Meat and Muscle Biology™

# Palatability of New Zealand Grass-Finished and American Grain-Finished Beef Strip Steaks of Varying USDA Quality Grades and Wet-Aging Treatments

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**Abstract:** The objective of this study was to evaluate palatability of strip loin steaks from grass- and grain-fed beef across 5 United States Department of Agriculture (USDA) quality grades and 3 wet-aging periods. Beef strip loins ($N = 200$; 20/USDA quality grade × fed cattle type) representing 5 USDA quality grades (USDA Prime, Top Choice [Average and High Choice], Low Choice, Select, and Standard) and 2 fed cattle types (New Zealand grass-finished and U.S. grain-finished) were used in the study. Each strip loin was equally portioned into thirds and randomly assigned to one of 3 wet-aging periods (7 d, 21 d, or 42 d). Consumer panelists ($N = 600$; 120/location: Texas, California, Florida, Kansas, and Pennsylvania) evaluated 8 grilled beef steak samples for palatability traits, acceptability, and eating quality. All palatability traits were impacted by the interaction of diet × quality grade ($P < 0.05$). Although similar ($P > 0.05$) to grass-fed Prime steaks for juiciness, tenderness, and overall liking, grain-fed Prime steaks rated higher ($P < 0.05$) than all other grass- and grain-finished treatments for all palatability attributes. Grass-finished Top Choice, Low Choice, and Standard steaks rated higher ($P < 0.05$) than the respective grain-finished quality grades for juiciness and tenderness. Grain-finished Standard steaks rated lower ($P < 0.05$) than all other grass- and grain-finished treatments for juiciness, tenderness, and overall liking but were similar ($P > 0.05$) to grass-finished Standard steaks for flavor liking. Our results indicate that beef strip loin steaks of similar quality grades from grass-finished New Zealand cattle produce similar eating experiences when compared with those from U.S. grain-finished beef, even following extended postmortem aging. This indicates improved palatability for consumers based on marbling without respect to grass- or grain-finishing diets.

**Key words:** aging, beef, grass-fed, grain-fed, marbling, palatability
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## Introduction

With an evolving population demanding more food choices, some consumers are becoming more interested in the idea of grass-fed beef (Martin and Rogers, 2004). Only 4% of the United States beef market sales come from grass-fed beef; however, the demand is drastically increasing as retail sales have doubled each year since 2012 (Cheung et al., 2017). Due to limited availability of year-long forage in the U.S., domestic grass-finished beef is often inconsistent in availability and quality. Therefore, as demand has increased, the U.S. has looked to other countries to meet consumer needs. Approximately 75% of grass-fed beef sales in the U.S. are imported from countries in the Southern Hemisphere such as New Zealand and Australia (Cheung et al., 2017). Due to the temperate climate, these countries can capitalize on forage feeding year-round in order to mass-produce the niche product for export. Grass-fed beef has been sought after due to its antioxidant properties, lower (healthier) ratio of omega-6 to omega-3 fatty acids, and greater concentration of conjugated linoleic acids (Cheung et al., 2017). While forage-based finishing systems can slightly enhance the nutritional value of beef, their effect on palatability traits remains unclear and inconsistent. To date, grass-fed beef has often had a negative connotation in the U.S. due to the yellow fat color, darker lean color, lack of marbling, tough eating experience, and grassy off-flavor (Jiang, 2011).

Most U.S. consumers are accustomed to the taste of domestic beef and prefer steaks from grain-fed beef due to their preference for superior taste attributes at a reasonable price (Umberger et al., 2002). Grain-fed cattle have been shown to produce carcasses with superior flavor and tenderness traits when compared with carcasses obtained from grass-fed cattle (Davis et al., 1981; Berry et al., 1988; Sitz et al., 2005), but others have concluded forage-finished steers exhibit comparable or superior palatability traits when compared with grain-fed cattle (Oltjen et al., 1971; Bidner et al., 1981). Many of the aforementioned studies comparing grass- and grain-fed beef were confounded by age at slaughter and varying percentages of intramuscular fat (IMF) in the samples, as most U.S.-sourced grass-fed products take longer to finish and contain less fat than traditional domestic grain-fed products.

Due to the extended length of time to finish cattle on grass and lack of high-quality forages available year-round in the U.S., very little grass-fed beef produced is from young animals with high IMF percentages. American consumers have, to date, not evaluated grain-fed compared with grass-fed beef within a similar IMF percentage from a wide range of quality grades (United States Department of Agriculture [USDA] Standard up to USDA Prime) due to the lack of domestic high-quality, grass-finished beef. One limitation to such imports arises as products must be shipped from international markets, and the transit time for chilled grass-finished beef to reach the U.S. can be extensive. Although aging up to 28 to 30 d has been reported to improve tenderness in beef steaks (Jeremiah and Gibson, 2003), extended wet-aging time of grass-finished beef has been reported to be detrimental to flavor (Gutowski et al., 1979; Sitz et al., 2005). Therefore, the objective of this study was to evaluate a wide range of marbling and wet-aging times' impact on the palatability of strip loin steaks from young U.S. grain-finished and New Zealand grass-finished beef.

# Materials and Methods

## *Experimental treatments and sample preparation*

Beef strip loins (Institutional Meat Purchase Specifications #180; USDA, 2020; $N = 200$; 20 per USDA quality grade × fed cattle type) representing 5 USDA quality grades (USDA Prime, Top Choice [Average and High Choice], Low Choice, Select, and Standard) and 2 fed cattle types (New Zealand grass-finished and U.S. grain-finished) were used in the study. Each carcass was evaluated by trained Texas Tech University personnel for beef grading measures such as lean maturity, skeletal maturity, USDA marbling score, Meat Standards Australia (MSA) marbling score, adjusted subcutaneous fat thickness (12th rib), ribeye area, hot carcass weight, pH, hump height, AUS-MEAT Fat Color, and AUS-MEAT Meat Color. All strip loins (*longissimus lumborum*) were selected by trained Texas Tech personnel at commercial beef packing facilities in Nebraska (grain-finished) and New Zealand (grass-finished) over a 1d and 4-d time period, respectively, to ensure that varying lots of cattle were represented. It is important to note that the New Zealand abattoir used electrical stimulation in practice, whereas the Nebraska facility did not. The U.S. grain-finished strip loins were sourced in August (summer) from a commercial packing facility that sources grain-finished cattle in the Midwest U.S. The New Zealand grass-fed strip loins were sourced in July (winter) from an abattoir on the eastern coast of the North Island from cattle exposed to high-quality forage in order to finish at a young age. Grass-fed and grass-finished New Zealand cattle are required to follow the Animal Status Declaration document that states, "Pasture (Grass) fed means that the animals have been raised under normal New Zealand farming conditions with year-round access to grass (e.g., hay, silage, lucerne, feed crops, or other grazed or conserved forages) and other supplementary feeds (including manufacturing feeds, provided that you have a statement from the manufacturer that the feed does not contain animal protein or animal fat, other than dairy). You must keep the manufacturers' declaration. Where animals have been fed on a feed pad or feedlot other than for short term periods (e.g., only as supplementary feed immediately prior to slaughter) then they would not be 'pasture fed' because of not having year-round access to grass" (ASD, 2012).

