J. BIOL. ENVIRON. SCI.,
2010, 4(10), 1-8

# Twinning in Cattle: Desirable or Undesirable?

**Özden Çobanoğlu***
Namık Kemal University, Faculty of Arts and Sciences, Department of Biology, 59030 Tekirdag, Turkey.

## ABSTRACT

**Twin calving in dairy cow production is an avoidable reproductive event. Twinning may have not only positive but definitely negative effects on cow-calf production system. Because of several detrimental effects related with this incidence, cow producers are mostly against to twin birth in dairy herds. On the other hands, having twin calves may enhance production efficiency if an appropriate nutrition and management system can be operated in beef cattle herds. Therefore, the purpose of this review is to discuss and summarize the effect of twinning on reproduction and production system for dairy and beef industries. Finally, it will give an idea whether twin calving is desirable or undesirable characteristic.**

**Key Words: Twinning, cow performance, reproduction, detrimental effects.**

## INTRODUCTION

*Bos taurus* is a uniparous species, which means that females give birth to one offspring in most cases. On the other hand, the natural incidence of multiple births in cattle is largely due to multiple ovulations and is around 1-5%, depending on breed, parity and environmental conditions (Sreenan and Diskin, 1989). There have been many studies conducted with regard to regulating multiple birth rates in cattle by selecting genetically favorable animals (Gregory et al., 1990a), utilizing hormonal treatments (Turman et al., 1971; McCaughe and Dow, 1977), or utilizing embryo transfer techniques (Anderson et al., 1979; Davis et al. 1989).

Monozygotic twins are genetically and physically identical since they are formed from one fertilized egg, which splits into two identical halves during early embryonic developmental stages. Thereby both individuals are always the same sex. However, monozygous births are biologically a unique phenomenon, which occurs for about 2 -10% of all liked sexed twins in cattle (Hancock, 1954).

In the case of dizygotic or fraternal twins, two different sperm fertilize two completely different ova at the same time. Thus the successful result of ovulation and fertilization of two oocytes will be dizygotic twins. Dizygotic twins are not identical genetically or phenotypically as monozygotic twins are. They are not necessarily the same sex as opposed to monozygotic twins. They can be also as similar or different as any two siblings born from the same parents during different gestations.

Twin birth is an unavoidable issue in dairy and beef cattle production systems since several factors such as breed, genetics, parity, and some other environmental effects greatly influence twinning rate of the cow. Thus twin calving causes to lessen overall cow reproductive efficiency, productivity and thus the profitability of enterprises. In this review, the effects of twin birth were discussed in detail under the various topics that follow.

### *Breeding Efficiency*

Several studies have documented the effect of multiple births on the productive and reproductive performance of cows. Multiple births reduce the reproductive efficiency of cows by increasing difficulties during the pregnancy and calving periods (Erb and Morrison, 1959). A study with Holstein-Friesian herds showed that 46% of twin-bearing cows were able to reproduce subsequently. However, 12.8% and 7.7% of them became infertile or were dead due to problems related with twinning, respectively (Pfau et al., 1948). Conception rates have been realized to be generally lower after multiple births. Percentage of inseminations resulting in pregnancy was used to calculate conception rates by Pfau et al. (1948) who reported 3.23 more service per conception after calving twins. Likewise, a reduced subsequent conception rate among twin-bearing cows has been noticed in Canadian dairy cows (Kay, 1978), Dutch Holsteins (Nielen et al., 1989), and *the U.S. Meat Animal Research Center* (MARC) twinner herd (Gregory et al., 1990b).

Twin calving also negatively affects the number of days between one calving to the next and subsequent calving to conception. After twin birthing, it was noted that the calving interval increased 2 to 3 weeks more, compared to single calving (Erb and Morrison, 1959). According to Johansson et al. (1974), since twin calving causes more complications during and after pregnancy; subsequent calving interval increased

