Reproductive, growth, feedlot, and carcass traits of twin vs single births in cattle[1,2]

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ABSTRACT: The frequency of fraternal twin births has increased 3.1% per year to an annual rate of 50 to 55% twins in a selected herd of cattle at the U. S. Meat Animal Research Center. Because twin ovulations are the first prerequisite for fraternal twins, breeding value for twinning was predicted by repeated measures of ovulation rate in all yearling heifers and of twinning rate in selected females. Gestation length was shorter (276.1 vs 283.1 d; $P < 0.01$) and birth weight was lower (37.2 vs 47.2 kg; $P < 0.01$) for twin vs single calves, respectively, but total birth weight (live) was increased 53.1% for twins. Respective weaning weights (200-d weight) were 232 vs 259 kg ($P < 0.01$). Number of calves weaned per cow calving was 0.89 for single, 1.52 for twin births, and 1.80 for triplets ($P < 0.01$); total weaning weight was increased 48.1% for twins and 66.8% for triplets. Single-born male calves gained 74 g more per day than twin-born males from birth to 200 d and 45 g more per day from 200 d to slaughter; males were weaned at an average of 172 d of age and were castrated at 200 d. Differences in carcass traits between twin and single steers were small. Freemartins, 96% of the females born co-twin to a male, did not differ from intact twin females in growth traits, but freemartins had higher ($P < 0.05$) scores for marbling and a greater ($P < 0.05$) percentage of carcasses were USDA Choice or higher quality grade. Efficiency constraints to twin births were increased ($P < 0.01$) incidence of retained placentas (27.9 vs 1.9%), of dystocia (46.9 vs 20.6%), and of perinatal calf mortality (14.1 vs 3.6%); calf survival at 200 d of age was 12.4% less for twin calves. Dystocia of twins resulted primarily from malpresentation of one or both calves at birth. Fertility was reduced 11.6% ($P < 0.01$) after a twin birth and 7.3% ($P < 0.05$) after a retained placenta, but the effect of twinning on fertility varied significantly ($P < 0.01$) among years and seasons. Collectively, twinning increased productivity at weaning by 54.2 kg (or 28.3%) per cow exposed at breeding.

Key Words: Twins, Calf Survival, Dystocia, Productivity, Carcass Quality, Cattle

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Introduction

The development of a cattle population with an annual twinning rate of over 50% fraternal twins presents a new paradigm in beef cattle management and production and affords an opportunity to increase both reproductive and economic efficiency in beef cattle. When the Twinning Project was formalized at the U.S. Meat Animal Research Center (**MARC**) in 1981, twinning rate in cattle ranged from about 0.5% in British beef breeds to 1 to 2% in the Continental breeds and to 4% in some dairy breeds (Rutledge, 1975). However during the past 20 yr, there has been a trend for the frequency of fraternal twins to increase in most cattle breeds (e.g., twinning rates of 10 to 15% in some Holstein herds; Fricke, 2001).

Based on their origin, twin births are classified as fraternal or identical twins. Fraternal, or dizygotic, twins are the most common type of twins. As the term *dizygotic* implies, fraternal twins originate from two separate ova or eggs. Thus, the first prerequisite for a set of fraternal twins is a twin ovulation, which can occur either on the same ovary or one on each ovary. A corpus luteum (**CL**) forms at the ovulation site as the result of luteinization and proliferation of the granulosa and thecal cells that originally lined the ovulatory follicle(s). Thus, ovulation rate can be measured by counting the number of CL present on the ovaries several days after ovulation; CL can be detected in cattle by either rectal palpation, ultrasonography, or laparoscopy of the ovaries. In contrast, identical, or monozygotic, twins

[1]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the same by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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Table 1. Breed composition (%) of the current MARC Twinner herd[a]

	Females		Males	
Breed	Mean	Range	Mean	Range
Pinzgauer	24.1	0–59	24.1	13–31
Holstein	17.7	3–38	19.4	13–28
Simmental	17.1	0–42	22.4	6–33
Swedish Friesian	14.4	0–48	14.4	6–28
Norwegian Red	8.9	0–50	7.2	0–19
Hereford/Angus	8.4	0–22	9.3	5–14
Charolais	4.9	0–31	3.5	0–16
Brown Swiss	1.5	0–25	1.4	0–13
Gelbvieh	1.0	0–11	0.6	0–6
Others	2.3	0–13	0.6	0–3

[a]Means (%) for the herd and ranges of breed composition within individual animals composing the 2001 breeding herd (n = 345 females and 19 males).

result from the dividing or splitting of an embryo during early development (i.e., within 8 to 10 d after conception). Generally, about 10% of the twin births in cattle population are identical twins.

