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REVIEWS

REVIEW: Cost of Reproductive Diseases and Conditions in Cattle[1]

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Abstract

Based on information from USDA National Animal Health Reporting System early State pilot studies and more recent national studies, the cost of reproductive diseases and conditions was estimated for beef and dairy cattle. We estimate the total yearly cost of female infertility, abortions/stillbirths, dystocia, retained placentas, and metritis/pyometra to be $441 to $502 million for beef producers and $473 to $484 million for dairy producers with an aggregate national total of approximately $1 billion annually. This loss is over six times more costly than that resulting from respiratory diseases. Three-fourths of the cost for reproductive diseases and conditions can be attributed to female infertility and dystocia and the failure to produce a healthy calf that will survive the first 24 h of life. Aggregate national costs are roughly evenly divided between beef and dairy; per cow costs are more than three times greater for dairy cows ($52.60) than for beef cows ($14.00). Approximately equal national costs are attained because there are more than three times more beef cows than dairy cows. One factor contributing to the greater cost for dairy cows is lost milk production associated with dystocia and retained placentas. Lost milk production accounts for one-third of the costs associated with reproductive diseases and conditions in dairy cattle. We conclude from this review and our resulting estimates that focusing on developing strategies to increase the probability of conception, minimize dystocia, and produce a healthy calf that survives beyond the first 24 h of birth must continue to receive high priority in both dairy and beef cattle management and research.

(Key Words: Cattle, Reproductive Losses, Costs, Economics.)

Introduction

Bovine reproductive diseases and conditions result in economic losses caused by decreased production and delayed reproduction as well as increased treatment and preventative measurement costs. Reproduction can be negatively affected in many ways (5). Viral and bacterial diseases can cause abortions, and dystocia may cause the death of calf or dam and reduce reproductive performance of the dam and subsequent BW gain in the calf (4, 6, 7, 10, 14, 20). Retained placentas and cesarean delivery can result in a prolonged postpartum interval to conception, causing increased days open and decreased milk production (2, 48). Infertility, regardless of cause, is a major reason for culling animals. Accurate quantification of these costs are straightforward when parameters are set and data analyses are confined to a few individual operations. On the other hand, national cost estimates based on parameter coefficients from several production studies and disease experiments are difficult to calculate because research goals, study methodology, and quantification criteria differ greatly from study to study. However, it is the purpose of this review to discuss such rates of occurrence and calculate cost impacts of selected bovine reproductive conditions and diseases.

Materials and Methods

During the 1980s, university and National Animal Health Monitoring System (NAHMS) Veterinary Services personnel conducted on-farm studies of dairy and beef cow-calf herds in California, Colorado, Georgia, Iowa, Michigan, Ohio, and Tennessee (11, 12, 28–47). These pilot studies gathered data on incidence and

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prevalence rates of selected diseases among beef cow-calf and dairy operations as reported by producers. A distinguished feature of these epidemiologic studies was that they also collected cost information by disease category. The pilot projects were designed to generate state-level estimates as opposed to the national estimates that NAHMS currently report, from its national studies. Thus, extrapolating findings from one or two states to the whole nation produces estimates that should be viewed as "ball park" estimates with wide confidence levels. In an attempt to narrow the confidence interval of the cost estimates reported, we used national prevalence estimates of the specific disease or condition from the NAHMS Dairy '96 (23) and Beef '97 (24) national studies. Cost estimates presented were based on data collected by USDA, NAHMS and supplemented by data from other published studies (5, 8, 9, 16, 19, 48). Extrapolation calculations of incidence cost rates to national herd numbers of 33.7 million beef cows and 9.1 million dairy cows (27) have assumed each additional unit of production, e.g., kilogram of calf or 45.4 kg (cwt) of milk, could be sold at average prices received; therefore, any impact of increased supply on price was not considered. Results presented are our best estimates of the costs of reproductive diseases and conditions to the U.S. cattle industry.