* Corresponding author: cobanog@yahoo.com

significantly in Swedish breeds. The time length between parturition and conception was longer after twinning, but the difference was not significant between twin and single births in a report published by Kay (1978). On the other hand, he reported that the time interval from parturition to first service was 128 and 113 days for cows having twins and cows having singles, respectively. The twin bearing cows had more days open than their single bearing counterparts. This period was calculated to be longer by 11 days by Syrstad (1974), 12 days by Nielen et al. (1989), and even 22 days by Chapin and Van Vleck (1980) for twin-bearing cows, relative to the single contemporaries. Twin-gestating cows increased this period from parturition to first estrus by 9.2 days in Holstein cows (Mellado and Reyes, 1994) and 12.7 days in MARC twinner herd (Echternkamp and Gregory, 1999b). Moreover, the interval from calving to conception were detected to be 5.7 days (Echternkamp and Gregory, 1999b), 10 days (Gregory et al., 1990b), 11.8 days (Nielen et al., 1989), 21.3 days (Mellado and Reyes, 1994), and 33 days (Eddy et al., 1991) longer after birth of twins in these studies, respectively. However, Kinsel et al. (1998) demonstrated 6-day shorter interval in case of twin-bearing cows in some North American dairy farms.

According to Nielen et al. (1989) not only breeding programs but also culling strategies might influence the variables affecting reproductive efficiency. All of these negative effects of multiple births eventually reduce the productive life of animals that have twinned. Therefore these cows are more often culled from the herds. Hendy and Bowman (1970) thought that if cows were healthy and fed and managed well, the negative effects of twinning on the efficiency of cows would not be seen too much. However, in reality it is not easy to keep cows in good condition. Johansson et al. (1974) stated that risk factors in reproduction and inappropriate selection programs cause an increased culling rate among twin-calving cows. In many studies the culling rate of the herds were given but the reasons of these actions were not discussed in details. However, according to Nielen et al. (1989) most of the time cows calving twins were excluded from the herd due to impaired fertility problems. On the other hand, the common reasons for culling the single-bearing cows were mostly low milk yield, rather than fertility issues. Percentages of culled individuals were 38% and 23.9% for twin and single-bearing cows, respectively. In a recent study conducted in Egypt, a culling rate was reported 61.53% for twin calving cows versus 30.73% for single bearing (Mostafa, 2009b).

Additionally, twinning causes reduced numbers of available heifers for use as replacements in dairy herds. Many researchers calculated a number of replacement heifers for both twin-bearing and single-bearing cows (Nielen et al., 1989; Day et al., 1995). The estimates were 0.42 versus 0.48 for the replacement heifers per pregnancy in the case of all twin births versus all single births, respectively (Nielen et al., 1989). However, Day et al. (1995) predicted 0.29 replacement heifers for all twin births in comparison to 0.42 for all single births.

***Gestation Length***

Gestation length is the total developmental period of offspring from fertilization to birth in livestock species. Hendy and Bowman (1970) have reviewed previous studies and reported that gestation length of cows calving twins ranged from 272.7 to 277.4 days which was 1.5 to 10 day shorter than that of single-carrying cows, depending on breed differences. In another study, Kay (1978) has examined 5200 calving records and reported a significantly lower gestation length in cows having twins (276 days), relative to 282 days of gestation in single calving cows.

Similarly, a study with various dairy cows has demonstrated that the gestation period was shorter by 5.2 days for twin-carrying cows than cows bearing singles (279 days; Cady and Van Vleck, 1978). A similar gestation period was found in a Dutch Holstein twin calving study when abortion records were excluded from analysis. Single calving cows had 5.7 day longer gestation; however, if abortions were added into the study, gestation length of singles was 9.9 days longer than that of twins (Nielen et al., 1989). Foote (1981) reviewed the gestation period in dairy cows as well as factors that influence it. He suggested that several factors such as breed differences, twinning, parity and calf sex cause variation in gestation length. Moreover, Penny et al. (1995) calculated that the median gestation period in twin-bearing animals was 10 day shorter than in single-carrying ones. In a study of over 5300 cows from 14 farms in the USA, significant differences in gestation length were observed between single pregnancies (278 days) and twin pregnancies (272 days; Day et al., 1995). Similarly reduced gestation lengths due to twinning were reported by de Rose and Wilton (1991) in a study of beef cattle experimental herds in Canada. In Saudi Arabia, Holstein-Friesian cows having twins have been found to have shorter gestation period (8.5 days), compared to their single-bearing counterparts. The mean gestation length was 269 day for twinners (Ryan and Boland, 1991).

