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2006

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Casas, E. and Cundiff, L. V., "Postweaning growth and carcass traits in crossbred cattle from Hereford, Angus, Norwegian Red, Swedish Red and White, Friesian, and Wagyu maternal grandsires" (2006). *Roman L. Hruska U.S. Meat Animal Research Center*. 371. <http://digitalcommons.unl.edu/hruskareports/371>

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Postweaning growth and carcass traits in crossbred cattle from Hereford, Angus, Norwegian Red, Swedish Red and White, Friesian, and Wagyu maternal grandsires^{1,2}

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ABSTRACT: The objective of this study was to characterize breeds representing diverse biological types for postweaning growth and carcass composition traits in terminal crossbred cattle. Postweaning growth and carcass traits were analyzed on 434 steers and 373 heifers obtained by mating F₁ cows to Charolais sires. Maternal grandsires represented Hereford, Angus, and MARC III (¼ Hereford, ¼ Angus, ¼ Pinzgauer, and ¼ Red Poll) dams to Hereford or Angus (British Breeds), Norwegian Red, Swedish Red and White, Wagyu, or Friesian breeds. Breed groups were slaughtered serially in each of 2 yr (2002 and 2003). Postweaning ADG, slaughter weight, hot carcass weight, dressing percentage, percentage Choice, LM area, marbling score, USDA yield

grade, fat thickness, retail product yield (percentage), retail product weight, fat yield (percentage), fat weight, bone yield (percentage), and bone weight were analyzed. Maternal grandsire breed was significant ($P < 0.05$) for all traits except dressing percentage, percentage Choice, and LM area. Marbling score for animals with Norwegian Red, Wagyu, Swedish Red and White, British Breeds, and Friesian inheritance was 550, 544, 532, 530, and 515, respectively (SEM = 8). Retail product weight for these animals was 224, 211, 227, 223, and 223 kg, respectively (SEM = 2 kg). Maternal granddam breed was not significant for any of the traits analyzed. Grandsire breed effects can be optimized by selection and use of appropriate crossbreeding systems.

Key words: beef cattle, breed, carcass composition, growth

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J. Anim. Sci. 2006. 84:305–310

INTRODUCTION

The Germplasm Evaluation (GPE) program at the US Meat Animal Research Center (MARC) characterizes breeds representing several biological types of cattle. In this program, postweaning growth has been evaluated in F₁ animals (Cundiff et al., 1981, 1984), and carcass composition and meat quality traits have been evaluated in F₁ steers (Wheeler et al., 1996, 2001, 2004). Casas and Cundiff (2003) evaluated postweaning growth and carcass composition in the terminal cross from Cycle V of the GPE program.

The sixth cycle of this program (Cycle VI) includes 2 Scandinavian breeds (Norwegian Red and Swedish Red

and White), Friesian, and Wagyu (Japanese Black and Japanese Red). Carcass composition and meat quality traits have been evaluated in the F₁ generation from this cycle (Wheeler et al., 2004). Evaluation of these traits is important in establishing the potential value of alternative germplasm resources in the beef industry; however, evaluation of postweaning growth and carcass traits in the terminal cross is needed. The objective of this study was to characterize breeds representing diverse biological types for postweaning growth and carcass composition traits in terminal crossbred cattle.

MATERIALS AND METHODS

Animals

Animals for this study were produced by F₁ cows from Cycle VI of the GPE program. Wheeler et al. (2004) described the mating scheme to produce these cows. Briefly, Hereford, Angus, and MARC III (¼ Hereford, ¼ Angus, ¼ Red Poll, and ¼ Pinzgauer) mature dams were mated by artificial insemination to Angus, Hereford, Norwegian Red, Swedish Red and White, Wagyu (14 black and 5 red full-blood bulls imported from Japan, and 4 upgraded bulls with 15/16 of Wagyu born

¹Mention of a trade name, proprietary product, or specified equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable.

²The authors thank D. Light for technical assistance and J. Watts for secretarial support. We express our appreciation to G. Hays and the Cattle Operations staff for outstanding husbandry.

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Received July 13, 2005.

Accepted September 14, 2005.