Project History

The primary objective of the MARC Twinning Project was to evaluate the feasibility of increasing twinning rate in cattle through genetic selection. The foundation herd of the project included 307 females, of which 96 were purchased from private herds and 211 females were transferred from other research herds on the Center (Gregory et al., 1990). The primary selection criterion for these cows was that they had produced two or more sets of twins. Breeds of cattle represented in the foundation herd were Holstein, Swedish Friesian, Norwegian Red, Swedish Red and White, and purebred and grade-up Pinzgauer, Simmental, Charolais, and Gelbvieh. The contribution of Hereford and Angus was through grade-up animals. The selection plan was to create a composite population and to limit breed contribution in an animal's pedigree to less than 33%, which was accomplished in progeny born in 1998. Table 1 provides the means and ranges for breed composite of females in the current breeding herd and for 19 bulls born in 1999; 12 of them were evaluated as potential herd sires. The MARC Twinner animals are large-type cattle with medium capacity for milk production and, except for color and color patterns, are relatively uniform in body size and conformation, carcass traits, milk production, and other production traits.

As with many reproductive traits, heritability estimates for twinning in cattle are low (i.e., 0.1; Gregory et al., 1997) and, thus, require obtaining several calving records on every female progeny to assess genetic variation. With the large number of cows required to study twinning, it was both economically and physically impossible to keep all of the female progeny for five or six parturitions. Because the first prerequisite for fraternal twins was twin ovulations, ovulation rate was measured for 8 to 10 consecutive estrous cycles in all female progeny starting at about 12 mo of age as an indirect predictor of the animal's propensity to twin (Echternkamp et al., 1990). Because the frequency of twin ovulations increased, the number of estrous cycles evaluated was reduced to five or six in 1997. This procedure also allowed the identification of potential elite sires based on ovulation rate of their daughters. In 1991, Van Vleck et al. (1991) developed the MTDFREML program to estimate breeding values for twinning. This analysis is a multiple-trait, repeated-records animal model that includes both ovulation rate and twinning rate records in one analysis.

The initial goal of the twinning project was to achieve a twinning rate of 40%. By 1997, progeny had a predicted twinning rate of ≥ 40%. Consequently, herd size was reduced from 750 to 250 calving females.

Twinning Rate

Figure 1 illustrates the change in twinning rate that occurred in the project between 1984 and 2000 for those females born in the project. Twinning rate increased from 4% in 1984 to > 50% in 2000, which was a linear increase of 3.1% per year. Exceptions to the linear increase occurred in 1997 and 1998. The diet of the 1996 fall-calving cows nursing twins was not supplemented with the high-energy, post-calving ration. Consequences were a prolonged postpartum anestrous period in cows nursing twins and a reduction in ovulation rate, which was reflected in a lower twinning rate in the fall herd in 1997. The sharp increase in twinning rate in 1998 resulted from the reduction in herd size from 750 to 250 calving cows by culling females with the lowest breeding values for twinning.

As noted earlier, fraternal twins originate from two separate ova or eggs, which result from the ovulation of two ovarian follicles. Table 2 shows the distribution of ovulations between the left and right ovary for cows having either a single or twin ovulation. In cattle, it is generally accepted that the right ovary is more active than the left and has a higher frequency of ovulations than the theoretical 1:1 ratio of ovulations between the

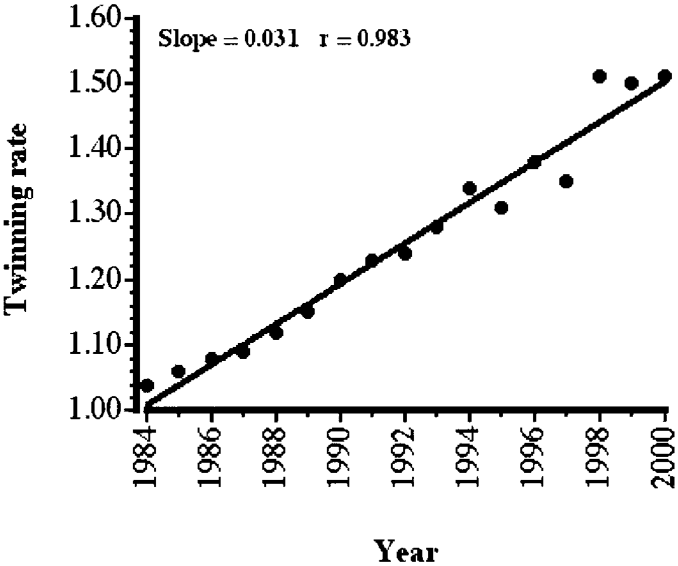

Figure 1. Change in twinning rate from 1984 to 2000 in female progeny.

two ovaries (Echternkamp et al., 1990). The same phenomenon existed in cattle with twin ovulations; the frequency of twin ovulations was also greater on the right ovary (Table 2). Theoretically, 25% of twin ovulations would occur on the left ovary, 25% on the right, and 50% bilaterally; again, the observed distribution differed ($P < 0.05$) from the theoretical.

