Growth, carcass and meat quality characteristics of beef cattle with 0, 50 and 75 percent Wagyu genetic influence

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Mir, P. S., Bailey, D. R. C., Mir, Z., Entz, T., Jones, S. D. M., Robertson, W. M., Weselake, R. J. and Lozeman, F. J. 1999. **Growth, carcass and meat quality characteristics of beef cattle with 0, 50 and 75 percent Wagyu genetic influence.** Can. J. Anim. Sci. **79**: 129–137. Feeding trials were conducted in two years to compare growth performance, carcass characteristics and quality of meat from beef cattle with 0, 50 or 75% Wagyu genetic influence. The cattle types used in the two years of the study were Continental crossbred steers (0% Wagyu), cattle with 50% Wagyu influence (Wagyu/Angus crossbreds) and 75% Wagyu influence (containing 25% from other European breeds). Cattle were housed in individual pens in the first year and in group pens in the second year. Cattle were fed a backgrounding diet containing 35% barley grain and 65% barley silage with protein, mineral and vitamin supplements until they weighed more than 380 kg, after which they were adapted to a finishing diet consisting of 80% barley and 20% barley silage with mineral and vitamin supplements. Cattle were weighed every 4 wk and at the end of the finishing period they were processed and carcass information was obtained. A three-rib section (10–12) was removed from 41 (year 1) and 44 (year 2) carcasses selected randomly from each group, and Warner–Bratzler shear force was determined. The year-by-cattle type interaction was significant for most parameters; thus all the data were also analysed by year using weight of cattle at initiation of the feeding trial as a covariate for the backgrounding and finishing phases of growth and using carcass weight and back fat depth as covariates for carcass and meat-quality parameters. Weight at the start of the trial influenced most growth parameters and age at slaughter. Continental crossbred steers had higher (P < 0.05) ADG than Wagyu crossbred cattle during the finishing phase (1.47 vs. 0.82 kg d^{-1}) in year 1, but not in year 2. Carcass weights of 75% Wagyu crossbred cattle were lower (P < 0.05) than those of Continental crossbred steers in both years. Warner–Bratzler shear force values were less than 5.3 kg to shear cores of 19 mm diameter. However, 92% in year 1 and 71% in year 2 of the carcasses from Wagyu crossbred cattle graded Canada AAA, and contained more than a "small" amount of intramuscular fat. Thirty percent of the carcasses from Wagyu crossbred cattle in year 1 graded Canada Prime. Only 30% of Continental crossbred steers in year 1 and 10% in year 2 graded Canada AAA. Wagyu genetic influence enhanced marbling in beef cattle without loss in carcass size for the 50% Wagyu steers.

Key words: Wagyu, Carcass characteristics, Warner–Bratzler shear force

Mir, P. S., Bailey, D. R. C., Mir, Z., Entz, T., Jones, S. D. M., Robertson, W. M., Weselake, R. J. et Lozeman, F. J. 1999. **Croissance, qualité de la carcasse et de la viande de bovins de type de boucherie possédant 0, 50 et 75 % d'ascendance Wagyu**. Can. J. Anim. Sci. **79**: 129–137. Des essais d'alimentation ont été réalisés durant 2 ans pour comparer les performances de croissance, les caractères de carcasse et la qualité de la viande de bovins possédant 0, 50 et 75 % de sang Wagyu. Les types d'animaux utilisés dans les 2 années de l'expérience était 1) des bouvillons croisés avec des races d'Europe continentale (0 % Wagyu), 2) des bovins à 50 % d'ascendance Wagyu (croisés Wagyu-Angus) et 3) à 75 % d'ascendance Wagyu (le 25 % restant provenant d'autres races européennes. Les animaux étaient logés en enclos individuels la première année et en parquets collectifs la seconde. Ils recevaient un régime de préfinition contenant 35 % de grain d'orge et 65 % d'ensilage d'orge, assorti des compléments protéiques, minéraux et vitaminiques, jusqu'à ce qu'ils pèsent au moins 380 kg, après quoi ils étaient acclimatés à un aliment de finition composé à 80 % de grain et 20 % d'ensilage d'orge avec condiment minéral-vitaminisé. La pesée était prise toutes les 4 semaines et au terme de la phase de finition, ils étaient abattus et dépecés puis la carcasse était évaluée. Une section de 3 côtes (de la dizième à la douzième) était prélevée sur 41 (année 1) et sur 44 (année 2) carcasses prises au hasard dans chaque type d'ascendance Wagyu et l'on mesurait la force de cisaillement au Warner-Bratzler. Comme l'interaction année × type d'animaux était significative pour la plupart des paramètres, toutes les données étaient également analysées année par année, utilisant le poids des animaux en début d'essai d'engraissement comme covariable pour les phases de préfinition et de finition et le poids de carcasse et l'épaisseur du gras de couverture comme covariables pour les paramètres qualitatifs de la carcasse et de la viande. Le poids au début de l'expérience influait sur la plupart des paramètres de croissance ainsi que sur l'âge à l'abattage. Dans l'année 1, les bouvillons croisés avec des races d'Europe continentale manifestaient un GMQ plus élevé (P < 0,05) que les sujets à ascendance Wagyu durant la phase de finition (1,47 contre 0,82 kg j^{-1}). Cette observation ne se retrouvait cependant pas dans l'année 2. Le poids de carcasse des sujets à 75 % d'ascendance Wagyu était plus bas (P < 0,05) que celui des sujets croisés avec des races d'Europe continental, et cela durant les 2 années de l'essai. Il suffisait de valeurs Warner-Bratzler de moins de 5,3 kg pour cisailler

