Differences among Wagyu sires for USDA carcass traits and palatability attributes of cooked ribeye steaks[1]

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ABSTRACT: The objective of this experiment was to evaluate the effects of various Wagyu sires on carcass quality traits and palatability attributes of cooked ribeye steaks. Wagyu sires were used and grouped as Old (n = 6) or New (n = 2) sires, based on the chronological order in which they were imported into the United States. One hundred thirteen F_1 heifer and steer calves sired by Wagyu bulls out of three different sources of cows were fed a backgrounding diet for 112 d consisting of an 80:20 ratio of roughage:concentrate then grazed on a mixture of orchardgrass and bluegrass pasture for 84 d and finished on a 10:90 ratio of roughage:concentrate diet for 231 d in a feedlot. Progeny from New sires had larger ($P < .05$) ribeye areas, higher ($P < .05$) marbling scores, and lower ($P < .05$) maturity scores than progeny from Old sires. Marbling was positively correlated ($P < .05$) to brightness (r = .56), texture (r = .60), and fat luster (r = .38). Progeny of New sires had lower shear force values ($P < .05$) than progeny of Old sires. These results indicate the superiority of New Wagyu sires to produce progeny with more marbling, lower shear force values, and larger ribeye areas than Old Wagyu sires. Furthermore, there are substantial differences between Wagyu sires for carcass quality traits and palatability attributes.

Key Words: Carcass Quality, Japanese Black Cattle, Palatability, Sires

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Introduction

The improvement of overall eating quality of cooked beef, the reduction of dietary cholesterol, and the contribution of beef to the total intake of saturated fatty acids (**SFA**) have become important issues to consumers and the meat industry (Mattson and Grundy, 1985; Rule et al., 1989; Morgan et al., 1991; Mills et al., 1992). In addition, a desirable beef product must be economically competitive, tender, juicy, and flavorful with an adequate amount of marbling, minimal external fat, and a high ratio of monounsaturated fatty acids to saturated fatty acids (Boylston and Morgan, 1992).

Japanese Wagyu cattle are characterized by their ability to produce very palatable beef containing high amounts of marbling (Yamazaki, 1981). Xie et al. (1996) indicated that the Wagyu genetics available in North America at that time contained highly variable marbling ability. However, that study involved a limited number of progeny, and the marbling ability, fat deposition, and palatability characteristics of newly imported Wagyu sires have not been reported. Therefore, the objective of this study was to evaluate New and Old Wagyu sires on USDA carcass grade traits and palatability attributes of cooked ribeye steaks and to identify Wagyu sires with low shear force values and high marbling scores.

Materials and Methods

Animals. Based on the chronological order in which the Wagyu sires have been imported into the United States, they can be described as Old and New Wagyu sires. Old Wagyu sires used in this experiment include three of the original five full-blood bulls or semen imported into the United States and Canada in 1974 through 1976 (Judo, Mazda, and Rueshaw). Additionally, Alvin, Konishiki, and Fame are in the group of Old sires. Alvin and Konishiki were sired by Mt. Fuji, another bull imported into the United States in 1976 and are considered purebred (containing 15/16 or greater Wagyu influence). Fame, a son of Itotani 7th (whose semen was imported into Canada in 1974) containing 63/64 Wagyu influence, is considered a purebred

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Table 1. Backgrounding and finishing diet composition

Item	Feeding period	
	Backgrounding	Finishing
	% of DM	
Ingredient		
Alfalfa hay cubes	54.5	—
Oatlage	20.0	9.5
Steam-rolled barley	25.0	90
Trace mineralized salt with Se	Ad libitum	Ad libitum
Melengesterol acetate[a]	.5	.5
	%, as Fed	
Chemical composition		
Dry matter, %	69.4	84.5
Crude protein, %	14.3	11.6
Neutral detergent fiber, %	45.1	25.0
Acid detergent fiber	31.3	13.2
Estimated NE_m, Mcal/kg	1.30	1.87
Estimated NE_g, Mcal/kg	.95	1.40

