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Effects of Time on Feed and Post-Mortem Aging on Palatability and Lipid Composition of Crossbred Wagyu Beef

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ABSTRACT

Twenty-seven Wagyu-sired steers were fed for 90 (14 steers) or 170 (13 steers) days to study the effects of time on feed on palatability and fatty acid composition, and the effects of post-mortem aging time (2, 4 or 10 days) on palatability. Hot carcass weight, fat thickness, longissimus dorsi *muscle area, yield grade, estimated kidney, pelvic and heart fat and maturity score were increased ($p<0.05$) by an additional 80 days on the high concentrate feed, but marbling was not changed ($p>0.05$). Feeding the high concentrate diet for 170 days increased Warner–Bratzler shear force values ($p<0.05$) and tended to decrease tenderness ($p>0.05$), flavor intensity and connective tissue scores. For the 90 day feeding group, 4 days of aging improved connective tissue score ($p<0.05$) and tended to increase ($p>0.05$) tenderness scores and decrease shear force, compared with 2 days of aging. For the 170 day feeding group, 10 days of aging improved ($p<0.05$) shear force and all sensory attributes except flavor intensity, compared to 2 days of aging. An additional 80 days on feed decreased ($p<0.05$) stearic acid and total saturated fatty acids (SFA) and generally increased ($p<0.05$) monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), MUFA:SFA, and PUFA:SFA in subcutaneous fat and* longissimus dorsi *muscle. The cholesterol content of fat and muscle increased ($p<0.05$) as time on feed increased. Ninety days on a high concentrate diet was adequate for yearling crossbred Wagyu steers to produce highly acceptable carcasses. The additional 80 days on feed produced little or no overall benefit and the steers became overfinished and less tender. Ten days post-mortem aging improved ($p<0.05$) all palatability attributes except flavor intensity. Copyright © 1996 Elsevier Science Ltd*

INTRODUCTION

Recent economic pressures have challenged the livestock and meat industries to provide consumers with highly palatable, low-cost products. Concurrently, concerns over high fat

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and cholesterol have caused many consumers to purchase leaner beef products, and/or reduce beef consumption. Consumer concerns regarding fat have led many retailers to remove much, if not all, external fat from retail cuts (NRC, 1988). Clearly, producing the fat and then trimming it off is inefficient. Thus, the beef industry and researchers alike recognize the need to produce palatable beef with less external fat (Dikeman, 1987; Morgan *et al.*, 1991).

Identification of optimum time on feed (May *et al.*, 1992; Duckett *et al.*, 1993), post-mortem technology (Dikeman, 1987) and genetic selection (NCA, 1994) are effective means to improve beef palatability and avoid unnecessary external fat. Most studies have shown little advantage in quality or palatability characteristics from feeding yearling cattle for more than 100 days (NCA, 1994). However, the influence of time-on-feed on beef palatability may be related to breed type. Brahman steers required 112–168 days of feeding to produce strip loin steaks of 'acceptable' tenderness and overall palatability, while Angus steers required only 56–112 days (McKeith *et al.*, 1985).

Japanese Wagyu cattle are characterized by their genetic ability to deposit high levels of marbling and produce highly palatable beef without depositing excessive external fat (Yamazaki, 1981). Wagyu beef may also be higher in monounsaturated fatty acids (MUFA) and lower in saturated fatty acids (SFA) than traditional North American breeds, which would be perceived as positive from a nutritional standpoint (Sturdivant *et al.*, 1992). Wagyu cattle, however, have traditionally been limit-fed for over 300 days. Little is known about the effects of ad-libitum access to a high concentrate diet for a shorter feeding period on carcass traits, palatability and fatty acid composition of Wagyu beef.

Post-mortem aging has been shown to improve ultimate tenderness of cooked meat (Wheeler *et al.*, 1990). Most research has indicated that aging beef for 10–14 days *post mortem* at temperatures of 0–2°C is optimum for tenderization (NCA, 1994). However, the effects of post-mortem aging time on the palatability attributes of crossbred Wagyu beef have not been previously evaluated. Therefore, our objectives were to: (1) determine the influence of time on feed on carcass grade traits, fatty acid profiles and cholesterol content of crossbred Wagyu beef and (2) determine the influence of time on feed and aging time on the palatability of crossbred Wagyu beef.