Fertility

In the first study to evaluate the effect of ovulation rate on embryonic survival and twinning rate (Echternkamp et al., 1990), a portion of the cows in the Twinner herd was laparoscoped 7 to 11 d after AI to determine the number and location of the CL. It was assumed that fertilization was ≥ 98% and, thus, each CL represented a potential embryo. Sixty-eight percent (Table 3) of the single ovulations yielded a calf, whether the single ovulation occurred on the left or right ovary. Embryonic survival was similar or a little lower for twin ovulations (Table 3). With the number of observations in the study, embryonic survival was similar whether the twin ovulations were on the same ovary or involved both ovaries. Also, 48% of the twin ovulations resulted in twin births.

Since 1990, the management procedure has been to determine by ultrasonography the number and location of the fetuses in the uterus and of the CL on the ovaries. The ultrasound examinations were performed transrectally by scanning the uterus and both ovaries with a 3.5-MHz convex-array probe connected to a real-time ultrasound scanner (Aloka 500 V, Corometrics Medical Systems, Wallingford, CT). Examination of the uterus between d 35 and 75 of gestation yielded the highest accuracy for determination of fetal number; twin fetuses were easily missed before d 35 and some uteri were too large for a complete scan after d 80 of gestation. Thus, the first ultrasound examination was conducted approximately 75 d after the first day of the breeding season. Females < 35 d of gestation or nonpregnant at the first examination were re-examined about 35 d later. The rationale for determining the number of fetuses was to provide cows gestating twins with a higher plane of nutrition and increased obstetrical care before and during calving because rumen capacity is compromised and dystocia is increased with a twin pregnancy.

About 10 wk before the projected beginning of the calving season, cows gestating twins were sorted off and fed a corn silage-alfalfa haylage diet at a rate to provide about 38 Mcal of ME·animal^{-1}·d^{-1} vs 28 Mcal for cows gestating a single. The nutritional goal was to achieve a body condition score of 6 or 7 on a 9-score scale. Likewise, cows gestating twins were observed more frequently and rendered obstetrical assistance quicker during calving; cows gestating twins have less overt signs of labor, or labor subsides before expulsion of the calves, in comparison to cows birthing a single. Such dystocia may result from the extra fetal weight of twins, which causes fatigue of the uterine musculature before parturition is completed.

After calving, the cows were grouped by whether they were nursing one or two calves. For triplets, one calf was grafted to another cow. Cows nursing twins were fed a supplemented corn silage-corn diet to provide about 58 Mcal·animal^{-1}·d^{-1} until the beginning of the breeding season, when the cows were allotted to breeding pastures and fed to nutritional need. Females nursing a single calf were fed about 31 Mcal·animal^{-1}·d^{-1} after calving. To better utilize human and production

Table 2. Distribution (%) of ovulations between the left and right ovary in cattle[a]

	Type of ovulation			
	Single[b]		Twin[c]	
Location	n	%	n	%
Left ovary	716	45.0	299	19.5
Right ovary	877	55.0	562	36.4
Bilateral	—	—	681	44.1

[a]Data collected from 1994 to 2000 and analyzed by chi-square analysis.
[b]Distribution of single ovulations between ovaries differs ($P < 0.05$) from the theoretical ratio of 1:1.
[c]Distribution differs ($P < 0.05$) from the theoretical ratio of 1:1:2.

Table 3. Effect of ovulation rate on embryonic survival[a]

	Type of ovulation[b]			
	Single		Twin	
Location	n[c]	%[d]	n[c]	%[d]
Left ovary	205	68.0	57	56.0
Right ovary	114	68.0	35	67.0
Bilateral	—	—	63	62.0

[a]Data from Echternkamp et al. (1990).
[b]Ovulation rate was determined by laparoscopy on d 7 to 11 after AI.
[c]Number of cows.
[d]Ratio of number of calves born to number of corpora lutea and expressed as a percentage.

resources and to reduce the calving interval in dams suckling twins, the MARC Twinner herd has two breeding seasons. The 70-d spring-breeding period lasts from late May to early August, and the 60-d fall period from late October to late December.

Ovulation data reported in Table 4 were collected at the two ultrasound examinations described above. Fertility was based on calving results rather than first trimester pregnancy diagnosis. Percentage of females that calved after a single ovulation (Table 4) was the same whether the ovulation was on the left or right ovary. Calving rates (conception) reported in Table 4 were the accumulative total for the breeding season and, thus, conception was greater than for one AI in the previous study (Table 3; Echternkamp et al., 1990).