Eddy et al. (1991) demonstrated that cows bearing twins tended to have a short gestation period (8 days), relative to single-carrying cows. Guerra-Martinez et al. (1990), studying beef cattle, also reported a shorter

gestation period by 3 day for twin gestating cows. The same year, another report was given from a long-term project at MARC (Gregory et al., 1990a). They found that cows birthing twins had 7-day shorter gestation lengths than cows having singles. In a follow up study, Echternkamp and Gregory (1999a) observed a significantly shortened gestation length for twin pregnancies (275.6 day), comparing the 281.3-day of gestation period for single calving cows. They also suggested that a gestation period possibly affects the tendency of retained placenta in case of twin calving (27.9% for twins versus 1.9% for singles. Similarly, in a recent publication based on an additional 5 years of data the twin calving cows had 7.6 day shorter gestation length than single calving cows; However, no differences have been detected between two groups of cows in terms of a distribution of gestation period (Echternkamp and Gregory, 2002).

***Retained Placenta***

Retained placenta occurs if all parts of placenta are not completely delivered in the uterus during the parturition. There are several reports that indicated an increase in the occurrences of retained placenta with multiple pregnancies. Retention of placenta after birth and chronic genital organ disease were observed noticeably with multiple births of cows (Johansson et al., 1974). Pfau et al. (1948) emphasized that cows with twins had more tendency to have retained fetal membrane and had also subsequent lower conception rates.

Sex differences also appeared to have an effect on retained placenta. Cows had retained placenta 73.3%, with male twin calving, 42.1% with mixed twin calving and 20.0% with female twin calving. A cause of the difference might be the heavier birth weight of male offspring (Johansson et al., 1974).

Many factors including abortion, disease, dystocia, twin birth, nutrition and gestation length, influence the tendency of retention of placenta according to Erb and Morrison (1959). Likewise, Bendixen et al. (1987) proposed that the incidence of retained placenta was increased by factors like twinning and the incidence of dystocia. According to Foote (1981), calving with retained placenta was greater when twins were born and was subsequently associated with decreased conception rates. As the risk of retained placenta increased in cows calving twins, they had more possibility of shorter gestation length as well as delayed uterine recovery. Israeli Holstein cows with twins experienced higher risk of retained placenta (17.8%), ranging with 15.1 to 23.3%, depending of the cows (Markusfeld, 1987). From a study in Dutch dairy farms, Nielen et al. (1989) observed 34.6% of twin-bearing dams versus 16.2% of single calving cows had retained placenta after giving birth. A study with Holstein cows in Mexico also demonstrated a higher rate of retained placenta in cows having twins (Mellado and Reyes, 1994). A big unfavorable effect of twinning on retained placenta, 62%, incidence compared with 3% in the case of cows bearing a single calf has also been observed by Penny et al. (1995) in a study of Scottish Hereford-Holstein Friesian cross herds. A study with beef cattle reported that the incidence of retained placenta was higher for not only heifers bearing twins (35%) but also cows calving twins (24%) compared with single bearing heifers (12%) and cows (4%; Guerra-Martinez et al., 1990).

According to Echternkamp and Gregory (1999b) retention of the placental membranes were detected most frequently in the spring calving than in the fall calving cows in MARC herds. Some studies have noted that twinning increased the risk of retained placenta, and retained placenta was associated with metritis (Mellado and Reyes, 1994, Markusfeld, 1987, and Kinsel et al., 1998) and displaced abomasums (Markusfeld, 1987).

***The Incidence of Dystocia***

Dystocia means a difficult or abnormal delivery which occurs more frequently with twin births than with single births. However, the causes of it are different between twin bearing and single bearing cows (Cady and Van Vleck, 1978). As cited by Johansson et al. (1974) from previous studies, dystocia was more often displayed at twin calving due to the competition between the twin calves to be born first, whereas most dystocia occurs because of the requirement of hand or mechanical traction in single calving cows (Gregory et al., 1996). Pfau et al. (1948) also thought that possibilities of observing difficulties during calving were increased with multiple births. Four times higher mortality rate in twin born calves was observed due to an increased dystocia and a reduced gestation length. Furthermore twin calves had a lower birth weight. From a study with beef cattle, Guerra-Martinez et al. (1990) reported more dystocia in heifer than in cows (28% versus 10%, respectively). On the other hand, single-bearing heifers had more tendencies to have dystocia than twin bearing heifers. From the MARC population, Gregory et al. (1996) demonstrated cows calving twins have had more dystocia incidence (42.2%) than cows that have singles at birth (20.4%). Similarly, an incidence of dystocia in cows gestating twins was much higher (22.5%) than cows calving a single (7.22%) in the recent study by Mostafa, (2009b).

