Effect of feeding barley based diets on animal performance, carcass characteristics and meat quality of crossbred beef cattle with and without Wagyu genetics

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Mir, P. S., Bailey, D. R. C., Mir, Z., Jones, S. D. M., Entz, T., Husar, S.D., Shannon, N. H. and Robertson, W. M. 1997. **Effect of feeding barley based diets on animal performance, carcass characteristics and meat quality of crossbred beef cattle with and without Wagyu genetics**. Can. J. Anim. Sci. **77**: 655–662. Growth performance, carcass characteristics and meat quality of European and British crossbred (EBC; no Wagyu genetics; 28 heifers and 30 steers) cattle were compared with crossbred cattle with 75% Wagyu genetics (WC; seven heifers and 14 steers) to determine the influence of Wagyu genetics on marbling grade of beef cattle fed barley-based diets in a factorial design experiment. Weaned calves (250 d average age) were fed, one of two diets (diet 1, 35% barley grain; diet 2, 40% hay cubes on DM basis, with barley silage, protein and vitamin/mineral premix) for 84 d and then fed diet 1 until they weighed 394 to 432 kg. All cattle were finished on an 80% (DM basis) rolled barley diet and slaughtered. Carcasses were graded and samples procured for meat quality and Warner-Bratzler shear force determination. Number of days on backgrounding diets to arrive at target weight (380 kg) was greater ($P < 0.05$) for the WC cattle, owing to relatively lower ADG, but days on the finishing diet were fewer for these cattle, compared with EBC cattle. Warm carcass yield (dressing percent) was greater ($P < 0.05$), but backfat depth was lower ($P < 0.05$) for WC cattle relative to that of EBC cattle, yet proportion of lean meat yield was similar. Eighty three percent of WC cattle carcasses had Canada AAA (small or more) marbling grade compared with 13% for EBC cattle carcasses. Mean shear force of meat samples from EBC and WC cattle was 4.2 and 3.8 kg, respectively. Results indicated that the extent of carcass marbling can be increased by incorporating Wagyu genetics but age at slaughter of WC cattle was 19 d greater than that of EBC cattle and carcass size was reduced.

Key words: Average daily gain, carcass characteristics, European and British crossbred, feed to gain ratio, meat quality, Wagyu crossbred cattle

Mir, P. S., Bailey, D. R. C., Mir, Z., Jones, S. D. M., Entz, T., Husar, S.D., Shannon, N. H. et Robertson, W. M. 1997. **Effet d'une alimentation à base d'orge sur les performances zootechniques, sur les caractères de carcasse et sur la qualité de la viande de bovins à viande croisés avec ascendance Wagyu**. Can. J. Anim. Sci. **77**: 655–662. Nous avons comparé avec celles de bovins croisés 75 % Wagyu (WC, 7 génisses et 14 bouvillons) les performances de croissance les caractères de carcasse et la qualité de la viande de bovins croisés de races britanniques et européenne (RBE, 28 génisses et 30 bouvillons), afin de déterminer l'influence de l'ascendance Wagyu sur l'indice de persillé de la viande de bovins recevant des régimes alimentaires à base d'orge. L'expérience était conduite selon un protocole expérimental factoriel. Des veaux sevrés d'un âge moyen de 250 j recevaient pendant 84 j l'un ou l'autre de deux régimes : 1–35 % de grain d'orge et 40 % de foin en cubes, calculé sur la matière sèche), complété d'un prémélange d'ensilage d'orge, de protéines et de supplément minéral vitaminisé. Après le 84^{e} j, on leur servait le régime 1 jusqu'à ce qu'ils atteignent un poids de 394 à 432 kg, puis un régime à 80 % (m.s.) d'orge aplatie jusqu'à l'abattage. Les carcasses étaient ensuite classées et des morceaux prélevés pour l'évaluation de la qualité et celle des valeurs de cisaillement Warner-Bratzler. Le nombre de jours de préengraissement pour arriver au poids cible de 380 kg était plus élevé ($P < 0,05$) pour les croisées Wagyu, en raison de leur GMQ relativement moindre, mais leur phase de finition était moins longue que chez les bovins RBE. Le rendement de carcasse chaude était meilleur ($P < 0,05$) mais le gras de couverture plus mince ($P < 0,05$) chez les croisés Wagyu, malgré une même proportion de maigre dans les deux groupes génétiques. Quatre-vingt-trois p.100 des carcasses Wagyu méritaient la cote de persillé Canada AAA (au moins un peu de persillé) contre 13 % seulement pour les carcasses RBE. Les valeurs de cisaillement moyennes de la viande des croisés Wagyu et RBE étaient, respectivement, de 4,2 et de 3,8 kg. Il ressort de ces résultats que si l'introduction de sang Wagyu permet d'accroître le persillé, il reste que l'âge à l'abattage des croisés Wagyu était de 19 j plus long que chez les croisés RBE et que leurs carcasses étaient plus petites.

