platter et al., 2003), and is currently an important determinant of carcass value for markets that desire meat with a high degree of marbling (Baud et al., 1998). Jersey cattle posses the genetic potential to produce a highly marbled product (Albertí et al., 2008), and thus might represent an opportunity for a niche market.

Jerseys are one of the slowest growing breeds of cattle (Smith et al., 1976; Barton et al., 1994; Burke et al., 1998; Albertí et al., 2008; Lehmkuhler et al., 2008). Further, as a result of this expectation, the optimal feeding regimen for finishing Jersey steers is not well understood. Forage is included in feedlot diets to alleviate problems associated with digestive disorders (Owens, 1998), because adding forage in the diet increases
rumination, provides physical stimulation of the rumen wall, and increases ruminal pH (Kucuk et al., 2001). Because Jerseys are slower growing than most other breeds, they may have increased incidence of digestive disorders due to the longer feeding period. Vogel and Parrott (1994) reported that feedlot bloat was higher in Holstein cattle than beef cattle; perhaps due to increased feed intake or increased time on feed to finish. Jersey steers fed in the feedlot might take up to 400 d to achieve acceptable market weights because of their relatively slow growth rate; however, to our knowledge there is no available information about the requirements for dietary forage in long-fed cattle and the effect on carcass characteristics and beef palatability.

Thus, developing growing and finishing diets for Jersey steers to optimize performance, and produce a high quality product, are paramount. The objective of this study was to evaluate the effects of forage level (12 vs. 24% sudangrass:alfalfa hay, DM-basis) in steam-flaked, corn-based finishing diets on carcass characteristics, palatability, and retail color stability of Jersey beef.
MATERIALS AND METHODS

Research All procedures involving animal care and management were in accordance with and approved by the University of California-Davis, Animal Care and Use Committee.

Animals, Diets, and Experimental Design

The feeding trial was conducted by Dr. Richard Zinn at the University of California-Davis. Seventy-nine Jersey steer calves were all born between April 17 and April 24, 2007 on nine dairies in Hilmar, CA and used in a 385-d feeding trial to evaluate the influence of forage level in finishing diets on carcass characteristics, sensory attributes, and palatability of Jersey beef. Day old calves were moved to one dairy and raised in elevated individual calf pens. Steers were received at the University of California Desert Research and Extension Center, El Centro, on October 5, 2007. Upon arrival, steers were vaccinated for bovine rhinotracheitis-parainfluenza3 (TSV-2, Pfizer Animal Health, New York, NY), clostridials (Fortress 7, Pfizer Animal Health), and Pasteurella hemolytica (One Shot, Pfizer Animal Health), treated for internal and external parasites (Dectomax Injectable, Pfizer Animal Health), and injected subcutaneously with 500,000 IU vitamin A (Vita-jec A&D 500, RXV Products, Kansas City, MO), branded, and ear-tagged. The feeding trial began upon arrival of steers. Steers were grouped by weight and randomly assigned within weight groups to 16 pens (5-6 steers/pen). Pens were 78 m² with 33 m² of overhead shade, automatic waterers, and fence-line feed bunks. Steers were implanted with Revalor-IS (80 mg of trenbolone
acetate plus 16 mg of estradiol) after 70 d on feed, and re-implanted with Revalor-S (120 mg trenbolone acetate and 24 mg estradiol) at 210 and 105 d prior to slaughter. Steers were fed steam-flaked corn based diets with 50% of the forage coming from sudangrass hay and 50% from alfalfa hay. Treatments were 1) Jersey low (12% forage DM, basis) forage and 2) Jersey high (24% forage DM, basis) forage (Table 1). Fresh feed was delivered twice daily to the feed bunks in each pen. Steers were individually weighed, at the start of the feeding trial, in 28-d intervals, and before shipment to the commercial abattoir located 32 km from the feedlot facility. The slaughter endpoint was set at 385-d on feed. This common slaughter endpoint was selected to allow comparison of composition and characteristics of carcasses of the same time on feed. Two steers were removed from the data set during the 385-d feeding period.

Carcass Data Collection

Jersey steers (n = 77) were humanly harvested after 385 d on feed trial in a USDA inspected facility (National Beef Packing Co., Brawley, CA). Final live weights (reduced by 3% to represent a standard industry shrink) were recorded before shipment to the plant to calculate dressing percent. Hot carcass weights (HCW) were obtained for all animals and carcasses were chilled at 2 ±1°C for 48 h before being split between the 12th and 13th ribs for carcass grading. Two trained evaluators measured and recorded: actual and adjusted 12th rib fat depth (BF), longissimus muscle (LMA) area, kidney, pelvic, and
heart (KPH) fat, marbling (USDA, 1997), maturity score, USDA Quality Grade, USDA Yield Grade, and ultimate pH.

**Carcass Value Determination**

Carcass value was determined for each carcass using a recent grid market (USDA, 2010).

**Objective Carcass Color**

Objective color data were obtained 48 h postmortem by a qualified technician using a Minolta chromatographer (Minolta Chroma Meter CR-310 colorimeter (Minolta Corp., Osaka, Japan). After carcasses were ribbed, the *longissimus* muscle was allowed a period of approximately 30 min to bloom before objective color analysis. Objective color data included lean and adipose Hunter $L^*$, $a^*$, and $b^*$ values. Lean and adipose objective color data were obtained at the medial area of the exposed *longissimus* at the 12th rib and on external fat located between the 10th and 12th rib region.

**Strip Loin Transportation and Aging**

Following data collection, strip loins were labeled, excised from the left side of each carcass, vacuum packaged, and transported (by truck which temperature monitored at 3°C) fresh to The Ohio State University Department of Animal Sciences Meat Science Laboratory for analyses. Strip loins were aged for 18 d PM at 3°C.
**Strip Loin Processing**

Following the aging period, strip loins were removed from vacuumed-packaged bags and percent purge was calculated \[\frac{((\text{Weight of bag } + \text{ purge weight}) - \text{ weight of bag})}{\text{ Weight of strip loin}} \times 100\].