MATERIALS AND METHODS

Animals

Twenty-seven 18 month old, half-blood Wagyu steers (524 kg) sired by two Wagyu bulls and out of Simmental cross or Gelbvieh dams were randomly assigned to one of two experimental groups. Fourteen steers were fed a high-concentrate diet for 90 days and the other 13 steers for 170 days. Steers were fed with seven or eight in a pen with either three or four from each slaughter group in each pen. All steers were given ad-libitum access to a high-concentrate finishing diet consisting of approximately 95 % concentrate and 5 % alfalfa cubes (Table 1). Prior to the beginning of the trial all steers were fed a backgrounding diet consisting of 80 % alfalfa cubes and 20 % barley for nine months and then adjusted to the high-concentrate diet over a four week period.

Sample preparation

Upon the termination of each feeding period, steers were slaughtered at the Washington State University Meat Laboratory. Carcasses were chilled at 1 ± 1°C. Approximately

TABLE 1
Diet Composition

Item	*Composition*
Ingredients	% of diet, DM basis
Steam-rolled barley	92.0
Alfalfa hay cubes	4.0
Rumensin supplement[a]	3.75
TM salt/selenium	0.25
Chemical Composition	%, as fed
DM	89.0
Crude protein	11.5
ADF	30.0
NDF	38.4
Ash	13.7

[a]300 mg/head/day Rumensin TM.

48 hr *post mortem*, carcass measurements and yield and quality grades (USDA, 1989) were determined. Approximately 10 g samples of *longissimus dorsi* muscle and the outer layer of subcutaneous fat at the 12th rib were obtained from the right side of each animal for analysis of cholesterol and fatty acids. The ribeye roll was removed from the left side of each carcass. For 90 day steers, five 2.5 cm steaks beginning from the posterior end were sliced from each ribeye roll and individually vacuum-packaged. Steaks from seven animals were aged for 2 days and steaks from the other seven 90 day animals were aged for 4 days at 2 ± 1°C. For steers fed for 170 days, six 2.5 cm steaks were sliced from the posterior end of the ribeye roll and individually vacuum-packaged. For each animal, two of these steaks were randomly selected and aged for 2 days, two for 4 days and two for 10 days at 2 ± 1°C. After the 90 day animals had already been slaughtered, the 10 day aging treatment was added to the experimental design to more effectively evaluate the effect of aging on Wagyu beef. This was done without compromising the statistical analysis of time on feed effects. After aging, steaks were frozen at −40°C for subsequent sensory evaluation and Warner–Bratzler shear force determinations.

Lipid extraction, fatty acid and cholesterol analysis

Procedures for lipid extraction and saponification are described in detail in our companion paper, Xie *et al.* (1996). After saponification, the unsaponifiables were extracted with 3 ml of hexane twice and used for the cholesterol assay. One milliliter of concentrated HCl was added to the alkaline saponifiable fraction to release free fatty acids which were extracted with 3 ml of hexane. Fatty acids were analyzed by gas chromatography according to Xie *et al.* (1996).

For cholesterol analysis, 0.1 ml of 100 μg/ml stigmasterol was added as an internal standard to the extracted hexane solution containing the unsaponifiable fraction. Hexane was dried off and the cholesterol extract was redissolved in chloroform. Samples were separated using a 30 m SP5361 (Supelco, Bellefonte, PA) capillary column (0.53 mm i.d., 0.10 μm film thickness) maintained at a temperature of 250°C with the injector and detector at 300°C and 300°C, respectively. Helium was the carrier gas at a flow rate of 2.0 ml/min. Cholesterol content was quantified by regression equations obtained from known cholesterol standards and then corrected according to the response of the internal standard.

Cooking procedure

The steaks were thawed at 2–5°C about 24 hr prior to cooking and cooked on a 46 cm×61 cm Hotpoint electric grill with a surface temperature of 163°C to a final internal temperature of 70°C. The temperature was monitored with iron-constantan thermocouple wires, which were inserted into the geometric center of the steak.

Determination of Warner–Bratzler shear force

After cooking, the steaks were allowed to cool to room temperature. Six 1.27 cm diameter cores were removed from each steak parallel to the muscle fibers. This ensured that the shearing action was perpendicular to the longitudinal orientation of the muscle fibers. Cores that were not uniform in diameter, had obvious connective tissue defects or were otherwise not representative of the sample were discarded. Each core was sheared once in the center to avoid the hardening that occurred toward the outside of the sample.