Mots clés : Croisés de races européenne et britannique, croisés Wagyu, GMQ, indice de conversion, caractère de carcasse, qualité de la viande

The amount of marbling fat or intramuscular fat in beef is recognized as an important carcass quality characteristic in North American and Asian markets, particularly when the meat is sold to food service institutions for consumption in an "upscale dining environment" (Huffman et al. 1996).

Abbreviations: **ADG**, average daily gain; **DMI**, dry matter intake; **EBC**, European and British crossbred; **F/G**, feed to gain ratio (kg feed per kg of liveweight gain); **WC**, Wagyu crossbred

Although reported correlation coefficients among marbling fat, tenderness and organoleptic appeal of meat are not substantial (Wheeler et al. 1994), they are of sufficient magnitude, that the retail and food service industries specify minimal levels of intramuscular fat when purchasing cuts of meat. In Canada, approximately 20–25% of carcasses have marbling scores qualifying them for the Canada AAA grade. The frequency of carcasses which grade AAA or better for marbling needs to be increased to 50% to meet the requirement of current domestic and export markets (Jones et al. 1991; Jones 1996). In order to enhance the percentage of carcasses that grade Canada AAA, the use of Wagyu genetics requires consideration because the Wagyu beef cattle are acclaimed for their ability to deposit large amount of intramuscular fat (Smith 1993).

Inclusion of the Japanese American Wagyu in breeding programs has been described as a strategy to improve the marbling potential of beef carcasses (Barker et al. 1995). Lunt et al. (1993) compared growth rate and carcass characteristics of Angus and American Wagyu cattle and found that Wagyu steers exhibited a higher propensity to deposit intramuscular fat than Angus steers, thus confirming previous reports (Yamazaki 1981; Zembayashi et al. 1988; Cameron et al. 1994). There have been suggestions that Wagyu cattle utilize forage diets better than crossbred beef cattle. Growth performance and carcass quality of either full or part Wagyu cattle have been compared with those of other breeds of cattle, such as Angus, that marble substantially (Lunt et al. 1992; Sturdivant et al. 1994; Barker et al. 1995), but not with commonly used EBC cattle. In many instances extended feeding regimen (450 d on feed for cattle weighing 300 kg at the beginning of the study) have been employed (Barker et al. 1995) to simulate production practices used in Japan or New Zealand. The majority of the trials which have attempted to compare performance of feedlot cattle have employed corn-based diets. In western Canada, most of the feedlot cattle are finished on barley silage and barley grain. Thus, a need exists to compare performance, with regard to ADG, DMI, F/G, carcass characteristics and meat quality of WC cattle to EBC cattle when fed predominantly barley silage based diets. Relative efficiency of utilization of diets containing either hay cubes or rolled barley grain following weaning of WC and EBC was also evaluated.

MATERIALS AND METHODS

Seventy nine spring born steers and heifers of various breed combinations (Table 1) were obtained at weaning in the fall from the Research Substation at Onefour AB and Lethbridge Research Centre, Lethbridge AB, and placed in individual pens at the Lethbridge Research Centre, Lethbridge AB. Cattle were maintained according to the guidelines set by the Canadian Council on Animal Care (1993). Calves with no Wagyu genetic influence were grouped as EBC cattle, while those with Wagyu genetic influence were grouped as WC cattle. Animals within each breed combination and gender were randomly assigned to one of two diet treatments for 84 d (phase 1). Cattle were further backgrounded on diet 1 (phase 2) until they weighed more than 380 kg for the WC cattle and 410 kg for EBC cattle. The different target weights were selected to accommodate the innate differences which exist in their relative mature size, and the two backgrounding phases were included to allow cattle to grow adequately because ad libitum intake of high concentrate diets early in life is reported to reduce mature size and reduce carcass weight (Owens et al. 1995). After phase 2 of backgrounding, they were adapted to a 80% (DM basis) rolled barley grain finishing diet and fed until they were slaughtered. Cattle were weighed every 4 wk for determination of ADG and DMI during the period, and the F/G was calculated.

