Carcass characteristics and meat quality of once-calved heifers

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Vincent, B. C., Jones, S. D. M., Jeremiah, L. E., Price, M. A. and Newman, J. A. 1991. **Carcass characteristics and meat quality of once-calved heifers.** Can. J. Anim. Sci. **71**: 311–319. Three groups of once-calved (OCH) heifers were slaughtered following the weaning of their calves at 3 (OCH3, $n=32$), 5 (OCH5, $n=33$) and 7 (OCH7, $n=31$) months postcalving. A fourth group of heifers was fed a silage/grain diet and slaughtered at 15 mo of age (C, $n=32$). Alternate sides of each carcass were electrically stimulated (ES) at 475 volts for 1 min (20 pulses m^{-1}, 60 Hz) at 45 min post-stunning. All left sides were dissected into fat, lean and bone and meat quality parameters recorded. Rib eye steaks were evaluated for palatability by a trained panel and for consumer acceptability after an aging period of 6 d. All OCH groups produced heavier carcasses with a higher level of marbling than the C group after adjustment of the data to a constant proportion of carcass fatness, but the proportional yields of lean and bone tissue were similar for all heifer groups. OCH groups produced meat that was darker with a lower drip loss and higher 45 min and 6 d pH than the C group. Consumer acceptability of rib eye steaks was similar for all heifer groups, but the OCH7 (oldest) group had a higher amount of connective tissue when evaluated by a trained panel than other heifer groups. Taste panel evaluations showed that ES increased meat tenderness and overall palatability and reduced the amount of connective tissue when compared to meat from unstimulated carcasses. ES also increased the consumer acceptability of tenderness by 14.3%, flavor by 5.6%, juiciness by 5.2% and overall palatability by 6.7% over meat from unstimulated carcasses. It was concluded that once-calved heifers could produce heavier carcasses of similar composition and meat with similar eating quality to conventionally managed nonpregnant feedlot heifers. Electrical stimulation improved the consumer acceptability of meat primarily through an improvement in meat tenderness.

Key words: Beef, carcass, electrical stimulation, meat quality, once-calved heifers

Vincent, B. C., Jones, S. D. M., Jeremiah, L. E., Price, M. A. et Newman, J. A. 1991. **Caractères de la carcasse et qualité de la viande de génisses primipares.** Can. J. Anim. Sci. **71**: 311–319. Trois groupes de génisses primipares (OCH) ont été sacrifiés après le sevrage de leurs veaux, 3 (OCH3, $n=32$), 5 (OCH5, $n=33$) et 7 (OCH7, $n=31$) mois après le vêlage. Un quatrième groupe de génisses a reçu une ration d'ensilage et de grain et a été sacrifié à l'âge de 15 mois (C, $n=32$). Les flancs de chaque carcasse ont été stimulés électriquement (ES) à 475 volts pendant 1 mn (20 impulsions m^{-1}, 60 Hz), 45 mn après l'étourdissement. Tous les flancs grauches ont été disséqués en gras, maigre et os, et les paramètres de qualité de la viande ont été enregistrés. Les biftecks de la noix de côte ont été évalués pour leur appétibilité par un jury expérimenté et pour leur acceptabilité par le consommateur après une période de vieillissement de six jours. Tous les groupes OCH produisent des carcasses plus lourdes à plus forte teneur en persillé que le groupe C après correction des données en fonction d'une proportion constante de gras de la carcasse, mais les rendements proportionnels de maigre et d'os sont comparables chez tous les groupes de génisses. Les groupes OCH produisent de la viande plus sombre caractérisée par une perte au ressuyage plus faible et un pH plus élevé après 45 mn et six jours que le groupe C. L'acceptabilité des biftecks de la noix de côte par le consommateur est semblable pour tous les groupes de génisses, mais le groupe OCH7 (le plus âgé) présente un plus fort pourcentage de tissu conjonctif après évaluation par un jury expérimenté que les autres groupes. Les évaluations du jury dégustateur révèlent que la ES améliore la tendreté et l'appétibilité globale de la viande, et

réduit le pourcentage de tissu conjonctif par rapport à la viande des carcasses non stimulées. La ES augmente également l'acceptabilité de la tendreté de 14,3%, de la saveur de 5.6%, de la jutosité de 5,2% et de l'appétibilité totale de 6,7% par rapport à la viande des carcasses non stimulées. Les auteurs concluent que les génisses primipares peuvent produire des carcasses plus lourdes de musculature et de composition semblables, et de qualité gustative analogue, que les génisses non gravides de parcs d'engraissement à régime d'élevage classique. La stimulation électrique augmente l'acceptabilité de la viande par le consommateur, essentiellement par l'amélioration de la tendreté.