Malpresentation is the major causes of dystocia in twinned cattle (77.8%). In further study with the same herd, Echternkamp and Gregory (2002) also confirmed that calves with heavy birth weight and large size caused the 17.7% requirement of traction. In contrast, twin calves with small body size and lower birth weight needed traction 11.1% of the time. However, incidence of dystocia due to malpresentation was found to be 38.6 vs. 4.5% in twin and single bearing cows, respectively. Their most recent study also showed that a high rate of dystocia in twin birth was associated with lower calf survival rate as well as reduced subsequent fertility rate. In a study with dairy cows in lactation from 10 large farms, Berry et al. (1994) reported that dystocia was greater in lactation 2 in twin births (30.0%) compared with in a single birth (11.8%).

***Milk Production***

Some studies showed that there is a positive correlation between twinning and milk production in dairy cattle. Correlation between twinning tendency and milk yield was predicted at 0.32 for first lactation and 0.19 at second lactation (Bar Anan and Bowman, 1974). According to Syrstad (1974) dairy cattle gave more milk during lactation due to twinning. Similarly, Kay (1978) reported higher milk production during the lactation in which twins were calved. But the milk output in subsequent lactation was not statistically different after twin birth than that in lactations after single calving. Twinner cows had low milk yields in a following lactation due to metabolic disorders observed on cows during the early part of lactation (Fricke, 2001).

In study conducted in 2009, it was displayed that cows having twins had lower daily, peak and 305-day milk productions than those with giving single birth (Mostafa, 2009a). However, Nielen et al. (1989) reported cows bearing twins had an average of 103 kg more milk production than that of cows bearing singles in the first 100 days of lactation. But in the following days of lactation, no significant differences were detected in terms of milk production. Milk yield was 25% higher in twin-bearing cows but also feed intake was increased (11%) for twin-calving cows to maintain body weight during lactation (Guerra-Martinez, 1990). Likewise, Kinsel et al. (1998) concluded that cows calving twins had better milk production than their singleton counterparts. Cows with twins had 2.71 kg more peak milk output. Even though the association between twinning and double ovulations are not understood completely, increased incidence of double ovulations were observed more often in high milk producing herds than in low producing counterparts (Fricke and Wiltbank, 1999). Apparently, it will be necessary to search and understand the complete mechanism causing the relationship among ovulation rate, twinning tendency, and milk production in dairy cows.

***Calf Survival***

Neonatal calf mortality and stillbirth are common detrimental effects of twin calving due to decreased gestation period and increased the incidence of dystocia among cows bearing twins. There is general agreement among different researchers regarding the higher mortality rate of twin born calves, relative to their singleton counterparts. Premature births are a main reason for many stillborns and limited capacity of the uterus due to weight and size of twin pairs is also the other factor affecting it. In an early report, the neonatal calf mortality rate was about 4 times higher in cows having twins than their single-bearing counterparts (Johansson et al., 1974). Calf mortality rates were 22.4% versus 5.9% in cows that had twins versus singles in a study by Cady and Van Vleck (1978). Markusfeld (1987), examining the calving records of dairy cattle, observed a higher risk for stillbirth (6.3%), ranging from 3.9 to 7.9% for cows having twins. From an animal disease study, Berry et al. (1994) also stated that male calves had higher mortality rate than female calves. They observed a mortality rate to be 8.7% for male calves versus 5.9% for female calves from single pregnancy, compared to 31.3% versus 22.1% for male and female calves from multiple births, respectively. Mortality rate for twins were 32% during birth or close to birth in first lactation and 27% in second lactation.

Hossein-Zadeh et al. (2008) made an observational analysis of twin calving in terms of mortality and abortion rates in Iranian Holstein. They found that 18.8% of twinning resulted in either one or both calves as stillborn versus 4.0% of single calving end up with stillborn cases. The effects of multiple births on calf mortality rate were also observed by Mostafa (2009b). It was reported that the survival rate for single calf was much higher (12.9%) than twin calves at birth. However, perinatal mortality rate for twins was 16.25% (9.37% for stillborn and 6.88% for dead right after delivery), compared with 3.33% for single, with 2.06% for stillborn and 1.27% for dead after birth. The contribution of incidence of dystocia to increased mortality rate in twins was much more than in singles.