Table 1. Breed combinations of cattle used in the trial

Breed type	Heifers	Steers	Total
European and British crossbred cattle (EBC)			
Hereford (H)	5	5	10
G3H[z]	8	8	16
HHA – H × H/ Angus	7	9	16
HSA – H × Simmental/ Angus	8	8	16
Wagyu crossbred cattle (WC)			
WAW – Wagyu × Angus/Wagyu	7	6	13
WOW – Wagyu × Holstein/Wagyu	–	4	4
Wlac – Wagyu × European Composite /Wagyu	–	4	4

[z] - G3 - Composite of 25% Charolais, 25% Simmental, 6.25% Limousin, 43.75% British crossbred breeds (H, Angus or Shorthorn) × Hereford.

Backgrounding Phase 1

Backgrounding diets (on DM basis) used for phase 1 were: diet 1, 35% rolled barley in barley silage with protein and vitamin/mineral premix; and diet 2, 40% hay cubes (alfalfa and straw cubes containing 16% crude protein) in barley silage with protein and vitamin/mineral premix. The composition of the beef vitamin/mineral premix was: white salt, 56.7 kg; dicalcium phosphate, 15.0 kg; limestone, 15.0 kg; dynamate, 10.0 kg; zinc sulphate, 1.3 kg; manganese sulphate, 1.5 kg; copper sulphate, 492 g; EDDI (80%), 7.8 g; sodium selenite, 5.5 g; cobalt sulphate, 6.0 g; and vitamins A (10 million IU kg^{-1}), D (1 million IU kg^{-1}), and E (100 000 IU kg^{-1}).

Backgrounding Phase 2

After phase 1, all cattle were fed diet 1 until their weight was greater than 410 and 380 kg for EBC and WC, respectively. During this phase, animals that were heavier than the target weight on each weigh day were switched to the finishing diet and the final weight for each animal and the number of days cattle received the backgrounding diet was recorded.

Finishing

Once cattle were of target weight they were adapted, over 10 d, to a finishing diet composed (on DM basis) of: 21% barley silage, 78% rolled barley grain and 1% vitamin/mineral premix. Cattle were maintained on this diet until the ultrasonically (Tokyo Keiki LS-1000 with a 3.5 MHz probe head from Tokyo Keiki Co. Ltd. Tokyo, Japan) assessed backfat thickness was greater than 10 mm. Ultrasonography was conducted every 4 wk, and those animals with backfat greater than the 10 mm were shipped to slaughter the following week.

Cattle were slaughtered at the Burns Meat Plant at Lethbridge without prior feed or water restriction and the carcasses were graded by Agriculture and Agri-Food Canada graders under their Blue Tag program. Carcasses were graded for extent of marbling on a 10 point inverse scale (10 = devoid of marbling, to 1 = very abundant marbling; Newman et al. 1994).

Meat Quality

A three bone rib (7, 8 and 9) section was collected the day after slaughter from 35 EBC cattle (five Hereford steers, five steers and heifers of HHA, HSA, G3H crossbred cattle) and all 21 of the WC cattle and analyzed for meat quality parameters. These parameters were colour intensity (muscle colour was assessed using a reflectance meter [Minolta Chroma Meter II, Minolta Camera Co., NJ]), drip loss, pH, moisture and fat content (Soxtec) and Warner-Bratzler shear force were determined for meat from the steaks after ten days of aging at 1°C. Briefly, the ribeye muscle was removed and trimmed of all external fat. After facing the ninth rib end, a steak of 20-mm thickness was fabricated, weighed and placed on an absorbent steak pad in a styrofoam retail tray, then allowed to bloom for 20 min. before three colour measurements were made. The three colour measurements were averaged to provide the objective assessment of colour. This steak was then overwrapped with oxygen permeable film (Vitafilm Choice Wrap, Plastic Films Division, Goodyear Canada Ltd., Toronto, ON) and held at 4°C for 6 d. The steak was removed, blotted dry on absorbent towel and reweighed to determine loss due to drip and evaporation.

A second steak of 28-mm thickness was fabricated from the posterior end of the remaining ribeye and subdivided into three muscle blocks for cooking. Each block was immersed in 0.9% saline solution and cooked in an 80°C water bath with an external circulating hot water supply to reduce temperature fluctuations. The blocks were cooked to 72°C internal temperature and immediately immersed in ice water for approximately 20 min to arrest the cooking process. Each block was separately packaged in a polypropylene container and stored overnight at 4°C. One 19-mm-diameter core was removed from each block, at right angles to the steak surface, and sheared in a Warner-Bratzler shear cell attached to an Instron Model 4301 Materials Testing System. Cross head speed was set at 50 mm/min^{-1}.