Because much of the NAHMS data was 10 yr old or more, it was necessary to update cost impacts to current dollars. This was done using the prices-paid index for farm producers reported by USDA-National Agricultural Statistics Service (25, 26). Costs in 1999 dollars were determined by multiplying original costs by the ratio of the 1999 index to study year's index. Annual costs were reported on a per-cow inventory basis, rounded to the closest $0.10. For some diseases, lost milk production estimates from non-NAHMS studies were included in total costs as the pilot studies did not report on lost milk production. Milk was valued at its 1999 farm price of $0.32/kg ($14.40/cwt) (26). Aggregate annual total national costs were based on January 1, 1999, national inventories of 9.1 million dairy cows (27). The underlying incidence rates were reported per 1,000 cows, as some incidence rates were very low, and conversion to percentage values requires only a simple operation of moving the decimal point. Values used to calculate averages were weighted by the cow inventory base reported. All averages presented are weighted averages.

Costs of Reproductive Diseases and Conditions.

Female Infertility. Infertility of cows and heifers or the inability to become pregnant in a defined breeding period may have the single greatest effect upon reproduction costs and efficiency (5, 13). Unfortunately, infertility is one of the least easily quantifiable conditions because of widely differing management practices and environments and the many factors that may contribute to the perceived problem of infertility. For example, the following questions may be posed: Was an inadequate number of bulls used in a natural service breeding program or were subfertile bulls used, or were nonpregnant cows truly infertile? Was poor detection of estrus in an artificial insemination breeding program the problem or were heifers and cows deemed non-cycling truly infertile? Even though recognition of infertility can be a symptom of other problems rather than a problem in itself, data from the NAHMS pilot studies carried out through the middle and late 1980s provide some insight.

Among beef cow-calf herds, annual infertility incidence rates ranged from 12 to 73 per 1,000 cows, averaging 36 cases per 1,000 cows (35, 36, 39). For dairy herds, infertility incidence rates ranged from 2 per 1,000 head in heifers (34) to 45 per 1,000 head in cows (46), averaging 29 cases per 1,000 head. The NAHMS Dairy '96 (23) reported an average prevalence of 116 cases per 1,000 cows. This higher rate is probably due to a broader definition of "not pregnant" 150 d after calving compared with the inability to become pregnant, the definition used in pilot studies.

Costs of infertility have been generally defined to include the cost of replacement of the animal culled and any labor, drug, or veterinary service expenses included in treatment and/or prevention. Greer et al. (13) concluded that infertility was often implicated as a leading cause of culling. In Colorado, 85% of all cows culled for reproductive problems were nonpregnant or had become pregnant late in the breeding season (36). A California report stated 4.5% of the study's total cow population was culled because of infertility (12). Early culling may delay genetic progress; however, the cost of such delays is difficult to quantify and was not estimated in this study. Costs ranged from $1.80 (41) to $23.60 (45) per cow inventory in dairy operations and averaged $15.00 per cow inventory; results are summarized in Figure 1. When extrapolated to the national dairy herd, average NAHMS-reported costs of infertility amount to $137 million per year (Figure 2). In beef operations, NAHMS-reported costs of infertility averaged $7.40 (40, 41, 43, 45, 47) per cow inventory for an extrapolated national cost of $249 million per year.

Because operation goals vary widely regarding animal type produced (e.g., purebred *vs* commercial) and because cattle prices are of a cyclic nature, we suggest that future economic studies separate replacement animal costs from drug, labor, and veterinary service costs. This separation is justified because cyclic animal prices may adversely affect cost data when combined with relatively constant drug, labor, and veterinary costs.

Abortions and Stillbirths. Abortions and stillbirths negatively impact the annual cow production rate (3). Mickelson (18) found that abortions decreased potential calf crop by 2.3% in beef cow-calf herds.