Abbreviations: **ADG**, average daily gain; **CC – S**, Continental crossbred steers; **DMI**, dry matter intake; **F:G**. feed to gain ratio; **W50 – H**, 50% Wagyu heifers; **W75 – H**, 75% Wagyu heifers; **W50 – S**, 50% Wagyu steers; **W75 – S**, 75% Wagyu steers

des carottes de muscle de 19 mm de diamètre. Cependant 92 % (année 1), et 71 % (année 2) des carcasses de bovins croisés d'ascendance Wagyu méritaient la catégorie Canada AAA et elles contenaient plus qu' «un peu» de gras intramusculaire. Trente pour cent des carcasses à ascendance Wagyu dans l'année 1 rentraient dans la catégorie «Canada première catégorie». Seulement 30 % dans l'année 1 et 10 % dans l'année 2 des bouvillons croisés à des races d'Europe continentale obtenaitent la catégorie AAA. Chez les sujets à 50 % de sang Wagyu, un observait une augmentation du persillé, sans pour autant compromettre la taille de la carcasse.

Mots clés: Wagyu, caractère de carcasse, force de cisaillement mesurée au Warner-Bratzler

The quality of beef carcasses is assessed by the extent of marbling or intramuscular fat present, especially when carcass fat and meat colour are not a concern. In the United States and Canada a higher price is paid for carcasses with higher marbling than for those with a lower level of marbling with the price differential being greater in the United States for carcasses that grade Choice as opposed to Select (Gaskins et al.1995). However, cattle have to be fed for extended lengths of time on high-energy feed for carcasses to grade "US-Choice" and if the lean yield grades decline owing to excessive overall fatness, then the advantages of marbling may be negated. An ideal combination would be to have high levels of marbling in relatively lean animals. It is known that animals with the Japanese Wagyu influence marble substantially (Lunt et al. 1993). However, growth rates were found to be lower for crossbred animals with 75% Wagyu genetic influence than for those of other crossbred cattle, especially during the finishing phase (Mir et al. 1997). As a result, there is interest in using cattle with varying percentages of Wagyu genetic influence to improve quality grades of beef carcasses without adversely affecting carcass yield and production characteristics of beef cattle. Previous comparisons of growth performance and carcass characteristics among animals with 50, 75 and 87.5% Wagyu genetic influence have been made, using corn-based diets with feeding protocols up to 36 mo (Barker et al. 1995). The diets were similar to ones used in Japan in order to produce carcasses suitable for export to Japan. Comparisons of growth performance and carcass characteristics of cattle with 75% Wagyu genetic influence and Continental crossbred cattle produced under prevailing north American conditions have been conducted at the Lethbridge Research Centre and it was found that the 75% Wagyu cattle can be finished with traditional barley-based diets within 18 mo of age, with marked improvement in marbling (Mir et al. 1997). However, carcass size was smaller than that of the Continental crossbred steers. It was, therefore, of interest to compare growth performance and carcass and meat quality of cattle with Wagyu genetic influence at the 50 and 75% levels with Continental crossbred steers, when provided with barley-based diets over a duration of 18 mo. Thus, a feeding trial was conducted to compare growth performance, age at slaughter, carcass characteristics and quality of meat from beef cattle with 0 (Continental crossbred steers), 50 and 75% Wagyu genetic influence fed barley-based backgrounding and finishing diets.

MATERIALS AND METHODS

Spring-born calves, obtained at weaning from the Agriculture and Agri-Food Canada Substation at Onefour and from the Lethbridge Research Centre, were placed in the Individual Feeding Barn in year 1 and in eight group pens in year 2 at the Lethbridge Research Centre. All animals were cared for according to the guidelines of the Canadian Council on Animal Care (1993). In year 1, six Continental crossbred steer calves (0% Wagyu influence), 16 steers and 24 heifers with 50% Wagyu influence (50/50: Wagyu/Angus crossbreds) and 12 steers and 15 heifers with 75% Wagyu influence and containing 25% from other European breeds were used. In year 2, 10 Continental crossbred steers, 24 steers and 23 heifers of 50% Wagyu and 15 steers and 10 heifers of 75% Wagyu were used in the feeding trials. In year 2, the Continental crosses and the 75% heifers were in a pen each while the other cattle were divided into two pens for each of the groups. In each year, calves were provided with a totally mixed backgrounding diet containing, on dry matter basis, 35% barley grain and 65% barley silage containing supplemental protein and beef mineral mix. The composition of the beef mineral mix per 100 kg was: white salt, 47.7 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 sulfate, 6.0 g; and vitamins A, D and E, 9.0 kg. The vitamin concentrations were: vitamin A, 10×10^6 IU kg^{-1}; vitamin D, 1×10^6 IU kg^{-1}; vitamin E, 100 000 IU kg^{-1}. In year 1, cattle were fed the backgrounding diet until all cattle within each percentage of Wagyu weighed more than 380 kg, after which they were initiated into the adaptation phase for the finishing period. In year 2, cattle were fed the backgrounding diet until the pen average was greater than 420 kg for the 0 and 50% Wagyu and greater than 400 for the 75% Wagyu cattle, before the animals were initiated into the adaptation phase for the finishing diet. This adaptation phase extended over 2 wk when the barley grain content of the diet was increased from 35 to 80% of diet dry matter. Cattle were provided with a finishing diet consisting of 80% barley and 20% barley silage with beef mineral mix on a dry matter basis. Cattle were weighed every 4 wk. During the finishing phase animals were selected for shipment when they weighed more than 500 kg for the Continental crossbred steers and 50% Wagyu cattle and more than 460 kg for the 75% Wagyu cattle. Information regarding ADG, DMI, feed conversion efficiency or F:G and days on feed during the backgrounding and finishing phases were obtained. The DMI in year 2 was determined on a pen basis and divided by the number of animals in each pen.