Ultimate pH was measured in triplicate on the remaining piece of ribeye following removal of the two steaks using a Hanna Instruments Model 8124 pH/temperature/mv meter (Hanna Instruments, Woonsocket, RI) equipped with an Ingold spear-type combination electrode (Ingold Messtechnik AG, Urdof, Switzerland) and automatic temperature compensation thermocouple. The remaining muscle sample was then ground and mixed three times through a plate with 3.2-mm holes. Approximately 100 g of ground sample was weighed into a 600-mL stainless steel beaker, pressed evenly against the walls of the container, dried at 105°C for 24 h. Moisture content was recorded as the proportion of the difference in initial and final weights over initial weight. The resultant dried product was pulverized and duplicate sub-samples of approximately 4 g were boiled in petroleum ether for 10 min, followed by a 20-min rinse cycle using a Tecator Model 1043 Soxtec Extraction System. Crude fat content of the original sample was worked back to wet basis using the previously determined moisture data.

Statistical Analysis

Analysis of variance for a factorial design using the GLM procedure of the SAS Institute, Inc. (1995) was used to analyse the data. Effects considered in the statistical model for the first backgrounding phase were type (B) where cattle of breeds without Wagyu genetic influence (EBC) were compared with cattle with Wagyu genetic influence (WC) (Table 1), gender (*S*), and diet (*D*), wherein each value (*Y*) in the model was comprised of the mean (*U*), the main and interactive effects of the factors and error (*E*) as follows:

$$Y_{ijk} = U + B_i + S_j + D_k + B_iS_j + B_iD_k + S_jD_k + B_iS_jD_k + E_{ijk}$$

Diet effect was removed from the model for analysis of the backgrounding phase 2, finishing phase, carcass characteristics and meat quality analysis and the model was:

$$Y_{ij} = U + B_i + S_j + B_iS_j + E_{ij}$$

Substantial differences in initial weight of the two breed types of cattle at the start of the three feeding phases were observed, thus the data were analyzed by conducting analysis of covarinace. Initial weight at start of each phase of the feeding trial was included as a covariate. Similarly, carcass characteristics were analyzed with warm carcass weight and backfat as covariates, while for the meat quality parameters only backfat was used as the covariate. Differences between the parameters evaluated were determined by the protected least square means procedure. Correlation coefficients among marbling score, muscle fat content and Warner-Bratzler shear force were determined.

RESULTS

Backgrounding Phase 1

The covariate did not interact ($P > 0.05$) with any of the parameters evaluated or their interactions for this phase of the trial. However, the covariate itself was significant for the parameters final weight, DMI and F/G but not for ADG. Interactions between type of cattle, gender and diet were not significant and least square means for initial weight from the analysis of variance are provided, but for the other parameters, means obtained after adjustment for the covariate are shown in Table 2. Animal weights at the start of the experiment were different for each type of cattle and EBC cattle were heavier ($P < 0.05$) than the WC cattle (Table 2). At the end of the 84 d, phase 1 of backgrounding, differences in weight observed at the beginning of the experiment pre-

Table 2. Least square means for performance of EBC and WC weaned calves fed different diets (phase 1)

	n^y	Initial weight (kg)	Final weight (kg)	DMI (kg d^{-1})	ADG (kg d^{-1})	F/G
Breed type[z]						
EBC	58	268*a*	340*a*	7.5	1.13*a*	6.7*b*
SEM		6.2	2.1	0.14	0.02	0.16
WC	21	173*b*	242*b*	7.3	0.80*b*	8.7*a*
SEM		10.1	4.5	0.32	0.037	0.36
Gender						
Heifers	35	206*b*	323	7.2	0.94	7.8
SEM		4.7	3.4	0.23	0.033	0.26
Steers	44	240*a*	328	7.5	0.99	7.7
SEM		3.7	2.2	0.15	0.025	0.17
Diet 1[x]	40	230	333*a*	6.9*b*	1.05*a*	6.6*b*
SEM		3.7	2.6	0.17	0.029	0.19
Diet 2[x]	39	220	318*b*	7.8*a*	0.88*b*	8.8*a*
SEM		3.9	3.1	0.21	0.036	0.23

[z]Breeds: **EBC**, G3H – (G3 – Composite of 25% Charolais, 25% Simmental, 6.25% Limousin 43.75% British breeds (Hereford, Angus or Shorthorn)) × Hereford, Hereford, HHA – Hereford × Hereford/ Angus, HSA – Herford × Simmental / Angus, **WC,** WAW – Wagyu × Angus/Wagyu; WOW – Wagyu × Holstein/Wagyu, WLac – Wagyu × European Composite/ Wagyu.
[y]*n*, number of animals.
[x]Diet 1, 35% barley in barley silage with protein and mineral supplement. Diet 2, 40% hay cubes, in barley silage with protein and mineral supplement.
*a,b*Means followed by a different within a column and category are different ($P < 0.05$).

vailed. Steer calves were heavier than heifer calves at the beginning but not at the end of phase 1 of backgrounding, and cattle receiving the grain diet were heavier ($P < 0.05$) than those fed the hay cube diet at the end of this phase.