Steaks measuring 2.54 cm in thickness were fabricated using cutting guides to provide uniformity and consistency. The anterior end was squarely faced and steaks were fabricated progressing from the anterior to posterior end for analysis of retail display color, Warner-Bratzler shear force (WBSF), proximate composition (percentage total lipid, protein, moisture, and ash), and sensory evaluation (consumer and semi-trained panels). For each strip loin within treatment (JL and JH), steaks 1, 2, 3, and 4 were designated for retail display, WBSF, semi-trained sensory evaluation, and proximate composition, respectively. Steaks (n = 16 per treatment) were randomly selected for consumer sensory evaluation. Retail display steaks were placed immediately on Styrofoam® trays and overwrapped with an oxygen-permeable plasticized polyvinyl chloride (pPVC) packaging film (Huntsman Packaging Corporation, Uniontown, OH). The steaks designated for WBSF, semi-trained sensory evaluation, and proximate composition were vacuum packaged and frozen (-20°C) for later analysis.

**Proximate Composition**

Samples were trimmed of external fat, ground (Hobart model 4822, Hobart Co., Troy, OH) 3 times, and sub-sampled for determination of ash, protein, moisture, and
ether-extractable lipid. Total ash content was determined as the residue after combustion at 550°C for 15 h. Protein content was calculated from the nitrogen content (%N x 6.25) analyzed by Kjeldahl (AOAC, 928.08, 1997) using the Büchi Digestion Automat K-438 and Büchi Distillation Unit B-324 (Büchi Laboratory Equipment, USA). Moisture content was determined by weight loss after freeze drying at -55°C for 5 d. Total lipid content was determined following the Ankom procedure (AOCS Am 5-04, 2004). Procedures were completed in duplicate and individual values were averaged for each steak for statistical analysis.

**Retail Display Conditions**

Steak packages (packaging described above) were randomly positioned on tables displayed under continuous, 1,600 lx of deluxe, warm-white, fluorescent lighting (bulb type: F4OT12, 40-W; Phillips Inc., Somerset, NJ) for 5 d (d 0-4) at 3°C to simulate retail display conditions.

**Color Measurements**

All packages of retail steaks were evaluated subjectively and objectively for color and appearance attributes during the retail display study under the lighting conditions previously described for simulated retail display. Trained panelists (n = 6) visually evaluated display color and surface discoloration once daily resulting in subjective color scores. The display color scale used was: 1 = very bright red, 2 = bright red, 3 = dull red,
4 = slightly dark red, 5 = slightly dark red or reddish tan, 5.5 = borderline acceptable to panelists, 6 = moderately dark red to tannish red, and 7 = tan to brown. Color scores were reported in half-point increments. Steak surface discoloration was subjectively evaluated as a percentage of metmyoglobin formation using the following scale: 1 = none (0%), 2 = slight discoloration (1-19%), 3 = small discoloration (20-39%), 4 = modest discoloration (40-59%), 5 = moderate discoloration (60-79%), 6 = extensive discoloration (80-99%), and 7 = total discoloration (100%). Discoloration scores were reported to the whole point. Panelists’ daily scores were averaged for statistical analysis.

Objective Hunter $L^*$, $a^*$, and $b^*$ values were measured with the Minolta Chroma Meter CR-310 colorimeter (Minolta Corp., Osaka, Japan) on all days of display. All $L^*$, $a^*$, and $b^*$ values were collected in triplicate through the pPVC film from random sites with the exception of avoiding irregular large flecks of marbling or small areas of severe discoloration. Values were averaged for statistical analysis.

**Thawing and Cooking**

Steaks for WBSF and sensory evaluation analysis were thawed for 24 h at 4°C. Steaks for WBSF and semi-trained sensory evaluation were cooked to a target internal temperature of 71°C on an impingement oven (Lincoln Impinger, Food Service Products Inc., Fort Wayne, IN) with an oven temperature of 176°C and drag set a 22 minutes. Steaks for consumer sensory evaluation were cooked to an internal temperature of 35°C, turned, and cooked to a final internal temperature of 71°C on an open hearth grill.
**Cooking Loss**

Steaks used for WBSF were weighed before cooking (initial weight) and weighed after cooking (final weight). Cooking loss was expressed as a percentage of weight loss and calculated by \[((\text{initial weight} - \text{final weight})/\text{initial weight})\]*100.

**Warner-Bratzler Shear Force**

Cooked steaks were cooled for 3 h at room temperature before coring. Four to six 1.27 cm diameter cores were removed parallel to the longitudinal orientation of the muscle fibers and shorn perpendicular to the longitudinal orientation of the muscle fibers with a Warner-Bratzler shear attachment (V-notch blade) at a cross-head speed of 200 mm/min, attached to a Texture Analyzer (model TAXT2 Plus, Texture Technologies Group, Scarsdale, New York). Peak shear force values were recorded in kg and the values from the cores were averaged to obtain a single WBSF value for each steak for statistical analysis.

**Consumer Sensory Evaluation**

Consumers (n = 77) were selected based on beef consumption (beef consumed at least 3x per week) and the panel was completed in a replication of four sessions. Cooked steaks were cut into 1 x 1 x 2.54 cm cube samples. Samples were identified by a randomized three digit number and cooked temperature was maintained by wrapping in heavy duty aluminum foil and storing in Pyrex glass containers (serving as a resting
period) prior to cutting and serving. Cooked steaks, trimmed of all external fat and major connective tissue, were cut into 1 x 1 x 2.54 cm cubes and served to panelists in a predetermined randomized order. Panelists were provided distilled water and unsalted crackers to cleanse their palates between samples. Consumers evaluated samples with a 9-pt hedonic scale (1 = highly unacceptable to 9 = highly acceptable) for tenderness, flavor, juiciness, and overall acceptability (AMSA, 1995). Individual consumers’ scores were averaged to obtain a single value for statistical analysis.