Cattle were slaughtered and carcasses were assessed by graders from the Canadian Beef Grading Agency the day after slaughter. The carcass characteristics evaluated include warm carcass weight, warm carcass yield per unit liveweight, lean carcass yield, fat grade and marbling (Newman et al. 1994). After grading, a three-rib section, from the 10th to the 12th rib, was obtained from all Continental crossbred steers and from randomly selected cattle from both sexes with 50 and 75% Wagyu influence. Thirty-five and thirty-six Wagyu crossbred cattle were selected in years 1 and 2, respectively. The rib section was analysed for meat quality by determining meat colour, final pH after aging the meat at 2°C for a week and Warner–Bratzler shear force test was conducted by determining the force required to shear a 19-mm diameter core (Mir et al. 1997). The meat was prepared for measurement of Warner-Bratzler shear force by heating a 2.54-cm-thick steak in a pyrex dish containing physiological saline to an internal temperature of 70°C. Following this, the sample was immediately cooled and the force required to shear three 19-mm cores was measured. The moisture and solvent-extractable fat content of the meat were determined (Mir et al. 1997).

Statistical Analysis

Since the Continental crossbred cattle consisted of steers only, the data could not be analysed as a factorial design. Consequently, for statistical analysis, the following cattle type classification was used: CC – S, Continental crossbred steers; W50 – S, 50% Wagyu steers; W50 – H, 50% Wagyu heifers; W75 – S, 75% Wagyu steers; W75 – H, 75% Wagyu heifers. To evaluate cattle type over the 2 yr of the experiment, a model with year, cattle type and their interaction as fixed factors was used for all measured parameters except DMI and F:G.

The data were also analysed separately for each year with only cattle type as a fixed factor in the model. In order to adjust for substantial differences in initial weight of the animals within cattle type, initial weight was used as a covariate when analysing growth parameters from the backgrounding and finishing phases of the experiment (Steel and Torrie 1980).

The first step in the analysis of covariance was to evaluate the interaction between the fixed factors and the covariate. If no covariate interaction was present and the covariate was significant, then only the covariate main effect was included in the model and least squares means were produced to evaluate differences among cattle types. In cases where the covariate interaction was significant, equations were produced for each level of the fixed factor in the interaction in order to relate the growth parameter to the covariate. Contrast statements were used to make meaningful comparisons among the fitted equations. Least squares means were not produced when the covariate interaction was significant since they would be meaningless.

Warm carcass weight and back fat depth were used as covariates when analysing carcass data and meat quality parameters. The methods of analysis were identical to those outlined above for the growth parameters. The DMI and F:G data in year 2 were analysed using pens as the experimental unit since individual animal data could not be obtained. All statistical analysis were performed using GLM procedure of the SAS institute Inc. (1995). Differences among least squares means were evaluated for significance using a protected least square difference test.

Table 1. Least squares means for initial weight and days on feed of cattle with and without Wagyu genetic influence during backgrounding (year 1)

Cattle type	*n*	Initial weight (kg)	Days on feed (d)
CC – S	6	264*a*	140*d*
W50 – S	16	225*b*	224*c*
W50 – H	24	215*b*	234*b*
W75 – S	12	184*c*	240*b*
W75 – H	15	179*c*	253*a*
SEM		6.9	3.8

a–d Means followed by a different letter within a column are different ($P < 0.05$).

RESULTS

The results from the statistical analysis with year in the model indicated a cattle-type-by-year interaction for all parameters except lean carcass yield and ribeye area. Consequently, only results from the analysis conducted for each year will be presented in detail.

Backgrounding Phase (Year 1)

The initial weight of the Continental crossbred steers, 50 and 75% Wagyu at the beginning of the trial were different from each other (Table 1). However, differences in initial weight between steers and heifers within each level of Wagyu influence were not present. The interaction between the initial weight of cattle and cattle type was significant for the parameters: weight at end of backgrounding (final weight), ADG, DMI and F:G. Thus, equations were developed for each of the parameters for each cattle type in year 1 and the slopes of the equations were compared.