Average daily gain of EBC cattle was greater ($P < 0.05$) than that of WC cattle, while the DMI of WC cattle was comparable ($P > 0.05$) to that of EBC cattle. Thus F/G of EBC cattle was lower ($P < 0.05$) than that of WC cattle. No significant effect of gender on final weight, ADG, DMI or F/G was observed during this first phase of the trial. Final weight, ADG and F/G of cattle receiving diet 2 was poorer than those receiving diet 1, while the DMI of diet 2 was greater than that of diet 1 (Table 2).

Backgrounding Phase 2

All cattle were fed diet 1 during this phase, thus only type and gender effects were evaluated and the final weight at the end of phase 1 of trial was used as the covariate (inwt2) for the second phase of the feeding trial. Since the aim of this second phase of the trial was to take cattle to a target weight, the days on feed to arrive at the weight was included in the analysis. The covariate did not interact ($P > 0.05$) with the parameters days on feed, ADG, DMI, or F/G. The interaction among covariate, breed type and gender of the cattle was significant for final weight at the end of the phase 2 of the feeding trial. Thus analyses were conducted to obtain regression solutions for final weight of heifers and steers of EBC and WC cattle. The equations were:

EBC heifers = 231.84 (±24.68) + 0.552 (±0.07) × inwt2
EBC steers = 324.29 (±26.20) + 0.309 (±0.07) × inwt2
WC heifers = 235.75 (±70.92) + 0.576 (±0.31) × inwt2
WC steers = 150.68 (±27.91) + 1.021 (±0.11) × inwt2

Interactions between the covariate, breed type and gender were not present ($P > 0.05$) for any of the other parameters, but the covariate inwt2 was significant. Breed type and gender interactions were not significant for ADG, DMI or F/G, but the parameter days on feed was affected by both breed type and gender. The days on feed to arrive at target weight for heifers and steers of EBC and WC cattle, respectively, were 72 d (±2.4), 63 d (±3.0), 105 d (±6.23) and 115 d (±4.5). European and British crossbred cattle had higher ($P < 0.05$) ADG and DMI than the WC cattle but differences were not present ($P > 0.05$) for F/G (Table 3).

The ADG of steers was 1.21 kg d^{-1} while heifers gained only 1.07 kg d^{-1} during backgrounding phase 2 (Table 3). As in the case of ADG, DMI of steers was greater than that of heifers, consequently, F/G did not differ between steers and heifers.

Finishing phase

Final weight at the end of backgrounding phase 2 was used as a covariate (inwt3) for analysis of data for the finishing phase. The covariate did not interact ($P > 0.05$) with any of the parameters or their interactions; however, the cavariate was significant for weight prior to slaughter. Interaction between breed type and gender was not observed for any of the parameters.

Days on feed required to finish were 77 d for EBC cattle, while WC cattle required only 42 d. However, the WC cattle were finished at substantially lighter ($P < 0.05$) weight than EBC cattle (Table 4). Average daily gain of WC cattle was lower ($P < 0.05$) than of EBC cattle. Wagyu crossbred cattle had lower ($P < 0.05$) DMI and poorer F/G during the finishing period in comparison to EBC cattle. No differences in performance of cattle due to gender were observed (Table 4).

Carcass Characteristics

Carcass information obtained from the Blue Tag program of Agriculture and Agri-Food Canada was analysed along with

Table 3. Least square means for performance of EBC and WC cattle fed a 35% barley grain diet (phase 2)

	n^y	DOF[x] (d)	DMI[w] (kg d^{-1})	ADG[x] (kg d^{-1})	F/G[y]
Breed type[z]					
EBC	58	67*b*	9.0*a*	1.24*a*	7.2
SEM		2.0	0.12	0.03	0.32
WC	21	110*a*	8.1*b*	1.05*b*	8.9
SEM		4.6	0.28	0.057	0.73
Gender					
Heifers	35	88	8.3*b*	1.07*b*	8.4
SEM		3.2	0.20	0.052	0.51
Steers	44	89	8.8*a*	1.21*a*	7.7
SEM		2.01	0.13	0.039	0.33

[z]EBC and WC, description of cattle breed combinations in each group provided in Table 2.
[y]*n*, number of animals.
[x]DOF, days on feed.
*a,b*Means followed by a different letter within a column and category are different ($P < 0.05$).