Sensory evaluation

Immediately after cooking, each steak was sectioned into 1.27×1.27×2.54 cm samples for sensory evaluation. A ten-member trained (Cross *et al.*, 1978) sensory panel evaluated the coded and randomized steak samples for juiciness, tenderness, flavor intensity, and connective tissue amount using eight-point scales (tenderness, flavor intensity, juiciness, and amount of connective tissue; 8 = extremely tender, extremely flavorful, extremely juicy and none, respectively and 1 = extremely tough, extremely bland, extremely dry, and extremely abundant). All sessions were conducted in well-ventilated, temperature-controlled, partitioned booths. Six samples were evaluated at each session and two sessions were conducted every day. Distilled water was provided to panelists to remove residual flavors between samples.

Statistical analysis

Data were analysed using the General Linear Model procedure of SAS (1988). Days fed was the main effect for the analysis of effects of time-on-feed on carcass traits, palatability and lipid composition and steer within each time on feed was used as the error term. For steers fed 90 days, aging time was the main effect for the analysis of the aging effect and the error term was steer within aging group. For steers fed for 170 days, aging time was the main factor for detection of the aging effect and steer×aging was used as the error term. Differences between means were determined using Duncan's multiple range test.

RESULTS AND DISCUSSION

Carcass characteristics

Hot carcass weight, fat thickness, *longissimus dorsi* muscle area, yield grade, estimated kidney, pelvic and heart fat and maturity score were increased ($p < 0.05$) by an additional 80 days on the high-concentrate feed, but marbling was not increased ($p > 0.05$) (Table 2). All 14 cattle in the 90 day group reached acceptable USDA grades (two Prime and 12 Choice), and quality grade was not improved ($p > 0.05$) by the additional 80 days on feed. These results were partially in agreement with those from previous researchers, who reported that, as time-on-feed increased, marbling score, quality grade, fat thickness and numerical yield grade also increased, and the optimum time on feed was 100 days (Tatum *et al.*, 1980; Dolezal *et al.*, 1982*a*) or 112 days (May *et al.*, 1992). Most carcass grade traits of Angus×Hereford steers increased linearly ($p < 0.01$) with days on feed, whereas marbling increased curvilinearly ($p < 0.05$) (May *et al.*, 1992). Marbling increased ($p < 0.05$) until 112 days and then did not increase ($p > 0.05$) from 112 days to 196 days. The carcass data from our study imply that crossbred Wagyu cattle fed a high-concentrate diet for 90 days produced highly acceptable carcasses and may have reached their genetic potential to deposit marbling by 90 days; no benefit was derived from the additional 80 days on feed.

Palatability attributes

Influence of time on feed

There were no time on feed×aging interactions ($p > 0.05$). Feeding the high-concentrate diet for 170 days increased Warner–Bratzler shear force values ($p < 0.05$) and tended ($p > 0.05$) to decrease tenderness, flavor intensity and connective tissue scores (Table 3). These results are similar to those of May *et al.* (1992), who found that juiciness and flavor intensity of *longissimus dorsi* muscle from Angus×Hereford steers were not influenced by feeding the high-concentrate diet from 0 to 196 days; but sensory tenderness ($p > 0.05$) and amount of perceived connective tissue peaked at 112 days and were slightly less desirable for longer feeding periods (quadratic term, $p < 0.01$). Shear force was also higher ($p < 0.05$) at day 196 than at day 112, although maturity remained within 'A' maturity (May *et al.*, 1992). Tatum *et al.* (1980) and Dolezal *et al.* (1982*a*) also found little improvement in palatability after 100 days on feed.

Carcasses from steers fed for 170 days were fatter and heavier than those from steers fed for 90 days (Table 2). Many studies have reported a close relationship between tenderness and subcutaneous fat thickness in beef (Dutson *et al.*, 1975; Bowling *et al.*, 1977; Meyer *et al.*, 1977; Lochner *et al.*, 1980; Marsh & Lochner, 1981; Tatum *et al.*, 1982). In those studies, generally, 6–10 mm of subcutaneous fat thickness was sufficient to retard the post-mortem chilling rate in order to assure that beef from young cattle was tender.