Several reports indicated that abortion also occurs more often during twin pregnancy (Kay, 1978; Cady and Van Vleck, 1978 and Hossein-Zadeh et al. 2008). Nielen et al. (1989) reported the relative risk of abortions as 11.6% versus 3.3% in twin-carrying versus single-carrying cows, respectively. Even if the real

causes of abortion are still not known, the speculation was that it might be due to the lack of nutrition during the fetal growing phase of two fetuses or abnormal hormonal mechanisms during pregnancy. Interestingly, the incidence of retained placenta was not affected by abortions among the twin-carrying cows (Nielen et al., 1989). Studies with Holstein cows in the USA showed that abortion rate in twin pregnancy were significantly higher (26.2% in bicornual and 32.4% unicornual) than that of single pregnancy (12%; Day et al., 1995). They also detected higher neonatal calf mortality in cows calving twins (15.7%), relative to cows bearing twins (3.2%). The observed mean abortion rate was found as 13.4% (4.2% for twin birth versus 13.8% for single calving in Iranian Holstein; Hossein-Zadeh et al. 2008).

Several studies also reported that selective prenatal mortality happens for male calves, which were born dead more frequently than female calves. This occurs most probably due to their greater demands on the mother's body, which might result in slightly earlier abortion during twin pregnancy. The negative effect of twin pregnancy on male calves was realized by Pfau et al. (1948) and Erb and Morrison (1959) in their studies. Environmental factors, especially nutrition of dams to fetuses, influenced greatly the mortality rate of twinborn calves (Hendy and Bowman, 1970). As the conditions for feeding and management improved, rearing rate of twins was increased. According to Gordon (1962) as cow feeding increases in the last months of pregnancy, positive effects of this practice could be seen on the survivability ratio in newborn calves. Survival rate was detected 15% and 17% higher in single born calves at birth and 72 hr after birth, respectively than that of twin-born calves. However, the difference was very small after birth to 200-day between two groups (92% in singles versus 89% in twins, Gregory et al., 1990b).

***Reproductive Ability***

One of the main reasons for reduced fertility is freemartinism. Freemartinism is a syndrome, observed in heifer calves born co-twin to bull calves, the females being infertile. Freemartinism occurs due to the fusion of placental blood vascular system of the two fetuses during early gestation (Jost et al., 1973). This fusion allows the interchange of primordial cells and endocrine hormones, which cause sexual differentiation between twin calves. These hormones, which are effective on male reproductive tracts, prevent the development of the fetal heifer's reproductive system, as a result of blood sharing. Instead her tract becomes masculinized (Plante et al., 1992). This event occurs over 90% of the time between male and female co-twins since sexual development happens earlier in males than in female fetuses in cattle.

The hormone that causes the changes is Anti-Mullerian hormone (Vigier et al., 1984). This hormone is secreted by sertoli cells to suppress development of the mullerian structures in males. Blood exposure from bull to heifer fetuses cause an abnormal development of the female reproductive organs with different degrees ranging from almost normal heifers to some resembling bull calves. Even though freemartinism has been observed in some livestock species, such as pig and sheep (Hunter, 1995), the incidence occurs more frequently in cattle (Zhang et al., 1994). Jost et al. (1972) stated that abnormal development of reproductive tracts of females due to freemartinism was observed about 50 days after fertilization. One of the early studies showed that 10% of females were able to breed among females born co-twin to bull calves (Johansson et al., 1974). Zhang et al. (1994) reported 17.5% of females co-twin to males had normal development of the reproductive organs; therefore, they were able to breed. However, Gregory et al. (1996) demonstrated that 96% of females had freemartinism syndrome from mixed sex twin pregnancies. On the other hand, calves born as a single had a low chance to have freemartinism. According to the Buoen et al. (1992), about 8% of females born as co-twins to males were not sterile which most probably was due to lack of fusion occurred between fetal membranes or the fusion happened after the developmental process for reproductive tracts was completed.

Although females are most affected by heterosexual twin pregnancies, a high proportion of bull calves co-twins to heifers also have been culled from breeding programs due to the their low reproductive abilities. One study reported that some chimeric bulls have had degeneration in their testicular tissue, which resulted in the reduction in not only quantity but also quality of the semen produced (Echternkamp, 1998).