Table 4. Least square means for performance of EBC and WC cattle on finishing diets (80% grain on dry matter basis)

	n^y	DOF[x] (d)	Final weight (kg)	DMI[w] (kg d^{-1})	ADG[x] (kg d^{-1})	F/G[y]
Breed type[z]						
EBC	58	77*a*	540*a*	8.8*a*	1.19*a*	7.8*b*
SEM		0.6	2.7	0.14	0.029	0.18
WC	21	42*b*	484*b*	8.0*b*	0.86*b*	9.4*a*
SEM		1.1	5.8	0.29	0.052	0.32
Gender						
Heifers	35	59	511	8.4	1.00	8.1
SEM		1.0	5.1	0.25	0.048	0.29
Steers	44	59	513	8.5	1.05	7.7
SEM		0.8	3.1	0.16	0.037	0.23

[z]EBC and WC, description of cattle breed combinations in each group provided in Table 2.
[y]*n*, number of animals.
[x]DOF, days on feed.
*a,b*Means followed by a different letter within a column and category are different ($P < 0.05$).

total days on feed and age at slaughter (Table 5). The data were analyzed with warm carcass weight and backfat as covariates. These covariates did not interact with any of the carcass characteristics investigated. The proportion of warm carcass weight to liveweight and ribeye area were influenced by warm carcass weight ($P < 0.05$) but not by backfat thickness ($P > 0.05$), and only the backfat thickness affected lean meat yield. However, both these covariates did not ($P > 0.05$) affect age at slaughter, days on feed and marbling score.

Wagyu crossbred cattle were on feed for 55 d longer ($P < 0.05$) than the EBC cattle (Table 5). However, the difference ($P < 0.05$) in age at slaughter between EBC and WC cattle was only 19 d. Lower final weights of WC cattle resulted in lighter ($P < 0.05$) carcass weights than those of EBC cattle. Covariate adjusted warm carcass yield in proportion to liveweight was greater ($P < 0.05$) for WC than for EBC cattle. No difference existed between EBC and WC cattle for lean meat yield ($P > 0.05$) after adjustment for backfat thickness and absence of the difference was related to WC cattle having lesser ($P < 0.05$) backfat than EBC cattle. However, scores for marbling fat indicated WC cattle (7.1) to have a greater ($P < 0.05$) amount of intramuscular fat than EBC cattle (8.0). The area of the longissimus thoracis (ribeye area) adjusted for the covariate was no different ($P > 0.05$) for WC cattle than for EBC cattle.

Heifers required a greater ($P < 0.05$) number of days on feed, and were older ($P < 0.05$) at slaughter, even though they weighed less ($P < 0.05$) than steers. As a result, carcass weight was lower for the heifers relative to steers but covariate adjusted warm carcass yields as proportion of liveweight, lean meat yield, backfat thickness, marbling score and ribeye area were similar ($P > 0.05$) for heifers and steers.

Meat Quality

The covariate backfat thickness neither interacted with nor affected ($P > 0.05$) any of the meat quality parameters.

Table 5. Least square means for grade characteristics of carcasses from EBC and WC cattle

	n^y	Age at slaughter (d)	DOF[x] (d)	Carcass weight (kg)	Warm carcass yield (g kg^{-1} liveweight)	Lean yield (g kg^{-1} carcass)	Backfat (mm)	Marbling score[w]	Ribeye area (cm^2)
Breed type[z]									
EBC	58	501*b*	234*a*	302*a*	541*b*	547	15.8*a*	8.0*a*	73.7
SEM		3.0	2.2	2.6	2.4	1.6	0.45	0.05	1.00
WC	21	520*a*	289*b*	239*b*	560*a*	546	12.8*b*	7.1b	76.0
SEM		5.3	3.8	4.7	5.6	2.9	0.81	0.10	2.22
Gender									
Heifers	35	515	265*b*	257*b*	552	549	14.9	7.4	76.0
SEM		4.8	3.5	4.3	4.2	2.5	0.74	0.08	1.68
Steers	44	506	254*a*	284*a*	549	545	13.6	7.6	73.7
SEM		3.7	2.7	3.3	2.5	2.0	0.56	0.07	1.00

[z]EBC and WC, description of cattle breed combinations in each group provided in Table 2.
[y]*n*, number of animals.
[x]DOF, days on feed.
[w]Marbling was scored on a 10-point inverse scale ranging from 10 (devoid of marbling) to 1 (very abundant marbling) (Newman et al. 1994).
*a,b*Means followed by a different letter within a column and category are different ($P < 0.05$).