The equations to determine final weight at the end of backgrounding for cattle with the different genetic compositions were:

CC – S: Continental crossbred steers: $n = 6$
$198.5 + 0.797 \times$ initial weight (kg)
$\pm 51 \quad \pm 0.19$

W50 – S: Wagyu 50%, steers $n = 16$
$203.5 + 1.13 \times$ initial weight (kg)
$\pm 60 \quad \pm 0.27$

W50 – H: Wagyu 50%, heifers $n = 24$
$129.8 + 1.36 \times$ initial weight (kg)
$\pm 42 \quad \pm 0.19$

W75 – S: Wagyu 75%, steers $n = 12$
$285.6 + 0.67 \times$ initial weight (kg)
$\pm 41 \quad \pm 0.22$

W75 – H: Wagyu 75%, heifers $n = 15$
$312.8 + 0.49 \times$ initial weight (kg)
$\pm 36 \quad \pm 0.20$

The equations for ADG during backgrounding for these cattle were:

CC – S: Continental crossbred steers:
$1.42 - 0.0014 \times$ initial weight (kg)
$\pm 0.27 \quad \pm 0.001$

W50 – S: Wagyu 50%, steers
$0.91 + 0.0006 \times$ initial weight (kg)
$\pm 0.32 \quad \pm 0.001$

W50 – H: Wagyu 50%, heifers
$0.08 + 0.0038 \times$ initial weight (kg)
$\pm 0.22 \quad \pm 0.001$
W75 – S: Wagyu 75%, steers
$0.71 + 0.0013 \times$ initial weight (kg)
$\pm 0.22 \quad \pm 0.001$
W75 – H: Wagyu 75%, heifers
$0.95 + 0.0004 \times$ initial weight (kg)
$\pm 0.19 \quad \pm 0.001$

The equations for DMI during backgrounding were:

CC – S: Continental crossbred, steers:
$6.25 + 0.007 \times$ initial weight (kg)
$\pm 1.27 \quad \pm 0.005$
W50 – S: Wagyu 50%, steers
$5.47 + 0.010 \times$ initial weight (kg)
$\pm 1.49 \quad \pm 0.006$
W50 – H: Wagyu 50%, heifers
$1.46 + 0.127 \times$ initial weight (kg)
$\pm 1.04 \quad \pm 0.005$
W75 – S: Wagyu 75%, steers
$3.89 + 0.017 \times$ initial weight (kg)
$\pm 1.01 \quad \pm 0.005$
W75 – H: Wagyu 75%, heifers
$3.92 + 0.016 \times$ initial weight (kg)
$\pm 0.89 \quad \pm 0.005$

The equations for F:G during backgrounding were:

CC – S: Continental crossbred, steers:
$2.91 + 0.019 \times$ initial weight (kg)
$\pm 1.58 \quad \pm 0.006$
W50 – S: Wagyu 50%, steers
$6.34 + 0.005 \times$ initial weight (kg)
$\pm 1.86 \quad \pm 0.008$
W50 – H: Wagyu 50%, heifers
$8.84 + 0.003 \times$ initial weight (kg)
$\pm 1.29 \quad \pm 0.006$
W75 – S: Wagyu 75%, steers
$5.91 + 0.009 \times$ initial weight (kg)
$\pm 1.25 \quad \pm 0.007$
W75 – H: Wagyu 75%, heifers
$3.65 + 0.023 \times$ initial weight (kg)
$\pm 1.11 \quad \pm 0.006$

The slope values for final weight and ADG of 50% Wagyu heifers were greater (P= 0.0026 and P = 0.0063, respectively) than those of the 75% Wagyu heifers, while the slope value for DMI of 50% Wagyu heifers was greater (P = 0.0441) than for 50% Wagyu steers. However, the slope for F:G was greater (P = 0.0030) for 75% Wagyu heifers than for 50% Wagyu heifers. The covariate initial weight was significant for days on feed during backgrounding, but the interaction with cattle type was not significant. Table 1 indicates that 75% Wagyu heifers required the longest time on backgrounding diet to arrive at target weight (380 kg), while the 50% Wagyu heifers and 75% Wagyu steers were on this diet for less time than the 75% Wagyu heifers, but for longer than the 50% Wagyu steers, which were on the backgrounding diet longer ($P < 0.05$) than Continental crossbred steers.

Backgrounding Phase (Year 2)

The interaction between the covariate, initial weight, and cattle type was not significant but the main effect was significant for the parameters. Thus the least squares means for the parameters were obtained after variation due to the covariate was removed (Table 2). Final weights of steers were not different from each other and only weights of Continental crossbred steers and 50% Wagyu steers were greater ($P < 0.05$) than those of the heifers. The 75% Wagyu heifers received the backgrounding diet for 204 d as opposed to 175 d for the other cattle. Differences in ADG were not observed for the cattle types studied; however DMI was greatest for the Continental crossbred steers and was comparable to that of the 75% Wagyu steers. The 50% Wagyu cattle and the 75% Wagyu heifers consumed less feed than the Continental crossbred steers. The 50% Wagyu steers had the lowest F:G, which was different ($P < 0.05$) from that for the 75 % Wagyu heifers.

Finishing Phase (Year 1)

The interaction between the covariate initial weight at the start of the trial and cattle type was not significant, but the covariate main effect was significant for the parameters. The variation due to initial weight was removed statistically for all parameters (Table 3). The weight at the end of the finishing period was greatest for the Continental crossbred steers and greater ($P < 0.05$) than that of the Wagyu cattle (Table 3). The final weights of the other cattle were influenced by the percentage of Wagyu genetic influence and the greater the influence the lower the final weight. Differences ($P > 0.05$) due to gender were not apparent. Days on feed for the 50% Wagyu cattle were greater ($P < 0.05$) than for the 75% Wagyu heifers. The ADG and DMI of the Continental crossbred steers was greatest and higher ($P < 0.05$) than for the Wagyu cattle which were similar. However, F:G for the 50% Wagyu steers and the 75% Wagyu heifers was greater ($P < 0.05$) than that for the Continental crossbred steers. On average the Wagyu cattle were less efficient than the Continental crossbred steers in converting feed to liveweight.