[a]Fed only to the heifers.

by the Canadian Wagyu Association. Sires described as New were imported in 1993. New sires used in this study were Haruki II and Michifuku, both sired by Monjiro. Sixty-two steers and 51 heifers were sired by artificial insemination using semen from these eight Wagyu sires that were randomly mated in 1994 to cows in three different herds, WSU Angus, WSU crossbreds, and commercial crossbreds owned by a private producer. All crossbred cows were combinations of Angus, Hereford, and Simmental breeds. Calves were born in the spring (February to April) of 1995, weaned in the fall (7 to 9 mo of age), and transported to the WSU Cattle Feeding Laboratory in December 1995.

Feeding Phases. Washington State University's Animal Care and Use Committee approved the use of animals in this study. Upon arrival at the cattle feeding facility, steers and heifers were limit-fed on an 80:20 ratio of roughage:concentrate diet for 112 d to achieve an ADG of .7 to .9 kg and then grazed on a mixed orchardgrass and bluegrass pasture for 84 d from April 16 to July 8, 1996. At the end of the grazing period, calves were weighed and allotted to pens by sex. Animals were allocated (six to seven animals/pen) based on full weight, sex, and sire distribution, so that progeny in the different sire groups were distributed equally across pens. Cattle were fed for 231 d (finishing phase) on a 10:90 ratio of roughage:concentrate diet prior to slaughter. In the finishing phase, cattle were initially fed 75% roughage and 25% concentrate. The roughage portion of the diet was decreased in five increments, whereas the concentrate portion was increased in the same manner over a 35-d period until the 10:90 ratio was reached. See Table 1 for composition and chemical analyses of the diets. During the finishing phase, melengesterol acetate was administered to the heifers as a feed additive to suppress estrus; all animals had ad libitum access to the diets. The cattle were fed similar to Japanese methods for producing highly marbled beef; steers weigh approximately 700 kg at slaughter.

Slaughter Process and Carcass Traits. The cattle were transported 192 km to a commercial plant for processing and were graded 48 h postmortem. The average weight of the F_1 steers and heifers at the time of slaughter was 707 and 651 kg, respectively. A total of 113 cattle were slaughtered using humane slaughter procedures and carcasses were evaluated according to the USDA quality grade factors (USDA, 1989). Percentage of kidney, pelvic, and heart fat and yield grades were not obtained because kidney fat was removed from the carcasses prior to inspection in order to speed up the cooling time. Meat quality attributes were also estimated based on standard procedures of the Japan Meat Grading Association (JMGA, 1988). Meat color and fat color were evaluated using the 7-point Beef Color Standard and 7-point Beef Fat Standard, respectively. Meat brightness, meat firmness, meat texture, and fat luster were evaluated according to 5-point descriptive scales.

Steaks (3.2 cm thick) of longissimus dorsi muscle (ribeye) were removed from each carcass between the 12th and 13th ribs 48 h postmortem. On the same day, steaks were transported to the Washington State University Meat Laboratory and cut to a final thickness of 2.5 cm, individually vacuum-packaged, and then aged at 2° ± 1°C for 14 d. After aging, steaks were frozen at –40°C until sensory evaluation and Warner-Bratzler shear force determination.

Cooking Process. Steaks (n = 113) were thawed at 2 to 5°C for 36 h and weighed (net weight, g) before they were broiled on Farberware Open Hearth grills (Model R4550; Farberware, Bronx, NY) to a final internal temperature of 71°C. During cooking, the steaks were turned when they reached an internal temperature of 35°C. Temperature was monitored with a scanning thermocouple thermometer (Digi-Sense, Cole Parmer, Vernon Hills, IL) equipped with copper-constant thermocouple wires (diameter < .05 cm, error < 2°C), which were inserted into the geometric center of each steak. Initial temperature of the steaks, cooking time, and cooked weight were recorded to obtain cooking loss percentage and rate of cooking (AMSA, 1995).