Mots clés: Boeuf, carcasse, stimulation électrique, qualité de la viande, génisses primipares

The production of meat from heifers that have produced a calf has been suggested as a method to increase the overall efficiency of meat production (Taylor et al. 1985). Once-calved heifers at slaughter are likely to be considerably older than heifers subject to conventional feedlot management, which could impact on the composition and eating quality of the meat. While it is well established that meat tenderness declines with advancing animal age or maturity (Hiner and Hankins 1950), the age range beyond which there is a reduction in the consumer acceptability of meat is poorly defined. Once-calved heifers at slaughter are likely to range in age from about 27 to 36 mo compared to 12–18 mo for conventionally managed heifers. Therefore, it was considered important to document if once-calved heifers produced meat with similar eating characteristics to maiden heifers fed for meat production.

High-voltage electrical stimulation has been shown to increase the tenderness of beef from young cattle (Cross et al. 1984), and also brighten muscle color within 24 h of slaughter. Improvements in meat quality through the use of high voltage electrical stimulation have also been noted in grain and range-fed heifers and cows (Stiffler et al. 1982), but no studies have been reported for once-calved heifers. Since the increased maturity of once-calved heifers compared to conventionnally fed heifers may result in lowered eating quality of the meat, the use of high voltage electrical stimulation may offset and improve the color and tenderness of meat from once-calved heifers.

The objectives of this study were to examine the carcass composition and quality of meat produced from once-calved heifers compared to conventionally managed heifers reared for beef production and to evaluate the effects of high voltage electrical stimulation on meat quality.

MATERIALS AND METHODS

The production system and slaughter procedures have been previously outlined in detail (Vincent et al. 1991). Three groups of once-calved heifers (OCH) were slaughtered after nursing their calves for 3 (OCH3), 5 (OCH5) and 7 (OCH7) mo. A fourth group consisted of conventionally managed heifers slaughtered at approximately 15 mo of age.

Alternate sides of each carcass were electrically stimulated at 475 volts for 1 min (20 pulses m^{-1}, 60 Hz) at 45 min post-stunning. Muscle pH was measured following stimulation on both carcass sides between the 12/13th ribs using a Corning pH meter (Corning Glassworks, Medfield, MA, U.S.A.) equipped with an Ingold spear-type combination electrode (Ingold Electronics, Andover, MA, U.S.A.). Muscle pH readings were repeated 24 h post-slaughter. All carcasses were chilled for 24 h at 1°C, following which both sides were ribbed at the 12/13th ribs to allow for color and marbling assessment. Color was measured in the center of the longissimus muscle three times using a Minolta Chroma Meter II (Minolta Camera Co., Meter Division, Ramsey, NJ, U.S.A.) and the results averaged. Color measurements were taken in the Commission Internationale de L'Eclairage (CIE) scale (L* = brightness, a* = red to green axis [hue], b* = yellow to blue axis [chroma]). Marbling was assessed on a 9-point scale by a two-member panel (1 = abundant and 9 = traces) and the results averaged. Carcass grades were assigned by a Federal grader.

All left carcass sides were fabricated into primal cuts 48 h post-slaughter and further separated into fat, lean and bone (Jones et al. 1989). The portion of the longissimus muscle from the 1–5th lumbar

vertebrae was removed from both carcass sides for meat quality assessment. A 25-mm thick steak from both muscles was cut and packaged in polystyrene trays overwrapped with oxygen-permeable film (Vitafilm Choice Wrap, Goodyear Canada Ltd, Toronto, ON) for 96 h. Drip losses were calculated as the loss in steak weight over this period of time. The remaining portions of each longissimus muscle were shrink wrapped and stored at 1°C for 96 h (total time postmortem = 144 h). At 144 h postmortem, a 25-mm steak was cut from the anterior end of each longissimus muscle and placed on a table top for 30 min. Color and pH were measured as previously described. The steak was then cooked in a microwave oven (Litton Menumaster XLC-20, Minneapolis, MN) to an internal temperature of 80°C. After 3 h of equilibration to room temperature, three 20-mm cores were removed parallel to the grain and each core was sheared once using an Ottawa Texture Measuring System (Canners Machinery, Simcoe, ON) fitted with a Warner-Bratzler test cell and peak shear force recorded. The remaining portion of the longissimus muscle was ground (3.2-mm plate) for the determination of chemical composition (moisture and fat) and expressible juice. Expressible juice was determined by centrifuging $20 \times g$ of ground muscle at $37000 \times g$ for 60 min and weighing the supernatant. Intramuscular fat was determined using petroleum ether as outlined by the Association of Official Analytical Chemists (1980).