Table 6. Meat characteristics from EBC and WC cattle

	n^{y}	Color L*	Color a*	Color b*	Drip loss (mg g^{-1})	pH
Breed type[z]						
EBC	35	42.1	20.1	9.4*b*	67*b*	5.51*b*
SEM		0.33	0.18	0.14	1.1	0.007
WC	21	42.9	20.0	10.2*a*	75*a*	5.47*a*
SEM		0.46	0.25	0.18	1.2	0.009
Gender						
Heifers	26	42.2	19.9	9.7	73	5.48*b*
SEM		0.45	0.25	0.18	1.6	0.009
Steers	30	42.6	20.2	9.8	69	5.51*a*
SEM		0.43	0.18	0.14	1.2	0.007

[z]EBC and WC: description of cattle breed combinations in each group provided in Table 2.
[y]*n*, number of animals.
*a,b*Means followed by a different letter within a column and category are different ($P < 0.05$).

Table 7. Composition and tenderness of meat from EBC and WC cattle

	n^{y}	Moisture (mg g^{-1})	Fat (mg g^{-1}) DM	Fat (mg g^{-1}) as is	Shear force (kg)
Breed type[z]					
EBC	35	725*a*	189*b*	53.1*b*	4.2*a*
SEM		2.0	7.5	4.32	0.08
WC	21	706*b*	246*a*	74.3*a*	3.9*b*
SEM		2.7	10.2	7.21	0.11
Gender					
Heifers	26	711*b*	233*a*	67.3*a*	4.1
SEM		2.6	10.6	4.8	0.11
Steers	30	720*a*	202*b*	56.6*b*	4.0
SEM		2.0	7.6	7.9	0.08

[z]EBC and WC, description of cattle breed combinations in each group provided in Table 2.
[y]*n*, number of animals.
[x]Calculated: mg g^{-1} {(1000 – Moisture content) × fat content on DM basis / 1000}.
*a,b*Means followed by a different letter within a column and category are different ($P < 0.05$).

Breed type of cattle exerted relatively minor effects on muscle colour, drip loss and final muscle pH (Table 6). Meat from WC cattle had higher values for the colour coordinate -b* than that from EBC cattle. Drip loss was 75 and 67 mg g^{-1} for meat from WC and EBC cattle and the value for WC cattle was higher ($P < 0.05$) than that of EBC cattle. Except for pH, differences due to gender were not observed for any other meat quality parameter. Fat content of the longissimus thoracis muscle whether expressed on a dry or as is basis, indicated that WC cattle had higher ($P < 0.05$) level of fat and lower ($P < 0.05$) content of moisture than EBC crossbred cattle (Table 7). Differences in fat content on an as is basis reflect differences in moisture content of the muscle from the carcasses of the types of cattle studied. Shear force for meat from EBC cattle was greater ($P < 0.05$) than that for meat from WC cattle. Shear force was poorly correlated to marbling score ($r = 0.26$; $P = 0.05$; $n = 56$).

Meat samples procured from heifers had greater ($P < 0.05$) proportions of fat but lower moisture content and pH relative to steers. Differences between heifers and steers were not significant for the other parameters.

DISCUSSION

Controversy regarding the significance of the contribution of intramuscular fat to organoleptic appeal exists (Jones et al. 1992; Wheeler et al. 1994). In the United States of America, there are economic benefits to be realized by the producer or packer when beef is well marbled (Gaskins et al. 1995) because the price difference is substantial for beef that is graded as “US Select” versus “US Choice”. Other studies have illustrated that beef from WC cattle has a greater proportion of intramuscular fat than other breeds (Lunt et al. 1993; Sturdivant et al. 1994). However, the nature of the feeding program and source of feed are different from employed in Canada.

During the first backgrounding phase, the ADG of EBC cattle fed the hay cube diet was comparable to values reported by Mir and Mir (1994a,b) for similar crossbred steers fed 75% alfalfa and 25% grain, but better than the ADG reported by Hironaka et al. (1994) for cattle fed all silage diets. Inclusion of barley grain at 35% of dry matter to the diet improved the ADG of EBC cattle to expected gains (Hironaka et al. 1994; Mathison and Engstrom 1995a) suggesting that the energy deficit in the hay cube diet affected both ADG and F/G similarly in both the EBC and WC cattle. Wagyu crossbred cattle are claimed to utilize poorer quality feed better than other types of cattle thus it was expected that WC cattle would have better F/G when fed the hay cube diet but none was observed. Weight gain of WC cattle fed the two diets was similar to results noted for EBC crossbred cattle, but ADG of cattle receiving the hay cube diet was better than reported values for Wagyu cattle fed forage diets (Barker et al. 1995). The ADG of WC cattle in this study when fed the 35% grain diet was better than reported values for forage based diets (Barker et al. 1995; Sturdivant et al. 1994). The lack of an interaction between breed type and diet for F/G indicated that WC cattle are not able to utilise forage diets more efficiently than EBC cattle as has been claimed previously. The ADG of heifers was poorer than of steers for both WC cattle and EBC cattle, confirming the observation of Beacom and Mir (1985).