Finishing Phase (year 2)

As observed in year 1, the covariate, initial weight, was significant, but the interaction between this factor and cattle type was not significant for the parameters investigated. Therefore, the values in Table 3 were obtained after the effect of the covariate was removed. Weight at the end of the finishing period was similar for the Continental crossbred steers and the 50% Wagyu steers and these cattle were heavier than the other Wagyu crossbred cattle in the study. The 50% Wagyu heifers and the 75% Wagyu steers were heavier than the 75% Wagyu heifers. Days on the finishing diet were greatest for the 50% Wagyu heifers and least for the 75% Wagyu heifers. The rate of liveweight gain was greater ($P < 0.05$) for 50% Wagyu steers than for the 75% Wagyu heifers during this phase of the trial, and similar differences in DMI were observed. As a result, differences ($P < 0.05$) in F:G were not present.

Table 2. Least squares means for performance of cattle with and without Wagyu genetic influence during backgrounding (year 2)

Cattle type	*n*	Initial wt. (kg)	Final wt. (kg)	Days on feed (d)	ADG (kg)	DMI (kg)	F:G
CC – S	10	261*a*	457*a*	175	1.1	7.9*a*	7.1*ab*
W50 – S	24	228*ab*	442*a*	175	1.2	7.5*bc*	6.1*b*
W50 – H	23	208*b*	402*b*	175	1.1	7.3*bc*	6.7*ab*
W75 – S	15	226*b*	432*ab*	175	1.2	7.7*ab*	6.5*ab*
W75 – H	10	196*b*	386*b*	204	0.9	7.1*c*	7.6*a*
SEM		7.3	7.4		0.04	0.08	0.29

a–d Means followed by a different letter within a column are different ($P < 0.05$)

Table 3. Least squares means for performance of cattle with and without Wagyu genetic influence during finishing

Cattle type	Final weight (kg)	Days on feed (d)	ADG (kg)	DMI (kg)	F:G
Year 1					
CC – S	531*a*	78*ab*	1.52*a*	10.6*a*	7.4*b*
W50 – S	491*b*	84*a*	0.75*b*	7.2*b*	9.9*b*
W50 – H	499*b*	88*a*	0.85*b*	7.5*b*	9.1*ab*
W75 – S	484*c*	77*ab*	0.81*b*	7.5*b*	9.6*ab*
W75 – H	480*c*	69*b*	0.86*b*	7.7*b*	10.0*a*
SEM	5.6	4.8	0.07	0.27	0.70
Year 2					
CC – S	550*a*	88*b*	1.0*ab*	9.5*a*	9.3
W50 – S	532*ab*	81*bc*	1.1*a*	9.0*ab*	8.3
W50 – H	504*c*	103*a*	1.0*ab*	8.3*bc*	8.3
W75 – S	510*c*	84*b*	0.9*ab*	8.5*bc*	9.0
W75 – H	444*d*	74*c*	0.8*b*	7.7*c*	9.2
SEM	5.5	2.3	0.04	0.16	0.29

a–d Means followed by a different letter within a column are different ($P < 0.05$).

Carcass Characteristics

Analysis of variance indicated substantial differences in both warm carcass weight and backfat depth. Therefore, these parameters were included as covartiates for all parameters except age at slaughter. Initial weight was used as the covariate for age at slaughter. An interaction ($P < 0.05$) was observed between initial weight and cattle type for the parameter age at slaughter and equations were derived for the different cattle types. The equations for age at slaughter for cattle in year 1 were:

CC – S: Continental crossbred, steers:
$$470 - 0.110 \times \text{initial weight (kg)}$$
$$\pm 38 \quad \pm 0.14$$
W50 – S: Wagyu 50%, steers
$$512 - 0.009 \times \text{initial weight (kg)}$$
$$\pm 46 \quad \pm 0.20$$
W50 – H: Wagyu 50%, heifers
$$598 - 0.344 \times \text{initial weight (kg)}$$
$$\pm 31 \quad \pm 0.14$$
W75 – S: Wagyu 75%, steers
$$504 + 0.196 \times \text{initial weight (kg)}$$
$$\pm 30 \quad \pm 0.16$$
W75 – H: Wagyu 75%, heifers
$$468 + 0.437 \times \text{initial weight (kg)}$$
$$\pm 27 \quad \pm 0.147$$

and the equations for age at slaughter for cattle in year 2 were:

CC – S: Continental crossbred steers $n = 10$:
$$500 + 0.024 \times \text{initial weight (kg)}$$
$$\pm 45 \quad \pm 0.16$$
W50 – S: Wagyu 50%, steers $n = 24$
$$459 + 0.080 \times \text{initial weight (kg)}$$
$$\pm 28 \quad \pm 0.11$$
W50 – H: Wagyu 50%, heifers $n = 23$
$$426 + 0.321 \times \text{initial weight (kg)}$$
$$\pm 42 \quad \pm 0.18$$
W75 – S: Wagyu 75%, steers $n = 15$
$$379 + 0.458 \times \text{initial weight (kg)}$$
$$\pm 30 \quad \pm 0.12$$
W75 – H: Wagyu 75%, heifers $n = 10$
$$368 + 0.680 \times \text{initial weight (kg)}$$
$$\pm 42 \quad \pm 0.19$$