**Semi-Trained Sensory Evaluation**

Panelists (n = 9) were trained according to American Meat Science Association Guidelines (1995) for steak evaluation. Samples were identified by a randomized three digit number and cooked temperature was maintained by wrapping in heavy duty aluminum foil and storing in Pyrex glass containers (serving as a resting period) prior to cutting and serving. Cooked steaks, trimmed of all external fat and major connective tissue, were cut into 1 x 1 x 2.54 cm cubes and served to panelists seated in individual booths under red lighting. Eight samples were served per session in a randomized order at approximately 3-min intervals between samples. Panelists were provided distilled water and unsalted crackers to cleanse their palates between samples. Panelists evaluated each steak for initial and sustained tenderness, initial and sustained juiciness, beef flavor intensity, and overall acceptability. The panelists assessed the attributes on an unstructured 10-cm line scale. The line scale was anchored on the left (0 cm), with the
term “tough” for initial and sustained tenderness, “dry” for initial and sustained juiciness, “none detectable” for beef flavor intensity, and “unacceptable” for overall acceptability. On the right end (10 cm) of the scale was the term “tender” for initial and sustained tenderness, “juicy” for initial and sustained juiciness, “pronounced” for beef flavor intensity, and “very desirable” for overall acceptability. Panelists entered data into a computer software program (Compusense® 5). Individual panelists’ scores were averaged to obtain a single value for each steak for statistical analysis.

**Statistical Analysis**

Data were analyzed as a completely randomized block design using the MIXED models procedure of SAS (SAS Inst. Inc., Cary, NC) for carcass characteristics, proximate composition, retail display, Warner-Bratzler shear force, consumer panel, and semi-trained sensory panel with carcass/steak as the experimental unit. The model for carcass characteristics and proximate composition included treatment as the fixed effect. The model for retail display included the fixed effects of treatment, day, and the day x treatment interaction, whereas panelist was specified as a random effect for subjective color evaluation. The REPEATED measure statement in MIXED was used to determine the effect of day on objective and subjective color measurements during retail display. The model for Warner-Bratzler shear force data included treatment as a fixed effect and day as a covariate. The model for semi-trained sensory panel included treatment as a fixed effect, whereas panelist was specified as a random effect. The model for consumer
panel included treatment as a fixed effect, whereas panelist and replication was specified as a random effect. Least square means were generated and separated using a pairwise $t$-test when the model displayed a treatment effect ($P<0.05$), using the PDIFF statement of MIXED.
RESULTS AND DISCUSSION

Treatment Effect on Carcass Characteristics and Value

We hypothesized that forage level in finishing diets would impact carcass characteristics. The experimental diets fed to Jersey steers and management were conducted by Dr. Richard Zinn at the University of California-Davis in El Centro, CA. The diets were steam-flaked corn based with 50% of the forage coming from sudangrass hay and 50% from alfalfa hay for the 385-d feeding period. The complete chemical composition of the experimental diets is shown in Table 1.

The main effects for carcass traits are reported in Table 2. Steers fed the low forage diet had greater ($P < 0.05$) $12^{th}$ rib fat depth compared to Jerseys fed the high forage diet. Similarly, Gorocica-Buenfil et al. (2005) reported greater backfat for beef steers fed a low forage diet compared with a high forage diet. Camfield et al. (1997) reported an increase in backfat as concentrate level increased. Live weight, hot carcass weight, longissimus muscle area, USDA Yield Grade were not ($P > 0.05$) affected by forage level, although low-forage fed steers had numerically greater values for these carcass characteristics. Gorocica-Buenfil et al. (2005) reported heavier carcass weights for low (5.2% corn silage DM-basis) forage feed beef steers compared to high (18.2% corn silage, DM-basis) forage fed beef steers. Lehmkuhler et al. (2008) compared dairy beef (Jersey vs. Holstein) fed different roughage levels (25% vs. 55%, lower forage vs. higher forage, respectively) and discovered carcasses fed lower forage diet had greater
*longissimus* muscle area compared with higher forage fed steers. The values for hot carcass weight (HCW) and *longissimus* muscle area for Jerseys fed the low forage diet meet the requirements (272 kg HCW with a 70.77 cm² ribeye) of beef cattle within the beef industry. Jerseys fed the high forage diet had an acceptable HCW although did not meet the requirement for ribeye.

Low-forage fed steers tended (*P* = 0.10) to have greater dressing percentages, kidney, pelvic, and heart fat, marbling scores, and USDA Quality Grades. Gorocica-Buenfil et al. (2005) reported greater dressing percent for beef steers fed a low forage diet compared with a high forage diet. Lehmkuhler et al. (2008), reported marbling scores were not affected by dietary treatment (25% vs. 55% forage, DM-basis). Jerseys have a high propensity to marble (Albertí et al., 2008) and can marble on higher forage. When averaged over forage level, marbling scores were 621 and 572 corresponding to USDA Ch° and Ch´ for JL and JH, respectively; however, USDA Quality Grades were 10.74 and 10.13 corresponding to USDA Ch´ for both forage levels. This difference is attributed to the scale and the distribution of USDA Quality Grades for steers within forage level (Table 3).

The distribution USDA Quality Grades is presented in Table 3. The number of cattle marketed through quality and yield grids has increased during the recent years (USDA, 2003). To receive premiums and avoid discounts, quality grades must be at least Low Choice and the Yield Grade must be less than 4. Therefore, it can be suggested from the present data that feeding high forage levels to Jersey steers tended (*P* = 0.10) to
reduce USDA Quality Grades and marbling scores, yet still met the requirement, and did not impact ($P > 0.05$) USDA Yield Grade. When carcass value was calculated, Jersey steers fed the low forage diet on average tended to bring a 6% greater value ($\$63.73/\text{head}$) compared to Jersey steers fed the high forage diet; therefore, feeding the low forage diet seemed to be more economically favored for these long-fed steers.

**Adipose and Lean Objective Color Evaluation**

One of the key issues impacting the high demand of Jersey beef in the marketplace is that Jersey carcasses are recognized in the beef industry as having more yellow fat than other breeds (Morgan and Pickering, 1969; Barton and Pleasants, 1993; Barton et al., 1994; Kruk et al., 1998; Pitchford et al., 2002; Siebert et al., 2003; Tian et al., 2009). We hypothesized that feeding the high forage diet to Jersey steers would cause an increased number of yellow fat carcasses.