Table 1. Number of offspring produced by crossbred dams in each year

Dam ¹	Years		
	2001	2002	Total
British Breed × Hereford	19	17	36
British Breed × Angus	45	47	92
British Breed × MARC III	72	67	139
Nor. Red × Hereford	10	10	20
Nor. Red × Angus	13	12	25
Nor. Red × MARC III	22	21	43
Red and White × Hereford	12	10	22
Red and White × Angus	15	17	32
Red and White × MARC III	16	13	29
Wagyu × Hereford	21	21	42
Wagyu × Angus	27	29	56
Wagyu × MARC III	43	41	84
Friesian × Hereford	20	18	38
Friesian × Angus	33	31	64
Friesian × MARC III	42	42	84
Total	411	396	807

¹MARC III = ¼ Hereford, ¼ Angus, ¼ Pinzgauer, and ¼ Red Poll; Nor. Red = Norwegian Red; and Red and White = Swedish Red and White.

in the United States), or Friesian sires. No purebred Hereford or Angus matings were made. Hereford and Angus were treated as one breed group (British Breeds). Mature females obtained from these crosses were mated to Charolais sires during 2 consecutive years. Matings were made by natural service in multiple-sire herds. Cows were run in 4 separate breeding pastures each year. Sires were randomly allocated to pastures. Individual sires of progeny were not identified. Therefore, this mating scheme assumes that the progeny per sire and the genetic merit of the sires was similar.

Offspring were born during the spring of 2001 (n = 411) and 2002 (n = 396). Table 1 shows the number of animals born by breed group and year. Male calves were castrated within 24 h of birth. Calves were creep-fed whole oats from early July or early August until weaning in early October. Calves were weaned in mid October at an average age of 175 ± 30 d. After an adjustment period of approximately 30 d, steers and heifers were randomly assigned to pens and fed for 260 ± 30 d. The growing diet that was fed from weaning until calves weighed approximately 320 kg included corn silage, corn, and a urea-based liquid supplement containing approximately 2.7 Mcal of ME/kg of DM and 12.5% CP. The finishing diet fed from about 320 kg to slaughter contained about 3.05 Mcal of ME/kg of DM and 13.1% CP. Animals were slaughtered during the summers of 2002 and 2003 in a commercial beef processing plant. In 2002, steers were slaughtered on May 15 and June 12, and heifers were slaughtered on June 5 and July 2. In 2003, steers were slaughtered on May 14 and June 11, and heifers were slaughtered on June 4 and July 2.

Table 2. Number of observations, mean, and SD for the traits studied

Trait	No.	Mean	SD
Postweaning ADG, kg/d	807	1.34	0.19
Slaughter weight, kg	807	562	56
HCW, kg	807	345	34
Dressing percentage, %	807	61.4	1.9
USDA Choice, %	807	61.5	48.7
LM area, cm ²	803	81.1	8.2
Marbling score ¹	803	530	79
USDA yield grade	803	2.76	0.65
Fat thickness, cm	803	1.02	0.42
Retail product yield, %	803	64.3	3.5
Retail product weight, kg	803	221.9	24.5
Fat yield, %	803	21.0	0.04
Fat weight, kg	803	72.6	17.4
Bone yield, %	803	14.95	0.7
Bone weight, kg	803	51.6	5.3

¹Marbling score: 400 = slight⁰⁰; 500 = small⁰⁰.

Traits

Traits analyzed for growth included postweaning ADG (kg/d) and slaughter weight. Carcass traits analyzed were HCW, dressing percentage, percentage of carcasses graded as USDA Choice, LM area, marbling score, USDA yield grade, fat thickness (cm), retail product yield (percentage), retail product weight (kg), fat yield (percentage), fat weight (kg), bone yield (percentage), and bone weight (kg). Retail product, fat, and bone yields were estimated using prediction equations that included carcass yield grade traits (LM area, adjusted fat thickness, and estimated kidney, pelvic, and heart fat) and marbling score (Shackelford et al., 1995). Table 2 shows the number observations for each trait and the mean and SD for the analyzed traits.

Statistical Analysis

Data were analyzed with the MIXED model procedure of SAS (SAS Inst., Inc., Cary, NC). The model included the fixed effects of maternal grandsire breed (British Breeds, Norwegian Red, Swedish Red and White, Wagyu, and Friesian), maternal granddam breed (Hereford, Angus, and MARC III), sex class (steers and heifers), year of birth (2001 and 2002), and all possible 2-way interactions among these fixed effects. The random effect of maternal grandsire within breed was included in the model, which is the true error term for maternal grandsire breed. Hereford and Angus were treated as one group to estimate this effect. Fixed effects and their interactions were tested against the residual mean square. Age at weaning was included in the model as a covariate for all traits. Days on feed was included as a covariate for all traits except for postweaning ADG. Least squares differences and probability values for differences were estimated for significant effects. Probability values were corrected for multiple testing. A Bonferroni adjustment was applied to the

Table 3. Levels of significance, least squares means, and SEM for factors affecting postweaning ADG (PWADG), slaughter weight (SWT), and HCW

Factor	Trait		
	PWADG ¹	SWT ²	HCW ²
	– (kg/d) –	— (kg) —	
Maternal grandsire breed			
Significance	<0.001	<0.001	<0.001
Least squares means			
British Breed	1.39 ^a	573.7 ^a	352.6 ^a
Friesian	1.32 ^{bc}	561.8 ^b	343.7 ^a
Nor. Red ³	1.31 ^{bc}	569.3 ^{ab}	351.8 ^a
Red and White ⁴	1.35 ^{ab}	577.4 ^a	353.0 ^a
Wagyu	1.28 ^c	529.6 ^c	325.1 ^b
SEM	0.01	5.1	3.4
Maternal granddam breed			
Significance	0.65	0.60	0.68
Least squares means			
Angus	1.33	560.5	344.4
Hereford	1.34	565.2	346.8
MARC III ⁵	1.32	561.5	344.5
SEM	0.01	3.5	2.2
Sex			
Significance	<0.001	<0.001	<0.001
Least squares means			
Male	1.47 ^x	603.1 ^x	368.8 ^x
Female	1.19 ^y	521.6 ^y	321.7 ^y
SEM	0.01	3.1	2.0

^{a-c}Within a column, means without a common superscript letter differ ($P < 0.05$).

^{x,y}Within sex, means without a common superscript letter differ ($P < 0.05$).

¹Trait adjusted by including age at weaning as covariate.

²Trait adjusted by including age at weaning and days on feed as covariates.

³Nor. Red = Norwegian Red.

⁴Red and White = Swedish Red and White.

⁵MARC III = ¼ Hereford, ¼ Angus, ¼ Pinzgauer, and ¼ Red Poll.

probability values using a factor of 15, which is the number of traits analyzed.

RESULTS

Levels of significance, least squares means, and SE of the means are reported in Tables 3, 4, and 5 for the effects of maternal grandsire, maternal granddam, and sex. Granddam breed effect was not significant for any of the traits analyzed. Year was a significant ($P < 0.05$) source of variation for all traits except for postweaning ADG, hot carcass weight, dressing percentage, percentage of carcasses classified as USDA Choice, and retail product and bone weights. Effects of year and its interactions are excluded from the results and discussion sections. Year effects cannot be predicted to recur in the future, and it is more appropriate for producers to make decisions about grandsire breeds, granddam breeds, and sex based on information averaged over years. No interactions were significant for any of the traits analyzed.

Maternal Grandsire Effects

Grandsire breed effects were significant for all traits ($P < 0.02$) except for dressing percentage, percentage of carcasses classified as USDA Choice, LM area, and marbling score. Animals with Wagyu, Friesian, and Norwegian Red inheritance had the lowest postweaning growth rate compared with British Breeds. Animals with Swedish Red and White inheritance had an intermediate postweaning growth rate. Animals with British Breed, Norwegian Red, and Swedish Red and White were heavier at slaughter compared with animals with Wagyu inheritance. Animals with Wagyu inheritance had the lightest hot carcass weight, the least amount of saleable product (measured as retail product weight), and the least amount of bone weight compared with animals produced by the other breeds. Animals with Wagyu inheritance had lower yield grade scores and less fat thickness than animals with inheritance from other breeds. Animals with British Breed inheritance had the largest amount of extramuscular fat. Animals with British Breed and Norwegian Red inheritance had the greatest yield grade score. Animals with Wagyu, Friesian, and Swedish Red and White had the greatest retail product yield; however, animals with Swedish Red and White inheritance were also similar to animals with Norwegian Red and British Breed inheritance for retail product yield. Animals with British Breed and Norwegian Red inheritance had the largest fat yields, and animals with Friesian, Swedish Red and White, and Wagyu inheritance had the smallest. Animals with British Breed and Norwegian Red inheritance produced the largest total fat weight, and animals with Friesian and Wagyu inheritance produced the smallest. Animals with Wagyu inheritance had the largest bone yields, and animals with British Breed inheritance had the smallest.

Sex Class Effects

Sex class was a significant ($P < 0.001$) source of variation for all traits except for percentage of carcasses classified as USDA Choice, marbling score, fat thickness, and retail product, fat and bone yields. Steers grew faster, were heavier and leaner, and had more bone than heifers.

DISCUSSION

In the current study, animals expressed differences on 0.25 of the direct genetic effects of breeds and 0.5 of the breed maternal genetic effects (Koch et al., 1983), assuming effects of paternal grandsire are negligible (Dickerson, 1973). In the report by Wheeler et al. (2004), animals expressed differences of 0.5 of the direct genetic effects (g_i) of breeds and none of the maternal genetic breed effects (g_m). Breed differences of $0.5 g_i + 0.0 g_m$ were relatively similar to animals in the current study with breed differences of $0.25 g_i + 0.5 g_m$. Thus, breed

Table 4. Levels of significance, least squares means, and SEM for factors affecting dressing percentage (DRESS), percentage of carcasses classified as Choice (CH), LM area (LMA), marbling score (MAR), USDA yield grade (YG), and fat thickness (FAT)

Factor	Trait ¹					
	DRESS, %	CH, %	LMA, cm ²	MAR ²	YG	FAT, cm
Maternal grandsire breed						
Significance	0.15	0.29	0.64	0.25	<0.001	<0.001
Least squares means						
British Breed	61.5	59.7	81.2	530	2.96 ^a	1.17 ^a
Friesian	61.2	57.1	81.3	515	2.73 ^b	1.00 ^b
Nor. Red ³	61.8	68.3	80.4	550	2.88 ^{ab}	1.05 ^b
Red and White ⁴	61.1	67.1	81.3	532	2.79 ^b	1.00 ^b
Wagyu	61.4	66.0	80.3	544	2.51 ^c	0.89 ^c
SEM	0.2	4.5	0.7	8	0.06	0.04
Maternal granddam breed						
Significance	0.85	0.39	0.48	0.09	0.23	0.27
Least squares means						
Angus	61.5	64.7	81.1	541	2.79	1.05
Hereford	61.4	66.1	80.4	536	2.81	1.02
MARC III ⁵	61.4	60.0	81.3	526	2.72	1.00
SEM	0.1	3.4	0.5	6	0.04	0.03
Sex						
Significance	0.001	0.63	<0.001	0.87	<0.001	0.96
Least squares means						
Male	61.1 ^x	64.8	82.6 ^x	535	2.88 ^x	1.02
Female	61.7 ^y	62.5	79.3 ^y	534	2.66 ^y	1.02
SEM	0.1	3.1	0.5	5	0.04	0.02

^{a-c}Within a factor and column, means without a common superscript letter differ ($P < 0.05$).

^{x,y}Within sex, means without a common superscript letter differ ($P < 0.05$).

¹Carcass traits adjusted by including age at weaning and days on feed as covariates.

²MAR: 400 = slight⁰⁰, 500 = small⁰⁰.

³Nor. Red = Norwegian Red.

⁴Red and White = Swedish Red and White.

⁵MARC III = ¼ Hereford, ¼ Angus, ¼ Pinzgauer, and ¼ Red Poll.

differences in g_i and g_m seemed to offset each other in the results from the 2 studies.

As an example, the difference in HCW between animals from British Breed and Wagyu grandsires was 28 kg (353 to 325 kg; present study), but the difference in the previous generation was 43 kg (377 to 334 kg; Wheeler et al., 2004). If only direct genetic effects were acting on the trait, the difference would be approximately one-half of that observed in the first generation (21.5 kg). The difference for hot carcass weight between animals with British Breed and Wagyu between the 2 generations was more than one-half because of the direct and maternal effects. This was expected in all traits analyzed.

Marbling is an economically important trait for international and domestic markets. Carcass marbling is a characteristic that determines the price of beef in the Japanese beef market (Baud et al., 1998). Interest in exporting beef to Japan has grown in the United States, Australia, and Canada (Hirooka et al., 1996). Thus, in the United States, there has been increased interest in evaluating growth and carcass characteristics using Japanese genetic material (Lunt et al., 1993; Wheeler et al., 2004). The potential to improve characteristics of economic importance to national and international markets is of importance to producers in the United States.

Marbling score has been evaluated in European, crossbred, and Wagyu cattle. In the current study, marbling score was similar for all breed crosses. Several studies have indicated that Angus cattle were similar to Wagyu in production of marbling (Lunt et al., 1993; Mears et al., 2001; Pitchford et al., 2002; Wertz et al., 2002; Wheeler et al., 2004). However, Wagyu cattle deposit more intramuscular fat than other breeds, such as Hereford or Limousin (Mir et al., 1999; Myers et al., 1999; Pitchford et al., 2002; Kuber et al., 2004; Wheeler et al., 2004). Animals with Hereford and Angus inheritance were evaluated as a single group (British Breed) in the current study, and they had similar marbling compared with animals with Wagyu inheritance.

Marbling score has seldom been evaluated in animals with Friesian, Norwegian Red, and Swedish Red and White. Wheeler et al. (2004) indicated that at a constant age, Hereford-, Friesian-, and Swedish Red and White-sired steers had lower marbling scores compared with Angus-, Wagyu-, and Norwegian Red-sired steers. Animals with Friesian inheritance had the lowest marbling score in the current study, but animals with Norwegian Red and Swedish Red and White inheritance had similar marbling score compared with animals with British Breed and Wagyu inheritance. Animals with Friesian inheritance consistently had a lower marbling score than other breeds evaluated here.

Table 5. Levels of significance, least squares means, and SE for factors affecting retail product yield (RPYD), retail product weight (RPWT), fat yield (FATYD), fat weight (FATWT), bone yield (BONEYD), and bone weight (BONEWT)

Factor	Trait ¹					
	RPYD, %	RPWT, kg	FATYD, %	FATWT, kg	BONEYD, %	BONEWT, kg
Maternal grandsire breed						
Significance	0.015	<0.001	<0.001	<0.001	<0.001	<0.001
Least squares means						
British Breed	63.4 ^b	222.8 ^a	22.1 ^a	78.2 ^a	14.68 ^c	51.6 ^a
Friesian	64.8 ^a	223.1 ^a	20.4 ^c	70.6 ^{cd}	14.99 ^b	51.6 ^a
Nor. Red ²	63.6 ^b	223.9 ^a	21.8 ^{ab}	76.5 ^{ab}	14.89 ^b	52.4 ^a
Red and White ³	64.4 ^{ab}	227.1 ^a	20.9 ^{bc}	73.2 ^{bc}	14.98 ^b	52.8 ^a
Wagyu	64.7 ^a	210.8 ^b	20.4 ^c	66.5 ^d	15.19 ^a	49.5 ^b
SEM	0.3	2.2	0.4	1.7	0.07	0.5
Maternal granddam breed						
Significance	0.06	0.31	0.07	0.12	0.23	0.30
Least squares means						
Angus	63.9	219.8	21.5	74.3	14.89	51.2
Hereford	64.1	222.6	21.2	73.4	14.96	51.9
MARC III ⁴	64.5	222.3	20.7	71.4	15.00	51.6
SEM	0.2	1.5	0.3	1.2	0.05	0.3
Sex						
Significance	0.30	<0.001	0.48	<0.001	0.89	<0.001
Least squares means						
Male	64.3	237.3 ^x	21.0	77.4 ^x	14.95	55.1 ^x
Female	64.0	205.8 ^y	21.3	68.6 ^y	14.94	48.0 ^y
SEM	0.2	1.3	0.3	1.1	0.04	0.3

^{a-d}Within a factor and column, means without a common superscript letter differ ($P < 0.05$).

^{x,y}Within sex, means without a common superscript letter differ ($P < 0.05$).

¹Carcass traits adjusted by including age at weaning and days on feed as covariates.

²Nor. Red = Norwegian Red.

³Red and White = Swedish Red and White.

⁴MARC III = ¼ Hereford, ¼ Angus, ¼ Pinzgauer, and ¼ Red Poll.

Postweaning ADG is a measure of growth in cattle. Mir et al. (1999) showed that animals with continental inheritance grew faster than animals with ½ or ¾ Wagyu inheritance. Myers et al. (1999) also reported that Wagyu cattle grew more slowly than British cattle. These findings are similar to results obtained here.

In the current study, animals with Wagyu inheritance had the lowest slaughter weight. Mears et al. (2001) reported that when comparing crossbred cattle, Hereford × Charolais and Hereford × Simmental animals were heavier at slaughter than were Wagyu crossbred animals. Kuber et al. (2004) found that Limousin purebred cattle were heavier than Wagyu × Limousin animals, and these were heavier than purebred Wagyu animals. Wheeler et al. (2004) indicated that Wagyu-sired cattle had the lightest live weight at slaughter.

Hot carcass weight is one of the factors that determines yield grade. Lunt et al. (1993) compared Angus to American Wagyu. Angus had heavier warm carcass weights than Wagyu. Mir et al. (1999) evaluated animals with 50 and 75% Wagyu inheritance with continental cattle. They observed that continental cattle had heavier warm carcass weights than animals with Wagyu inheritance. Pitchford et al. (2002) reported that animals with Hereford, Angus, Limousin, and South Devon inheritance had heavier hot carcass weights than did animals with Wagyu inheritance. Kuber et al. (2004), comparing Wagyu purebred to Limousin and a

crossbred between these 2 breeds, found that crossbred cattle had a heavier hot carcass weight than Wagyu, and Limousin cattle had heavier hot carcass weights when compared with the crossbred and Wagyu cattle. Wheeler et al. (2004) also reported that Hereford- and Angus-sired animals had heavier hot carcass weights than Wagyu-sired animals.

The USDA yield grade is an accurate predictor of carcass composition (Abraham et al., 1980). Conflicting results on yield grade exist in the literature. In some studies, no difference has been observed between European cattle and Wagyu (Lunt et al., 1993; Myers et al., 1999; Wertz et al., 2002); other studies have reported differences (Kuber et al., 2004; Wheeler et al., 2004). Kuber et al. (2004) indicated that Limousin produced carcasses with a lower yield grade than Wagyu and Wagyu × Limousin cattle. This would suggest that Limousin would have a better carcass composition; however, the number of observations used by Kuber et al. (2004) was small ($n = 12$). Conversely, Wheeler et al. (2004), using a large population of crossbred cattle, detected differences between breeds. They found that carcasses from Hereford- and Angus-sired steers had the greatest yield grades, and Wagyu-, Norwegian Red-, Swedish Red and White-, and Friesian-sired steers had lower yield grades than Hereford- and Angus-sired animals. Here, animals with Wagyu inheritance had the lowest yield grade, followed by animals with Norwegian

Red, Swedish Red and White, and Friesian inheritance. Animals with British Breed inheritance had the greatest yield grades.

Differences in fat thickness have been identified in studies in which comparisons are made between European and Wagyu cattle (Mir et al., 1999; Mears et al., 2001; Wheeler et al., 2004). Mears et al. (2001) found inconsistent results in the production of backfat in a 2-yr study; however, overall Hereford and Angus cattle had greater backfat compared with Wagyu crossbred animals. Mir et al. (1999) found that animals with 50% Wagyu had greater fat thickness compared with animals with 75% Wagyu, but they indicate that this was probably because these animals were crossbred with Angus. Wheeler et al. (2004) reported that carcasses from Hereford- and Angus-sired steers had the greatest fat thickness compared with animals sired by the other breeds. In the current study, animals with British Breed inheritance had the greatest fat thickness, and animals with Wagyu inheritance had the lowest.

Wheeler et al. (2004) found that Wagyu-sired animals had a higher percentage of USDA Choice yield Grade 1 and 2 carcasses. This is similar to the results of the current study.

IMPLICATIONS

Grandsire breed effects can be optimized by selection and use of appropriate crossbreeding systems. The current beef production system in the United States is designed for the production of high quality meat for the national market. In this system, Scandinavian breeds could be used because they produce crossbred animals with similar carcass composition traits as breeds traditionally used. If alternative germplasm sources are to be used in crossbred systems to compete in international markets, such as Wagyu for the Japanese market, the producer needs to know that animals produced will have the least amount of saleable meat.

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