As noted previously (Echternkamp et al., 1990), about one-half of the twin ovulations produced a twin birth (Table 4). However, in this comparison, twinning rate was greater ($P < 0.01$) when the twin fetuses were located in separate uterine horns compared with both fetuses in the same horn. Conversely, the incidence of single births was reduced ($P < 0.01$) when the twin ovulation was bilateral. The percentage of nonpregnant females was the same for all three groups. Because the percentage of nonpregnant females did not differ between bilateral and unilateral twin ovulations, speculation is that fertilization rate was decreased and(or) early embryonic mortality (i.e., before placental anastomosis between twins) was increased with unilateral twin ovulations rather than increased abortions from uterine crowding. Although the placenta will grow into and attach in the contralateral uterine horn, migration of bovine embryos between uterine horns is rare (Scanlon, 1972; Echternkamp, 1992). Presumably, the local embryonic regulation of the uterine luteolytic factor has prompted natural selection against embryo migration in monotonous cattle. The detection of an embryo in the uterine horn contralateral to a single ovulation is very rare in either cattle or sheep (Scanlon, 1972). The number of triplet ovulations has also increased in the Twinner herd, but only a small percentage of the triplet ovulations (Table 4) produced triplet births. A significant percentage of the triplets were aborted during gestation, especially when all three were in the same uterine horn.

Fetal Survival

A unique characteristic of multiple fetuses in cattle is the fusion or anastomosis of the chorionic blood vessels

Table 4. Effect of number and location of ovulations on fertility

Corpora lutea no. and location[a]	n[b]	Type of birth[c]			
		Nonpregnant, %	Single, %	Twin, %	Triplet, %
Single ovulation					
Left ovary	697	15.1	84.9	—	—
Right ovary	849	17.2	82.8	—	—
Twin ovulation					
Left ovary	298	16.8	27.9	55.4	—
Right ovary	594	19.4	27.0	53.6	—
Bilateral	674	17.8	20.9*	61.3*	—
Triple ovulation					
Same ovary	23	52.2	0.0	34.8	13.0
Bilateral	85	31.8	14.1	29.4	24.7

[a]Ovulation rate category and location were determined by ultrasonography at 75 and 110 d after the beginning of the breeding period.
[b]Number of females.
[c]Distribution (%) of females within an ovulatory location (row) by type of birth (yr 1994 to 2000).
*Means differ within an ovulation rate category ($P < 0.05$).

Table 5. Comparisons between fetal number and subsequent type of birth

Fetal diagnosis[a]	n[b]	Type of birth[c]			
		Nonpregnant, %	Single, %	Twin, %	Triplet, %
Single	890	6.0	92.2	1.8	—
Twin	583	12.2	4.6	81.8	1.4
Triplet	28	50.0	3.6	14.3	32.1

[a]Number of fetuses was determined by ultrasonography between d 35 and 75 of gestation.
[b]Number of diagnosed pregnancies.
[c]Distribution (%) of births within a fetal category (yr 1994 to 2000).

between fetuses so that fetuses share a common blood supply (Echternkamp, 1992). Chorionic membranes may fuse between fetuses in sheep and swine, but rarely do the blood vessels anastomose (Hunter, 1995). Fusion of the chorionic blood vessels between fetuses has two major consequences: 1) freemartin syndrome and 2) increased fetal mortality. Fusion of the placenta between fetuses occurs at about d 35 of gestation, which is several days before sexual differentiation of bovine fetuses (Jost et al., 1973). Also, sexual differentiation occurs several days earlier in male than in female fetuses. Thus, when the twin fetuses are of different sex, anti-Mullerian hormone from the developing male gonad is transported to the female fetus via the common blood supply and suppresses development of the Mullerian duct system in the female (Vigier et al., 1984); the Mullerian duct system is the precursor of the female reproductive tract. The consequence is a genetic female with very small, undifferentiated gonads and cords of connective tissue instead of a uterus, cervix, and an anterior vagina (see review by Echternkamp, 1998). Because the exterior vagina originates from the urinary system, most freemartins have a short exterior vagina. Over 95% of the females born co-twin to a male are a freemartin and, thus, sterile (Gregory et al., 1996).

The second consequence of placental fusion is increased fetal mortality. When one fetus in a placental unit dies, the other fetus(es) dies also (Echternkamp, 1992). At each ultrasound pregnancy diagnosis, two or three of the approximately 50 twin pregnancies were composed of a live and a dead fetus; all of these cows were nonpregnant when rediagnosed 30 to 40 d later. Also, the incidence of a single-born freemartin female calf has been very rare, further suggesting that when one twin fetus dies both fetuses die.