Warner-Bratzler Shear Force Determination. Cooked ribeye steaks (n = 113) were cooled at room temperature (23°C) for 4 h and then weighed. Nine cores (1.3 cm diameter) were removed parallel to the orientation of the muscle fibers with a manual coring device. Only cores that were uniform in diameter, without connective tissue abnormalities and other structure problems, were used. A Texture Analyzer (TA-XT2, Texture Technologies, Scarsdale, NY) equipped with a Warner-Bratzler shear attachment was used to shear each core. Cores were sheared once in the center in order to maintain accuracy. Peak shear force was recorded. Crosshead speed was set at 20 cm/min.

Sensory Evaluation. Forty of the 113 ribeye steaks were randomly selected to represent each of the eight Wagyu sires (five per sire) for sensory panel evaluation and cooked as previously described for shear force determination. After cooking, each steak was cut into cubes (1.3 × 1.3 × 2.5 cm) and served at 32 to 35°C for sensory evaluation. One sample was served at a time, and 12 steaks were served at each session, which was held midmorning each day. A 10-member descriptive attribute sensory panel was trained and tested according to methods described by Cross et al. (1978) and AMSA (1995). Panelists in individual booths evaluated the steak samples for tenderness, flavor, and juiciness using 10-point descriptive scales (10 = extremely tender, extremely flavorful, and extremely juicy and 1 = extremely tough, extremely bland, and extremely dry).

Statistical Analysis. Dependent variables were analyzed using a linear model that included eight sires, three sources of dam (WSU Angus, WSU crossbred, and commercial) and two sexes (steers and heifers) (SAS, 1996). Two- and three-way interactions of all independent variables (sire × sex; sire × source; sex × source; sex × sires × source) were tested. The only significant interaction was sire × sex for ribeye area ($P < .04$). Because this interaction represented less than 5% of the total number of interaction tests, and because it was not highly significant, we decided to ignore it and not include interactions in the model. Differences between means for sire and cow herds were tested using least significance difference. A contrast was computed and tested for a significant difference for each dependent variable between Old and New Wagyu sires using the Student's *t*-test. Simple correlation coefficients were computed to evaluate the relative importance of various carcass traits on palatability attributes.

Table 2. Least squares means and standard errors for average daily gain, carcass weight, and yield and grade traits, comparing Old and New Wagyu sires

	Group		
Carcass trait	New sires	Old sires	*P*-value
Number	25	88	—
ADG, kg	1.32 ± .03	1.31 ± .02	.90
Hot carcass wt, kg	415 ± 6.6	407 ± 3.5	.24
Dressing %	60.2 ± .34	60.4 ± .17	.08
Ribeye area, cm^2	98.8 ± 3.2	89.5 ± 2.5	.001
Fat thickness, cm	2.21 ± .13	2.44 ± .08	.19
Adjusted fat thickness, cm	2.34 ± .13	2.62 ± .08	.17
Maturity[a]	87.0 ± 5.9	100.1 ± 3.1	.03
Lean color[b]	3.15 ± .17	3.77 ± .09	.02
Brightness[b]	4.06 ± .15	3.35 ± .08	.01
Firmness[b]	4.06 ± .16	3.47 ± .08	.09
Texture[b]	4.02 ± .14	3.40 ± .07	.02
Fat color[b]	2.81 ± .10	2.89 ± .05	.37
Fat luster[b]	4.23 ± .13	3.69 ± .06	.01
Marbling[c]	900 ± 26.7	771 ± 13.9	.001

[a]USDA maturity score: 0–99 = A; 100–199 = B.
[b]Japan Meat Grading Association, 1988.
[c]USDA marbling score: 400–499 = slight; 500–599 = small; 600–699 = modest.