The main effects for initial carcass objective color and other measured meat quality traits are reported in Table 4. The adipose $L^*$ values, corresponding to levels of lightness, were not ($P > 0.05$) by forage level; however, steers fed to high forage diet tended ($P = 0.10$) to have more red color adipose (higher $a^*$ values) than Jersey steers fed the low forage diet. Hunter $b^*$ values, corresponding to levels of yellowness were not ($P > 0.05$) by forage level, which could be attributed to $\beta$-carotene levels were too low to affect adipose color. Correlation coefficients showed that adipose $L^*$ values were negatively correlated (Table 8; $r = -0.33; P < 0.01$) to adipose $a^*$ and $b^*$. The lean $L^*$, $a^*$,
and \( b^* \) values were not affected (\( P > 0.05 \)) by forage level, which could be attributed to the similar pH values (5.40 for JL and JH). Correlation coefficients showed that lean \( L^* \) values were positively correlated to lean \( a^* \) and \( b^* \) values (Table 8; \( r = 0.25, P < 0.05 \) and \( r = 0.42, P < 0.10 \), respectively) and lean \( a^* \) and were positively correlated to lean \( b^* \) (Table 8; \( r = 0.82, P < 0.0001 \)), indicating a combination of \( L^* , a^* \), and \( b^* \) played a significant role in lean color determination. Adipose \( b^* \) and lean \( b^* \) values were moderately correlated (Table 8; \( r = 0.42, P < 0.01 \)).

There was no difference between forage levels groups for pH of the longissimus muscle measured 48 h post mortem and pH values were within an acceptable pH range (Table 4). There was no apparent difference reported for purge between forage levels groups.

**Proximate Composition**

Ash, protein, moisture, and intramuscular fat (IMF) content were not different (\( P > 0.05 \)) between forage level groups (Table 4). Correlation coefficients showed that marbling scores were highly and positively correlated to IMF (Table 8; \( r = 0.80; P < 0.0001 \)). Rincker et al. (2006) reported a correlation coefficient of 0.63 between carcass marbling scores and intramuscular fat in Simmental cattle.
Retail Display Subjective Color and Discoloration

We hypothesized that steaks from Jersey steers receiving the high forage diet (24%) would maintain color stability better because of increased α-tocopherol content than steaks from Jersey steers receiving the low forage diet. Arnold et al. (1993) concluded that the target α-tocopherol level in fresh muscle for optimum protection against discoloration was approximately 3.5 mg α-tocopherol/g meat depending on the muscle in question. O’Sullivan et al. (2003) evaluated the effect of pre-slaughter rations of forage and/or concentrates on beef quality during retail display and reported no significant differences in color. O’Sullivan et al. (2003) determined no group had the recommended optimum α-tocopherol level, although the high herbage group (18 kg grass hay, DM basis and 0 kg concentrate) had the highest α-tocopherol levels (2.49 mg/g) and lowest proportion of metmyoglobin formation during retail display compared with steers offered medium herbage (12 kg grass hay, DM basis and 2.5 kg concentrate), low herbage (6 kg grass hay, DM basis and 5 kg concentrate), and ad libitum concentrate diets.

Panelist scoring of display color and discoloration for treatment groups are shown in Figure 1 and 2, respectively. A lower numerical number for display color and discoloration indicates bright red color and none, respectively. Panelists preferred a bright red color and discriminated against any brown color observed. Statistical analysis showed no forage level or forage level by day interaction for display color and discoloration scores. Display color scores for steaks remained lower than 5.0 for the
entire retail display period, regardless of forage level group and increased \((P < 0.05)\) over time of display (Figure 1). Discoloration scores increased \((P < 0.05)\) over time of display indicating more metmyoglobin formation on the surface of the steaks as display time increased (Figure 2). Steaks from JL and JH steers had approximately a one unit discoloration score greater from day 2 to 3 and day 3 to 4. The results suggest that steaks performed similarly to the trained panelist during retail display and became less desirable at the same rate.

**Retail Display Objective Color Evaluation**

Objective color readings were measured to complement visual color panel evaluations. Color coordinate values of \(L^*\) (lightness), \(a^*\) (redness), and \(b^*\) (yellowness) are reported in Figure 3, 4, and 5, respectively. As display time increased, all color coordinates (\(L^*, a^*,\) and \(b^*\)) gradually decreased \((P < 0.05)\) indicating that steaks became darker, less red, and less yellow, respectively, in color over time of display. In agreement with results of the present study, Nelson et al. (2000) and O’Sullivan et al. (2003) observed that \(L^*, a^*,\) and \(b^*\) values decreased overtime on retail display. There was no forage level or forage level by day interaction for \(L^*\) readings; however, forage level had a significant effect on Hunter \(a^*\) and \(b^*\) in which JH was more \((P < 0.05)\) red (higher \(a^*\) values) and more \((P < 0.05)\) yellow (higher \(b^*\) values) color, overall during retail display (Figure 2 and 3, respectively).
O’Sullivan et al. (2003) evaluated the effect of pre-slaughter rations of forage and/or concentrates on beef quality during retail display and reported no significant differences in color. O’Sullivan et al. (2003) reported the high herbage group (18 kg grass hay, DM basis and 0 kg concentrate) had the highest, \(a^*\) values (was more red) during retail display compared with steers offered medium herbage (12 kg grass hay, DM basis and 2.5 kg concentrate), low herbage (6 kg grass hay, DM basis and 5 kg concentrate), and ad libitum concentrate diets. Thus suggesting, in the present study the increased forage level provided increased antioxidants levels (\(\alpha\)-tocopherol) which helped maintain color stability during retail display.

**Warner-Bratzler Shear Force (WBSF)**

The main effects for Warner-Bratzler shear force are presented in Table 6. There were no \((P > 0.05)\) forage level differences detected. Binder et al. (1981) reported WBSF values were similar for steaks from all treatment groups (steers finished all-Forage, forage-plus-grain or high Energy diets).