Table 5 summarizes the relationship between the number of fetuses diagnosed by ultrasonography between d 35 and 75 of gestation (left column) and the resulting type of birth. Of the cows diagnosed with a single fetus, 6.0% aborted before calving, 92.2% produced a single, and a few (1.8%) cows were diagnosed incorrectly and yielded a twin birth. Twice the percentage of cows with twin vs single fetuses (i.e., 12.2 vs 6.0%) aborted during gestation, 4.6% gave birth to a single (possibly diagnostic errors), and 81.8% gave birth to twins. Several females were diagnosed incorrectly and birthed triplets. Embryonic (fetal) mortality was significantly increased with triplet fetuses. Of the cows diagnosed with triplets, 50.0% aborted during gestation, 14.3% produced twins, and 32.1% produced triplet calves.

Gestation Length

Figure 2 illustrates the distribution of gestation lengths for cows gestating twins vs a single calf. The protocol was to record births if the calf was totally developed and covered with hair. The mean for gestation length was 7.6 d shorter for cows gestating twins compared with a single, but the distribution pattern was similar between the two groups.

Retained Placenta

A frequent consequence of twinning in cattle is an increased incidence of retention of placental membranes after a twin birth (Pfau et al., 1948; Turman et al., 1971; Bellows et al., 1974). The incidence of placental retention was further increased after a twin birth with dystocia (type of birth × dystocia, $P < 0.01$; Table 6). Premature induction of parturition in cattle increased the incidence of placental retention (Echternkamp et al., 1987). Gestation length was about a week

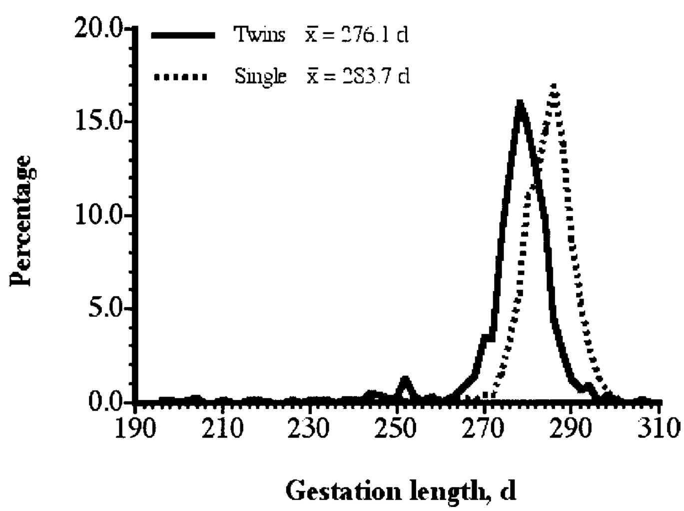

Figure 2. Distribution of gestation lengths for single and twin births. Data from Echternkamp and Gregory (1999).

Table 6. Incidence of retained placenta[a]

Variable	n[b]	%[c]
Type of birth ($P < 0.01$)		
Single	3,370	1.9
Twin	1,014	27.9
Type of birth × dystocia ($P < 0.01$)		
Single without dystocia	2,630	1.7
Single with dystocia	740	2.5
Twin without dystocia	528	23.7
Twin with dystocia	486	32.7

[a]Data from Echternkamp and Gregory (1999).
[b]Number of parturitions.
[c]Means for percentage of parturitions with a retained placenta.

shorter for twin births (Figure 2), which may account for the increased incidence of retained placenta with twins. A statistically significant relationship was not found between gestation length and incidence of retained placenta among 672 twin births in the MARC herd (Table 7); however, gestation length only ranged from 270 to 284 d for the majority of the dams (i.e., 80.3%). Also, the increase ($P < 0.01$) in placental retention associated with malpresentation dystocia (Table 7) was substantially greater than the effect of gestation length. In addition to increasing labor and veterinary costs, retention of placental membranes also reduced subsequent conception rates 7 to 8% after either a single or twin birth (Table 8).

Dystocia

The incidence of dystocia was greater ($P < 0.01$) with twin births and differed in cause between single and twin births (Table 8). The MARC Twinner cattle are large-type cattle and produce calves with heavy birth weights (Gregory et al., 1996); thus, 17.7% of the single births required traction (Table 8). In contrast, the smaller twin calves had a lower ($P < 0.01$) incidence of births requiring traction (11.1%) but a higher ($P < 0.01$) incidence (38.6 vs 4.5%) of malpresentations due to abnormal positioning of one or both calves in the birth canal (Table 8). As reported previously (Bellows et al., 1971), major consequences of dystocia were reduced calf survival (Table 9) and fertility (type of birth × dystocia, $P < 0.01$; Table 8). Malpresentation of a twin calf at parturition further reduced its survival at birth compared with traction only (Table 9). Also, the incidence of malpresentation was less (32.9 vs 46.7% for bilateral vs unilateral twins) and calf survival was increased (Table 10) when the twins were gestated in separate uterine horns. Dystocia with a twin birth (i.e., compared with no dystocia) did not affect ($P > 0.10$) subsequent fertility (Table 8).