The slopes for the parameter age at slaughter for the 50 and 75% Wagyu heifers were different ($P = 0.0003$) from each other in year 1, while in year 2 the slope for the 75% Wagyu steers differed from the 50% Wagyu steers ($P = 0.02$) and the Continental crossbred steers ($P = 0.03$). The year effect was not significant for lean carcass yield, but both warm carcass weight and back fat thickness were significant covariates for this parameter. The covariate adjusted means for lean carcass yield were 54.4*c*, 55.6*ab*, 56.5*a*, 55.3*b* and 56.4*a* ± SE = 0.29% for Continental crossbred steers, 50% Wagyu steers, 50%Wagyu heifers, 75% Wagyu steers and 75% Wagyu

Table 4. Least squares means for carcass characteristics of cattle with and without Wagyu genetic influence (year 1)

Cattle type	Warm carcass weight (kg)	Carcass wt/ live weight (%)	Days on feed (total) (d)	Backfat depth (mm)	Marbling score[z]
Year 1					
CC – S	293*a*	60.3*a*	218*c*	7.7*c*	7.8*a*
W50 – S	295*a*	57.8*b*	308*b*	16.0*a*	6.0*b*
W50 – H	279*b*	58.4*b*	321*a*	18.7*a*	5.1*cb*
W75 – S	259*c*	59.3*ab*	317*a*	11.3*b*	5.7*b*
W75 – H	251*c*	58.3*b*	322*a*	11.3*b*	4.0*c*
SEM	6.8	0.46	2.6	1.0	0.35
Year 2					
CC – S	319*a*	57.3	263*ab*	12.5*b*	8.2*a*
W50 – S	304*ab*	56.8	256*b*	17.2*a*	6.9*b*
W50 – H	291*b*	57.5	278*a*	16.9*a*	6.8*b*
W75 – S	294*b*	57.3	259*b*	14.2*b*	7.1*b*
W75 – H	253*c*	57.6	278*a*	11.2*b*	7.4*ab*
SEM	6.2	0.42	2.6	0.86	0.32

[z]Marbling score was determined by the inverse score where 1= abundant marbling and 10 = devoid of marbling.
a–d Means followed by a different letter within a column are different ($P < 0.05$).

heifers, respectively. The lean carcass yield for the Wagyu heifers was greater than that for Wagyu steers, which was greater ($P < 0.05$) than that for Continental crossbred steers.

The rib eye area was not affected by either cattle type or year and the average values ranged between 73 and 84 mm^2 but an interaction ($P < 0.05$) was observed between cattle type and both the covariates, warm carcass weight and backfat depth, and the equation for the parameter was:

$$\text{Rib eye area} = 28.76 + 0.194 \times \text{warm carcass weight} - 0.327 \times \text{back fat depth}$$
$$\text{SE} \pm 5.701 \pm 0.02 \quad \pm 0.137$$

Other carcass characteristics were affected by the main effects of the covariates, warm carcass weight and backfat depth, but the interaction between the covariates and cattle type was not significant.

Year 1

Unadjusted warm carcass weights of Continental crossbred steers and the 50% Wagyu cattle were similar ($P > 0.05$) but greater ($P < 0.05$) than that of the 75% Wagyu cattle (Table 4). The proportion of carcass weight to liveweight was highest for the Continental crossbred steers, which was greater ($P < 0.05$) than that of the 50% Wagyu cattle and the 75% Wagyu heifers. Continental crossbred steers were on feed for less ($P < 0.05$) time than the Wagyu cattle (Table 4). However, the Continental crossbred steers had less backfat thickness and marbling than the Wagyu cattle. The backfat depth of the 50% Wagyu cattle was the highest, and different ($P < 0.05$) from that of the 75% Wagyu cattle. The average marbling fat was higher (4.85 for marbling score) for carcasses of 75% Wagyu cattle than of the 50% Wagyu cattle (5.55 for marbling score) and the parameter was not affected by either covariate.

Year 2

The differences in warm carcass weight among cattle type were similar to those observed for year 1, except that most of these carcasses were heavier in year 2 (Table 4). The proportion of carcass weight to liveweight was similar for all cattle. Days on feed ranged from 256 to 278 d with the duration of feeding being lower ($P < 0.05$) for the Wagyu steers relative to the heifers. Differences in backfat thickness indicated that the 50% Wagyu had greater backfat ($P < 0.05$) than the Continental crossbred steers and the 75% Wagyu cattle. The Continental crossbred steers had less marbling fat, as indicated by the higher marbling scores, than the 50% Wagyu cattle and the 75% Wagyu steers, but not the 75% Wagyu heifers.

Meat Quality: Colour

Differences ($P > 0.05$) in colour did not exist within year for the cattle type studied, and the values were not affected by either covariate.