Warner-Bratzler shear force values were negatively correlated with trained panelists perceptions of palatability (Table 8; \(r = -0.25\) to -0.50; \(P < 0.05\)), indicating that as WBSF values increased (became tougher) trained panelists responses were scored less favorable. Platter et al. (2003) reported that carcasses with a high degree of marbling have less variation in tenderness.
Consumer and Semi-Trained Sensory Evaluation

Consumer and semi-trained sensory panel evaluation differences did not exist due to forage level; however, steaks from steers fed the low forage diet were scored by panelist, in both the consumer and semi-trained sensory evaluation, as expressing numerically greater scores for all measured attributes (Figure 6 and 7, respectively). Jenschke et al. (2008) reported steaks from cattle finished on low alfalfa (4%, DM-basis) diet were more tender and juicy than steaks from cattle finished on high alfalfa (8%, DM-basis) diet. Wheeler et al. (1994) reported tenderness decreased and steaks were more juicy as marbling scores increased.

Marbling has been reported to be highly correlated to sensory tenderness (Seideman et al., 1998), juiciness, and beef flavor intensity ratings (Platter et al., 2003). Platter et al. (2003) reported that carcasses with a high degree of marbling have less variation greater consumer acceptability. Killinger et al. (2004) reported that steaks in the upper 2/3 USDA Choice were rated more desirable in palatability by consumers than USDA Select steaks and they were willing to pay more for the upper 2/3 USDA Choice steaks. Meat juiciness is a key contributor to eating quality and plays a role in meat texture (Dransfield, Francombe, and Whelehan, 1984; Jowitt, 1974; Hutchings and Illford, 1988). Correlation coefficients showed low positive correlations between marbling score and initial and sustained tenderness (Table 9; r = 0.24 and 0.27, respectively; P < 0.05). In addition, IMF was found to demonstrate a low, positive correlation to sustained tenderness (Table 9; r = 0.27; P < 0.05).
Between all measured consumer and semi-trained sensory attributes, high significant correlations (Table 9; $r = 0.67$ to $1.00$; $P < 0.0001$) were observed, thus suggesting all attributes (tenderness, juiciness and beef flavor intensity) played an important role in consumer palatability. Consumer panel attributes had the greatest correlations between the measured attributes when compared to the semi-trained panel attributes, which could be due to the different scale used for scoring as well as semi-trained panelist could discern more minute differences between samples within and across treatment distinction.
CONCLUSION

Forage level had minimal effects on carcass characteristics, color stability, and beef palatability; however, feeding a low forage diet decreases input cost and results in a greater value carcass. During retail display JH had greater ($P < 0.05$) $a^*$ and $b^*$ values than JL.
IMPLICATIONS

Although increasing forage level might be desirable in long-fed Jersey steers to help mitigate digestive disorders, it is not economically efficient. Jersey steers fed the low forage diet tended to have increased carcass value when compared to Jersey steers fed the high forage diet. Carcass characteristics (i.e. HCW, REA, and USDA Quality and Yield Grade) indicated that Jersey steers can be fed in conventional systems to meet beef industry standards; therefore, beef production opportunities may exist for steers with Jersey ancestry in conventional feeding systems.
Table 1. Composition of experimental diets fed to Jersey steers

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>Growing period (1 to 140 d)</th>
<th>Finishing period (141 to 385 d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>JL</td>
<td>JH</td>
</tr>
<tr>
<td>Ingredient composition, % DM basis</td>
<td></td>
<td>JL</td>
<td>JH</td>
</tr>
<tr>
<td>Steam-flaked corn</td>
<td></td>
<td>57.20</td>
<td>46.10</td>
</tr>
<tr>
<td>Sudangrass hay</td>
<td></td>
<td>6.00</td>
<td>12.00</td>
</tr>
<tr>
<td>Alfalfa Hay</td>
<td></td>
<td>6.00</td>
<td>12.00</td>
</tr>
<tr>
<td>Canola meal</td>
<td></td>
<td>3.50</td>
<td>2.60</td>
</tr>
<tr>
<td>Fish meal</td>
<td></td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Distillers Gr.</td>
<td></td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Tallow</td>
<td></td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Cane molasses</td>
<td></td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Limestone</td>
<td></td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td>Urea</td>
<td></td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Magnesium oxide</td>
<td></td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Trace mineral salt</td>
<td></td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Monensin, g/T</td>
<td></td>
<td>28.00</td>
<td>28.00</td>
</tr>
<tr>
<td>Nutrient composition, (^4) DM basis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE(_m), Mcal/kg</td>
<td></td>
<td>2.15</td>
<td>2.02</td>
</tr>
<tr>
<td>NE(_g), Mcal/kg</td>
<td></td>
<td>1.49</td>
<td>1.37</td>
</tr>
<tr>
<td>CP, %</td>
<td></td>
<td>17.00</td>
<td>17.60</td>
</tr>
<tr>
<td>Ca, %</td>
<td></td>
<td>0.88</td>
<td>0.98</td>
</tr>
<tr>
<td>P, %</td>
<td></td>
<td>0.48</td>
<td>0.46</td>
</tr>
<tr>
<td>K, %</td>
<td></td>
<td>0.90</td>
<td>1.13</td>
</tr>
<tr>
<td>Mg, %</td>
<td></td>
<td>0.28</td>
<td>0.31</td>
</tr>
<tr>
<td>S, %</td>
<td></td>
<td>0.24</td>
<td>0.24</td>
</tr>
</tbody>
</table>

\(^1\) JL = Jersey low forage, 12% sudangrass:alfalfa hay, DM basis; JH = Jersey high forage, 24% sudangrass:alfalfa hay, DM basis.

\(^2\) Trace mineral salt contained: CoSO\(_4\), 0.68%; CuSO\(_4\), 1.04%; FeSO\(_4\), 3.57%; ZnO, 0.24%; MnSO\(_4\), 1.07%; KI, 0.052%; and NaCl, 92.96%.

\(^3\) Rumensin 80, Elanco Animal Health, Greenfield, IN.