Table 7. Effect of gestation length and dystocia on incidence of retained placenta (twin pregnancies)[a]

Variable	n[b]	%[c]
Gestation length, d		
≤ 264	40	52.5
265–269	23	43.5
270–274	97	26.8
275–279	247	26.7
280–284	196	24.5
285–289	51	37.5
≥ 290	18	38.8
Dystocia[d] ($P < 0.01$)		
No assistance	352	28.9
Traction	63	24.1
Malpresentation	104	45.9
Malpresentation with traction	153	42.1

[a]Data from Echternkamp and Gregory (1999).
[b]Number of parturitions.
[c]Means for percentage of parturition with a retained placenta.
[d]Classifications of dystocia were: no assistance, dystocia requiring traction assistance, malpresentation of calf within the birth canal, or malpresentation followed by traction.

Calf Survival

Table 9 illustrates differences in survival among single-, twin-, and triplet-born calves at birth, at 72 h after birth, and at 200 d of age. Essentially all of the differences in calf survival among the three types of birth occurred at or within a few hours after birth; mortality rates from birth to 72 h and from 72 h to 200 d were similar among the three birth groups. Dystocia significantly reduced perinatal calf survival, especially for twins (type of birth × dystocia, $P < 0.01$; Table 9). Age of dam did not affect calf survival but preliminary observations indicate that first-parity heifers may have difficulty gestating triplets to term. Table 10 illustrates the effect of uterine location on calf birth weight and survival. Of particular interest in this comparison was the increased ($P < 0.01$) calf weight and survival at birth when the twins were located in separate uterine horns. A possible contributing factor to the increased survival of bilateral twins was the lower ($P < 0.01$) incidence of fetal malpresentations for bilateral twins (32.9%) compared with unilateral twins (46.7%).

Body Weight, ADG, and Carcass Traits: Steers

A comparison of growth traits (Table 11) between single- and twin-born male calves revealed that the

Table 8. Effect of type of birth, retained placenta, and dystocia on fertility

Variable	n	%[a]
Retained placenta (RP; $P < 0.05$)		
Single birth[b]		
Without RP	1,716	83.0*
With RP	39	76.1
Twin birth[c]		
Without RP	694	75.2*
With RP	275	67.9
Type of birth × dystocia ($P < 0.01$)		
Single birth		
No assistance	1,365 (77.8)[d]	84.8**
Traction	311 (17.7)[d]	77.2
Malpresentation[e]	79 (4.5)[d]	76.1
Twin birth		
No assistance	487 (50.3)[d]	73.1
Traction	108 (11.1)[d]	78.7
Malpresentation[e]	374 (38.6)[d]	70.9

[a]Percentage of dams subsequently calving.
[b,c]Superscripts denote an effect of type of birth on fertility ($P = 0.06$).
[d]Distribution (%) of dystocia in parenthesis.
[e]Malpresentation with and without traction.
*,**Means differ within type of birth; *$P < 0.05$, **$P < 0.01$.

twin calves were about 20% lighter ($P < 0.01$) at birth and about 10% lighter ($P < 0.01$) at weaning (Gregory et al., 1996). Not only were the twin calves lighter ($P < 0.01$), but they were also 3 wk older ($P < 0.01$) at slaughter. The males were weaned at 172 d of age, castrated at 200 d of age, and fed a diet of 2.69 Mcal of ME/kg of DM and 12.88% CP until an average BW of 276 kg, then a diet of 3.12 Mcal ME and 11.50% CP until slaughter. Likewise, the larger single-born calves had greater ($P < 0.01$) ADG both before (1.08 vs 1.01 kg/d) and after weaning (1.44 vs 1.39 kg/d) compared with twins, presumably reflecting both pre- and postnatal maternal effects on calf growth.