Grain content of the finishing diet used in the present study was 10% lower and weight of cattle at the start of the finishing phase was greater than in the studies by Mathison and Engstrom (1995a,b). Animals were neither implanted nor provided with feed additives such as ionophores during either the backgrounding or finishing phase in the present study. These are some of the reasons for the lower ADG noted in the present investigation, but the rate of gain was comparable to those observed by Hironaka et al. (1994) when the diet contained a comparable amount of grain. Rate of gain of WC cattle receiving the finishing diet were lower than that of Wagyu × Angus steers on the deferred program of Barker et al. (1995). This difference in rate of gain may be due to the use of corn (Barker et al. 1995) as opposed to the barley-based diet used in the present study. Wagyu crossbred cattle in the current study were 75% Wagyu in genetic composition which may have contributed to their low initial weight and low ADG throughout the trial.

Carcasses were graded a day after slaughter. Since feed was not withdrawn prior to slaughter, the warm carcass yields were lower than reported values of 56 to 57% (Mathison and Engstrom 1995a,b). Warm carcass yield was comparable to those reported by McCaughey and Cliplef (1996) when calculations were based on preshrunk weight. Cattle used in the investigation by McCaughey and Cliplef (1996) were larger at slaughter than the EBC cattle in the present investigation. Final weights in the present investigation were comparable to those in studies by Mathison and Engstrom (1995a,b) thus the lean meat yields and ribeye areas of cattle in the present study were similar to those reported by these authors. Wagyu crossbred cattle were younger and smaller than the cattle in the study by Lunt et al. (1993) thus the carcass size and ribeye area were smaller in the present study. However the backfat depth of the EBC cattle was greater than that of the WC cattle and greater than backfat depths reported by McCaughey and Cliplef (1996). Marbling grade was better for carcasses from WC cattle and 18 out of 21 (83%) cattle graded the Canadian "AAA" grade which is equivalent to small or greater amounts of marbling fat. Only eight out of 58 (14%) carcasses from the EBC cattle graded "AAA". The relatively poor F/G ratio observed in WC during the finishing phase may be due to the fact that these cattle were storing energy as marbling fat rather than as growth.

Meat quality in terms of moisture and fat composition and characteristics such as pH and colour was determined from meat from randomly selected animals from each type of cattle. The higher value for colour coordinate b* for meat from WC cattle than that of EBC cattle may be a breed characteristic or related to the long duration of backgrounding and short length of finishing periods for these cattle. However the significance of this factor in consumer appeal is reported to be small (Aalhus et al. 1992, 1994). Marbling fat content of WC cattle was greater than of EBC cattle and a majority of the meat samples contained in excess of 20% fat (on dry matter basis). Marbling score assignment is a visual assessment of intramuscular fat and is subjective (Aalhus et al. 1992), thus the score does not account for all the extractable fat in meat samples. If the marbling score was assigned solely on chemically extractable fat content carcasses of WC cattle could have been categorized as containing a "modest to moderate amount of fat" which would be equivalent to mid to high "US Choice" (Jones et al. 1992) and on a similar basis more carcasses from the EBC cattle would have graded "AAA" than indicated in the study. The pH of the meat after 10 d of aging was lower than values reported for ultimate pH by Aalhus et al. (1992, 1994) but within normal ranges.

Shear force values observed for the meat samples tested were low (3.9 to 4.2 kg). These values are substantially lower than those reported by Aalhus et al. (1992, 1994) for meat from beef carcasses which had been electrically stimulated. Huffman et al. (1996) reported that beef with shear force values as low as those obtained in this study would be in the category of samples rated as "extremely tender" by consumers and that such meat had a 95% or greater consumer approval rating. Greater meat fat content (Savell et al. 1987), longer feeding duration (Aberle et al. 1981; Rompala and Jones 1984; Miller et al. 1987) have been suggested as reasons for the low shear force.

Results from the present investigation indicate that extent of carcass marbling can be increased by including Wagyu genetics in beef cattle that are fed barley-based diets. However, there is an associated loss in carcass size compared with common breed crosses. Days on feed were greater for Wagyu crossbred cattle than for European and British crossbred cattle, though age at slaughter was only 19 d more for the Wagyu crossbred cattle in comparison with European and British crossbred cattle.

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