***Economical Evaluations of Twinning***

Beerepoot et al. (1992) analyzed data including 381 twin calvings recorded on 33 farms over 6.5 years in the Netherlands and estimated about $109 economic loss for every twin birth, compared with singleton births. Eddy et al. (1991) studied the effect of twinning on the reproductive performance, production, and health of dairy cattle. They used data including about 20,000 calving records over three years from 32 farms in England. They estimated $135 average loss of income per cow. In addition, Kossaibati and Easlement (1997) examined economic output due to common health problems like mastitis, twinning, calf mortality and aid at

calving in 100 dairy cows in England during 1992-1993 seasons. They estimated at $11,500 lost per year. On average, economic loss due to twinning was estimated about $201. This loss was caused by enhanced culling rate as well as longer calving intervals. Even if there are no recent reports about economic effects of twinning on dairy farm enterprises, most dairy and many beef cattle producers do not want to keep cows which give twin births since overall twinning is not profitable under a typical management system.

***Effect of Twinning on Beef Cattle Production***

The low reproductive performance of beef cattle is one of the critical factors that greatly affect beef cattle production. Production costs are mostly due to feeding and management expenses of reproducing beef cows, thus it reduces the overall efficiency of the system. Producing an extra calf in twin calving would be an opportunity to enhance the production output since an additional calf would be available for slaughtering purposes. A study showed that total production costs could be reduced 20-30% per unit beef returns by the increase in total weights of the calves produced at weaning by twinning (Bar-Anan and Bowman, 1974).

Guerra-Martinez et al. (1990) reported even though twin calves had 13% and 17% lower birth and weaning weights, respectively, twin calves had 18% higher growth rate than single calves during the feeding period after weaning. In addition, a study from Canada showed that even if twinning reduced the gestation period (2%), twin calves had 25.5 kg more weight at birth and 186.0 kg more total adjusted weight at weaning per cow. The difference between twin and single was not significant in terms of post-weaning growth rate (de Rose and Wilton, 1991). In a study of the MARC twinner herd, Gregory et al. (1990b) reported total calf weight could be increased up to 40% at 100 day of age due to twinning. Further study by Gregory et al. (1996) reported total weight of calves at 200 day of age was enhanced up to 58% with twins, comparing to single-born calves.

Echternkamp and Gregory (1999b) concluded that total beef production could be enhanced with an appropriate technology, even if twinning causes many negative effects on reproductive performance of cows. In a recent study with the MARC twinner herd, it was reported that cows with twins had 70% more live calves than cows with singles which resulted in 48% more weaning weight due to twin calving (Echternkamp and Gregory, 2002). A general agreement in many studies is that even females born as freemartins do not have a negative effect on a beef cattle production system since most of the calves will eventually be slaughtered after weaning. According to Gregory et al. (1996) freemartin females are similar to normal female in terms of growth rate. A higher percentage of freemartins will have choice carcass quality grade relative to normal females, due to more marbling in the longissimus muscle. Additionally, Echternkamp and Gregory (2002) reported that freemartin females had higher birth weight than their normal counterparts. Moreover, there were no distinguishable differences between twin heifers and single heifers in terms of carcass characteristics. As Guerra-Martinez et al. (1990) suggested that beef meat production cost was 24% lower for twin calving than single birth, even accounting for high health care expenses in beef cattle production.

## CONCLUSIONS

In general, many studies displayed evidently that a bearing more than one calf at the end of pregnancy might be the cause of several negative or detrimental effects on cow reproductive performance as well as calf production which subsequently results to reduce overall productivity of the animals. On the other hand, even if twinning affects the fertility of the cow negatively, twin calving could reduce substantially beef meat production costs owing to more calf growth at weaning. Therefore, an economic gain from twin calf production could be enhanced by applying an appropriate management system to identify and cope with twin-bearing cows, correctly and nutrition program to feed them in proper manner.

## REFERENCES

Anderson GB, Cupps PT, and Drost M (1979). Induction of twins in cattle with bilateral and unilateral embryo transfer. J. Anim. Sci. Vol. 49, No. 4.

Bar-Anan R and Bowman JC (1974). Twinning in Israeli Friesian dairy herds. Anim Prod 18, 109-115.

Beerepoot GM, Dykhuizen A A, Nielen M, and Schukken YH. (1992). The economics of naturally occurring twinning in dairy cattle. J. Dairy Sci. 75:1044-1051.

Bendixen PH, Vilson B, and Ekesbo I (1987). Disease frequencies in dairy cows in Sweden. II. Retained Placenta. Preventative Veterinary Medicine. 4:377-387.

Berry SL, Ahmadi A, and Thurmond MC (1994). Periparturient disease on large, dry lot dairies: Interrelationships of lactation, dystocia, calf number, calf mortality, and calf sex. J. Dairy Sci. 77 (Supl. 1):379.

Buoen LC, Zhang TQ, Wever AF, and Ruth GR (1992). Non-freemartin rate in Holstein heterosexual twins. Am. Assoc. Bov. Pract. Confr. 1:300.
Cady RA and Van Vleck LD (1978). Factors affecting twinning and effects of twinning in Holstein Dairy cattle. J. Anim. Sci. 46:950-956.
Chapin CA and Van Vleck, LD (1980). Effects of twinning on lactation and days open in Holsteins. J. Dairy Sci., 63: 1881-1886.
Davis ME, Harvey WR, Bishop MD, and Gearheart WW (1989). Use of embryo transfer to induce twinning in beef cattle: embryo survival rate, gestation length, birth weight and weaning weight of calves. J. Anim Sci. 67(2):301-10.
Day JD, Weaver LD, and Franti CE (1995) .Twin pregnancy diagnosis in Holstein cows: discriminatory powers and accuracy of diagnosis by transrectal palpation and outcome of twin pregnancies. Canadian Veterinary Journal. 36:93-97.
de Rose EP and Wilton JW (1991). Productivity and profitability of twin births in beef cattle. J. Anim Sci. 69:3085-3093.
Echternkamp SE and Gregory KE (1999a). Effects of twinning on gestation length, retained placenta, and dystocia. J. Anim. Sci. 77:39-47.
Echternkamp SE and Gregory KE (1999b). Effects of twinning on postpartum reproductive performance in cattle selected for twin births. J. Anim. Sci. 77:48-60.
Echternkamp SE and Gregory KE (2002). Reproductive, growth, feedlot, and carcass traits of twin vs single births in cattle. J. Anim. Sci. 80 (E. Suppl. 2): E64-E73.
Echternkamp SE (1998). Freemartin in *Encyclopedia of Reproduction* (edited by E. Knobil and J. D. Neill), 406-417. Academic Press, San Diego, California.
Eddy RG, Davies O and David C (1991). An economic assessment of twin births in British dairy herds. Vet. Rec. 129:526-529.
Erb RE and Morrison RA (1959). Effects of Twinning on reproductive efficiency in a Holstein-Friesian herd. J. Dairy Sci. 42:512-519.
Foote RH (1981). Factors affecting gestation length in dairy cattle. Theriogenolgy. 15:552-559.
Fricke PM (2001). Review: Twinning in Dairy Cattle. The Professional Animal Sci. 17:61-67.
Fricke PM and Wiltbank MC (1999). Effect of milk production on the incidence of double ovulation in dairy cows. Theriogenology. 52:1133-1143.
Gordon I, Williams G, and Edwards J (1962). The use of serum gonadotrophin (PMS) in the induction of twin pregnancy in the cow. J. Agr. Sci. (Camb). 59:143.
Gregory KE, Echternkamp SE, and Cundiff LV (1996). Effects of twinning on dystocia, calf survival, calf growth, carcass traits, and cow productivity. J. Anim. Sci. 74:1223-1233.
Gregory KE, Echternkamp SE, Dickerson GE, Cundiff LV, Koch RM, and Van Vleck LD (1990a). Twinning in cattle: I. Foundation animals and genetic and environmental effects on twinning rate. J. Anim. Sci. 68:1867-1876.
Gregory KE, Echternkamp SE, Dickerson GE, Cundiff LV, Koch RM, and Van Vleck LD (1990b). Twinning in cattle: III. Effects of twinning on dystocia, reproductive traits, calf survival, calf growth and cow productivity. J. Anim. Sci. 68:3133-3144.
Guerra-Martinez P, Dickerson GE, Anderson GB, and Green RD (1990). Embryo-transfer twinning and performance efficiency in beef production. J. Anim. Sci. 68:4039-4050.
Hancock J (1954). Monozygotic twins in cattle in Advances In Genetics. 141-181. Academic Press, New York, New York.
Hendy CRC and Bowman JC (1970). Twinning in cattle. Animal Breeding Abstrct. 38:22-37.