The longissimus muscle from both sides of nine carcasses from each heifer group (total 36 carcasses) between the 6th and 12th ribs were aged for 6 d and frozen at −18°C. One steak from each longissimus muscle was evaluated by a trained and experienced six-member laboratory taste panel. The steaks were cooked in a convection oven preheated to 177°C to an internal temperature of 75°C. All samples were evaluated warm (40°C) by a panel that was trained according to the guidelines of the American Meat Science Association (1978). The panel used an unstructured 9-point scale to evaluate: initial and overall tenderness (1=extremely tough, 9=extremely tender), amount of connective tissue (1=abundant, 9=none), juiciness (1=extremely dry, 9=extremely juicy), flavor intensity (1=extremely bland flavor, 9=extremely intense beef flavor), flavor and overall palatability (1=extremely undesirable, 9=extremely desirable). Connective tissue was assessed from the amount of residual tissue following chewing.

The remaining portion of each longissimus muscle was cut into 25-mm rib eye steaks which were packaged in pairs (stimulated, nonstimulated) and distributed to 550 households in Lacombe, Alberta. Consumers were requested to score the steaks for flavor, juiciness, tenderness and overall palatability on a 4-point scale (1=unacceptable, 2=slightly unacceptable, 3=slightly acceptable, 4=acceptable).

A least squares analysis of covariance was used to analyze the carcass composition data with treatment (heifer group) and electrical stimulation as main effects, all two-way interactions and a covariate of dissected fat using the GLM procedure of Statistical Analysis System Institute, Inc. (SAS 1985). A least squares analysis of variance without the above covariate was used to analyze the meat quality, panel and consumer acceptability data.

RESULTS AND DISCUSSION

The proportion of carcasses assessed by a Federal grader as maturity class 1 (youthful) decreased as average age at slaughter advanced from 765 d (OCH3) to 883 d (OCH7). Conventionally managed heifers all produced carcasses which remained in the maturity class 1 category. In the OCH3 group, 31 carcasses were maturity class 1 and 1 carcass maturity class 2, whereas in the OCH5 group 31 carcasses were maturity class 1 and 2 carcasses in the older categories (1 carcass maturity class 2 and 1 carcass maturity class 3). For the OCH7 group, 27 carcasses were placed in the maturity class 1 category, 3 carcasses in the maturity class 2 category and 1 carcass in the maturity class 3 category. These results suggest that as animals age chronologically beyond 25 months, an increasing proportion will be assessed as too mature for the maturity class 1 (youthful) category.

The OCH5 and OCH7 heifer groups had greater carcass fat thickness at the grading site than the OCH3 and conventionally managed heifers (Table 1). This would tend to suggest that carcass fat deposition increased after 3 mo of calf nursing. Marbling fat and intramuscular fat were higher in all once-calved heifer groups compared to the conventionally managed heifers (Table 1). The greater amount of marbling fat for the OCH5 and OCH7 heifer groups may be partly explained through their greater carcass

Table 1. Least squares means (ISE) of carcass characteristics and composition for once-calved and conventionally managed heifers