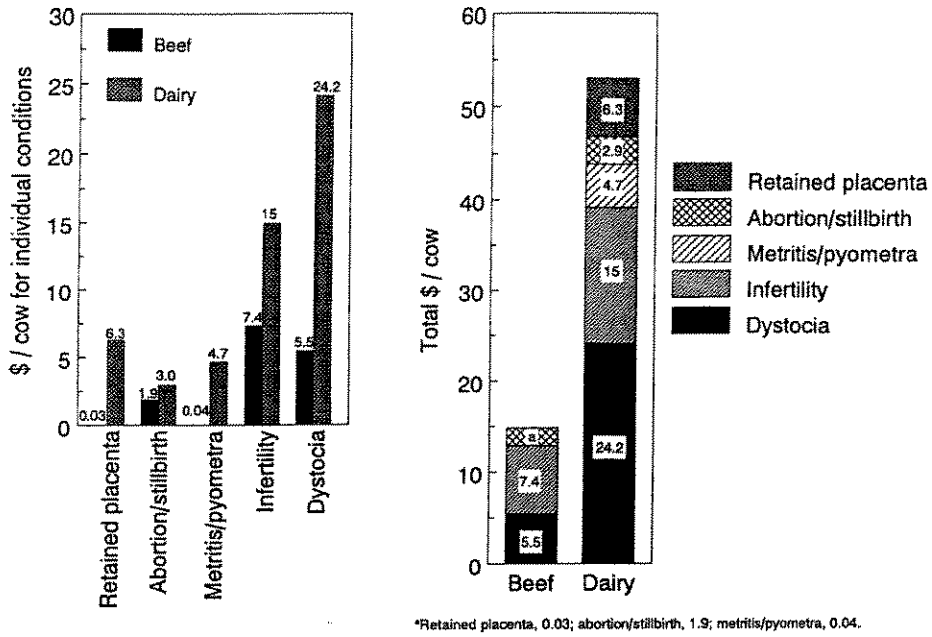


Figure 1. Annual per-cow cost of cattle reproductive diseases and conditions in the U.S.

Rates have been estimated at 46 per 1,000 known pregnancies yearly in Tennessee beef cow-calf herds (47). Only pregnancies resulting in a "reproductive product" (live or dead calf or fetus) were included in this study, which would tend to underestimate abortion rate because it would not include early mortality in which the fetus was absorbed or lost and not noticed. In Georgia, abortion occurred at a rate of 26 and 17 per 1,000 cows and stillbirths at 17 and 23 per 1,000 cows, in beef and dairy cows, respectively (38, 39). Producers in the NAHMS Beef '97 (24) reported an abortion rate of 3 per 1,000 cows; 21 calves per 1,000 births were born dead. In the NAHMS Dairy '96 Study (23), producers estimated that 35 per 1,000 cows aborted their calves.

Based on NAHMS Beef '97 (24) and Dairy '96 (23) information and assuming a conservative value of a newborn calf at $85 per head, abortion and stillbirths cost beef cow-calf operations $1.90 per cow inventory in lost calves. Unfortunately, information on stillbirths was not collected in the Dairy '96 study. For dairy operations, abortions alone cost $3.00 per cow inventory in lost calves. Based on these data, national costs associated with stillbirths and abortion costs are estimated at approximately $64 million yearly for beef cow-calf producers and $27 million per year for dairy producers.

Dystocia. Of the many factors affecting calf survival, dystocia is the most important (1, 3, 20). Dystocia results in death of calves and cows, production losses in both dam and calf, and delayed reproduction rates (6, 8, 9, 10, 17).

Patterson et al. (20) reported that 45.9% of all preweaning deaths can be attributed to dystocia, and Laster and Gregory (15) reported that calves born to cows experiencing difficult births were four times as likely to die as were calves born to cows not experiencing dystocia. Among California dairies, dystocia was responsible for 6.4% of all cow deaths reported and 24% of deaths in first-calf heifers (28). In Colorado beef cow-calf operations, calving difficulty occurred at a rate of 28 per 1,000 cows yearly (33); Tennessee reported dystocia occurrence at 28.6 per 1,000 cows per year (47). Averaging NAHMS pilot studies (29–47) reveals a dystocia rate of 59 cases per 1,000 dairy cows and 31 cases per 1,000 beef cows.

In addition to death losses and veterinary and drug costs, dystocia often causes other, seemingly less