Hossein-Zadeh NG, Nejati-Javaremi A, Miraei-Ashtiani SR, and Kohram H (2008). An observational analysis of twin birds, calf stillbirds, Calf sex ratio, and abortion in Iranian Holsteins. J. Dairy Sci. 91:4198-4205.
Hunter RHF (1995). Anomalous sexual development in domestic species. In sexual determination, differentiation and Intersexuality in Placental Mammals. Cambridge Univ. Press, New York.
Johansson I, Lindhé B, and Pirchner F (1974). Causes of variation in the frequency of monozygous and dizygous twinning in various breeds of cattle. Hereditas. 78:201-234.
Jost A, Vigier B, and Prepin J and Perchhellet JP (1973). Studies on sex differentiation in mammals. Recent Prog. Horm. Res. 29:1-41.
Jost A, Vigier B, and Prepin J (1972). Freemartins in cattle: The first steps of sexual organogenesis. J. Reprod. Fertility. 29:349-379.
Kay R M (1978). Changes in milk production, fertility and calf mortality associated with retained placentae or the birth of twins. Vet. Rec. 102:477-479.
Kinsel ML, Marsh WE, Ruegg PL, and Etherington WG (1998). Risk factors for twinning in dairy cows. J. Dairy Sci. 81:989-993.
Kossaibati MA and Esslemont RJ (1997). The costs of production diseases in dairy herds in England. The Veterinary Journal. 154:41-51.
Markusfeld O (1987). Periparturient traits in seven high dairy herds. Incidence rates, association with parity, and interrelationships among traits. J. Dairy Sci. 70:158-166.
McCaughe WJ and Dow C (1977).Hormonal induction of twinning in cattle.Vet.Rec.100:29-30.
Mellado M and Reyes C (1994). Associations between periparturient disorders and reproduction efficiency in Holstein cows in Northern Mexico. Preventive Veterinary Medicine. 19:203-212.
Mostafa AS (2009a). Twinning in dairy cattle and its effect on milk yield, lactation lenght, dry period length and calf performance. Bs. Vet. Med. J. July. 19, no:2, p. 13-18.
Mostafa AS (2009b). Effect of twin vs. single births on gestation length, reproductive performance, dystocia, calf survival rate and culling in Holstein cows. Bs. Vet. Med. J. July. Vol. 19, No. 2, p. 19-23.
Nielen M, Schukken YH, Scholl DT, Wilbrink HJ and Brand A (1989). Twinning in dairy cattle: a study of risk factors and effects. Theriogenology. 32:845-862.
Penny CD, Lowman BG, Scott NA, Voelke SL, and Davies DAR (1995). Management aspect of induced twinning in beef suckled cows using in vitro fertilized embryos.Vet.Rec.506-510.
Pfau K, Bartlett O JW, and Shuart CE (1948). A study of multiple births in a Holstein-Friesian herd. J. Dairy Sci. 31:241-254.
Plante Y, Schmutz SM, Lang KDM, and Moker JS (1992). Detection of leucochimaerism in bovine twins by DNA fingerprinting. Animal Genetics. 23:295-302.
Ryan DP and Boland MP (1991). Frequency of twin births among Holstein-Friesian cows in a warm dry climate. Theriogenology. 36:1-10.
Sreenan JM and Diskin MG (1989). Effect of a unilateral or bilateral twin embryo distribution on twinning and embryo survival rate in the cow. J. Reprod. Fertil. 87:657–664.
Syrstad O (1974). Genetic aspects of twinning in dairy cattle. Acta. Agricult Scandinavica. 24.

Turman EJ, Laster GB, Renbarger RE and Stephens DF. 1971. Multiple births in beef cows treated with equine gonadotropin (PMS) and chrionic gonadotropin (HCG). J. Anim. Sci. 32:962.

Vigier B, Tran D, Legeai L, Bezard J, and Josso N (1984). Origin of Anti-Mullerian hormone in bovine freemartin fetuses. J. Reprod. Fertility. 70:473-479.

Zhang T, Buoen LC, Seguin BE, Ruth GR, and Weber AF (1994). Diagnosis of freemartinism in cattle: the need for clinical and cytogenic evaluation. Journal of American Veterinary Medical Association. 204:1672-1675.