Table 11 also provides a comparison of carcass traits between the single- and twin-born steers. The heavier slaughter weight of the singles was reflected in a heavier ($P < 0.01$) carcass weight. Dressing percentage and estimated subcutaneous and perirenal fat (**KPH**) mea-

Table 9. Effect of type of birth and of dystocia on calf survival (%)[a]

		Age of calf		
Variable	n[b]	Birth	72 h	200 d
Type of birth ($P < 0.01$)				
Single	2,045	96.4	94.2	88.6
Twin	2,274	85.9	83.0	76.2
Triplet	123	71.5	66.7	60.2
Type of birth × dystocia[c] ($P < 0.01$)				
Single birth				
No assistance	1,581	98.0	96.9	91.9
Traction	369	93.5	88.1	80.2
Malpresentation	11	54.5	36.4	36.4
Malpresentation with traction	84	84.5	78.6	69.0
Twin birth				
No assistance	1,104	90.8	88.2	80.8
Traction	270	88.9	85.6	78.9
Malpresentation	358	84.4	81.0	76.3
Malpresentation with traction	542	75.5	72.3	65.5
Triplet birth				
No assistance	48	79.2	72.9	66.7
Traction	—	—	—	—
Malpresentation	42	64.3	59.5	54.8
Malpresentation with traction	33	69.7	66.7	57.6

[a]Percentage of calves alive at birth, 72 h, and 200 d of age.
[b]Number of calves born.
[c]Classifications of dystocia were: no assistance, dystocia requiring traction assistance, malpresentation of calf within the birth canal, or malpresentation followed by traction.

Table 10. Effect of fetal location in utero on calf weight and survival at birth

	Type of birth					
	Single			Twin		
Location[a]	n[b]	Birth wt, kg	Survival, %	n[b]	Birth wt, kg	Survival, %
Left horn	603	47.4	96.9	346	36.7	80.6[c]
Right horn	728	47.1	96.8	616	36.2	81.5[c]
Bilateral	—	—	—	862	37.9	92.2[d]

[a]Location of pregnancy in uterus.
[b]Number of calves born.
[c,d]Within a column, means without a common superscript letter differ ($P < 0.01$).

surements were similar ($P > 0.10$) for the two birth groups. Marbling in the longissimus muscle was small to modest and was increased ($P < 0.05$) in the older twin carcass. Conversely, area of the longissimus muscle (**REA**) was smaller ($P < 0.05$) for the carcass of the twin vs single steers; thus, the estimated weight of retail product was also less ($P < 0.05$) for the twin carcass. Because of the increased marbling, 6% more ($P < 0.05$) of the twin carcasses had a USDA grade of Choice or above. Hallford et al. (1976) also found higher marbling scores, as well as perirenal fat, in carcasses of the older multiple-birth beef steers compared with single-birth steers, but, because of small numbers of observations, differences in carcass traits between single and multiple births were not statistically different. The increased marbling in twin steers may have resulted from twins being fed the high-energy diet 3 wk longer and(or) from twins being less mature with less testicular growth and androgen production prior to castration. In general, carcasses from the MARC Twinner population are yield grades 1 or 2 and ≥ 75% are USDA grade Choice or above.

Body Weight, ADG, and Carcass Traits: Females

A similar comparison of growth traits (Table 12) was conducted among single- and twin-born intact females and freemartin females (Gregory et al., 1996). The intact heifers were culled from the herd because of a low incidence of twin ovulations. After weaning at an average of 172 d of age, the heifers were fed a growing ration until about 12 mo of age. Animals were fed a maintenance diet during the 6 mo of ovulation rate evaluation followed by a finishing diet until slaughter. The freemartins were housed in the same pens with the intact heifers throughout their life. As with the steers, single-born females were heavier ($P \le 0.05$) at birth than twin-born females, and freemartins were heavier ($P \le 0.05$) than intact twin females. Singles were also heavier ($P < 0.05$) than twins at 150 d of age and continued to be heavier ($P < 0.05$) as yearlings and at slaughter.

A comparison of carcass traits among the three groups of females is reported in Table 12. Again, the heavier single-born females had a heavier ($P < 0.05$)

Table 11. Least squares means for growth and carcass traits of singles and twins (steers)[a]

	Type of birth		
Trait	Single	Twin	P-value
Number of steers	808	273	—
Birth wt, kg	48.2	38.4	0.01
200-d wt, kg	264	240	0.01
Slaughter age, d	448	468	0.01
Slaughter wt, kg	600	589	0.01
Carcass wt, kg	365	358	0.01
Dressing percentage, %	60.9	60.8	ns
Fat thickness, cm[b]	0.62	0.62	ns
Est. KPH, %[c]	3.1	3.1	ns
Marbling score[d]	5.30	5.41	0.05
REA, cm^2 [e]	77.9	76.6	0.05
Est. retail prod., kg[f]	221	216	0.01
≥ USDA Choice, %	70.2	76.2	0.01

[a]Males castrated at 200 d of age. Data from Gregory et al. (1996).
[b]Adjusted fat thickness at 12th rib.
[c]KPH = estimated perirenal fat.
[d]5.00 to 5.90 = small.
[e]REA = area of longissimus muscle.
[f]Estimated retail product adjusted to 20% fat.