\(^4\) Based on tabular values for individual feed ingredients (NRC, 1996).
Table 2. Effect of two forage levels\(^1\) on slaughter weight and carcass characteristics of Jersey steers

<table>
<thead>
<tr>
<th>Trait</th>
<th>JL(^1)</th>
<th>SEM</th>
<th>JH(^1)</th>
<th>SEM</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of steers</td>
<td>38</td>
<td></td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Live weight, kg</td>
<td>479</td>
<td>±7.44</td>
<td>466</td>
<td>±7.34</td>
<td>NS</td>
</tr>
<tr>
<td>Hot carcass weight, kg</td>
<td>291</td>
<td>±5.85</td>
<td>278</td>
<td>±5.77</td>
<td>NS</td>
</tr>
<tr>
<td>Dressing percentage</td>
<td>60.67</td>
<td>±0.46</td>
<td>59.59</td>
<td>±0.45</td>
<td>0.10</td>
</tr>
<tr>
<td>Kidney, pelvic, and heart fat, %</td>
<td>2.34</td>
<td>±0.10</td>
<td>2.07</td>
<td>±0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>12(^{th}) rib fat depth, mm</td>
<td>7.49(^a)</td>
<td>±0.41</td>
<td>6.30(^b)</td>
<td>±0.40</td>
<td>0.05</td>
</tr>
<tr>
<td><em>Longissimus</em> muscle area, cm(^2)</td>
<td>71.16</td>
<td>±1.67</td>
<td>68.32</td>
<td>±1.65</td>
<td>NS</td>
</tr>
</tbody>
</table>

\(^1\)JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sundangrass:alfalfa hay (50% each, DM basis).

\(^a,b,c\)Means within a row with different superscripts differ \((P < 0.05)\).
Table 3. Effect of two forage levels\(^1\) on marbling scores and USDA Quality and Yield Grade and carcass value of Jersey steers

<table>
<thead>
<tr>
<th>Trait</th>
<th>JL(^1)</th>
<th>SEM</th>
<th>JH(^1)</th>
<th>SEM</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of steers</td>
<td>38</td>
<td></td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDA Yield Grade</td>
<td>2.61</td>
<td>±0.12</td>
<td>2.47</td>
<td>±0.12</td>
<td>NS</td>
</tr>
<tr>
<td>Marbling Score(^2)</td>
<td>621</td>
<td>±20.68</td>
<td>572</td>
<td>±20.42</td>
<td>0.10</td>
</tr>
<tr>
<td>USDA Quality Grade(^3)</td>
<td>10.74</td>
<td>±0.20</td>
<td>10.13</td>
<td>±0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>USDA Select, %</td>
<td>8</td>
<td></td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDA Select(^+), %</td>
<td>5</td>
<td></td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDA Choice, %</td>
<td>33</td>
<td></td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDA Choice(^0), %</td>
<td>31</td>
<td></td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDA Choice(^+), %</td>
<td>13</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDA Prime, %</td>
<td>5</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDA Prime(^+), %</td>
<td>5</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carcass Value(^4)</td>
<td>934.89</td>
<td>±24.83</td>
<td>871.16</td>
<td>±24.51</td>
<td>0.10</td>
</tr>
</tbody>
</table>

\(^1\) JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).

\(^2\) U.S. marbling score: Small = 500 to 599; Modest = 600 to 699; Moderate = 700 to 799; and Slightly Abundant = 800.

\(^3\) USDA Quality Grade: 8 = low select; 9 = high select; 10 = low choice; 11 = average choice; 12 = high choice; 13 = low prime; 14 = average prime.

\(^4\) Based on USDA beef carcass price equivalent index value (USDA, 2010).
Table 4. Effect of two forage levels\textsuperscript{1} on initial carcass objective color and meat quality traits of Jersey steers

<table>
<thead>
<tr>
<th>Trait</th>
<th>JL\textsuperscript{1}</th>
<th>SEM</th>
<th>JH\textsuperscript{1}</th>
<th>SEM</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of steers</td>
<td>38</td>
<td></td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH at 48 h</td>
<td>5.40 ± 0.20</td>
<td>5.40</td>
<td>±0.02</td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>Purge, %</td>
<td>1.27 ± 0.07</td>
<td>1.31</td>
<td>±0.07</td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>Adipose\textsuperscript{2}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L*</td>
<td>79.71 ± 0.56</td>
<td>78.64</td>
<td>±0.55</td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>a*</td>
<td>0.49 ± 0.16</td>
<td>0.89</td>
<td>±0.16</td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>b*</td>
<td>12.21 ± 0.59</td>
<td>11.39</td>
<td>±0.58</td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>Lean\textsuperscript{2}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L*</td>
<td>40.37 ± 0.51</td>
<td>39.23</td>
<td>±0.51</td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>a*</td>
<td>25.76 ± 0.20</td>
<td>25.79</td>
<td>±0.20</td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>b*</td>
<td>9.48 ± 0.12</td>
<td>9.28</td>
<td>±0.12</td>
<td></td>
<td>NS</td>
</tr>
</tbody>
</table>

\textsuperscript{1}JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).

\textsuperscript{2}L* = a measure of darkness (higher L* values indicate a lighter color); a* = a measure of redness (higher a* values indicates a redder color; and b* (a measure of yellowness (higher b* values indicates a more yellow color).
Table 5. Effect of two forage levels\(^1\) on chemical composition of the *longissimus* muscle from Jersey strip loins

<table>
<thead>
<tr>
<th>Trait</th>
<th>JL(^1)</th>
<th>SEM</th>
<th>JH(^1)</th>
<th>SEM</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of steers</td>
<td>38</td>
<td></td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composition, % wet tissue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>2.99</td>
<td>±0.13</td>
<td>2.82</td>
<td>±0.13</td>
<td>NS</td>
</tr>
<tr>
<td>Protein</td>
<td>26.42</td>
<td>±1.08</td>
<td>25.72</td>
<td>±1.04</td>
<td>NS</td>
</tr>
<tr>
<td>Moisture</td>
<td>71.29</td>
<td>±0.45</td>
<td>72.10</td>
<td>±0.43</td>
<td>NS</td>
</tr>
<tr>
<td>Intramuscular fat</td>
<td>5.81</td>
<td>±0.37</td>
<td>5.39</td>
<td>±0.35</td>
<td>NS</td>
</tr>
</tbody>
</table>

\(^1\)JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).
Figure 1. *Longissimus dorsi* display color scores of steaks from Jersey steers fed two different two forage levels* during retail display.