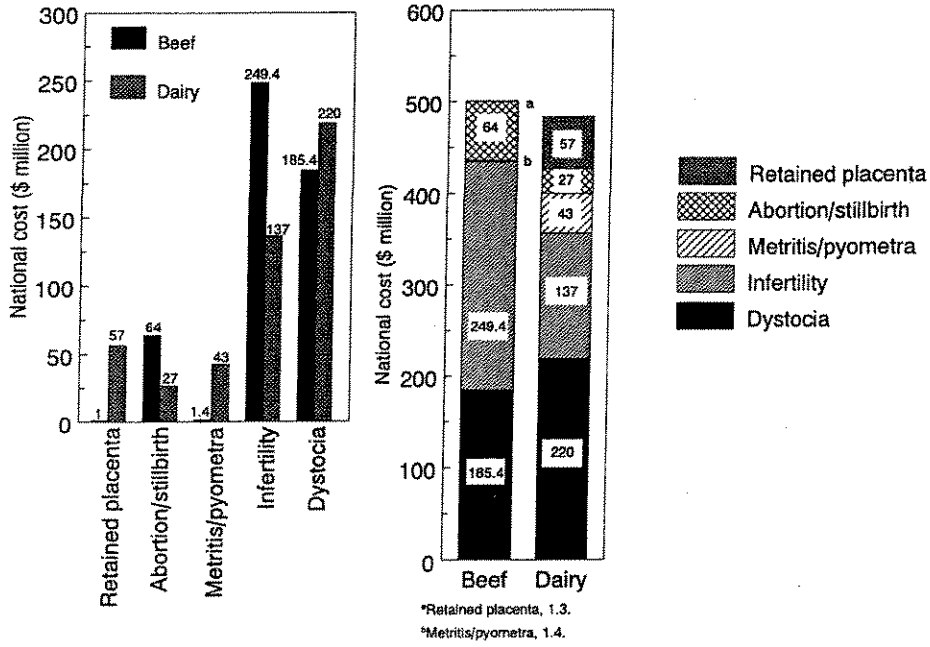


Figure 2. Total annual cost of cattle reproductive diseases and conditions in the U.S.

noticeable, losses. These losses include lower weaning BW among calves experiencing difficult births, higher number of days open in dams, lower conception rates, and decreased milk production in dairy cows (5, 6, 8–10, 17). Dairy cattle requiring cesarean section delivery because of advanced dystocia had longer dry periods (15 d) than the mean dry period of cows undergoing normal parturition (2). Beef females suffering dystocia also exhibit lower conception rates. Beef cows experiencing dystocia had a 15.6% lower conception rate to artificial insemination and a 15.9% lower overall conception rate than did cows not experiencing difficult births (14). In addition, cows detected in estrus during the insemination period that experienced dystocia had a 6.1% lower conception rate than did cows detected in estrus that did not experience dystocia. We recognize the potential economic importance of these losses, but resulting cost values were not included in studies reviewed and could not be quantified for inclusion in this study.

In a 1987 study involving over 141,000 lactations with dystocia in dairy cattle, first-calf heifers experiencing dystocia scores of 5 (most difficult) produced 465 kg less milk and 20.7 kg less milkfat than did first-calf heifers with dystocia scores of 1 (least difficult). Second parities with scores of 5 produced 576 kg less milk and 20.9 kg less milkfat than did age contemporaries with dystocia scores of 1, and third and greater parities produced 725 kg less milk and 25 kg less milkfat when compared with age contemporaries with dystocia scores of 1 (9). In a more recent study involving almost 123,000 lactating dairy cows, dystocia reduced average milk production by 38.4 kg per cow (8). At the national level, this totals 349 million kg lost milk production and translates into a $12.30 per cow inventory loss.

A 1985 estimate by Smith et al. (21) found average dystocia costs of $35 for first-lactation dairy heifers. In NAHMS pilot studies, dystocia was often the highest reproductive health cost. In Georgia, yearly costs totaled $5.70 per cow inventory for prevention alone in dairy cattle; the same survey found annual dystocia costs of $2.70 per cow inventory in beef cattle (39). When death loss and treatment costs are included, overall studies reviewed, dystocia is estimated to cost $11.90 per cow inventory in dairy operations and $5.50 per cow inventory in beef cow-calf operations. Adding the $12.30 per cow inventory in lost milk production in dairy herds brings the total cost associated with dystocia to $24.20 per cow inventory. This is very similar to the total cost estimate of $24.24 per cow by Dematawewa and Berger (8). We estimate the annual total cost of dystocia at $220 million per year in dairy herds and $185 million in beef cow-calf herds.

Retained Placenta. Retained placentas can occur spontaneously or result from conditions that shorten gestation length, and their occurrence can incur added costs and production losses (14). Retained placentas seem more prevalent in dairy cattle than in beef cattle (17), but a difference in rates could be partly due to the higher visibility of dairy cows to dairy managers. For example, a beef producer may consider the placenta retained after 24 h, but a dairy producer may consider it retained after observing it for 10 h.

Retained placentas accounted for 1.3% of all beef operation health events (35) and occurred at a rate of 7 per 1,000 cows per year in beef cow-calf operations (36). Dairy cattle showed an incidence rate of 24 per 1,000 cows per year (39). