Effects of Twinning on Dystocia, Calf Survival, Calf Growth, Carcass Traits, and Cow Productivity[1,2]

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ABSTRACT: This paper reports results from a long-term experiment with a primary objective to increase twinning rate in cattle at the Roman L. Hruska U.S. Meat Animal Research Center. Survival of singles was 13% higher ($P < .01$) than that of twins at birth, and the difference in survival in favor of singles was of similar magnitude at 72 h (12.9%, $P < .01$), 150 d (14.8%, $P < .01$), and 200 d (15.2%, $P < .01$). Survival of calves with no dystocia was higher than survival of calves with dystocia: 8.6% ($P < .01$) at birth, 10.8% ($P < .01$) at 72 h, 12% ($P < .01$) at 150 d, and 12.2% ($P < .01$) at 200 d. The effect of dystocia on survival was greater ($P < .01$) in twins than in singles at birth and at 72 h. Least squares means for dystocia were 20.4% in singles compared with 42.2% in twins. Most of the dystocia in singles resulted from a traction requirement (84.7%) of normal presentations, whereas most of the dystocia in twins (77.8%) resulted from malpresentations, with 59.2% of the malpresentations accompanied with a requirement for traction. Survival in singles ranged from 10.7% to 15.3% greater than in twins at different ages when there was no requirement for assistance in either singles or twins. Calves born as singles were 8.8 kg heavier ($P < .01$) at birth and 28 kg heavier ($P < .01$) at 200 d than calves born and reared as twins. Calf weight produced per cow calving was 53.1%, 54.7%, and 58.4% greater ($P < .01$) at birth, 150 d, and 200 d, respectively, in cows producing twins than in cows producing singles. Cows producing twins had 65.2% more ($P < .01$) live calves at 200 d than cows producing singles. Single male calves gained 74 g more per day than twin males from birth to 200 d, 45 g more ($P < .01$) per day from 200 d to slaughter and 57 g more ($P < .01$) per day from birth to slaughter. Differences between twin and single males in carcass traits were small. A sample of steers from the Twinning Project gained significantly faster and produced significantly more desirable carcasses than a sample of steers from a high performance reference population. Freemartins did not differ ($P > .05$) from normal females in growth traits, but freemartins had higher ($P < .05$) scores for marbling with a higher percentage ($P < .05$) of USDA Choice or better quality grade carcasses and lower estimated percentage retail product.

Key Words: Cattle, Twinning, Dystocia, Calf Production, Growth, Carcass, Freemartins

J. Anim. Sci. 1996. 74:1223–1233

Introduction

Rate of reproduction has a major impact on life cycle costs of production of different animal species and upon their competitiveness for use of different types of production resources. In beef cattle, the average reproducing female is capable of producing about .7 of her body weight per year in progeny market weight; comparable values are about eight in pigs, more than 70 in meat chickens, and more than 1,000 in some aquatic species (Gregory and Dickerson, 1989). High-producing dairy cows are capable of producing a unit of milk protein for about one fifth the feed energy required to produce a unit of beef protein (Reid et al., 1980). On the basis of results from experimentation (twins produced by embryo transfer) and production systems simulation, assuming increased labor and veterinary costs of 40% per cow, the estimated increase in efficiency of producing beef by twinning was 24% when marketed at 400 d (Guerra-Martinez et al., 1990). Results from the project providing data for the present report suggest that it should be feasible to increase twinning rate in cattle to an economically viable level (Echternkamp et al., 1990; Van Vleck and Gregory, 1996) using ovulation rate in puberal heifers as a primary selection

[1]Cooperation of the Nebraska Agric. Res. Div., University of Nebraska, Lincoln, is acknowledged.

[2]Appreciation is expressed to Gordon Hays, Dave Powell, and Patricia Beska and their staff for operations support provided to this project, to Darrell Light for data analyses, and to Deborah Brown for secretarial support.

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Received August 21, 1995.

Accepted December 1, 1995.

criterion. There was a reason to obtain comparative data on growth and carcass traits of steers from the Twinning Project with a reference population to aid in making a decision on the release to the public of germplasm with a high breeding value for twinning. If a twinning technology is implemented, almost one fourth of the animals born as twins will be freemartin. Thus, there was a need to evaluate the freemartin effect on growth and carcass traits. The primary objective of this study was to further quantify some of the biological factors relevant to a twinning technology in cattle.

Materials and Methods

Animals and Experimental Design

Twin Population. Data for this study were from a project, "Twinning in Cattle" that was established at the Roman L. Hruska U.S. Meat Animal Research Center (**MARC**) in 1981 (Gregory et al., 1990a). The experimental population that provided these data is a composite with mean breed contribution of calves born from 1989 through 1994 (given in Table 1). Foundation females contributing to this experiment (n = 307) were from other projects at MARC (n = 211) and from private sources (n = 96). Foundation sires were a Pinzgauer and a Charolais whose daughters had produced twins at a relatively high frequency in another project at MARC and Swedish Friesian (n = 8), Norwegian Red (n = 2), and Swedish Red and White (n = 5) sires whose daughters had produced twins ≥8% of their parturitions.

Calves providing data were born from 1989 through 1994. Females in the Twinning Project calve in approximately equal numbers in spring and fall. Mating season is approximately 70 d in spring (late May to early August) and approximately 60 d in fall (late October to late December). In females ≥2.5 yr, approximately one half of the mating season in both spring and fall is by artificial insemination followed by natural service in individual sire pastures. All virgin females, except high breeding value females that are mated by artificial insemination to progeny proven sires, are mated at an average age of 21 mo by natural service in individual sire pastures for the full mating season. Thus, females produce their first calves at an average age of 2.5 yr. Triplet births (n = 28 sets) were excluded from all analyses.

Calving difficulty was subjectively evaluated using descriptive scores: 1 = no assistance, 2 = little assistance by hand, 3 = little assistance with calf jack, 4 = slight assistance with calf jack, 5 = moderate assistance with calf jack, 6 = major assistance with calf jack, 7 = Caesarean birth, and 8 = malpresentation. When a calf received a score of 8 because of malpresentation and if traction assistance was required, a second score was given consistent with the 1 through 7 assistance scores and descriptions given. Percentage of calving difficulty was analyzed (scores 1 and 2 = 0; scores 3, 4, 5, 6, and 7 = 1).

Calves were weaned at an average age of 172 d. Spring-born calves were weaned in early September, and fall-born calves were weaned in late January or early February. All calves were offered feed (creep feeder) at an average age of 30 d. Calves were fed a diet of 2.63 Mcal ME/kg DM and 14.4% CP from weaning to an average age of 200 d. At an average age of 200 d, approximately 30 male calves to be developed as sire prospects were identified, and the remaining male calves were castrated using the banding procedure. Castrated males were grouped into three weight classes of equal number and fed in separate pens. Generally, the heaviest weight class was approaching or had attained an average weight of 272 kg by 200 d; the intermediate and light weight classes were fed a diet of 2.69 Mcal of ME/kg of DM and 12.88% CP until they attained an average weight of 272 kg. Starting at an average weight of 272 kg, each of the three weight classes of castrate males was fed in separate pens a diet of 3.12 Mcal ME and 11.50% CP until they attained an average pen weight of 590 to 600 kg, at which time they were slaughtered.

Twin vs. Reference Steers. The genetic merit of the cattle in the Twinning Project for growth and carcass traits was evaluated relative to a crossbred reference population. The reference population was males produced by Composite MARC III cows (1/4 Hereford,

Table 1. Mean breed composition (%) of calves born by year of birth

Breed	1989	1990	1991	1992	1993	1994	Mean
Holstein	24.8	21.8	22.3	20.1	19.5	18.6	21.1
Swedish Friesian	12.3	15.0	15.6	18.7	19.5	16.0	16.3
Simmental	23.6	21.3	21.3	18.4	15.4	17.0	19.4
Pinzgauer	7.5	9.3	10.0	10.6	16.5	19.0	12.3
Charolais	5.8	5.9	7.5	6.5	6.1	4.9	6.1
Swedish Red and White	0.0	0.0	0.0	5.8	2.5	1.3	1.7
Norwegian Red	6.6	8.3	7.3	5.6	6.0	9.3	7.2
Hereford and Angus combined	11.2	10.2	10.2	8.4	8.9	8.8	9.6
Other breeds	8.2	8.2	5.8	5.9	5.6	5.1	6.3

1/4 Angus, 1/4 Red Poll, 1/4 Pinzgauer) and Simmental sires. The experimental protocol of the reference population was identical to that for the males in the Twinning Project. Both singles and twins (i.e., born and reared as twins) were included in this experiment; calves born as twins but reared as singles were not included in the comparison. The only known difference in treatment protocol between the reference population and animals from the Twinning Project was the absence of twin births in the reference population. There were 80 calves born and reared as twins from a total of 292 available male calves from the Twinning Project born in the autumn of 1992 and 1993 (i.e., 27% of animals).

Freemartin vs. Normal Females. Freemartin animals (n = 150) born in fall of 1990, spring and fall of 1991 and 1992, and spring of 1993 were evaluated for growth and carcass traits relative to normal females (204 singles and 37 twins) from the Twinning Project. Contemporaries with which they were compared were normal females removed from the breeding population because of low predicted breeding value for twinning based primarily on ovulation rate for eight estrous cycles. From weaning to 200 d, all heifers were fed a diet of 2.63 Mcal ME/kg DM and 14.4% CP; from 200 to 368 d all heifers were fed a diet of 2.24 Mcal ME/kg DM and 12.3% CP; from 368 to 573 d all heifers were fed a diet of 2.18 Mcal ME/kg DM and 11.7% CP. Freemartins were fed and managed in the same pens with all normal females during the period when ovulation rate was determined in normal females (368 to 573 d) except they were not palpated. At the end of the palpation schedule to determine ovulation rate, at an average age of 573 d, freemartins and contemporary normal females for slaughter were separated from the normal females being retained for breeding and were fed in a single pen on a diet of 3.12 Mcal ME/kg DM and 11.50% CP to an average slaughter age of 685 d.

Carcass Measurements. Animals were slaughtered in a commercial facility, and hot carcass weights were recorded. Following a chill period of 24 h, actual fat thickness at the 12th rib, fat thickness at the 12th rib adjusted for differences in distribution of subcutaneous fat over the entire carcass, estimated perirenal fat percentage (**KPH**), and marbling score and area of longissimus muscle (**REA**) were obtained on the right side of each carcass.

In this study, the estimated percentage of retail product was defined as the percentage of steaks, roasts, and lean trim based on removal of all subcutaneous and accessible intermuscular fat and all bone from the carcass with lean trim adjusted to 20% fat. The prediction equation used to estimate the percentage of retail product was derived from a data set where complete cut-out data were obtained (Shackelford et al., 1995) and had an R^2 of .72 when evaluated on a second data set. The equation was: Estimated percentage retail product = 74.9 − 5.8402 (adj. fat, cm) − 2.0500 (marbling score) + .1018 REA (cm^2) − 1.0384 est. KPH (%).

Data Analysis. Data were analyzed by least squares fixed-model procedures (Harvey, 1985). The models included fixed effects as indicated by the tables, and significant interactions were included in final analysis. Interactions that were not significant were deleted from final analyses.

Results and Discussion

Calf Survival

Calf survival for both twins and singles was computed based on calves born even though some calves were born premature. For a few premature births in which sex was not recorded, sex code was assigned on a random basis.

Type of Birth. The effect of type of birth on calf survival relative to all calves born was important (P < .01) at birth, 72 h, 150 d, and 200 d (Table 2). Survival of calves born as singles was greater than that of calves born as twins by 13%, 12.9%, 14.8%, and 15.2% at birth, 72 h, 150 d, and 200 d, respectively. Additive postnatal losses to 200 d were similar in calves born as singles (7.6%) or as twins (9.8%).

Dystocia. The effect of dystocia (no assistance vs. assistance) on calf survival was important (P < .01) at birth, 72 h, 150 d, and 200 d (Table 2). Survival of calves with no dystocia was greater by 8.6%, 10.8%, 12.0%, and 12.2% at birth, 72 h, 150 d, and 200 d, respectively, than when assistance was required. The interaction of dystocia with type of birth on survival was important (P < .01) at birth and 72 h, but not at 150 d and 200 d. At birth and 72 h, the effect of dystocia on survival was greater in twin than in single births, whereas the magnitude of the difference in survival with dystocia and with no dystocia between twin and single births was similar at 150 and 200 d.

The interaction of dystocia with season on calf survival was significant at all ages. This significant interaction was the result of a greater effect of dystocia on survival in fall-born calves than in spring-born calves (Table 2).

Cow Age. The main effect of cow age on survival was not important (P > .05). However, the interaction of type of birth with cow age on survival was significant at 72 h and 150 d as a result a difference of greater magnitude in survival between twins and singles in 5-yr-old and ≥6-yr-old cows than was observed in younger cows.

Year and Season. The effect of year was important only for survival at birth (P < .01), whereas the effect of season was significant on survival at 72 h, 150 d, and 200 d as a result of higher survival in spring than of fall born calves (Table 2).

Regressions. The regressions of survival at birth and 72 h on date of birth (%/d) were .047 (P < .01) and .027 (P < .01), respectively.

Table 2. Summary of *F* statistics from analysis of variance and least squares means for calf survival

Item	df or n	Survival, % Birth	72 h	150 d	200 d
Analysis of variance					
Type of birth (B)	1	260**	207**	183**	185**
Dystocia (D)	1	121**	155**	126**	126**
Cow age (A)	4	1.5	2.0	1.6	1.5
Year	5	3.7**	1.7	.6	1.1
Season (S)	1	2.1	4.5*	29.4**	32.2**
Sex	1	.1	.4	1.2	3.3
B × D	1	24.4**	7.6**	.5	.6
B × A	4	1.8	2.8*	2.8*	2.0
D × S	1	8.0**	11.5**	12.6**	11.7**
Birth date - b_1 linear	1	8.0**	15.4**	1.4	.0
Residual	5,377	587.9	724.3	1,086.4	1,127.4
Least squares means					
μ	5,398	89.9	87.4	81.8	81.2
Type of birth					
Single (1)	3,370	96.4	93.9	89.2	88.8
Twin (2)	2,028	83.4	81.0	74.4	73.6
Dystocia					
No assistance (1)	3,965	94.2	92.9	87.8	87.3
Assistance (2)	1,433	85.6	82.1	75.8	75.1
Year					
1989	710	89.7	87.6	83.8	83.6
1990	841	90.4	87.9	81.3	80.8
1991	968	91.1	88.5	81.1	80.7
1992	981	88.5	86.2	81.4	79.9
1993	930	91.7	88.7	81.7	80.8
1994	968	87.8	85.9	81.5	81.4
Season					
Spring (1)	2,724	90.4	88.4	84.6	84.2
Fall (2)	2,674	89.3	86.6	79.0	78.2
Sex of calf					
Male	2,802	89.8	87.2	81.3	80.4
Female	2,596	90.0	87.7	82.3	82.0
Interactions					
B × D					
11	2,630	98.8	98.1	94.8	94.4
12	740	94.0	89.7	83.6	83.1
21	1,335	89.6	87.6	80.8	80.1
22	693	77.2	74.4	68.0	67.2
D × S					
11	1,974	93.7	92.3	88.7	88.4
12	1,991	94.7	93.4	86.8	86.1
21	750	87.2	84.4	80.4	79.9
22	683	84.0	79.8	71.3	70.4

*$P < .05$, **$P < .01$.

Sex. The effect of sex on survival was not significant at any age.

Dystocia Classification and Survival of Singles and Twins

To quantify the different types of dystocia in singles and twins and their effect on survival, separate analyses were conducted for singles and twins with two analyses for each; i.e., one with dystocia included in the model as a main effect and another with dystocia analyzed as a trait (Table 3). When analyzed as a trait, least squares means for dystocia were 20.4% in singles and 42.2% in twins. Only 15.3% of the dystocia observed in singles was the result of malpresentation (3.5% of all parturitions), whereas 77.8% of the dystocia in twins resulted from malpresentation, with 59.2% of the malpresentations in twins accompanied with a requirement for traction. Survival of singles was 10.7%, 12.4%, 15.3%, and 15.3% greater than twins at birth, 72 h, 150 d, and 200 d, respectively, when there was no requirement for assistance in either birth type. These values include the higher percentage of premature births of twins. Among twins with normal presentation, the requirement for traction assistance was 15.9%. Among singles, survival was greater ($P < .01$) at all ages when assistance was not required, with the magnitude

Table 3. Dystocia classification and least squares means for survival of singles and twins: Separate analyses for singles and twins

	No.	%	Birth wt, kg	Dystocia, %	Survival Birth	72 h	150 d	200 d
				Singles				
Overall mean	3,370	100	48.1	20.4	96.5	94.0	89.3	88.7
Dystocia			**		**	**	**	**
No assistance	2,630	78	46.0		98.9	98.4	94.8	94.4
Assistance	740	22	50.1		94.1	89.6	83.7	83.0
Sex			**	**				
Male	1,785	53	49.7	26.4	96.4	94.0	89.1	88.5
Female	1,585	47	46.5	14.3	96.6	93.9	89.5	88.9
				Twins				
Overall mean	1,958[a]	100	37.1	42.2	83.5	81.7	75.5	74.4
Dystocia			**		**	**	**	**
No assistance	1,056	54	35.6		88.2	86.0	79.5	79.1
Traction assistance[b]	200	10	39.4		91.5	90.4	79.4	76.9
MP no traction[c]	286	15	36.1		80.6	79.2	75.9	75.9
MP with traction[d]	416	21	37.1		73.6	71.0	67.1	65.8
Sex			**	**	*	**	*	**
11[e]	532	27	37.6	48.4	80.4	77.4	71.3	69.7
12	896	46	37.3	43.4	84.7	83.5	76.1	75.0
22	530	27	36.3	34.8	85.2	84.1	78.9	78.6

[a]Traction scores were not recorded on all malpresentations born in 1989. These animals were deleted from the analysis.
[b]Calving difficulty scores 3, 4, 5, 6, and 7 with no malpresentations.
[c]Malpresentations with no further assistance required.
[d]Malpresentations with traction scores of 3, 4, 5, 6, and 7.
[e]11 = Both twins male, 12 = unlike sex twins, 22 = both twins female.
$*P < .05$, $**P < .01$.

of the difference increasing between birth and 72 h. Among twins with normal presentation, differences in survival between no assistance and traction assistance were small at all ages. This difference in survival between singles and twins with normal presentations associated with a traction requirement may be associated with the higher birth weight of singles (50.1 vs 39.4 kg). Among twins with malpresentation, survival of twins requiring traction was greatly reduced at all ages relative to calves with no requirement for traction. Among twins, survival was reduced ($P < .05$) when both were males relative to when both were females; survival of twins of mixed sex was intermediate but closer to that of males (Table 3). In a separate summary, we determined that birth order of twins did not affect survival.

The effects of type of birth and dystocia on survival are in close agreement with an earlier report on calves born in this experiment before 1989 (Gregory et al., 1990b). We expected that the effects of dystocia on survival of twins should be reduced relative to the earlier study, because closer observation at parturition was possible for birth years 1991 through 1994 following use of ultrasound to diagnose twin pregnancies. The percentage of both twins and singles requiring assistance and survival rates for different classes of dystocia have not changed significantly. A major change in the population has been in twinning frequency. Mean twinning rate before 1989 of females born in the project was 11% (Gregory et al., 1990a), whereas mean twinning rate during the period of this study from 1989 through 1994 was 23.1%.

Growth to 200 Days: All Calves Surviving to 200 Days

Type of Birth and Rearing. The effects of type of birth and rearing were important ($P < .01$) for all measures of growth to 200 d (Table 4). Calves born as singles were 8.8 kg heavier ($P < .01$) at birth and 28 kg heavier at 200 d than calves born and reared as twins. Calves born as singles gained significantly faster than calves born and reared as twins from birth to 150 d and to 200 d. Even though significant, differences in ADG were small between the three birth and rearing classes from 150 d to 200 d (Table 4). Calves born as twins but reared as singles were intermediate to calves born and reared as singles vs calves born and reared as twins in ADG from birth to 150 d. Approximately one third of the difference in 150-d and 200-d weight between calves born and reared as singles vs calves born and reared as twins was present at birth.

Cow Age. The effect of cow age was significant for all measures of growth to 200 d. Most of the effect was

Table 4. Summary of F statistics from analysis of variance and least squares means for growth to 200 days

Item	df or n	Birth wt, kg	150-d wt, kg	200-d wt, kg	ADG, kg Birth to 150 d	ADG, kg Birth to 200 d	ADG, kg 150 to 200 d
Analysis of variance							
Type of birth and rearing (B)	2	1000**	602**	455**	318**	252**	5.6**
Cow age (A)	4	75**	53**	38**	30**	22**	.5
Year (Y)	5	6.7**	100**	86**	110**	92**	58**
Season (S)	1	46**	389**	421**	580**	577**	147**
Sex	1	90**	263**	250**	230**	225**	45**
B × Y	10	2.1*	3.7**	2.6**	4.1**	2.6**	1.3
B × sex	2	1.6	3.5*	4.4**	3.7*	4.8**	.3
A × Y	20	3.0**	3.0**	2.5**	2.4**	2.1**	2.0**
Y × S	5	5.9**	54.5**	65**	73**	87**	298**
Y × sex	5	1.8	5.1**	5.0**	5.7**	5.1**	32**
S × sex	1	.2	2.2	5.0*	3.3	6.5**	27**
Birth date - b_1 linear		45**	415**	414**	614**	567**	109**
Remainder	4,526	34.5	454.9	726.0	.016	.015	.082
Least squares means							
μ	4,584	41.0	184	243	.957	1.010	1.238
Type of birth and rearing							
11[a]	3,062	47.0	199	259	1.014	1.061	1.264
21	220	38.0	181	239	.956	1.006	1.214
22	1,302	38.2	173	231	.901	.964	1.236
Cow age							
2 y	1,063	38.2	176	234	.917	.977	1.243
3 y	974	40.7	184	242	.955	1.009	1.238
4 y	809	42.2	188	247	.972	1.024	1.247
5 y	642	42.3	189	248	.978	1.028	1.235
≥6 y	1,096	41.8	186	244	.963	1.013	1.229
Year							
1989	636	40.7	177	244	.908	1.017	1.530
1990	714	39.2	170	221	.872	.909	1.026
1991	816	41.2	174	230	.883	.943	1.196
1992	829	42.0	200	258	1.050	1.083	1.217
1993	785	41.4	187	244	.970	1.015	1.192
1994	804	41.7	200	260	1.058	1.094	1.270
Season							
Spring	2,366	40.4	192	252	1.010	1.061	1.298
Fall	2,218	41.7	177	234	.904	.959	1.179
Sex of calf							
Male	2,338	42.5	193	254	1.006	1.058	1.288
Female	2,246	39.6	176	232	.907	.963	1.189

[a]11 = born single, reared single; 21 = born twin, reared single; 22 = born twin, reared twin.
*P < .05, **P < .01.

the result of lighter birth weight and lower rate of gain by calves with 2.5-yr-old dams and to a lesser degree by calves with 3.5-yr-old dams. The interaction of cow age with type of birth and rearing was not significant.

Year. The effect of year was significant for all measures of growth to 200 d. There was a tendency for increasing ADG and thus 150-d and 200-d weight during the period from 1989 through 1994. This reflects general improvements in nutritive environment for cows and calves.

Season. Spring-born calves grew significantly faster and were significantly heavier at 150 and 200 d than fall-born calves. Even though twinning frequency was greater in fall-born calves than in spring-born calves (Table 5), fall-born calves averaged 1.3 kg (P < .01) heavier at birth. This is not in agreement with results from other populations at MARC in which heavier birth weights are observed in spring-born calves.

Sex. Male calves were significantly heavier than female calves in all measures of growth to 200 d (Table 4).

Interactions. Even though many of the interactions were significant for most of the growth traits evaluated, the interaction of greatest importance was year × season. This resulted from improvement in the feeding and management protocol of the fall-born calves in the later years, which greatly reduced the magnitude of difference in ADG between fall- and spring-born calves and thus weights at 150 d and 200 d.

Table 5. Summary of *F* statistics from analysis of variance and least squares means for calf weight produced per cow calving

Item	df or n	Birth, kg	150 d, kg	200 d, kg	No. calves/ cow calving at 200 d	Twinning rate
Analysis of variance						
Type of birth (B)	1	2,592**	513**	547.9**	681.4**	
Cow age (A)	4	57**	5.7**	4.6**	2.0	6.3**
Year (Y)	5	19**	15.1**	12.5**	1.7	13.1**
Season (S)	1	14**	57.1**	53.5**	16.4**	2.6
B × A	1	7.2**	2.0	1.5	2.6*	
B × Y	4	1.8	2.3*	2.2*	1.7	
B × S	1	.8	5.1*	4.1*	1.7	
Birth date - b_1 linear	1	12.4**	16.8**	19.2**	.1	97.8**
Residual	4,361	79.0	6,267.7	11,007.6	.2	.2
Least squares means						
μ	4,384	59.8	230	301	1.22	1.23
Type of birth						
Single	3,370	47.3	181	233	.92	
Twin	1,014	72.4	280	369	1.52	
Percentage increase for twins		53.1	54.7	58.4	65.2	
Cow age						
2 y	1,036	55.5	218	288	1.21	1.19
3 y	905	59.0	234	306	1.24	1.26
4 y	751	62.0	236	309	1.24	1.28
5 y	611	61.7	236	308	1.22	1.23
≥6 y	1,081	61.0	227	296	1.19	1.21
Year						
1989	624	59.7	229	310	1.27	1.15
1990	707	56.5	216	280	1.19	1.19
1991	790	60.6	215	284	1.22	1.24
1992	797	61.9	243	310	1.19	1.24
1993	734	59.8	231	300	1.22	1.26
1994	732	60.6	247	321	1.22	1.32
Season						
Spring	2,229	59.2	241	315	1.25	1.22
Fall	2,155	60.4	220	287	1.19	1.24

*$P < .05$, **$P < .01$.

Calf Weight Produced Per Cow Calving

Calf weight produced per cow calving is a product of calf weight and calf survival on a per cow calving basis. For the 6 yr (1989 through 1994) reported in this study, 1,014 sets of twins were produced in 4,384 parturitions for an average rate of 23.1% twin births. The 28 sets of triplets, or 2.8% of the multiple births or .64% of all parturitions, were not included in any analyses. Calf survival for both twins and singles was computed based on calves born even though some calves were born premature. For the 6 yr included in this study, twinning rate increased from 15% to 32% for an average rate of increase of 2.8% per year (Table 5).

Type of Birth. The effect of type of birth on calf weight produced per cow calving was significant at birth (53.1%), 150 d (54.7%), and 200 d (58.4%). Cows calving twins produced 65.2% more calves at 200 d than cows calving singles (Table 5).

Cow Age. The effect of cow age was significant for all measures of weight produced per cow calving (Table 5) but not for number of calves per cow at 200 d. Cows 2 yr old and cows ≥6 yr old had lower twinning rates and lower number of calves per cow calving at 200 d than 3-, 4-, and 5-yr-old cows and similarly for calf weight per cow at 150 d and 200 d.

Year. The effect of year was significant for all measures of calf weight produced per cow calving but not for number of calves per cow at 200 d. However, the effect of year on twinning rate was significant.

Season. The effect of season was significant for all measures of calf weight produced per cow calving and for number of calves per cow at 200 d. Calf weight produced at 150 and 200 d and number of calves per cow calving were greater for spring-born than for fall-born calves, even though twinning rate was greater for fall-born than for spring-born calves. This result is accounted for by higher survival of spring-born calves than of fall-born calves.

Table 6. Least squares means for growth traits of twins and singles (males)

Birth group	No.	Birth weight, kg	200-d wt, kg	Actual slaughter wt, kg	ADG Birth to 200 d, kg	ADG 200 d to slaughter, kg	ADG Birth to slaughter, kg	Actual slaughter age, d
Overall mean	1,081	43.3	252	594	1.044	1.414	1.233	458
		**	**	**	**	**	**	**
Singles	808	48.2	264	600	1.081	1.436	1.262	448
Twins	273	38.4	240	589	1.007	1.391	1.205	468

**$P < .01$.

Growth and Carcass Traits of Steers

Data were recorded on postweaning growth and carcass traits of castrate males born in the fall of 1990 and in both spring and fall of 1991, 1992, and 1993 (Tables 6 and 7). Because the 48 calves born as twins but reared as singles did not differ from calves born and reared as twins in birth weight or in average daily gain from birth to slaughter, they were grouped in the analysis as one class (i.e., twins).

Growth Traits. Singles were 9.8 kg heavier ($P < .01$) than twins at birth, 24 kg heavier ($P < .01$) at 200 d, and 11 kg heavier but 20 d younger at slaughter. Singles had 57 g greater ($P < .01$) ADG than twins from birth to slaughter (Table 6).

Carcass Traits. Singles produced 7 kg more ($P < .01$) carcass weight and 5 kg more ($P < .01$) estimated retail product weight than twins. This was a result of greater slaughter weight of singles. Twins and singles did not differ ($P > .05$) in dressing percentage, adjusted fat thickness at 12th rib, estimated percentage perirenal fat (KPH), and estimated percentage of retail product. Twins had slightly higher ($P < .05$) scores for marbling and slightly higher ($P < .05$) percentage of carcasses that were USDA Choice or better quality grade. This is interpreted to result from the 20 d greater age at slaughter (Table 7). In a separate analysis, males born twin to females were compared with male twins for growth and carcass traits, and they did not differ in growth and carcass traits.

Comparative Results: Growth and Carcass Traits of Steers

If twinning technology is to be implemented it will require the use of the cattle from this population because they are the only known source of germplasm available with high breeding value for twinning. Thus, it was desirable to evaluate this population for growth and carcass traits relative to a reference population of known merit for growth and carcass traits.

Comparative results on steers from the Twinning Project relative to steers from a population known to be superior in growth and carcass traits are presented in Tables 8, 9, and 10, for growth, carcass, and gain efficiency, respectively. Calves in this comparison were born in fall of 1992 and 1993.

Growth Traits. Twins and singles from the Twinning Project did not differ ($P > .05$) in postnatal growth, but singles from the twinning population were 9.7 kg heavier than twins at birth and 11 kg heavier at slaughter (Table 8). The two populations (i.e., twinning and reference) did not differ in birth weight, but the animals from the twinning population exceeded ($P < .01$) those from the reference population at all intervals in which growth was evaluated and weighed 21 kg more ($P < .01$) at an adjusted slaughter age of 439 d (Table 8).

Table 7. Least squares means for carcass traits of twins and singles (males)

Birth group	No.	Carc. wt, kg	Dressing percentage, %	Marbling score[a]	Adj. fat 12th rib, cm	REA,[b] cm^2	Est. KPH,[c] %	Est. retail prod.,[d] %	Est. retail prod. wt, kg	≥USDA Choice, %
Overall mean	1,081	361	60.8	5.36	.62	77.2	3.1	60.4	218	73.2
		**		*		*			**	*
Singles	808	365	60.9	5.30	.62	77.9	3.1	60.5	221	70.2
Twins	273	358	60.8	5.41	.62	76.6	3.1	60.2	216	76.2

[a]5.00–5.90 = small.
[b]REA = area of longissimus muscle.
[c]KPH = estimated perirenal fat.
[d]Estimated retail product is based on removal of all subcutaneous and accessible intermuscular fat and all bone from the carcass with lean trim adjusted to 20% fat.
*$P < .05$, **$P < .01$.

Table 8. Least squares breed group and type of birth and rearing means for growth traits (males)

Breed group	No.	Birth weight, kg	150-d wt, kg	200-d wt, kg	ADG Birth to 150 d, kg	ADG Birth to 200 d, kg	Slaughter wt, kg	ADG Birth to slaughter, kg	Adjusted slaughter age, d
			**	**	**	**	**	**	
Twin population	292	44.7	196	254	1.005	1.044	584	1.268	439
Reference[a] population	234	45.1	184	240	.929	.975	563	1.221	439
Type of birth and rearing within twin population									
		**	**	**			*		
Singles	212	49.6	199	259	.999	1.054	590	1.271	439
Twins	80	39.9	192	249	1.012	1.044	579	1.264	439

[a]Reference population was 1/2 Simmental, 1/8 Hereford, 1/8 Angus, 1/8 Red Poll, and 1/8 Pinzgauer.
$^*P < .05$, $^{**}P < .01$.

Carcass Traits. Carcass traits of animals from the twinning population relative to the reference population had heavier ($P < .01$) carcass weight, lower ($P < .01$) dressing percentage, higher ($P < .05$) marbling score, lower ($P < .01$) adjusted fat thickness at 12th rib, smaller ($P < .01$) longissimus muscle area, higher ($P < .05$) estimated percentage KPH, higher ($P < .01$) estimated retail product weight, higher ($P < .05$) percentage of carcasses that were USDA Choice or better quality grade, with no difference ($P > .05$) in estimated percentage of retail product. The most unusual result was relatively high marbling score and percentage of USDA Choice or better quality grade carcasses with less adjusted fat at 12th rib in favor of the twinning population. Generally there is a high positive correlation among breed group means for these traits (Gregory et al., 1994).

Thus, animals from the Twinning Project exceeded animals from the reference population in all measures of growth and were generally equal to, or exceeded, the reference population animals in most measures relating to carcass merit (Tables 8 and 9).

Gain Efficiency. Animals in each breed group were fed in three separate pens in each year and slaughtered at three times. Feed consumption was recorded on a pen basis. The regression procedures of Cundiff et al. (1984) were used to estimate gain efficiency to three end points: 1) time constant (228 d); 2) gain constant (255 to 575 kg); and 3) marbling score constant (5.00). The two populations did not differ ($P > .05$) in any measure of gain efficiency (e.g., gain/ Mcal ME, g) (Table 10).

Freemartin and Normal Females

If twinning technology is implemented, almost one fourth of the animals born as twins will be freemartin. In the period from 1989 through 1994, 1,014 sets of twin births were produced, and only 20 females of 463 born twin to males were fertile, i.e., 4.3% were fertile and 95.7% were freemartin. Thus, there was a need to

Table 9. Least squares breed group and type of birth and rearing means for carcass traits (males)

Breed group	No.	Carcass wt, kg	Dressing percentage, %	Marbling score[b]	Adj. fat,[c] cm	REA,[d] cm^2	Est. KPH,[e] %	Est. ret. prod.,[f] %	Est. ret. prod. wt, kg	≥USDA Choice, %
		**	**	*	**	**	*		**	*
Twin population	292	356	60.9	5.44	.63	75.5	3.0	60.2	214.1	75.4
Reference[a] population	234	347	61.6	5.30	.96	78.8	2.9	60.4	209.5	65.3
Type of birth and rearing within twin population		**				**	*		*	
Singles	212	360	61.1	5.46	.63	76.8	3.1	60.1	216.5	75.6
Twins	80	351	60.7	5.43	.63	74.3	3.0	60.3	211.8	75.3

[a]Reference population was 1/2 Simmental, 1/8 Hereford, 1/8 Angus, 1/8 Red Poll, and 1/8 Pinzgauer.
[b]5.00–5.90 = small; 6.00–6.90 = modest.
[c]Adjusted fat thickness at 12th rib.
[d]REA = area of longissimus muscle.
[e]KPH = estimated perirenal fat.
[f]Estimated retail product is based on removal of all subcutaneous and accessible intermuscular fat and all bone from the carcass with lean trim adjusted to 20% fat.
$^*P < .05$, $^{**}P < .01$.

Table 10. Breed group means for different measures of gain efficiency (males)

Trait	Time constant: 228 d		Gain constant: 255 to 575 kg		Marbling score 5.00	
	Twin	Reference[a]	Twin	Reference[a]	Twin	Reference[a]
Initial wt, kg	265	247	255	255	265	247
Final wt, kg	609	578	575	575	544	536
Gain, kg	344	331	320	320	279	288
Days fed	228	228	214	220	184	198
Mcal ME consumed	7,188	6,812	6,482	6,621	5,471	5,650
Est. net energy for maintenance Mcal ME	1,673	1,604	1,510	1,555	1,274	1,339
Gain/Mcal ME, g	48	49	50	48	51	51

[a]Reference population was 1/2 Simmental, 1/8 Hereford, 1/8 Angus, 1/8 Red Poll, and 1/8 Pinzgauer.

evaluate the freemartin effect on growth and carcass traits.

Growth Traits. Results for singles, normal twins, and freemartins are presented in Table 11 for growth traits. Freemartins were significantly heavier than normal twins at birth (37.6 vs. 35.2 kg) but did not differ ($P > .05$) from normal twins for subsequent growth traits. Singles were heavier ($P < .05$) than normal twins and freemartins at birth, 150 d, 368 d (when palpation for ovulation rate started), 573 d (when palpation for ovulation rate ended), and 685 d (slaughter). Singles did not gain significantly faster ($P > .05$) than normal twins or freemartins from birth to slaughter. This is not in agreement with results presented on males on difference between single and twin males from birth to slaughter and is interpreted to result from a longer period between weaning to slaughter reflecting greater compensatory gain in the twins. Approximately one half of the difference in 685-d weight between singles compared with normal twins and with freemartins was accounted for by differences in birth weight.

Carcass Traits. Results for singles, normal twins, and freemartins are presented in Table 12 for carcass traits. Singles had significantly heavier carcasses than normal twins and freemartins, which did not differ ($P > .05$) from each other. Singles had greater ($P < .05$) adjusted fat thickness at 12th rib than freemartins but not significantly greater than normal twins, which did not differ ($P > .05$) from freemartins. Freemartins had significantly higher marbling scores and percentage of carcasses that were USDA Choice or better quality grade than singles and normal twins, which did not differ from each other in either trait. Freemartins had lower ($P < .05$) estimated percentage of retail product than singles and normal twins. This resulted primarily from higher scores for marbling, because marbling score has a negative coefficient in the prediction equation for estimated percentage of retail product. Also, freemartins had smaller ($P < .05$) longissimus muscle areas than singles or normal twins.

Freemartins exhibited development of primary and secondary sex characteristics of intact males to various degrees. Some freemartins had an enlarged clitoris, and at least one had a scrotal pouch below the vulva. Many freemartins had an abnormal amount of hair at the lower part of their vulva of a texture similar to hair on the sheath of intact males. Also, in some freemartins the vulva was further removed from the anus than observed in normal females. In regard to secondary sex characteristics of males, freemartins generally exhibited thickened necks with some crest, and curly hair characteristic of intact males was observed on the head of a few freemartins.

Intact males have lower scores for marbling and thus lower carcass quality grade than castrate males or normal females (Field, 1971). Also, intact males have a higher percentage of retail product and larger longissimus muscle area than castrate males and normal females. The higher scores for marbling and higher carcass quality grades and smaller longissimus muscle area of freemartins than observed in normal females are not in harmony with expectation based on

Table 11. Least squares means for growth traits of freemartin and normal females

Female birth group	n	Birth wt, kg	150-d wt, kg	368-d wt, kg	573-d wt, kg	685-d wt, kg	ADG, birth to slaughter, kg
Single	204	44.6[a]	190[a]	365[a]	455[a]	623[a]	.855[a]
Normal twin	37	35.2[b]	164[b]	335[b]	448[ab]	603[b]	.838[a]
Freemartin	150	37.6[c]	168[b]	340[b]	446[b]	608[b]	.843[a]

[a,b,c]Within a column, values having no superscript letters in common differ at $P < .05$.

Table 12. Least squares means for carcass traits of freemartin and normal females

Female birth group	n	Carcass wt, kg	Adj. fat th.,[d] cm	Marbling score[e]	REA,[f] cm^2	Est. KPH,[g] %	Est. ret. prod,[h] %	Est. ret. prod. wt, kg	≥USDA Choice, %	Yield grade
Single	204	380[a]	.86[a]	5.58[a]	86[a]	3.4[a]	59.3[a]	225[a]	80.2[a]	2.44[a]
Normal twin	37	364[b]	.79[ab]	5.47[a]	86[a]	3.4[a]	59.7[a]	217[b]	76.6[a]	2.17[b]
Freemartin	150	367[b]	.73[b]	6.30[b]	79[b]	3.5[a]	57.9[b]	212[b]	90.6[b]	2.57[a]

[a,b,c]Columns having no superscript letters in common differ at $P < .05$.
[d]Adjusted fat thickness at 12th rib.
[e]5.00–5.90 = small; 6.00–6.90 = modest.
[f]REA = longissimus muscle area.
[g]KPH = estimated perirenal fat.
[h]Estimated retail product is based on removal of all subcutaneous and accessible intermuscular fat and all bone from the carcass with lean trim adjusted to 20% fat.

their development of some primary and secondary sex characteristics of intact males. We are not aware of physiological factors that will explain these phenomena.

Implications

Calf weight produced at 200 d per cow calving can be increased by 58.4% in cows producing twins relative to cows producing singles. However, the requirement for assistance at calving was more than twice as great in twins than in singles (42.2% vs. 20.4%), and calf survival to 200 d was 15.2% greater in singles than in twins. Thus, greater dystocia and lower calf survival are major constraints to twinning technology. Differences between twin and single males in rate of gain, although significant, were small (57 g/d) from birth to slaughter. This population, which has been selected intensively for twinning rate, is equal or superior to a high performance reference population for growth and carcass traits. Thus, twinning technology could be implemented using germplasm from this population without compromise of growth rate or carcass merit.

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