The most anterior "wedge" steak was cut by hand from the anterior end of the strip loin, vacuum packaged and frozen within 5 d of harvest. The "wedge" steak was used for proximate analysis. The remaining strip loin was equally portioned into 3 pieces at the processing facility and randomly assigned to one of 3 aging periods (7 d, 21 d, or 42 d) under vacuum at 2°C to 4°C. The New Zealand grass-finished strip loin portions were aged at the processing facility under vacuum for the assigned aging periods. Following the aging period, the New Zealand grass-finished strip loin portions were frozen (−20°C) and shipped to the Gordon W. Davis Meat Laboratory in Lubbock, Texas. The Nebraska grain-finished strip loin portions were vacuum packaged at the processing facility and transported, under refrigeration (2°C), to the Gordon W. Davis Meat Science Laboratory in Lubbock, Texas, where aging was completed. After aging, all strip loin portions were frozen (−20°C), then fabricated (while still in the frozen state) into 2.5-cm-thick steaks using a band saw (Hobart Corporation, Model 6801, Troy, Ohio), individually vacuum packaged, and stored frozen (−20°C) until subsequent analysis. The strip loin portions were fabricated into steaks from anterior to posterior. The anterior end of each strip loin portion was faced and saved for other analyses, the first two 2.5-cm-thick steaks were used for consumer testing, and the third steak was used for slice shear force (SSF). All steaks were individually identified, vacuum packaged, and stored frozen (−20°C).

### Proximate analysis

Steaks for proximate analysis were thawed for 24 h at 2°C to 4°C. Steaks were trimmed of external fat and connective tissue, cut into 2.5 cm by 2.5 cm pieces, and ground through a 4-mm plate. Proximate analysis of raw steaks was conducted by an AOAC official method (Anderson, 2007) using a near infrared spectrophotometer (FoodScan, FOSS NIRsystems, Inc., Laurel, MD). Percentages of fat, moisture, and protein were determined for each strip loin.

### Cooked sample preparation

Before cooking, samples were thawed at 2°C to 4°C for 24 h and were trimmed to remove external fat. Two steaks from each strip loin portion were cooked to a target internal temperature of 71°C on a clamshell grill (Cuisinart Griddler Deluxe, East Windsor, NJ) monitored by cooking time and internal temperature checks (Thermapen Mk4, Thermoworks, American Fork, UT). Immediately following cooking, steaks were allowed to rest to reach a peak internal temperature (Thermapen Mk4, Thermoworks, American Fork, UT). Peak temperatures were recorded for both steaks following cooking and averaged for calculation of peak endpoint temperature. Cooked steaks were trimmed of any remaining external fat and connective tissue, then portioned into four 2.5-cm by 5-cm pieces each, and each of the 8 portions was immediately served in a random order to 8 consumers on a Styrofoam plate.

### Consumer panel evaluation

The Texas Tech University Institutional Review Board approved procedures for use of human subjects for sensory panel evaluations (IRB2016-860). Consumer panelists ($N = 600$; 120 per city) were recruited by email list and paid for their participation in Lubbock, Texas; San Francisco, California; Gainesville, Florida; Manhattan, Kansas; and State College, Pennsylvania. Consumers were recruited based on the criteria that they are beef consumers who consume beef at least once per week and are at least 18 years of age. Twenty-five panel sessions (5 in each city) were conducted with 24 consumers seated in individual sensory booths/areas for approximately 1 h duration. Panelists were provided with a ballot, plastic fork and knife, toothpick, napkin, expectorant cup, cup of water, and palate cleansers (unsalted crackers and diluted sugar-free apple juice: 90% water and 10% sugar-free apple juice) to use between samples. Each ballot packet contained an information sheet, demographic questionnaire, beef steak purchasing behavior sheet, and 8 sample ballots. Before the start of each panel, panelists were given verbal instructions about the ballot and use of the palate cleansers. No consumer was sitting next to another consumer sampling the same steak. Consumers were served 8 samples immediately post cooking in a predetermined, random order approximately 6 to 7 min apart.

Attributes for all 8 samples were ranked on a paper ballot with 10-cm continuous line scales for juiciness, tenderness, flavor liking, and overall liking. The zero anchors were labelled as not juicy, not tender, dislike extremely, and dislike extremely, whereas the 10-cm anchors were labelled as very juicy, very tender, like extremely, and like extremely. Also, each consumer rated each sample as either acceptable or unacceptable (yes/no) for each palatability trait. Finally, consumers were asked to designate each sample as unsatisfactory, everyday quality, better than everyday quality, or premium quality.

### Slice shear force

Before cooking, steaks were thawed at 2°C to 4°C for 24 h and were trimmed to remove external fat. The steaks were cooked as previously described, and peak internal temperatures were recorded. Tenderness was evaluated by SSF as described by

Shackelford et al. (1999). In brief, following the endpoint temperature reading, a 1–2 cm slice was removed across the width of the steak from the lateral end to square off the steak and expose the muscle fibers. Using a cutting guide, a 5-cm long × 1-cm thick section was obtained from the lateral end by cutting at a 45° angle, parallel to the muscle fiber orientation. The sample was center sheared perpendicular to the muscle fiber using a G-R Shear Machine (Model GR-152 [Slice Shear Speed], G-R Electric Manufacturing Company LLC, Manhattan, KS) equipped with a load cell of 50 kg operating at a cross-head speed of 500 mm/min.

### Statistical analyses

Statistical analyses were conducted using the procedures of SAS (version 9.3; SAS Institute Inc., Cary, NC). Treatment comparisons were tested for significance using PROC GLIMMIX with $\alpha = 0.05$. Sensory panels were fed in an unbalanced incomplete block design with panel (8 consumers) as block. Strip loin section (third) was considered the experimental unit, so the 8 consumer ratings were averaged for each strip loin section. Sensory and SSF data were analyzed with a split-plot arrangement of factors, with diet × quality grade as the main plot factor and age as the sub-plot factor. Acceptability data for each palatability trait and quality level were analyzed with a model that included a binomial error distribution. For all analyses, the Kenward-Roger approximation was used for estimating denominator degrees of freedom, and the PDIFF option was used to separate treatment means when the *F*-test on the main effect or effect interaction was significant ($P < 0.05$). Consumer demographic information was summarized using PROC FREQ.

## Results

### Carcass characteristics and proximate composition

Carcass characteristics are presented in Table 1. All carcasses were A-maturity, young carcasses, and there was little variation of magnitude within average skeletal maturity (140 to 186) among all grass-finished and grain-finished treatments. As expected, U.S. marbling scores increased ($P < 0.05$) as quality grade improved from Standard to Prime; however, grass Prime was higher ($P < 0.05$) than grain Prime, and grass Standard was lower ($P < 0.05$) than grain Standard for U.S. marbling

**Table 1.** Least-squares means for beef grading measures of New Zealand (NZ) grass-fed and U.S. grain-fed carcasses from varying quality grades

| Quality Treatment | U.S. Lean Maturity | U.S. Skeletal Maturity | USDA Marbling Score[1] | MSA Marbling[2] | Adjusted Fat Thickness, mm | Ribeye Area, cm$^2$ | Hot Carcass Weight, kg | pH | Hump Height, mm | Fat Color[3] | Meat Color[4] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **NZ Grass** | | | | | | | | | | | |
| Prime | 181$^{bcd}$ | 186$^{a}$ | 798$^{a}$ | 804$^{b}$ | 7$^{cd}$ | 79$^{c}$ | 341$^{bcd}$ | 5.49$^{cd}$ | 49$^{c}$ | 3.6$^{a}$ | 3.7$^{a}$ |
| Top Choice[5] | 184$^{bc}$ | 173$^{b}$ | 602$^{c}$ | 641$^{c}$ | 11$^{b}$ | 76$^{cd}$ | 330$^{cd}$ | 5.50$^{cd}$ | 46$^{cd}$ | 2.6$^{b}$ | 2.9$^{b}$ |
| Low Choice | 174$^{cd}$ | 154$^{cd}$ | 450$^{d}$ | 470$^{d}$ | 9$^{bc}$ | 73$^{d}$ | 315$^{de}$ | 5.52$^{bc}$ | 46$^{cd}$ | 2.4$^{b}$ | 2.8$^{b}$ |
| Select | 190$^{b}$ | 156$^{cd}$ | 347$^{e}$ | 340$^{e}$ | 5$^{de}$ | 74$^{cd}$ | 291$^{ef}$ | 5.56$^{ab}$ | 40$^{d}$ | 2.6$^{b}$ | 2.9$^{b}$ |
| Standard | 221$^{a}$ | 140$^{e}$ | 240$^{g}$ | 243$^{f}$ | 3$^{e}$ | 75$^{cd}$ | 267$^{f}$ | 5.59$^{a}$ | 41$^{d}$ | 2.3$^{b}$ | 2.8$^{b}$ |
| **U.S. Grain** | | | | | | | | | | | |
| Prime | 159$^{ef}$ | 159$^{c}$ | 756$^{b}$ | 878$^{a}$ | 14$^{a}$ | 88$^{b}$ | 401$^{a}$ | 5.52$^{cd}$ | 56$^{b}$ | 1.0$^{c}$ | 1.6$^{c}$ |
| Top Choice[5] | 144$^{g}$ | 152$^{cd}$ | 589$^{c}$ | 656$^{c}$ | 14$^{a}$ | 86$^{b}$ | 365$^{b}$ | 5.50$^{cd}$ | 51$^{bc}$ | 1.1$^{c}$ | 1.1$^{d}$ |
| Low Choice | 150$^{fg}$ | 149$^{de}$ | 452$^{d}$ | 512$^{d}$ | 14$^{a}$ | 88$^{b}$ | 354$^{bc}$ | 5.46$^{d}$ | 57$^{b}$ | 0.9$^{c}$ | 1.9$^{c}$ |
| Select | 150$^{fg}$ | 155$^{cd}$ | 354$^{e}$ | 359$^{e}$ | 11$^{b}$ | 89$^{b}$ | 353$^{bc}$ | 5.52$^{bc}$ | 57$^{ab}$ | 1.1$^{c}$ | 1.5$^{cd}$ |
| Standard | 170$^{de}$ | 161$^{c}$ | 265$^{f}$ | 257$^{f}$ | 5$^{de}$ | 98$^{a}$ | 357$^{bc}$ | 5.59$^{a}$ | 63$^{a}$ | 2.3$^{b}$ | 3.1$^{b}$ |
| **SEM**[6] | 4 | 4 | 8 | 20 | 1 | 2 | 12 | 0.02 | 2 | 0.2 | 0.2 |
| ***P* value** | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

[1]200: Traces, 300: Slight, 400: Small, 500: Modest, 600: Moderate, 700: Slightly abundant.

[2]Meat Standards Australia (MSA) marbling score: ranges from 100 (no visible marbling) to 1,190 with increments of 10.

[3]Fat color: recorded using AUS-MEAT chips from 0 (white) to 9 (yellow).

[4]Meat color: recorded using AUS-MEAT standard meat color chips.

[5]Top Choice includes marbling scores Modest and Moderate.

[6]SE (largest) of the least-squares means.

[a–g]Least-squares means in the same column without a common superscript differ ($P < 0.05$).

score. Grass Top Choice, Low Choice, and Select did not differ ($P > 0.05$) from their respective grain treatments for U.S. marbling score. MSA marbling scores increased ($P < 0.05$) with increasing U.S. quality grades; however, alternatively from U.S. marbling, grain Prime carcasses were higher ($P < 0.05$) for MSA marbling score than grass Prime carcasses.

New Zealand grass-finished carcasses had darker ($P < 0.05$) colored lean when measured as U.S. lean maturity score and AUS-MEAT color for Prime, Top Choice, Low Choice, and Select grass-finished carcasses, whereas Standard was similar ($P > 0.05$) to grain-finished Standard AUS-MEAT color scores. Expectedly, grain-finished carcasses (11 to 14 mm) were fatter ($P < 0.05$) for the adjusted 12th rib fat thickness than grass-finished (5 to 11 mm) Prime, Top Choice, Low Choice, and Select carcasses but were similar ($P > 0.05$) within the Standard grade ($P > 0.05$). All grain-finished treatments had larger ($P < 0.05$) ribeye areas (86 to 98 $cm^2$) than the grass-finished treatments (73 to 79 $cm^2$). Similarly, grain-finished treatments had heavier ($P < 0.05$) carcass weights (353 to 401 kg) than respective grass-finished treatments (267 to 341 kg). New Zealand grass-finished Prime, Top Choice, Low Choice, and Select carcasses had more yellow colored ($P < 0.05$) fat than grain-finished carcasses, whereas Standard carcasses were similar ($P > 0.05$) for fat color.

A diet × quality grade interaction ($P < 0.05$) for percentage fat, moisture, and protein of samples is presented in Table 2. Fat percentage increased ($P < 0.05$) with increasing marbling score within both diets; however, grain Prime contained a higher ($P < 0.05$) percentage fat than grass Prime. The same trends were observed in the MSA marbling scores. Moisture and protein percentages increased ($P < 0.05$) as fat percentage decreased.

**Table 2.** Least-squares means for the interaction between diet[1] and quality grade[2] for proximate analysis of raw beef strip loin steaks of varying diet and quality grades

| Diet/Quality Grade | Fat % | Moisture % | Protein % |
|---|---|---|---|
| **NZ Grass** | | | |
| Prime | 11.39$^{b}$ | 66.72$^{f}$ | 20.86$^{f}$ |
| Top Choice[3] | 7.69$^{c}$ | 69.39$^{e}$ | 21.71$^{e}$ |
| Low Choice | 4.72$^{d}$ | 71.88$^{c}$ | 22.34$^{d}$ |
| Select | 2.54$^{e}$ | 73.45$^{b}$ | 23.02$^{c}$ |
| Standard | 1.17$^{f}$ | 74.29$^{a}$ | 23.19$^{bc}$ |
| **U.S. Grain** | | | |
| Prime | 12.98$^{a}$ | 65.26$^{g}$ | 21.14$^{f}$ |
| Top Choice[3] | 6.86$^{c}$ | 69.58$^{e}$ | 22.84$^{c}$ |
| Low Choice | 4.56$^{d}$ | 70.81$^{d}$ | 23.63$^{a}$ |
| Select | 3.12$^{e}$ | 71.96$^{c}$ | 23.83$^{a}$ |
| Standard | 1.51$^{f}$ | 73.58$^{ab}$ | 23.56$^{ab}$ |
| **SEM**[4] | 0.36 | 0.30 | 0.15 |
| ***P* value** | 0.02 | 0.04 | 0.01 |

[1]Diet: Diets fed to cattle included grass-finished in New Zealand (NZ) and grain-finished in the United States.

[2]Quality Grade: United States Department of Agriculture (USDA) quality grades included Prime, Top Choice (Upper 2/3 Choice), Low Choice, Select, and Standard.

[3]Top Choice includes marbling scores Modest and Moderate.

[4]SE (largest) of the least-squares means.

[a–g]Least-squares means in the same column without a common superscript differ ($P < 0.05$).

## Slice shear force

A diet × quality grade interaction ($P < 0.05$) for SSF is represented in Table 3. There was no difference ($P > 0.05$) observed between quality grades within the grass-finished treatment in SSF. Grain-fed Prime samples had the lowest ($P < 0.05$) SSF values within U.S. grain samples, and the remaining grain-fed quality grades were similar ($P > 0.05$) for SSF. Within like quality grades, the effect of diet on SSF was only observed in Top Choice and Standard steaks, for which the grass-finished treatment was lower ($P < 0.05$) than the grain-finished treatment. No diet × aging or quality grade × aging interactions were present ($P > 0.05$) for SSF. Mean separations for SSF from different wet-aging periods are also presented in Table 3. Slice shear force least-squares means for samples aged for 21 and 42 d were similar ($P > 0.05$) and lower ($P < 0.05$) than those representing steaks wet aged for 7 d.

## Consumer demographics and consumption behaviors

Table 4 contains the demographic and consumption behavior information from the 600 consumers (120 per state) who participated in the consumer sensory testing in California, Florida, Kansas, Pennsylvania, and Texas. By a small margin, the majority of the consumers in the study were female (55.5%) and single (58.39%). Households with 2 people were most represented (29.08%) in the study, followed by 4-person households (21.01%) and 3-person households (18.49%). Most consumers who participated in the study were Caucasian/white (78.88%), between 20 and 29 years of age (39.09%), had some college/technical school (41.65%), and were a college graduate (29.17%) or a post graduate degree (17.05%). The majority of consumers indicated they eat beef from 1 to 3 times per week (63.5%) and

**Table 3.** Least-squares means for the interaction between diet[1] and quality grade[2] and least-squares means for the main effect of age[3] for slice shear force, kg of grilled beef strip loin steaks of varying quality treatments

| Diet/Quality Grade | Slice Shear Force, kg |
|---|---|
| **NZ Grass** | |
| Prime | 11.98[de] |
| Top Choice | 12.21[de] |
| Low Choice | 12.65[de] |
| Select | 13.36[bcd] |
| Standard | 13.22[cde] |
| **U.S. Grain** | |
| Prime | 11.35[e] |
| Top Choice | 15.36[ab] |
| Low Choice | 13.60[bcd] |
| Select | 14.89[abc] |
| Standard | 16.72[ab] |
| **SEM**[4] | 0.75 |
| ***P* value** | 0.01 |
| **Age** | |
| 7-d | 15.02[a] |
| 21-d | 13.17[b] |
| 42-d | 12.41[b] |
| **SEM**[4] | 0.46 |
| ***P* value** | <0.01 |

[1]Diet: Diets fed to cattle included grass-finished in New Zealand (NZ) and grain-finished in the United States.

[2]Quality Grade: United States Department of Agriculture (USDA) quality grades included Prime, Top Choice (Upper 2/3 Choice), Low Choice, Select, and Standard.

[3]Age: Wet-aging periods included 7-d, 21-d, and 42-d.

[4]SE (largest) of the least-squares means.

[a–e]Least-squares means in the same column and section without a common superscript differ ($P < 0.05$).

prefer beef more than all other meat products for flavor (60.64%). Flavor (48.99%) was the most important palatability trait when eating beef, followed by tenderness (39.93%) and juiciness (11.07%). The most preferred degree of doneness when eating beef was medium rare (46.17%) followed by medium (23.5%) and medium well (17.83%).

## Consumer panel evaluation

Juiciness, tenderness, flavor liking, and overall liking were impacted by the interaction of diet × quality grade ($P < 0.05$; Table 5). Grass- and grain-finished Prime steaks were similar ($P > 0.05$) for juiciness and tenderness and higher ($P < 0.05$) than all other treatments. Although similar ($P > 0.05$) to grass Prime steaks for overall liking, grain Prime steaks rated higher ($P < 0.05$) than all other quality grades for overall liking and all other treatments for flavor liking. Grass-finished Top Choice, Low Choice, and Standard samples were higher ($P < 0.05$) than the respective grain-finished quality grades for juiciness and tenderness. Grain-finished Standard steaks rated lower ($P < 0.05$) than all other grass- and grain-finished treatments for juiciness, tenderness, and overall liking. No differences ($P > 0.05$) were found between grain Top Choice and Low Choice as well as grain Low Choice and Select steaks for juiciness, tenderness, flavor liking, and overall liking. Grass Top Choice and Low Choice steaks were similar ($P > 0.05$) for all palatability attributes and rated higher ($P < 0.05$) than grass Select and Standard steaks for overall liking. Within grass-finished samples, Standard samples rated lower ($P < 0.05$) for juiciness, tenderness, flavor liking, and overall liking than Prime, Top Choice, and Low choice but were similar ($P > 0.05$) to Select samples.

For flavor and overall liking, an age × diet interaction ($P < 0.05$) is presented in Table 6. No difference ($P > 0.05$) was found between grass- and grain-finished samples for flavor liking when samples were aged 7 and 21 d. When samples were aged for the extended period of 42 d, flavor liking was higher ($P < 0.05$) for grain-finished than grass-finished samples. For overall liking, grass-finished beef rated higher ($P < 0.05$) than grain-finished beef when aged for 7 and 21 d; however, there was no difference ($P > 0.05$) when aged 42 d. Wet aging affected the least-squares means for consumer ratings of juiciness and tenderness (Table 7). Steaks aged for 21 d and 42 d rated juicier ($P < 0.05$) than steaks aged for 7 d. Tenderness increased ($P < 0.05$) as wet age time increased (7 d < 21 d < 42 d).

## Consumer acceptability

An age × diet interaction ($P < 0.05$; Table 6) was found for tenderness acceptability and overall acceptability. Tenderness acceptability of grain 42-d samples was similar ($P > 0.05$) to grass 42-d and 21-d samples but higher ($P < 0.05$) than grain 21-d and grass and grain 7-d treatments. Grain 7-d aged samples were the least acceptable ($P < 0.05$) for tenderness compared with all other treatments. Grain-finished tenderness acceptability increased as age time increased ($P < 0.05$); however, grass-finished tenderness acceptability only increased ($P < 0.05$) from 7 d to 21 d. A higher ($P < 0.05$) percentage of grass-finished samples were rated as acceptable for tenderness than grain-finished samples when aged for 7 and 21 d; however, no difference ($P > 0.05$) was found for samples aged 42 d.

**Table 4.** Demographic characteristics and consumption behavior of consumers ($N = 600$) who participated in consumer sensory panels

| Characteristic | Response | Percentage of Consumers |
|---|---|---|
| **Gender** | Male | 44.50 |
| | Female | 55.50 |
| **Household Size** | 1 person | 16.30 |
| | 2 people | 29.08 |
| | 3 people | 18.49 |
| | 4 people | 21.01 |
| | 5 people | 10.42 |
| | 6 people | 3.03 |
| | >6 people | 1.68 |
| **Marital Status** | Single | 58.39 |
| | Married | 41.61 |
| **Age, y** | Under 20 | 10.57 |
| | 20–29 | 39.09 |
| | 30–39 | 12.25 |
| | 40–49 | 12.75 |
| | 50–59 | 12.42 |
| | Over 60 | 12.92 |
| **Ethnic Origin** | African American | 4.01 |
| | Asian | 9.95 |
| | Caucasian/white | 78.88 |
| | Hispanic | 5.76 |
| | Native American | 0.17 |
| | Other | 1.22 |
| **Annual Household Income** | Under $23,000 | 19.80 |
| | $23,000–$43,999 | 16.41 |
| | $44,000–$71,999 | 17.60 |
| | $72,000–$116,999 | 24.37 |
| | >$117,000 | 21.83 |
| **Education Level** | Non-high school graduate | 0.35 |
| | High school graduate | 11.78 |
| | Some college/ technical school | 41.65 |
| | College graduate | 29.17 |
| | Post graduate | 17.05 |
| **Weekly Beef Consumption** | None | 1.00 |
| | 1 to 3 times | 63.50 |
| | 4 to 6 times | 30.33 |
| | 7 or more times | 5.17 |
| **Most Important Palatability Trait When Eating Beef** | Flavor | 48.99 |
| | Juiciness | 11.07 |
| | Tenderness | 39.93 |
| **Degree of Doneness Preferred When Eating Beef** | Very rare | 1.17 |
| | Rare | 5.83 |
| | Medium rare | 46.17 |
| | Medium | 23.50 |
| | Medium well | 17.83 |
| | Well done | 4.33 |
| | Very well done | 1.17 |
| **Meat Product Preferred For Flavor** | Beef | 60.64 |
| | Chicken | 14.91 |
| | Fish | 3.85 |
| | Lamb | 6.03 |
| | Mutton | 0.17 |
| | Pork | 6.53 |
| | Shellfish | 3.52 |
| | Turkey | 1.34 |
| | Veal | 1.17 |
| | Venison | 1.84 |

No differences ($P > 0.05$) were observed for overall liking acceptability within respective 7-, 21-, and 42-d aged product, but U.S. grain 7-d treatment was rated lower ($P < 0.05$) than the grass-finished 21- and grain-finished 42-d treatments.

A diet × quality grade interaction ($P < 0.05$) for tenderness acceptability is characterized in Table 8. Following a similar trend to the tenderness ratings, grain Prime steaks rated higher ($P < 0.05$) and grain Standard steaks lower ($P < 0.05$) than all other grain-finished treatments for tenderness acceptability. No differences ($P > 0.05$) were found between grain Top Choice, Low Choice, and Select steaks for tenderness acceptability. Grass-finished Prime, Top Choice, and Low Choice samples were all similar ($P > 0.05$) for tenderness acceptability and higher ($P < 0.05$) than grass Standard samples.

Aging had no impact ($P > 0.05$) on juiciness acceptability and flavor liking acceptability (Table 7). Quality grade and diet effect on least-squares means for percentage of beef strip steaks of varying quality treatments rated as acceptable for juiciness, flavor, and overall liking by consumers is represented in Table 9. Like the palatability ratings for each trait, Prime samples were the most acceptable ($P < 0.05$) and Standard samples the least acceptable ($P < 0.05$) for juiciness acceptability, flavor liking acceptability, and overall liking acceptability. A higher ($P < 0.05$) percentage of grass-finished steaks were rated acceptable for juiciness than grain-finished steaks; however, there was no difference ($P > 0.05$) between grass and grain samples for flavor liking acceptability and overall liking acceptability.

## *Consumer-perceived quality levels*

A diet × quality grade interaction was found for unsatisfactory quality (Table 8). Percentage of samples

**Table 5.** Least-squares means for the interaction between diet[1] and quality grade[2] for consumer ratings[3] ($N = 600$) of the palatability traits of grilled beef strip loin steaks of varying quality treatments

| Diet/Quality Grade | Juiciness | Tenderness | Flavor Liking | Overall Liking |
|---|---|---|---|---|
| **NZ Grass** | | | | |
| Prime | 73.9[a] | 72.8[a] | 67.2[b] | 69.8[ab] |
| Top Choice | 69.2[b] | 66.4[b] | 66.0[bc] | 67.2[bc] |
| Low Choice | 66.4[bc] | 63.9[bc] | 62.9[cd] | 64.2[cd] |
| Select | 62.3[cd] | 60.2[cd] | 58.5[df] | 59.9[ef] |
| Standard | 59.0[d] | 57.3[d] | 55.6[fg] | 56.7[f] |
| **U.S. Grain** | | | | |
| Prime | 74.7[a] | 73.6[a] | 72.5[a] | 73.4[a] |
| Top Choice | 62.3[cd] | 55.5[d] | 62.0[d] | 61.8[de] |
| Low Choice | 61.5[d] | 58.3[d] | 62.9[cd] | 62.1[de] |
| Select | 61.3[d] | 57.8[d] | 60.3[de] | 59.9[ef] |
| Standard | 53.1[e] | 47.1[e] | 53.4[g] | 51.2[g] |
| **SEM**[4] | 1.2 | 2.1 | 1.4 | 1.6 |
| ***P* value** | <0.05 | 0.02 | 0.01 | 0.01 |

[1]Diet: Diets fed to cattle included grass-finished in New Zealand (NZ) and grain-finished in the United States.

[2]Quality Grade: United States Department of Agriculture (USDA) quality grades included Prime, Top Choice (Upper 2/3 Choice), Low Choice, Select, and Standard.

[3]Sensory scores: 0 = extremely dry/tough/dislike extremely; 100 = extremely juicy/tender/like extremely.

[4]SE (largest) of the least-squares means.

[a–g]Least-squares means in the same column without a common superscript differ ($P < 0.05$).

rated unsatisfactory was the lowest ($P < 0.05$) for grain Prime samples (5.4%) among grass- and grain-finished treatments. Grain Standard samples (29.4%) were more unsatisfactory ($P < 0.05$) than all other grass- and grain-finished quality grades but were similar to ($P > 0.05$) grass Standard steaks (24.0%). There was no difference ($P > 0.05$) in the percentage of unsatisfactory samples between grain-finished Top Choice, Low Choice, and Select steaks and grass-finished Top Choice and Low Choice steaks.

Table 10 has least-squares means for percentage of beef strip steaks of varying quality treatments rated at different perceived quality levels by consumers ($N = 600$). The percentage of samples rated as premium quality was higher ($P < 0.05$) for steaks aged 42 d (10.1%) than 7 d (7.3%) and 21 d (7.7%), which were similar ($P > 0.05$). Wet age time had no impact ($P > 0.05$) on the other perceived quality levels: unsatisfactory, everyday quality, or better than everyday quality. Prime samples were characterized as premium quality (20.0%) and better than everyday quality (36.57%) more ($P < 0.05$) than all other quality grades. A higher ($P < 0.05$) percentage of grain-fed samples (46.8%) were characterized as everyday quality than

**Table 6.** Least-squares means for the interaction between age[1] and diet[2] for consumer ratings[3], percentage of beef strip steaks of varying quality treatments rated as acceptable for tenderness and overall acceptability by consumers ($N = 600$)

| Age/Diet | Flavor Liking | Overall Liking | Tenderness Acceptability | Overall Liking Acceptability |
|---|---|---|---|---|
| **7-d** | | | | |
| NZ grass | 62.5[ab] | 62.7[ab] | 80.0[b] | 81.0[ab] |
| U.S. grain | 61.5[ab] | 59.6[c] | 69.5[c] | 79.1[b] |
| **21-d** | | | | |
| NZ grass | 63.2[a] | 65.2[a] | 85.5[a] | 84.4[a] |
| U.S. grain | 62.3[ab] | 61.2[bc] | 79.7[b] | 81.5[ab] |
| **42-d** | | | | |
| NZ grass | 60.5[b] | 62.7[ab] | 85.3[a] | 80.7[ab] |
| U.S. grain | 63.2[a] | 64.3[a] | 87.0[a] | 84.4[a] |
| **SEM**[4] | 1.3 | 1.4 | 1.8 | 1.6 |
| ***P* value** | <0.05 | 0.01 | 0.01 | 0.04 |

[1]Age: wet-aging periods included 7-d, 21-d, and 42-d.

[2]Diet: Diets fed to cattle included grass-finished in New Zealand (NZ) and grain-finished in the United States.

[3]Sensory scores: 0 = dislike extremely; 100 = like extremely.

[4]SE (largest) of the least-squares means.

[a–c]Least-squares means in the same column without a common superscript differ ($P < 0.05$).

**Table 7.** Least-squares means for consumer ratings[1] of the juiciness and tenderness of grilled beef strip loin steaks of varying quality treatments and percentage of beef strip steaks of varying quality treatments rated as acceptable for juiciness and flavor liking acceptability by consumers ($N = 600$)

| Quality Treatment | Juiciness | Tenderness | Juiciness Acceptability | Flavor Liking Acceptability |
|---|---|---|---|---|
| **Age**[2] | | | | |
| 7-d | 62.5[b] | 56.9[c] | 82.9 | 81.9 |
| 21-d | 65.5[a] | 61.7[b] | 84.5 | 82.4 |
| 42-d | 65.1[a] | 65.2[a] | 84.0 | 79.9 |
| **SEM**[3] | 1.1 | 1.1 | 1.1 | 1.1 |
| ***P* value** | 0.01 | <0.01 | 0.48 | 0.20 |

[1]Sensory scores: 0 = extremely dry/tough; 100 = extremely juicy/tender.

[2]Age: wet-aging periods included 7-d, 21-d, and 42-d.

[3]SE (largest) of the least-squares means.

[a–c]Least-squares means in the same column without a common superscript differ ($P < 0.05$).

**Table 8.** Least-squares means for the interaction between diet[1] and quality grade[2] of least-squares means for percentage of beef strip steaks of varying quality treatments rated as acceptable for tenderness and for unsatisfactory quality levels by consumers ($N = 600$)

| Diet/Quality Grade | Tenderness Acceptability | Unsatisfactory |
|---|---|---|
| **NZ Grass** | | |
| Prime | 89.5[ab] | 9.9[e] |
| Top Choice | 86.6[bc] | 11.2[de] |
| Low Choice | 84.1[bcd] | 13.3[cde] |
| Select | 80.2[cde] | 18.1[bc] |
| Standard | 75.4[e] | 24.0[ab] |
| **U.S. Grain** | | |
| Prime | 92.7[a] | 5.4[f] |
| Top Choice | 78.2[de] | 15.0[cde] |
| Low Choice | 78.1[de] | 16.6[cd] |
| Select | 79.0[de] | 14.8[cde] |
| Standard | 60.1[f] | 29.4[a] |
| **SEM**[3] | 4.0 | 3.1 |
| ***P* value** | 0.04 | 0.04 |

[1]Diet: Diets fed to cattle included grass-finished in New Zealand (NZ) and grain-finished in the United States.

[2]Quality Grade: United States Department of Agriculture (USDA) quality grades included Prime, Top Choice (Upper 2/3 Choice), Low Choice, Select, and Standard.

[3]SE (largest) of the least-squares means.

[a–f]Least-squares means in the same column without a common superscript differ ($P < 0.05$).

grass-fed samples (42.6%) and vice versa for better than everyday quality and premium quality.

# Discussion

Composition differences seem to have impacted the results of many studies that claim that grain-fed beef tastes better and is more tender than grass-fed beef. However, no studies, to date, have assessed grain-fed beef compared with grass-fed beef finished at a young age with similar marbling scores and IMF percentages from USDA Standard up to Prime. We selected for marbling scores within the 5 quality grade treatments, whereas many other studies reported higher marbling scores for grain-finished beef compared with grass-finished (Oltjen et al., 1971; Schroeder et al., 1980; Hedrick et al., 1983; Larick et al., 1987; Berry et al., 1988; Miller et al., 1996; Realini et al., 2004; Garmyn et al., 2010; Pfeiffer, 2016). Because of these inherent differences in marbling and composition in the majority of research previously published, our results will negate much of the previous work on grass-fed versus grain-fed beef.

**Table 9.** Least-squares means for percentage of beef strip steaks of varying quality treatments rated as acceptable for juiciness, tenderness, flavor, and overall liking by consumers ($N = 600$)

| Quality Treatment | Juiciness Acceptability | Flavor Liking Acceptability | Overall Liking Acceptability |
|---|---|---|---|
| **Quality Grade**[1] | | | |
| Prime | 92.0[a] | 89.6[a] | 89.5[a] |
| Top Choice | 86.1[b] | 82.6[b] | 83.7[b] |
| Low Choice | 83.9[bc] | 82.4[b] | 83.5[bc] |
| Select | 80.5[c] | 78.8[b] | 79.0[c] |
| Standard | 70.5[d] | 69.5[c] | 69.8[d] |
| **SEM**[2] | 2.0 | 1.7 | 2.1 |
| ***P* value** | <0.01 | <0.01 | <0.01 |
| **Diet**[3] | | | |
| NZ Grass | 85.3[a] | 80.2 | 82.1 |
| U.S. Grain | 82.2[b] | 82.6 | 81.8 |
| **SEM**[3] | 1.1 | 0.9 | 1.1 |
| ***P* value** | 0.02 | 0.06 | 0.82 |

[1]Quality Grade: United States Department of Agriculture (USDA) quality grades included Prime, Top Choice (Upper 2/3 Choice), Low Choice, Select, and Standard.

[2]SE (largest) of the least-squares means.

[3]Diet: Diets fed to cattle included grass-finished in New Zealand (NZ) and grain-finished in the United States.

[a–d]Least-squares means in the same column and section without a common superscript differ ($P < 0.05$).

### *Carcass characteristics and proximate composition*

It was an objective of the current study to compare New Zealand grass-finished and U.S. grain-finished beef of wide ranges of USDA quality grades representing a wide range of marbling scores (USDA Prime, Top Choice [USDA Average and High Choice], Low Choice, Select, and Standard). Since the U.S. does not have a regular source of high-quality (marbling) grass-finished beef, the strip loins were sourced from carcasses from an abattoir in New Zealand, whereas the grain-finished strip loins were sourced from an abattoir in Nebraska, U.S. Due to differences in live animal production practices, genetics, and feeding regimens between New Zealand and the U.S., there were some variations in carcass weight, ribeye area, adjusted fat thickness, hump height, fat color, and meat color. These variations are not uncommon, but the aim of the present study was to compare New Zealand grass-finished and U.S. grain-finished strip loins as normally produced in that country.

**Table 10.** Least-squares means for percentage of beef strip steaks of varying quality treatments rated at different perceived quality levels by consumers ($N = 600$)

| Quality Treatment | Unsatisfactory | Everyday Quality | Better than Everyday Quality | Premium Quality |
|---|---|---|---|---|
| **Quality Grade**[1] | | | | |
| Prime | 7.4 | 32.2[c] | 36.6[a] | 20.0[a] |
| Top Choice | 13.0 | 45.5[b] | 28.7[b] | 8.5[b] |
| Low Choice | 14.9 | 46.56[ab] | 26.9[bc] | 8.8[b] |
| Select | 16.4 | 51.2[a] | 23.6[c] | 6.0[bc] |
| Standard | 26.6 | 48.8[ab] | 16.8[d] | 4.1[c] |
| **SEM**[2] | 2.1 | 1.8 | 1.7 | 2.0 |
| ***P* value** | <0.01 | <0.01 | <0.01 | <0.01 |
| **Age**[3] | | | | |
| 7-d | 16.4 | 45.1 | 24.9 | 7.3[b] |
| 21-d | 13.4 | 45.8 | 26.1 | 7.7[b] |
| 42-d | 14.2 | 43.3 | 26.9 | 10.1[a] |
| **SEM**[2] | 1.1 | 1.3 | 1.2 | 0.9 |
| ***P* value** | 0.07 | 0.37 | 0.45 | 0.01 |
| **Diet**[4] | | | | |
| NZ Grass | 14.6 | 42.6[b] | 27.9[a] | 9.5[a] |
| U.S. Grain | 15.6 | 46.8[a] | 24.2[b] | 7.2[b] |
| **SEM**[2] | 1.0 | 1.3 | 1.0 | 0.8 |
| ***P* value** | 0.97 | 0.01 | 0.01 | 0.03 |

[1]Quality Grade: United States Department of Agriculture (USDA) quality grades included Prime, Top Choice (Upper 2/3 Choice), Low Choice, Select, and Standard.

[2]SE (largest) of the least-squares means.

[3]Age: Wet-aging periods included 7-d, 21-d, and 42-d.

[4]Diet: Diets fed to cattle included grass-finished in New Zealand (NZ) and grain-finished in the United States.

[a–d]Least-squares means in the same column and section without a common superscript differ ($P < 0.05$).

Many studies have shown that cattle fed a concentrate diet produced heavier carcasses (Larick et al., 1987; Realini et al., 2004; Garmyn et al., 2010; Frank et al., 2016), more backfat (Oltjen et al., 1971; Larick et al., 1987; Berry et al., 1988; Realini et al., 2004; Garmyn et al., 2010) and increased ribeye areas when compared with grass-finished cattle (Schroeder et al., 1980; Realini et al., 2004; Frank et al., 2016). Our results agree with research that shows that grass-fed beef tend to produce leaner, lighter-weight carcasses with more yellow colored fat, and darker lean color (Davis et al., 1981; Hedrick et al., 1983; Pfeiffer, 2016). USDA marbling score and MSA marbling differed between grass and U.S. grain Prime treatments, whereas all other quality grades were similar. The differences observed are likely due to the wide range of marbling included in the Prime grade and the inclusion of marbling distribution in the MSA marbling standards.

The fat percentages for the quality grades in our study are similar to previous research with the same represented quality grades (Emerson, 2011; Corbin et al., 2015; Lucherk et al., 2016). The difference reported in U.S. grain and New Zealand grass Prime fat percentages could be due to varying marbling scores within the Prime grade that may have been selected during carcass selection. Additionally, our results agree with previous research that shows an inverse relationship between fat percentage and moisture and protein percentages (O'Quinn et al., 2012; Corbin et al., 2015; Lucherk et al., 2016).

### Slice shear force

Our results for Top Choice and Standard steaks mirror those of Realini et al. (2004) that showed a decrease in shear force for steaks from grass-fed beef when compared with grain-fed beef. Our results contradict the majority of research that note that grass-finished steaks record higher shear force values compared with grain-finished steaks (Schroeder et al., 1980; Sapp et al., 1999; French et al., 2001; Kerth et al., 2007; Faucitano et al., 2008; Garmyn et al., 2010); however, many of these studies have cattle age differences and/or a higher percentage of lipid in the grain-finished treatments. Others have reported similar Warner-Bratzler shear force (WBSF) in beef steaks from grass-fed and grain-fed carcasses (Hwang and Joo, 2017).

Grain-fed Prime was the only treatment that differed from other quality grades within the same feeding type. The similarities in shear force between quality grades within grass-finished beef and within Top Choice through Standard grain-finished steaks is noteworthy and is likely because all treatments would be considered "Certified Tender" and most "Certified Very Tender" by the USDA Tenderness Program (ASTM, 2011). Although shear force decreased from 7 to 21 d of aging, there was no improvement in shear force by aging beef longer than 21 d. Similar to our research, others found that SSF of beef steaks did not differ with extending aging time from 14 d to 28 d (Pfeiffer, 2016). After a decrease in WBSF from 0 to 14 d of wet aging, a plateau in WBSF up to 4 wk was reported (Jeremiah and Gibson, 2003). Others found improved WBSF after vacuum aging strip loins from grass-fed and short-fed carcasses for 21 d; however, they found no difference in forage-fed and long-fed treatments (Gutowski et al., 1979). Miller et al. (1997) and others reported improved WBSF when aging increased from 7 d to 14 d of USDA Select and Low Choice beef strip loins. Similarly, others found an improvement in WBSF up to 21 d of wet aging (Moon et al., 2006).

## Consumer demographics and consumption behaviors

Demographic profiles and beef eating characteristics of consumers in the present study were similar to previous work (O'Quinn et al., 2012; Corbin et al., 2015; Lucherk et al., 2016; McKillip et al., 2017). Previous research has reported tenderness to be the most important palatability attribute when eating beef (Lucherk et al., 2016; Killinger et al., 2004b). In our study, flavor was selected by the majority of consumers as the most important palatability trait when eating beef steaks.

## Quality impact on consumer ratings

Our results are in agreement with previous work showing that increases in marbling correspond with increased (more desirable) consumer palatability traits, such as flavor, juiciness, and tenderness (Smith et al., 1985; Lorenzen et al., 1999; O'Quinn et al., 2012; Corbin et al., 2015; Lucherk et al., 2016). Similar to the current results, numerous previous studies have reported higher overall acceptability in high marbled steaks when evaluated by consumers (Savell et al., 1987; Savell and Cross, 1989; Neely et al., 1998; O'Quinn et al., 2012; Corbin et al., 2015). One treatment in the current study that did not align with previous research was the Top Choice grain-finished treatment. In an untrained panel of consumers, flavor can be confounded during sensory assessment due to the halo effect (Maughan, 2011). It is possible that consumer tenderness ratings had a halo effect on the flavor liking and juiciness of Top Choice grain-finished steaks, since upper 2/3 Choice steaks are not usually rated as similar to Select for flavor liking or juiciness (Lucherk et al., 2016).

## Cattle diet impact on consumer ratings

It has been commonly reported that grain-fed cattle produce carcasses with superior tenderness traits when compared with carcasses obtained from grass-fed cattle (Gutowski et al., 1979; Davis et al., 1981; Berry et al., 1988; Aberle et al., 2001; Sitz et al., 2005; Garmyn et al., 2010). It is important to note that the concentrate-finished carcasses in many of the aforementioned studies were of a younger age and/or a higher fat percentage than the grass-fed samples used for comparison. In an Australian beef steak trained sensory panel, Angus grass-fed beef was on average less tender and less juicy compared with Angus grain fed; however, the Angus grass-finished steaks were lower in IMF compared with Angus grain-finished (Frank et al., 2016). When samples were adjusted for the level of marbling using IMF as a covariate, minimal differences in sensory results were found between Angus grass- and Angus grain-finished steaks (Frank et al., 2016). Other studies have found no differences for tenderness in grass- and grain- finished beef steaks (Sapp et al., 1999; French et al., 2001). All of the carcasses in our study were young, and quality grade was controlled. When comparing within quality grade, our results negate previous research that found that steaks from forage-finished carcasses were tougher than steaks from concentrate-finished carcasses. In the current study, grass-finished Top Choice, Low Choice, and Standard steaks were more tender than the respective grain-finished quality grades.

Like tenderness, it has been reported that grain-fed cattle produce meat with superior flavor when compared with carcasses obtained from grass-fed cattle (Gutowski et al., 1979; Schroeder et al., 1980; Davis et al., 1981; Larick et al., 1987; Berry et al., 1988; Sitz et al., 2005; Garmyn et al., 2010); however, the increased IMF percentage in some of these studies could impact that conclusion. There are similar studies to ours that have controlled for marbling to get a direct comparison of cattle diets. Some have agreed with our findings (for Low Choice, Select, and Standard) that concluded that forage-finished steers exhibit comparable flavor traits when compared with grain-fed cattle (Oltjen et al., 1971; Reagan et al., 1981; Sapp et al., 1999), and some found consumers liked flavor of domestic beef more than Argentine grass-fed beef of similar marbling and shear force (Killinger et al., 2004a). Corbin et al. (2015) conducted a study evaluating varying quality treatments of tender (WBSF < 3.4 kg) beef steaks. In a trained panel, Corbin et al. (2015) reported grass-fed strip steaks with 3.81% IMF were characterized by flavors including barnyard, refrigerator/stale, oxidized, warmed-over, and fish identity, when compared with grain-finished strip steaks of various IMF levels ranging from 2% to 27%. When the grass-finished steaks (3.81% IMF) were compared with grain-finished steaks of similar IMF levels (USDA Select: 3.31% IMF and USDA Select from Holstein cattle: 3.45% IMF), consumers found tenderness and juiciness to be similar ($P > 0.05$) to grass-finished samples, which mirror effects of our study (Corbin et al., 2015). However, USDA Select and USDA Select, Holstein samples rated significantly higher for flavor liking and overall liking than grass-finished samples (Corbin et al., 2015), whereas we saw no difference within the Select grade for flavor and overall liking. In our study, diet did not influence percentage of steaks rated as acceptable for flavor liking or overall liking.

Similar to the previous research that reported on flavor and tenderness, Maughan et al. (2011) found that grain-finished steaks were liked more overall than grass-finished steaks; however, it is important to note that the grain-finished steaks were of much higher marbling scores and IMF percentages. Many studies have shown that overall acceptability is improved in grain-fed beef versus grass-fed beef (Davis et al., 1981; Berry et al., 1988; Umberger et al., 2002; Sitz et al., 2005; Kerth et al., 2007). However, in many experiments, the dietary effects were confounded by differences in animal age, carcass fatness, and specifically IMF percentage (Sitz et al., 2005; Garmyn et al., 2010).

Our results underpin the importance of marbling to beef flavor, regardless of production type. When marbling was controlled in our study, diet only influenced flavor of higher marbling treatments. Grain-finished Prime steaks were higher for flavor liking than New Zealand grass-finished Prime steaks; however, the effect was reversed within the Top Choice grade (possibly due to the tenderness halo effect). All other treatments were similar within quality grade for flavor liking. With palatability in mind, it is important that consumers know to select steaks with higher amounts of marbling when purchasing beef steaks, regardless of cattle diet. The results of this study show the importance of high-quality forage as the source of feed for beef that will be considered "grass-finished." In summary, New Zealand grass finishing versus U.S. grain feeding had only minimal impacts on beef palatability when comparing steaks within the same quality grade.

### *Wet-aging impact on consumer ratings*

In the current study, the long-aged samples were chilled for 42 d to mimic the shipment of fresh beef from New Zealand to the U.S. Although many acceptability attributes were not affected by aging time, tenderness increased with each age time, and juiciness improved when aged longer than 7 d. Tenderness is usually the most common palatability trait affected by wet aging. Jeremiah and Gibson (2003) also reported improvement in initial tenderness and overall tenderness in trained panels from 0 to 4 wk of aging. Conflicting with our results, no difference between 7-d and 21-d wet-aged barley-fed product was found for trained tenderness except for the steaks from the Brown Swiss breed (Campo et al., 1999). Contrary to Campo et al (1999) and us, Miller et al. (1997) reported improved WBSF and sensory traits when aging increased from 7 d to 14 d of USDA Select and Low Choice beef strip loins.

In the current study, it is no surprise that, when samples were aged 42 d, grain-finished steaks rated higher for flavor liking than grass-finished steaks. Extended wet aging of grass-fed beef can cause inappropriate off-odors and increases in grassy, sour, bloody, and metallic flavors (Warren and Kastner, 1992; Xiong et al., 1996; Campo et al., 1999; Sitz et al., 2005). Similar to our findings, other studies have reported that concentrate-fed cattle can tolerate longer aging periods than grass-finished cattle without a reduction in flavor liking. Gutowski et al. (1979) reported aging *longissimus* muscle under vacuum for 21 d had no influence on sensory panel tenderness or juiciness ratings; however, flavor significantly decreased in all treatments (grass-fed, forage-fed, and short-fed) except the long-fed (concentrate). After aging 14 and 28 d, Pfeiffer (2016) also reported similar results of higher flavor scores for steaks from grain-finished carcasses than grass-finished carcasses.

Moon et al. (2006) reported that, after wet aging approximately 20 to 30 d, most palatability traits are optimized. Although overall liking and tenderness acceptability were higher for grass-finished than grain-finished steaks at 7 and 21 d, no differences were found in our study between diets at 42 d of wet aging for overall liking, tenderness acceptability, and overall liking acceptability. This proves that although flavor was more favorable for grain-finished than grass-finished steaks at 42 d, it was not a drastic enough difference to affect overall liking or overall liking acceptability in the current study.

## Conclusion

Finishing diet, quality grade, and wet aging affected carcass traits, SSF, and consumer ratings of palatability traits of New Zealand grass- and U.S. grain-finished beef strip loin steaks. New Zealand grass-finishing versus U.S. grain feeding had only minimal impacts on beef palatability when comparing steaks within the same quality grade. Findings from this study underpin improved palatability for consumers based on marbling without respect to grass- or grain-finishing diets. If it is feasible to produce young, highly marbled, grass-finished beef, these results show that New Zealand grass-fed beef is another extremely tender, juicy, and flavorful option in addition to our domestic grain-fed beef, even after 42 d of wet aging.

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