Results and Discussion

Differences were observed ($P < .05$) for several carcass traits between Old and New Wagyu sires (Table 2). The mean marbling score for progeny of New sires (900) was 1.29 of a USDA marbling degree higher ($P < .05$) than the mean (771) for progeny of Old sires. Moreover, progeny of New sires had 10.9% larger ribeye areas (98.8 vs 89.5 cm^2) and tended to have less external fat than progeny of Old sires. In addition, progeny of New sires had younger maturity scores, brighter, firmer texture of lean, and more desirable fat luster ($P < .05$). These results indicate that recently imported sires are superior to those imported earlier. The superiority of the newly imported sires indicates that genetic improvement has been made by Japanese producers during the last 20 yr; American producers have not made the same amount of progress in the Old sires. This gives a rough estimate of improvement in carcass quality from 1975 to 1991. Progeny of New and Old sires did not differ in growth rate, but the New sires excelled in marbling, which is an extremely important economic trait, especially for the U.S. and Japanese markets. In both countries, marbling plays a central role in determining quality grade and is related to meat palatability (Covington et al., 1970; Parrish, 1974; Jennings et al., 1978; Davis et al., 1979).

Other quality attributes such as beef brightness and texture scores were higher for New sires. The larger ribeye areas of the New sires and the tendency for them to have a lower adjusted fat thickness is also a positive and somewhat unusual attribute, because selection for increased muscling and decreased subcutaneous fat is often antagonistic to selection for marbling (Dunn et al., 1970).

The score for meat color was higher ($P < .05$) for Old sires than for New sires (Table 2). Marbling was positively correlated to firmness (r = .59), brightness (r = .56), texture (r = .60) and fat luster (r = .38) ($P < .05$), which enhance meat quality.

Least squares means for carcass traits as shown in Table 3 further illustrate the differences between Old and New sires but also illustrate important differences between sires within those groupings. Progeny from Michifuku, one of the New sires, had the most marbling and largest ribeye areas ($P < .05$). Progeny of Haruki II and Judo had lower ($P < .05$) shear force values than progeny from other sires (Table 4). These results indicate the superiority of New Wagyu sires to produce progeny with more marbling, lower shear force values, larger ribeye areas, and less external fat than Old Wagyu sires. Furthermore, there are substantial differences between Wagyu sires for carcass quality traits and palatability attributes.

There were differences between cow herds for marbling, fat luster, and meat firmness ($P < .05$). Marbling score for progeny of WSU Angus cows (902) was 100 and 162 points higher ($P < .05$) than the means for

Table 3. Least squares means and standard errors for average daily gain, carcass weight, and yield and grade traits for eight Wagyu sires

	Old sires						New sires	
Carcass trait	Judo	Mazda	Rueshaw	Fame	Konishiki	Alvin	Haruki II	Michifuku
Number	7	19	10	16	21	15	6	19
ADG, kg	1.31 ± .01	1.30 ± .03	1.31 ± .05	1.32 ± .04	1.22 ± .06	1.32 ± .05	1.33 ± .01	1.30 ± .04
Hot carcass wt, kg	374 ± 13.2	421 ± 7	427 ± 1.2	403 ± 8.3	396 ± 7.2	406 ± 9.3	415 ± 14	414 ± 8.2
Dressing %	60.1 ± .68	61.5 ± .37	61.2 ± .52	59.9 ± .43	60.5 ± .35	59.2 ± .45	60.1 ± .72	60.2 ± .40
Ribeye area, cm^2	85.3 ± 3.4^{ef}	92.3 ± 2.2^{efg}	92.1 ± 2.3^{efg}	91.1 ± 2.3^{ef}	88.4 ± 2.0^{efg}	88.1 ± 2.5^{efg}	97.5 ± 4.1^{d}	100.1 ± 2.3^{d}
Fat thickness, cm	2.26 ± .25	2.46 ± .15	2.31 ± .20	2.34 ± .15	2.08 ± .13	3.23 ± .18	2.36 ± .28	2.11 ± .15
Adjusted fat thickness, cm	2.26 ± .25	2.64 ± .13	2.49 ± .18	2.51 ± .15	2.36 ± .13	3.38 ± .15	2.56 ± .25	2.26 ± .15
Maturity[a]	90.0 ± 13.4^{f}	88.3 ± 6.7^{f}	104.2 ± 9.6^{e}	93.1 ± 7.8^{f}	104.0 ± 6.4^{e}	123.2 ± 8.1^{d}	75.1 ± 13.2^{g}	92.4 ± 7.3^{f}
Color[b]	3.42 ± .34^{eg}	3.54 ± .18^{g}	3.45 ± .26^{g}	3.33 ± .21^{e}	4.28 ± .18^{f}	4.23 ± .22^{f}	3.28 ± .36de	3.09 ± .20^{d}
Brightness[b]	3.85 ± .30^{f}	3.56 ± .16^{f}	3.61 ± .23^{f}	3.57 ± .19^{f}	3.01 ± .15^{e}	3.01 ± .19^{e}	3.67 ± .32^{f}	4.20 ± .17^{d}
Firmness[b]	3.84 ± .33	3.24 ± .18	3.79 ± .26	3.20 ± .21	3.60 ± .17	3.56 ± .22	3.59 ± .35	4.19 ± .20
Texture[b]	4.01 ± .29^{d}	3.41 ± .16^{eg}	3.57 ± .22^{e}	3.62 ± .18^{e}	3.24 ± .15^{h}	3.04 ± .19^{f}	3.66 ± .31^{e}	4.14 ± .17^{d}
Fat color[b]	3.00 ± .21	2.86 ± .12	2.82 ± .16	2.69 ± .13	3.06 ± .11	2.92 ± .14	2.68 ± .23	2.86 ± .13
Fat luster[b]	3.42 ± .26^{g}	3.81 ± .14^{ef}	3.93 ± .20^{e}	3.66 ± .17^{f}	3.66 ± .14^{f}	3.73 ± .17^{f}	3.86 ± .28^{e}	4.40 ± .16^{d}
Marbling[c]	903 ± 48.2^{d}	807 ± 26.5^{g}	827 ± 37.1^{g}	751 ± 3.2^{f}	703 ± 24.9^{h}	757 ± 31.5^{f}	863 ± 51.3^{e}	907 ± 28.5^{d}

[a]USDA maturity score: 0–99 = A; 100–199 = B.
[b]Japan Meat Grading Association, 1988.
[c]USDA marbling score: 400–499 = slight; 500–599 = small; 600–699 = modest; 700–799 = moderate; 800–899 = slightly abundant.
[d,e,f,g,h]Means with different subscript in the same row differ ($P < .05$).

Table 4. Least squares means and standard errors for sensory panel traits, Warner-Bratzler shear force, cooking rate, and cooking loss by eight Wagyu sires[a]

	Old sires						New sires		
Trait	Judo	Mazda	Rueshaw	Fame	Konishiki	Alvin	Haruki II	Michifuku	Old vs New *P*-value
Number	5	5	5	5	5	5	5	5	—
Tenderness	6.71 ± .60	6.59 ± .38	7.04 ± .58	5.59 ± .59	5.25 ± .39	5.62 ± .59	6.37 ± .60	7.01 ± .59	.25
Juiciness	6.21 ± .58	6.64 ± .36	7.13 ± .56	6.50 ± .57	5.89 ± .37	6.21 ± .57	5.80 ± .58	7.25 ± .57	.82
Flavor	6.50 ± .39	6.57 ± .24	6.88 ± .38	6.01 ± .38	5.99 ± .25	5.81 ± .38	6.05 ± .39	6.84 ± .38	.58
Number	7	19	10	16	21	15	6	19	—
Cooking loss, %	23.46 ± 2.26	24.47 ± 1.26	25.19 ± 1.72	24.30 ± 1.41	24.06 ± 1.16	22.80 ± 1.47	25.37 ± 2.39	23.79 ± 1.32	.50
Cooking rate, min	31.90 ± 1.63	28.48 ± .91	27.99 ± 1.24	25.40 ± 1.01	28.21 ± .83	26.53 ± 1.06	30.94 ± 1.72	26.15 ± .95	.64
Shear force, kg	3.34 ± .30	3.90 ± .16	3.89 ± .22	4.06 ± .18	3.87 ± .15	3.70 ± .20	3.33 ± .31	3.43 ± .17	.02