TABLE 2
Effect of Time On-Feed on Carcass Characteristics of Steers

Item	*Time-on-feed, days*		p-*Value*
	90	*170*	
Number of observations	14	13	
Slaughter weight, kg	648.9 + 18.1	725.9 + 18.7	0.007
USDA maturity score[a]	165.0 + 2.4	172.3 + 2.5	0.043
USDA marbling score[b]	449.3 + 24.5	483.8 + 25.4	0.337
USDA quality score[c]	450.7 + 8.3	458.5 + 8.6	0.522
USDA yield grade	2.65 + .21	3.56 + .22	0.006
Carcass weight, kg	380.5 + 11.7	447.7 + 12.2	0.0005
longissimus dorsi muscle area, cm^2	92.2 + 2.6	101.4 + 2.7	0.021
Fat thickness, mm	10.6 + 1.2	17.2 + 1.3	0.0012
KPH, %	2.50 + 0.11	3.27 + 0.12	0.0001

[a]A = 100–199.
[b]300–399 = Small; 400–499 = modest; 500–599 = moderate.
[c]300–399 = Select; 400–499 = Choice; 500–599 = Prime.

The insulatory effects of moderate levels of subcutaneous fat reduce the post-mortem chilling rate of carcasses and improve beef tenderness by lessening the extent of cold-induced toughening and by enhancing the rate and extent of post-mortem muscle proteolysis (Smith *et al.*, 1976; Bowling *et al.*, 1977). However, Marsh (1983) and Lee & Ashmore (1985) showed that rapid glycolytic activity induced by high early post-mortem temperature was associated with meat toughness. Marsh *et al.* (1987) found that tenderness was maximal when early post-mortem glycolysis proceeded at an intermediate rate, and declined if the rate was either slower or faster. Thus, for a given post-mortem environment, there should be an optimum range of subcutaneous fat thickness that will provide optimum conditions for post-mortem meat proteolysis and hence meat tenderness. In fact, several studies have found progressive increases in palatability when subcutaneous fat increased up to 7.6 mm, but fat thickness greater than 7.6 mm did not improve palatability (Dolezal *et al.*, 1982*b*; Riley *et al.*, 1983; May *et al.*, 1992). In our study, Wagyu steers had optimum marbling and subcutaneous fat thickness to produce palatable beef after 90 days on a high-concentrate diet.

Another possible cause for the decreased tenderness of the steers fed for 170 days may be carcass maturity. Zinn *et al.* (1970), using Hereford cattle, found that tenderness appeared to be influenced adversely after 180 days on feed. However, Bidner *et al.* (1981) and Dolezal *et al.* (1982*a*) reported no apparent detrimental effects from feeding calves for longer than 200 days. Clearly, cattle age and weight differences at the onset of feeding must be considered when comparing time on feed studies (May *et al.*, 1992). Palatability of young, lightweight, late maturing cattle may be improved by an extended time on feed, whereas palatability of heavy yearling cattle, such as those used in our study, may not benefit from an extended time on high-concentrate diet.

Influence of aging time

For the 90 day feeding group, 4 days of aging improved ($p < 0.05$) connective tissue score and tended to increase ($p > 0.05$) tenderness scores and decrease shear force, compared with 2 days of aging (Table 4). For the 170 day feeding group, 10 days of aging improved ($p < 0.05$) shear force and all sensory attributes except flavor intensity, compared to 2 days of aging. These results were generally in agreement with those of Smith *et al.* (1978), who reported that aging for 11 days, rather than 5 or 8 days increased ($p < 0.05$) flavor desirability, tenderness and overall palatability for loin steaks from US Choice beef. Numerous

TABLE 3

Effect of Time On-Feed on Palatability Attributes of Beef Ribeye Steaks

Item	*Time on-feed, days*	
	90	*170*
No. of observations	14	13
Juiciness[a]	5.60 ± 0.16	5.34 ± 0.10
Tenderness[a]	5.33 ± 0.31	4.51 ± 0.20
Flavor intensity[a]	5.43 ± 0.15	5.01 ± 0.13
Connective tissue[b]	5.32 ± 0.22	4.68 ± 0.17
Shear force, kg	2.78 ± 0.24[c]	3.53 ± 0.17[d]

[a]1 = Extremely dry, extremely tough, extremely bland; 8 = extremely juicy, extremely tender, extremely intense.
[b]1 = Extremely abundant; 8 = none.
[c,d]Means in the same row bearing different superscripts differ significantly ($p < 0.05$).

studies have shown that improvement of tenderness is proportional to post-mortem aging time (NCA, 1994). Beef from crossbred Wagyu steers appears to respond to aging in a similar fashion.

Fatty acid and cholesterol content

For subcutaneous fat, an additional 80 days on feed increased ($p < 0.05$) myristoleate, palmitoleate, oleate, linoleate, total MUFA, MUFA:SFA and PUFA:SFA, and decreased ($p < 0.05$) stearic acid and total SFA (Table 5). For the *longissimus dorsi* muscle, feeding the cattle to 170 days increased ($p < 0.05$) myristoleate, palmitoleate, MUFA, polyunsaturated fatty acids (PUFA), MUFA:SFA and PUFA:SFA, and decreased ($p < 0.05$) stearic acid and SFA (Table 6). The greater unsaturation of *longissimus dorsi* muscle caused by an additional 80 days on high-concentrate feed is in agreement with results from Duckett *et al.* (1993), who reported that the neutral lipid and total lipid of *longissimus dorsi* muscle became more unsaturated as time on feed increased primarily due to a linear ($p < 0.01$) increase in oleic (18:1) acid concentration. As a result, advanced time on feed increased the MUFA content by 22 % from 0 to 196 days and 12.7 % from 84 to 168 days. The PUFA content decreased by 72 % from 0 to 196 days, but did not change ($p > 0.05$) from 112 to 196 days. In our study, increasing time on feed from 90 to 170 days increased MUFA by 3.6 % and PUFA by 23.5 % in *longissimus dorsi* muscle. According to Duckett *et al.* (1993), the bacterial biohydrogenation in the rumen could be limited by the reduced ruminal pH caused by high-concentrate diets and, therefore, more unsaturated fatty acids entered the small intestine for absorption and incorporation into tissues, which led to increased MUFA with increased time on feed. The increased unsaturated fatty acids caused by the additional 80 days on feed may improve consumer perception of beef nutritional value.

The cholesterol contents (mg/100 g) of subcutaneous fat and *longissimus dorsi* muscle were increased ($p < 0.05$) by an additional 80 days on feed (Tables 5 and 6). Duckett *et al.* (1993) showed that cholesterol content of *longissimus dorsi* muscle had cubic trends ($p < 0.05$) across time on feed. The highest concentration was at day 168 (59.2 mg/100 g) and the lowest at day 84 (43.1 mg/100 g) and intermediate at days 0, 28, 56, 112, 140 and

TABLE 4
Effect of Aging Time on Palatability Attributes of Beef Ribeye Steaks from Steers Fed for 90 or 170 Days

Days fed	*90*		*170*		
Days aged	*2*	*4*	*2*	*4*	*10*
No. of observations	7	7	13	13	13
Juiciness[a]	5.32 ± 0.22	5.89 ± 0.18	5.38 + 0.15[c]	5.30 + 0.13[c]	5.85 + 0.16[d]
Tenderness[a]	4.81 ± 0.47	5.85 ± 0.34	4.43 + 0.30[c]	4.58 + 0.26[c]	5.22 + 0.23[d]
Flavor intensity[a]	5.300.24	5.56 ± 0.19	5.07 + 0.17	4.94 + 0.19	5.05 + 0.17
Connective tissue[b]	4.90 ± 0.29[c]	5.75 ± 0.26[d]	4.52 + 0.25[c]	4.83 + 0.23[c]	5.18 + 0.20[d]
Shear force, kg	3.12 ± 0.35	2.45 ± 0.30	3.74 + 0.21[c]	3.31 + 0.25[d]	3.19 + 0.22[d]

[a]1 = Extremely dry, extremely tough, extremely bland; 8 = extremely juicy, extremely tender, extremely intense.
[b]1 = Extremely abundant; 8 = none.
[c,d]Means in the same row under the same days fed with different superscripts differ significantly ($p < 0.05$).

TABLE 5
Effect of Time On-Feed on Fatty Acid Profiles and Cholesterol Content of Subcutaneous Fat from Steers[a]

Fatty acid, %	*Time on feed, days*		p-*value*
	90	*170*	
Number	14	13	
14:0	2.47 ± 0.11	2.46 ± 0.12	0.919
14:1	0.66 ± 0.08	0.94 ± 0.09	0.025
16:0	24.45 ± 0.36	24.17 ± 0.39	0.607
16:1	3.04 ± 0.23	4.08 ± 0.25	0.005
18:0	16.64 ± 0.76	12.87 ± 0.82	0.002
18:1	49.74 ± 0.68	52.10 ± 0.74	0.027
18:2	1.79 ± 0.11	2.12 ± 0.11	0.047
SFA[b]	43.56 ± 0.81	39.49 ± 0.87	0.002
MUFA[c]	54.02 ± 0.79	57.75 ± 0.85	0.004
PUFA[d]	2.03 ± 0.11	2.36 ± 0.12	0.051
MUFA:SFA	1.25 ± 0.05	1.48 ± 0.05	0.002
PUFA:SFA	0.047 ± 0.003	0.060 ± 0.003	0.007
Cholesterol, mg/100g	92.87 ± 2.78	103.51 ± 2.99	0.015

[a]Fatty acids are reported as percentages of total fatty acids.
[b]Sum of 14:0, 16:0, 18:0, 20:0 and 22:0.
[c]Sum of 14:1, 16:1, 18:1, 20:1 and 22:1.
[d]Sum of 18:2, 18:3, 20:2, 20:3, 20:4 and 22:6.

TABLE 6
Effect of Time on Feed on Fatty Acid Profiles and Cholesterol Content of *Longissimus Dorsi* Muscle from Steers[a]

Fatty acid, %	*Time on feed, days*		p-*value*
	90	*170*	
Number	14	13	
14:0	2.31 ± 0.11	2.43 ± 0.12	.495
14:1	0.64 ± 0.07	0.85 ± 0.07	0.036
16:0	26.11 ± 0.38	25.74 ± 0.40	0.509
16:1	3.46 ± 0.15	4.12 ± 0.16	0.006
18:0	13.99 ± 0.44	11.65 ± 0.45	0.001
18:1	48.96 ± 0.70	50.02 ± 0.73	0.305
18:2	2.80 ± 0.19	3.31 ± 0.20	0.082
SFA[b]	42.41 ± 0.67	39.82 ± 0.70	0.013
MUFA[c]	53.14 ± 0.68	55.35 ± 0.71	0.033
PUFA[d]	3.04 ± 0.26	3.87 ± 0.27	0.036
MUFA:SFA	1.26 ± 0.04	1.40 ± 0.04	0.022
PUFA:SFA	0.07 ± 0.007	0.10 ± 0.007	0.018
Cholesterol, mg/100 g	48.80 ± 0.85	54.35 ± 0.89	0.000

[a]Fatty acids are reported as a percentage of total fatty acids.
[b]Sum of 14:0, 16:0, 18:0, 20:0 and 22:0.
[c]Sum of 14:1, 16:1, 18:1, 20:1 and 22:1.
[d]Sum of 18:2, 18:3, 20:2, 20:3, 20:4 and 22:6.

196. On the other hand, Wheeler *et al.* (1987) found no differences in the cholesterol content of muscle from steers fed for 0, 77, 128 or 182 days. The increased cholesterol content of subcutaneous fat and *longissimus dorsi* muscle by an additional 80 days on feed in our study might not be perceived positively by consumers (NRC, 1988), but would probably be of little nutritional consequence.

CONCLUSIONS

Crossbred Wagyu cattle fed a high-concentrate diet for 90 days produced highly acceptable carcasses, and may have reached their genetic potential to deposit marbling. An additional 80 days on feed did not improve quality grades or enhance palatability, but increased waste fat, such as subcutaneous fat, and kidney, pelvic and heart fat. On the other hand, the additional 80 days on feed increased levels of unsaturated fatty acids, which would improve consumer perception of beef nutritional value, but the cholesterol contents of subcutaneous fat and *longissimus dorsi* muscle were also increased ($p < 0.05$). Our data suggest that 90 days on a high-concentrate diet is adequate for crossbred Wagyu cattle to produce highly acceptable carcasses and little or no overall benefit was obtained by an additional 80 days on feed. Most palatability attributes of ribeye steaks from cattle fed for 170 days were improved significantly by 10 days of post-mortem aging.

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