Table 12. Least squares means for growth and carcass traits of intact and freemartin females[a]

Trait	Type of birth: Single	Twin	Freemartin
Number of animals	808	37	150
Birth wt, kg	44.6[g]	35.2[h]	37.6[i]
150-d wt, kg	190[g]	164[h]	168[h]
368-d wt, kg	365[g]	335[h]	340[h]
Slaughter wt, kg	623[g]	603[h]	608[h]
Carcass wt, kg	365[g]	358[h]	367[h]
REA, cm^2 [b]	86[g]	86[g]	79[h]
Marbling score[c]	5.58[g]	5.47[g]	6.30[h]
Fat thickness, cm[d]	0.86[g]	0.79[gh]	0.73[h]
Est. KPH, %[e]	3.4	3.4	3.5
Est. retail prod., kg[f]	225[g]	217[h]	212[h]
≥ USDA Choice, %	80.2[g]	76.6[g]	90.6[h]

[a]Data from Gregory et al. (1996).
[b]REA = area of longissimus muscle.
[c]5.00 to 5.90 = small; 6.00 to 6.90 = modest.
[d]Adjusted fat thickness at 12th rib.
[e]KPH = estimated perirenal fat.
[f]Estimated retail product adjust to 20% fat.
[g,h,i]Within a row, means without a common superscript letter differ ($P < 0.05$).

carcass than twins at slaughter. The REA of freemartin carcasses was consistently smaller ($P < 0.05$) compared with those of the intact females; REA did not differ ($P > 0.10$) between intact single- and twin-born heifers. The longissimus muscle of the freemartin had noticeably more ($P < 0.05$) marbling, but subcutaneous fat thickness over the 12th rib was less ($P < 0.05$) for freemartin carcasses than for the single-born carcasses. The gonads of most freemartins are very small, undifferentiated, and nonfunctional; gonads from 28 of 34 freemartins weighed ≤ 0.5 g per pair at 15 mo of age (Echternkamp et al., 1997). Estradiol was nondetectable in the blood of these 15-mo-old freemartins, but serum testosterone concentrations were similar between freemartin and intact females (0.21 ng/mL) and greater ($P = 0.09$) than for steers (0.14 ng/mL). Absence of the anabolic and metabolic effects of the gonadal steroids on muscle development and fat deposition was evident in the carcass of the freemartin. Similar differences have been observed in comparisons between carcasses of intact and castrated animals. Estimated percentage of perirenal fat was similar ($P > 0.10$) for the three groups. Again, the smaller twin carcass yielded less ($P < 0.05$) estimated retail product. Increased marbling in the longissimus muscle of the freemartin resulted in a high percentage ($P < 0.05$) of the freemartin carcasses being USDA Choice or above. Hallford et al. (1976) found no difference in carcass characteristics between single- and multiple-birth heifers when slaughtered at a similar BW, but the younger single heifers tended to have more lean and less fat.

Cow Productivity

A summary of the effect of single, twin, and triplet births on cow productivity is provided in Table 13. Included in the comparison were means for total birth weight, number of calves weaned, and total weaning weight. Total weaning weight was the total calf weight weaned per cow calving; dams not weaning a calf were recorded as 0 kg. Grafted calves (e.g., triplets) were credited to their biological dam. Total birth weight was 57.3% greater for a set of twins and 92.1% greater for a set of triplets compared with a single birth. Although twinning reduced calf survival, dams producing a twin birth weaned 70.8% more calves than dams with a single birth, which resulted in a 48.1% increase in total weaning weight (335.7 vs 226.6 kg). Dams producing a triplet birth weaned twice as many calves (102.2%) as dams with a single birth for a 66.8% increase in total kilograms of calf weaned. However, because of the increased mortality of triplets, the increase in weaning

Table 13. Effect of type of birth on total calf weight produced per cow calving

Type of birth	n	Birth wt, kg	200-d wt, kg	No. weaned
Single	2,045	47.1[a]	226.6[a]	0.89[a]
Twin	1,137	74.1[b]	335.7[b]	1.52[b]
Triplet	41	90.5[c]	377.9[c]	1.80[c]

[a,b,c]Within a column, means without a common superscript letter differ ($P < 0.01$).

weight of triplets over twins was relatively small (i.e., 12.5%). Using results from experimentation and production systems simulation, Guerra-Martinez et al. (1990) estimated that twinning increased the efficiency of producing beef 24%. An economic assessment of twinning in beef cattle has not been conducted for the MARC Twinner herd.

Implications

Collectively, these results indicate that a twinning technology can increase productivity of beef cattle. However, the final assessment of the potential benefit of twinning awaits an economic assessment of twin production in cattle. Because the Twinner animals are managed with other research herds at the Center, accurate data on actual labor, feed, and overhead costs of the Twinner animals have not been collected. In contrast, the increased fetal and calf mortality for a triplet pregnancy questions the potential application of triplet births in cattle.

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