Display color score (1 = very bright, 2 = bright red, 3 = dull red, 4 = slightly dark red, 5 = slightly dark red or reddish tan).

*JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sundangrass:alfalfa hay (50% each, DM basis).

*a-c* Days with different superscripts differ ($P < 0.05$).
Figure 2. *Longissimus dorsi* discoloration color scores of steaks from Jersey steers fed two different forage levels during retail display.

1 Discoloration color score [1 = none (0%), 2 = slight discoloration (1 to 19%), 3 = small discoloration (20 to 39%)].

*JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).*
Figure 3. *Longissimus dorsi* Hunter $L^*$ values of steaks from Jersey steers fed two different two forage levels* during retail display.

*JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).*

*a-c Days with different superscripts differ ($P < 0.05$).
Figure 4. *Longissimus dorsi* Hunter a* values of steaks from Jersey steers fed two different two forage levels* during retail display.

*JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).

*a-d Days with different superscripts differ (*P* < 0.05).

*a,b Treatments with different superscripts differ (*P* < 0.05).
Figure 5. *Longissimus dorsi* Hunter $b^*$ values of steaks from Jersey steers fed two different two forage levels* during retail display.

*JL* = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); *JH* = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).

*a-d* Days with different superscripts differ ($P < 0.05$).

*a,b* Treatments with different superscripts differ ($P < 0.05$).
Table 6. Effect of two forage levels\(^1\) on Warner–Bratzler shear force values and cooking loss of strip loin steaks from Jersey steers

<table>
<thead>
<tr>
<th>Trait</th>
<th>JL(^1)</th>
<th>SEM</th>
<th>JH(^1)</th>
<th>SEM</th>
<th>(P)-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of samples</td>
<td>36</td>
<td></td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warner-Bratzler shear force, kg</td>
<td>2.63 ±0.11</td>
<td></td>
<td>2.64 ±0.10</td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>Cooking loss, %</td>
<td>24.86 ±0.87</td>
<td></td>
<td>22.94 ±0.84</td>
<td></td>
<td>NS</td>
</tr>
</tbody>
</table>

\(^1\) JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).
Figure 6. Consumer sensory evaluation means of steaks from Jersey steers fed two different two forage levels.

JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sundangrass:alfalfa hay (50% each, DM basis).

Sensory scale: Sensory attributes were based on a 9-point hedonic scale, where 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely.
Figure 7. Semi-trained evaluation means of steaks from Jersey steers fed two different two forage levels.

*JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).

2Sensory Scale: Initial and sustained tenderness and juiciness, beef flavor intensity, and overall acceptability were evaluated on a 10-cm continuous line scale with 0 = tough, dry, none detectable, and unacceptable, respectively, and 10 = tender, juicy, pronounced, and very desirable, respectively.
Table 7. Correlation coefficients for live weight and carcass traits of Jersey steers

<table>
<thead>
<tr>
<th>Trait</th>
<th>LWT</th>
<th>HCW</th>
<th>DP</th>
<th>ADBF</th>
<th>LMA</th>
<th>KPH</th>
<th>YG</th>
<th>MBS</th>
<th>QG</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWT</td>
<td></td>
<td>0.94***</td>
<td>0.50***</td>
<td>0.64***</td>
<td>0.30**</td>
<td>0.55***</td>
<td>0.55***</td>
<td>0.46***</td>
<td>0.46***</td>
</tr>
<tr>
<td>HCW</td>
<td>0.75***</td>
<td></td>
<td>0.75***</td>
<td>0.67***</td>
<td>0.35**</td>
<td>0.59***</td>
<td>0.56***</td>
<td>0.45***</td>
<td>0.45***</td>
</tr>
<tr>
<td>DP</td>
<td>0.48***</td>
<td>0.67***</td>
<td></td>
<td>0.47***</td>
<td>0.37**</td>
<td>0.33**</td>
<td>0.33**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADBF</td>
<td>0.24*</td>
<td>0.68***</td>
<td>0.47***</td>
<td></td>
<td></td>
<td>0.32**</td>
<td>0.35**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LMA</td>
<td>0.11</td>
<td>0.64***</td>
<td>0.33**</td>
<td>0.31**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KPH</td>
<td>-</td>
<td>0.64***</td>
<td>0.33**</td>
<td>0.31**</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YG</td>
<td>-</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MBS</td>
<td>0.48***</td>
<td>0.64***</td>
<td>0.33**</td>
<td>0.31**</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QG</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.97***</td>
</tr>
</tbody>
</table>

1JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).

2Trait:  LWT = live weight, kg; HCW = hot carcass weight, kg; ADBF = 12th rib fat depth, mm; LMA = longissimus muscle area, cm²; KPH = kidney, pelvic, and heart fat, %; YG = USDA Yield Grade; MBS = U.S. marbling score: Small = 500 to 599; Modest = 600 to 699; Moderate = 700 to 799; and Slightly Abundant = 800; QG = USDA Quality Grade: 8 = low select; 9 = high select; 10 = low choice; 11 = average choice; 12 = high choice; 13 = low prime; 14 = average prime.