	Heifer group							
	Conventional	SE	OCH 3	SE	OCH 5	SE	OCH 7[z]	SE
Number of animals	32		31		33		31	
Carcass characteristics:								
Fat thickness (mm)	9.1*a*	0.74	8.8*a*	0.73	12.8*b*	0.72	12.0*b*	0.75
Marbling score	6.8*a*	0.06	6.3*b*	0.06	6.3*b*	0.06	6.4*b*	0.06
Intramuscular fat (g 100 g^{-1})	4.9*a*	0.09	5.4*b*	0.09	6.3*c*	0.08	6.3*c*	0.10
Side weight (kg)	116.0*a*	2.70	138.9*b*	2.77	147.0	2.72*c*	144.3*bc*	2.73
Carcass composition[y]								
Bone weight (kg)	17.5*a*	0.39	22.2*b*	0.40	22.7*b*	0.40	22.4*b*	0.40
Lean weight (kg)	61.6*a*	1.49	72.7*b*	1.53	77.4*c*	1.50	75.8*bc*	1.51
Bone (g 100 g^{-1})	15.1*a*	0.17	16.0*b*	0.18	15.5*ab*	0.17	15.6*b*	0.17
Lean (g 100 g^{-1})	53.2*a*	0.17	52.4*b*	0.18	52.8*ab*	0.17	52.8*ab*	0.17

[z]OCH3, OCH5, OCH7 = once calved heifers which had nursed their calves for 3, 5 and 7 mo.
[y]Side weight and composition were adjusted to a constant side fat content (31.7 g 100 g^{-1}).
*a–c*Means in the same row with different letters are significantly different ($P<0.05$).

fatness, since intramuscular fat generally increases in relation to total carcass fat (Cianzio et al. 1982). However, this was not the case for the OCH3 heifer group which had a similar carcass fat thickness to the conventionally managed heifers, but still had about 0.4% more intramuscular fat. Possibly the greater amounts of marbling were partly related to animal maturity, but on an overall basis the differences recorded in marbling were not large and probably have minor commercial significance.

When the carcass data were adjusted to a constant proportion of total dissectable fat, the OCH heifer groups produced heavier carcass sides (24%) than conventionally managed heifers (Table 1). The OCH heifer groups also produced a greater weight of bone (28%) and lean (22%) than conventionally managed heifers. On a proportional basis, there was a trend for the OCH heifer groups to produce more bone and less lean than the conventionally managed heifers (Table 1), although this was only significant for two OCH groups in the case of bone (OCH3 and OCH7) and one OCH group (OCH3) in the case of lean. On an overall basis the differences in composition among all heifer groups were small; the most notable finding being that the once-calved heifer groups could produce heavier carcasses of similar composition to that of conventionally managed heifers.

Muscle pH at all times tended to be lower for conventionally managed heifers compared to all once-calved heifer groups (Table 2). It is well established that muscle pH increases with animal age (Tuma et al. 1963) and that mature cows produce higher levels of dark, firm and dry beef (pH > 6.0) than young steers and heifers (Tarrant 1981). While there was not indication of dark, firm and dry meat in the once-calved heifer groups, and the meat pH of all heifer groups fell within the normal range reported under commercial conditions (Murray 1989), the results of this study suggest that once-calved heifers will produce meat with a slightly higher pH than conventionally managed heifers. The slightly higher meat pH may be related to the slaughter of all once-calved heifers immediately following weaning, but no measurements of weaning stress were made in this study.

Meat from all once-calved heifer groups was darker (lower L* value) both at 24 h and 6 d postmortem than the meat of conventionally managed heifers (Table 2). Small and inconsistent differences were recorded in a* (hue; red to green axis) and b* (chroma; yellow to blue axis) which did not appear to be related to treatment. The main finding of importance was the darker color of meat

Table 2. The effect of heifer group and electrical stimulation on muscle quality

	Heifer group								Electrical stimulation				
	Conventional	SE	OCH3[z]	SE	OCH5[z]	SE	OCH7[z]	SE	Unstimulated	SE	Stimulated	SE	P^y
Muscle pH:													
45 min	6.55*a*	0.02	6.80*b*	0.02	6.71-*c*	0.02	6.75*bc*	0.02	6.70	0.01	6.32	0.01	0.001
24 h	5.67*a*	0.01	5.71*b*	0.01	5. 69-*ab*	0.01	5.80*c*	0.01	5.72	0.01	5.64	0.01	0.001
6 d	5.48*a*	0.01	5.61*b*	0.01	5. 61*b*	0.01	5.65*c*	0.01	5.59	0.01	5.56	0.01	0.001
Muscle color:													
24 h													
L*	36.6*a*	0.24	33.8*b*	0.24	34. 8*c*	0.24	33.7*b*	0.24	34.7	0.12	36.3	0.12	0.001
a*	21.2*a*	0.22	20.3*b*	0.22	22. 8*c*	0.22	21.7*a*	0.23	21.5	0.11	23.4	0.11	0.001
b*	9.6*a*	0.19	9.0*b*	0.19	10. 4*c*	0.19	9.2*ab*	0.19	9.5	0.09	10.9	0.09	0.001
6 d													
L*	38.4*a*	0.24	34.5*b*	0.24	34. 7*b*	0.24	34.8*b*	0.25	35.6	0.12	36.7	0.12	0.001
a*	21.2	0.22	21.6	0.22	21. 8	0.22	21.9	0.23	21.6	0.11	22.7	0.11	0.001
b*	9.9	0.16	9.7	0.16	9. 9	0.16	9.4	0.16	9.7	0.08	10.5	0.08	0.001
Drip loss ($g\ 100g^{-1}$)	0.94*a*	0.04	0.62*b*	0.03	0. 67*b*	0.03	0.68*b*	0.03	0.73	0.02	0.81	0.02	0.001
Expressible juice ($g\ 100g^{-1}$)	25.2*a*	0.20	22.9*b*	0.19	22. 8*b*	0.19	21.2*c*	0.20	23.0	0.09	23.4	0.09	0.005
Shear value (kg)	7.8*a*	0.22	9.4*b*	0.22	7. 4*a*	0.22	7.2*a*	0.23	7.9	0.11	5.8	0.11	0.001

[z]OCH3, OCH5, OCH7 = once-calved heifers which had nursed their calves for 3, 5 and 7 mo.
[y]P = Probability of significance for unstimulated and stimulated groups.
*a–c*Heifer group means in the same row with different letters are different ($P<0.05$).

produced by once-calved heifers compared to conventionally managed heifers. Similar results have been found in other studies (Bond et al. 1986; Waggoner et al. 1988). The darker meat of once-calved heifers is most likely explained by an increase in the muscle pigment myoglobin, which increases rapidly until an animal approaches 36 mo of age (Lawrie 1979). Muscle drip losses and expressible juice were lower in all once-calved heifer groups than conventionally managed heifers and were probably related to the pH differences previously discussed. All heifer groups had similar shear values apart from the OCH3 group which was significantly higher than the others (Table 2). Bouton et al. (1978) reported that animals at 27 mo of age had shear values that were 10% higher than those from animals at 16 mo of age.

Electrically stimulated (ES) carcass sides had lower meat pH at all measurement times than unstimulated (NES) sides which reached a maximum difference at 6 h post-slaughter (Table 2). ES therefore accelerated post-mortem muscle glycolysis in agreement with other studies (Cross 1979; Asghar and Henrickson 1982). ES improved muscle color both at 24 h and 6 d postmortem through an increase in muscle brightness (higher L* value), hue or redness (higher a* value) and chroma or yellowness (higher b* value). Other authors (Smith et al. 1977; Calkins et al. 1980) have shown that ES improves the brightness and redness of muscle, but have considered it to be a transient effect lasting up to 48 h post-slaughter. Although the differences attributed to ES in color recorded in this study were less at 6 d than at 24 h, they were still significant and could possibly exert an improvement in appearance at the retail level. Significant treatment (once-calved heifer group) × stimulation interactions were found for pH and a* and b* values made at 24 h (interaction means not shown). The treatment × stimulation interactions for pH were concluded to be caused by slight changes in the magnitude of pH decline in ES and NES sides and considered to have no obvious effect on muscle quality. All ES once-calved heifer groups had meat of a redder color than their NES counterparts. The use of high voltage ES in this study improved the color of meat from once-calved heifers and made it similar to meat from NES conventionally managed heifers. ES significantly increased drip loss and expressible juice which differs from the results of other reports (Morgan 1979; Hall et al. 1980; Jeremiah and Martin 1982). On an overall basis, ES reduced the shear values of meat by 27% (Table 2), which is similar to results from other studies (Cross 1979).

Trained taste panel results indicated that there were few major differences in

Table 3. The effect of heifer group and electrical stimulation on cooking losses and palatability on cooking losses and palatability of rib eye steaks as measured by a trained taste panel

	Heifer group					Electrical stimulation			
	Conventional	OCH3	OCH5	OCH7[z]	SEM[y]	Unstimulated	Stimulated	SEM	*P*
Cooking loss (g 100 g^{-1})	24.9*ab*	25.3*ab*	26.2*b*	24.3*a*	0.59	25.2	25.4	0.29	0.63
Initial tenderness[x]	5.3	5.0	5.3	4.3	0.18	4.9	5.7	0.09	0.001
Overall tenderness	5.1	4.9	5.4	4.4	0.25	4.9	5.6	0.12	0.003
Connective tissue	6.8*a*	6.8*a*	7.2*a*	6.1*b*	0.22	6.7	7.3	0.11	0.001
Juiciness	5.9	6.1	6.0	5.8	0.16	5.9	5.8	0.08	0.23
Flavor	5.5	5.6	5.8	5.4	0.16	5.6	5.6	0.08	0.75
Flavor intensity	5.2	5.2	5.5	5.1	0.17	5.2	5.3	0.08	0.52
Overall palatability	5.2*b*	5.1*b*	5.6*b*	4.5*a*	0.20	5.1	5.5	0.10	0.003

[z]OCH3, OCH5, OCH7 = once-calved heifers which had nursed their calves for 3, 5 and 7 mo.
[y]SEM Standard error of the mean.
[x]All palatability traits ranked on a 9-point scale. Higher numbers infer higher quality meat.
*a,b*Means in the same row with different letters are different.

palatability traits among all heifer groups (Table 3). All heifer groups had similar ratings for tenderness, juiciness, and flavor. The OCH7 heifer group had a significantly greater amount of connective tissue and a lower overall palatability than the other heifer groups.

ES improved trained panel ratings for tenderness, connective tissue and overall palatability, but had no effect on juiciness or meat flavor (Table 3). These results are similar to other studies defining the effects of high voltage stimulation on meat quality in young cattle (West 1982), but contrary to those previously reported on A, C and D grade cattle in Canada (Wood and Froelich 1983).

Consumer panel results (Table 4) indicated that all heifer groups had similar ratings for tenderness, juiciness, flavor and palatability. Meat tenderness is the main factor influencing consumer-eating satisfaction and has the greatest influence on acceptability (Jeremiah 1982). The tenderness of meat from once-calved heifers and maiden heifers of the same age has been found to be similar using both a shear test (Bond et al. 1986; Waggoner et al. 1988) and a trained laboratory panel (Joseph and Crowley 1971; Bond et al. 1986).

ES improved the consumer acceptability of tenderness, juiciness, flavor and overall palatability for rib eye steaks. When the consumer acceptability data was further analyzed to examine the percentage of acceptable (defined as scores >2 on the 4-point scale) steaks, ES was found to increase tenderness acceptability by 14.3%, flavor acceptability by 5.6%, juiciness acceptability by 5.2% and overall palatability by 6.7%. ES improved the consumer acceptability of meat from once-calved heifers and exerted its main effect through an improvement in tenderness.

It was concluded that once-calved heifers produced heavier carcasses than those from conventionally managed heifers but of similar composition. Meat quality, laboratory and consumer panel assessments revealed only minor differences among heifer groups, the most important being the slightly darker red color of meat from once-calved heifers

Table 4. The effect of heifer group and electrical stimulation on the acceptability of meat as measured by a consumer panel

	Heifer group								Electrical stimulation			
	Conventional	SE	OCH3[z]	SE	OCH5	SE	OCH7	SE	Unstimulated	Stimulated	SEM[y]	*P*
Tenderness	2.7	0.12	3.1	0.11	2.9	0.11	3.1	0.14	2.9	3.3	0.06	0.001
Juiciness	2.9	0.11	3.3	0.11	3.2	0.10	3.3	0.13	3.2	3.4	0.06	0.003
Flavor	3.2	0.09	3.5	0.09	3.5	0.08	3.5	0.10	3.4	3.6	0.04	0.004
Palatibility	2.9	0.11	3.5	0.10	3.2	0.09	3.3	0.12	3.2	3.5	0.05	0.001

[z]OCH3, OCH5, OCH7 = once-calved heifers which had nursed their calves for 3, 5 and 7 mo.
[y]SEM Standard error of the mean.
All traits ranked on a 4-point scale. Higher numbers infer higher quality meat.

compared to conventionally managed heifers. The results support the conclusion that once-calved heifers produce carcasses and meat of a similar quality to that produced by maiden heifers fed for beef production. High voltage electrical stimulation improved muscle color and the consumer acceptability of steaks.

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