[a]Palatability characteristics: 10 = extremely tender, extremely juicy, extremely flavorful, and extremely acceptable; 1 = extremely tough, extremely dry, extremely unflavorful, and very unacceptable.

progeny of WSU crossbred (802) and commercial crossbred cows (740), respectively (data not shown). The offspring of the commercial crossbred cows had higher ($P < .05$) mean fat luster scores (4.0) than the mean of progeny of WSU crossbred cows (3.6). The progeny of the WSU Angus cows had higher ($P < .05$) average meat firmness scores (4.0) than the mean of offspring of the WSU crossbred and commercial crossbred cows (3.4).

Results for heifers (average weight, 393 kg) and steers (average weight, 421 kg) were generally as expected (Hendrick et al., 1989). Heifers grew more slowly and had higher dressing percentage (61%), lower carcass weights (178 kg), older maturity scores (116), and greater fat thickness (2.8, cm) than steers, which had means of 60%, 191 kg, 76, and 2.3 cm for dressing percentage, hot carcass weight, maturity score and fat thickness, respectively ($P < .05$). The color scores and the brightness scores were higher for heifers than for the steers ($P < .05$). Color scores for both sexes were very acceptable, indicating dark-cutting beef was not a problem.

Shear Force and Palatability Characteristics. Least squares means of sires for palatability characteristics from steers and heifers are presented in Table 4. New sires had lower shear force values than Old sires ($P = .02$) (Table 4). Shackelford et al. (1991a) reported that threshold levels of consumer dissatisfaction for Warner-Braztler shear force were 4.6 kg for retail beef and 3.9 kg for food-service beef. Old Wagyu sires had 67% and New Wagyu sires had 100% of the values below the 3.9-kg threshold, and Old and New sires had 100% of the values below the 4.6-kg threshold.

The difference in shear force values between the Wagyu sires was related to the amount of marbling. When including marbling as a covariate there were no significant differences between sires. In our study, marbling was negatively correlated to shear force (r = –.31, $P < .05$). There is evidence suggesting that marbling (Gilpin et al., 1965; Breidenstein et al., 1968; Parrish, 1974; Miller et al., 1996) may be associated with beef tenderness and palatability. One of the largest studies on the relationship between marbling and beef longissimus dorsi muscle tenderness was reported by Shackelford et al. (1991b). This study involved 1,602 calf-fed steers of different cattle types, and it clearly showed that Warner-Bratzler shear force decreased ($P < .05$) and sensory panel tenderness increased ($P < .05$) with increases in degree of marbling.

In the present study, marbling was also positively correlated ($P < .05$) to flavor (r = .41), tenderness (r = .36), and juiciness (r = .21). Our correlation of flavor with marbling was higher than that reported by Seideman et al. (1988) (r = .16, $P < .05$) and lower for tenderness than that indicated by the same author (r = .59, $P < .05$). In addition, the correlation for juiciness (r = .16, $P < .05$) reported by Seideman et al. (1988) was lower than that obtained in our study.

Implications

Genetic differences in carcass characteristics between Old and New Wagyu sires show that it is possible to identify sires that excel in marbling and ribeye area with less subcutaneous fat. The sires with the most desirable carcass characteristics also had excellent palatability attributes. However, the effectiveness of selecting for more than one trait simultaneously depends on genetic correlations between traits within Wagyu sires; therefore, more research has to be done to evaluate genetic correlations for these specific traits. This study clearly indicates the genetic superiority of New Wagyu sires to produce progeny with lower shear force values, larger ribeye areas, and more marbling compared to Old Wagyu sires.

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