Meat Composition (Year 1)

The covariate backfat depth was not significant for moisture and fat content or the shear force of the meat from the different types of cattle. The meat from Wagyu heifers appeared to contain less moisture than that from the steers (Table 5), while the fat content of the meat from the 75% Wagyu heifers was greater than that from the steers when measured on a wet basis. Fat content, on a dry basis, of meat from 75% Wagyu heifers was the greatest ($P < 0.05$) and was greater ($P < 0.05$) than that of the meat from Continental crossbred steers. Significant differences in Warner–Bratzler shear force were not observed for cattle type.

Meat Composition (Year 2)

In year 2 the moisture and fat on wet basis were least and greatest, respectively, for the 50% Wagyu heifers and these were different only from those of the Continental crossbred steers (Table 5). However, when the fat content was measured on a dry basis the fat content of the 50% Wagyu heifers was higher ($P < 0.05$) than that of the 75 % Wagyu heifers and the fat content of the meat from the Continental

Table 5. Least squares means for meat composition and Warner–Bratzler shear force of cattle with and without Wagyu genetic influence

Cattle type	Moisture (%)	Fat: wet wt basis mg g^{-1}	Fat: dry basis mg g^{-1}	WBSF[z] (kg)
Year 1				
CC – S	72.2*a*	54.6*b*	156.2*c*	4.31
W50 – S	70.5*ab*	73.6*b*	266.8*ab*	4.52
W50 – H	69.6*bc*	83.5*ab*	296.3*ab*	3.85
W75 – S	70.5*ab*	77.8*b*	250.2*b*	4.03
W75 – H	68.3*c*	104.7*a*	307.8*a*	3.85
SEM	0.63	8.7	20.6	0.21
Year 2				
CC – S	72.7*a*	45.7*b*	153.1*c*	4.57*b*
W50 – S	71.9*ab*	56.6*ab*	220.8*ab*	4.83*ab*
W50 – H	70.9*b*	67.4*a*	249.1*ab*	5.30*a*
W75 – S	71.1*b*	66.8*ab*	232.4*ab*	4.65*ab*
W75 – H	71.7*ab*	55.5*ab*	169.2*b*	5.20*ab*
SEM	0.62	8.6	20.5	0.22

[z]Warner–Bratzler shear force required to shear a 19-mm-diameter core from a cooked steak after aging for 7 d.
a–d Means followed by a different letter within a column are different ($P < 0.05$).

crossbred steers was the least. The Warner–Bratzler shear force for meat from the 50% heifers was greater than that of the Continental crossbred steers.

DISCUSSION

While the role of marbling or intramuscular fat on organoleptic parameters of meat that influence meat quality remains to be decided (Jones et al. 1992; Wheeler et al.1994), the North American beef industry pays a high price for carcasses with a "small" amount of marbling. Recent work by Luchak et al. (1990) indicated that cuts from "USDA Choice" beef remained more tender than similar cuts from "USDA Select" when cooked to an internal temperature of 82°C. This concurs with unpublished data from our laboratory where increasing marbling fat led to a decrease in shear force of meat by decreasing time required to attain a standard internal temperature of 72°C. Irrespective of the effect of marbling on tenderness, it does impact eating quality of beef positively (Jeremiah 1996). Therefore many institutions advertise that they serve only beef with small or greater amounts of marbling, because consumer preference for beef with a "small" amount of marbling is well documented. These palatability factors, along with the fact that fewer than 2% of all beef carcasses produced in North America have adequate intramuscular fat to grade "US-Prime" or "Canada- Prime", contribute to the high price that well-marbled beef commands.

The proportion of carcasses that have high levels of marbling is usually greater in carcasses with low yield rather than in carcasses with high yield (Van Donkersgoed et al.1997). Thus, the premium gained for the high extent of marbling in a carcass can be lost if yield grades are poor. Jones (1996) and later the Canadian Beef Industry Audit (Van Donkersgoed et al.1997) have outlined targets for carcass quality parameters, wherein a need to increase the number of carcasses that grade Canada AAA or US-Choice from 30 to 60% of all carcasses processed has been indicated. Furthermore, they suggest an improvement should occur in carcasses with high lean meat yield (greater than 59%). This denotes a move from overall fatness of carcasses towards a greater deposition of intramuscular fat.

The ability of Wagyu cattle to partition energy to muscle as fat is well documented (Lunt et al. 1993; Cameron et al. 1994; Yamazaki 1994; Mir et al. 1997; Zembayashi et al. 1988). Wagyu cattle appear to perform this energy partitioning better than Angus cattle (Barker et al. 1995), which are also noted for their ability to deposit more marbling fat than common crossbred beef cattle. Mir et al. (1997) found that while inclusion of Wagyu genetic influence at the 75% level resulted in 83% of the carcasses containing at least a "small amount" of intramuscular fat compared with 14% of carcasses from cattle without Wagyu genetic influence, the carcass size was reduced. The present study indicated interesting information with respect to production, carcass and meat quality characteristics of cattle with 50% Wagyu genetic influence relative to Continental crossbred steers and cattle with 75% Wagyu genetic influence.

The impact of interaction of cattle type with year for many of the production characteristics may indicate the effect of differences in housing and the differences in environment between the 2 years. However, trends in performance parameters between the 2 years in which the trials were conducted were comparable.