*** = P < 0.0001, ** = P < 0.01, and * = P < 0.05.
Table 8. Correlation coefficients for meat quality traits of Jersey carcasses

<table>
<thead>
<tr>
<th>Trait</th>
<th>pH</th>
<th>purge</th>
<th>FL</th>
<th>Fa</th>
<th>Fb</th>
<th>LL</th>
<th>La</th>
<th>Lb</th>
<th>MBS</th>
<th>IMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>-0.04</td>
<td>-0.03</td>
<td>-0.04</td>
<td>-0.09</td>
<td>-0.14</td>
<td>-0.12</td>
<td>-0.01</td>
<td>-0.09</td>
<td>-0.11</td>
</tr>
<tr>
<td>purge</td>
<td>-</td>
<td>-0.11</td>
<td>0.12</td>
<td>-0.11</td>
<td>0.12</td>
<td>0.25*</td>
<td>0.10</td>
<td>-0.30**</td>
<td>-0.33**</td>
<td></td>
</tr>
<tr>
<td>FL</td>
<td>-</td>
<td>-0.33**</td>
<td>0.33**</td>
<td>0.10</td>
<td>0.09</td>
<td>0.21</td>
<td>0.14</td>
<td>0.21</td>
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<td></td>
</tr>
<tr>
<td>Fa</td>
<td>-</td>
<td>-0.05</td>
<td>-0.13</td>
<td>-0.04</td>
<td>-0.14</td>
<td>0.01</td>
<td>-0.04</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fb</td>
<td>-</td>
<td>0.09</td>
<td>0.10</td>
<td>0.23*</td>
<td>0.35**</td>
<td>0.30**</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LL</td>
<td>-</td>
<td>0.25*</td>
<td>0.42**</td>
<td>0.16</td>
<td>0.24*</td>
<td>0.21</td>
<td></td>
<td></td>
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<tr>
<td>La</td>
<td>-</td>
<td>0.82***</td>
<td>-0.13</td>
<td>-0.15</td>
<td></td>
<td></td>
<td></td>
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<td>Lb</td>
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<td>0.02</td>
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<td></td>
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<tr>
<td>MBS</td>
<td>-</td>
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<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>IMF</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1JL = Jersey low forage, 12% sudangrass:alfalfa hay (50% each, DM basis); JH = Jersey high forage, 24% sudangrass:alfalfa hay (50% each, DM basis).

2Trait: FL, Fa, and Fb = adipose L*, a*, and b* values, respectively; LL, La, and Lb = lean L*, a* and b* values, respectively; L* = a measure of lightness/darkness (higher L* values indicate a lighter color); a* = a measure of redness/greeness (higher a* values indicate a redder color; and b* a measure of yellowness/blueness (higher b*values indicates a more yellow color). MBS = U.S. marbling score: Small = 500 to 599; Modest = 600 to 699; Moderate = 700 to 799; and Slightly Abundant = 800. IMF = intramuscular fat content.

*** = P < 0.0001, ** = P < 0.01, and * = P < 0.05.
Table 9. Correlation coefficients for consumer and semi-trained sensory panel attributes, Warner–Bratzler shear force value, and marbling score of Jersey steaks

<table>
<thead>
<tr>
<th>Trait</th>
<th>COA</th>
<th>TEND</th>
<th>CJUIC</th>
<th>FLAV</th>
<th>IT</th>
<th>ST</th>
<th>IJ</th>
<th>SJ</th>
<th>BFI</th>
<th>TOA</th>
<th>WBSF</th>
<th>MBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>COA</td>
<td>-</td>
<td>1.00***</td>
<td>1.00***</td>
<td>0.12</td>
<td>0.12</td>
<td>0.10</td>
<td>0.06</td>
<td>0.04</td>
<td>0.08</td>
<td>-0.01</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>TEND</td>
<td>-</td>
<td>1.00***</td>
<td>1.00***</td>
<td>0.12</td>
<td>0.12</td>
<td>0.10</td>
<td>0.06</td>
<td>0.04</td>
<td>0.08</td>
<td>-0.01</td>
<td>0.19</td>
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</tr>
<tr>
<td>CJUIC</td>
<td>-</td>
<td>1.00***</td>
<td>0.12</td>
<td>0.12</td>
<td>0.10</td>
<td>0.06</td>
<td>0.04</td>
<td>0.08</td>
<td>-0.01</td>
<td>0.19</td>
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<tr>
<td>FLAV</td>
<td>-</td>
<td>-</td>
<td>0.12</td>
<td>0.12</td>
<td>0.10</td>
<td>0.06</td>
<td>0.04</td>
<td>0.08</td>
<td>-0.01</td>
<td>0.19</td>
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<td></td>
</tr>
<tr>
<td>IT</td>
<td>-</td>
<td>-</td>
<td>0.98***</td>
<td>0.67***</td>
<td>0.70***</td>
<td>0.60***</td>
<td>0.86***</td>
<td>-0.50***</td>
<td>0.24*</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>ST</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.67***</td>
<td>0.70***</td>
<td>0.58***</td>
<td>0.86***</td>
<td>-0.50***</td>
<td>0.27*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IJ</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.95***</td>
<td>0.82***</td>
<td>0.86***</td>
<td>-0.26*</td>
<td>0.20</td>
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<td></td>
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</tr>
<tr>
<td>SJ</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.82***</td>
<td>0.90***</td>
<td>-0.25*</td>
<td>0.17</td>
<td></td>
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</tr>
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<td>BFI</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>0.84***</td>
<td>-0.29*</td>
<td>0.12</td>
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<tr>
<td>TOA</td>
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<tr>
<td>WBSF</td>
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<td>-1.4</td>
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</tr>
</tbody>
</table>

1Trait: COA = Consumer overall acceptability, CJUIC = consumer juiciness, FLAV = consumer flavor desirability, IT = Trained initial tenderness, ST = trained sustained tenderness, IJ = trained initial juiciness, SJ = trained initial juiciness, BFI = beef flavor intensity, TOA = trained overall acceptability. Consumer panel used a 9-point hedonic scale, where 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely. Trained panel used a 10-cm continuous line scale with 0 = tough, dry, none detectable, and unacceptable and 10 = tender, juicy, pronounced, and very desirable for initial and sustained tenderness and juiciness, beef flavor intensity, and overall acceptability, respectively. WBSF = Warner-Bratzler shear force, kg. MBS = U.S. marbling score: Small = 500 to 599; Modest = 600 to 699; Moderate = 700 to 799; and Slightly Abundant = 800.

*** = P < 0.0001, ** = P < 0.01, and * = P < 0.05.
REFERENCES