The Wagyu crossbred cattle were lighter than the Continental crossbred steers at the initiation of the trials and quite similar in weight to previous observations (Mir et al. 1997). However, the 50% Wagyu cattle were heavier at initiation of the trial than the 75% Wagyu cattle. The duration on backgrounding diet appeared to be influenced by initial weight, gender (Owens et al. 1995) and extent of Wagyu genetic influence (Mir et al. 1997), especially in the first year of the trial. Lighter calves, heifers and calves with greater Wagyu genetic influence took longer to reach target weight than heavier calves, steers and those with lesser Wagyu genetic influence. However, in year 2, differences in average initial weight were less by 20 kg relative to that in year 1; thus, the days on feed during the backgrounding stage were similar and the weights of the steers were comparable. Major differences in ADG, DMI and F:G were not observed during this period and values for growth parameters were comparable to values published for non-implanted cattle consuming similar diets without feed additives (Hironaka et al.1994).

During the finishing phase, marked differences due to year were noted, and ADG of Continental crossbred steers was substantially greater in the first year relative to that in year 2 and this was reflected in differences in F:G for the cattle. Differences were not observed between the 50 and 75% Wagyu crossbred cattle and values compare with those observed earlier. In general, the feed conversion efficiency of Wagyu crossbred cattle while receiving the finishing diet was poorer than that noted for Continental crossbred steers. Probable explanations for this difference in feed conversion efficiency may be related to the amount of fat deposited in the two types of cattle or to differences in physiological responses triggered by absorbed nutrients or to both factors. Efficiency of fat deposition is less than that of muscle (Owens et al. 1995) because these two tissue components differ in specific gravity, water associations and energy density, thus increase in fat growth would lead to lower weight gains than increases in muscle growth resulting in low ADG and F:G. Alternately, when insulin responses to fasting and intravenous glucose challenge were studied, for steers with 0, 50 or 75% Wagyu genetic influence, it was found that while differences in plasma glucose concentrations were not present, the fasting plasma insulin concentrations and those up to 15 min after glucose administration were lower for cattle with Wagyu genetic influence than for Continental crossbred steers (Mir et al. 1998). These results raise the possibility that animals with Wagyu genetic influence may be less able to physiologically respond to high-energy diets and therefore utilize high-energy diets less efficiently. In contrast, Matsuzaki et al.(1997) reported higher insulin concentrations in Japanese Black than in Japanese Brown and Holstein steers. These three breeds are noted for their ability to deposit greater than average amount of marbling fat. These authors however collected blood samples from animals without prior feed restriction and the difference among the breeds in plasma insulin concentrations was evident only at ages and weights greater than that of cattle used in the trial by Mir et al. (1998).

Carcass weights of Continental crossbred steers and 50% Wagyu steers were comparable in both years. The weights of carcasses from 75% Wagyu cattle in year 1 and the 75% Wagyu heifers in year 2 were less than the targets outlined in the Canadian Beef Quality Audit (Van Donkersgoed et al.1997). However, the total days on feed were greater by 100 d in year 1 for 50% Wagyu steers relative to Continental crossbred steers but similar for both types of cattle in year 2. The 50% Wagyu cattle had greater backfat depth than the other types of cattle, which is perhaps due to the 50% Angus genetic influence in these cattle. The ribeye area of the carcasses were similar for both years and values were found to interact with the covariate warm carcass weight, indicating that carcass weight and ribeye area are inter-related.

Differences in marbling fat deposition were observed as expected with both 50 and 75% Wagyu cattle, as indicated by the lower marbling scores for carcasses (inverse scoring relative to amount of visual marbling [Newman et al.1994]) of these animals relative to those observed in the Continental crossbred steers. In year 1, 92% of all Wagyu crossbred cattle graded Canada AAA or better, which is equivalent to US-Choice, and 30% of the Wagyu crossbred cattle had sufficient marbling fat to receive the Canada Prime or the US-Prime grade. In comparison, only 30% of Continental crossbred steers received the Canada AAA grade and none graded prime. In year 2, 71% of the Wagyu crossbred cattle graded Canada AAA while only 10% of the Continental Crossbred steers graded similarly. Ten percent of the Wagyu crossbred cattle graded Canada AAA, with lean carcass yield greater than 59%, thereby qualifying for the 10% premium paid by packers for carcasses that exhibit greater than a “small amount” of marbling along with high lean yield. These data further indicate the merit of Wagyu genetic influence in its ability to enhance production of improved quality beef within existing production systems.

The differences in fat and moisture were predictable and followed differences observed in marbling scores for the different types of cattle studied. Even though all shear force values were low and mean shear force values were lower than those reported by Aalhus et al. (1992, 1994) the values obtained in year 1 were lower than those observed in year 2. The shear force values obtained in year 1 indicate that the meat would be rated as “extremely tender”while that from year 2 would qualify for a rating of “tender” according to reports of Huffman et al. (1996). However if the difference in core diameter (13 vs. 19 mm) used for the determination of shear force is taken into account then the shear forces observed for the meat samples in the second year would be lower and merit the “extremely tender” rating as well.

CONCLUSION

These results indicate that 50% Wagyu/Angus steers exhibited growth, carcass and meat quality characteristics that were comparable to Continental crossbred steers, except that the time required to finish may be longer for the Wagyu crossbred steers owing to their lower weaning weight relative to the Continental crossbred steers. However Wagyu crossbred steers produced a standard size carcass with extensive depots of marbling fat, even at ages ranging between 16 and 18 mo, when fed barley-based diets .

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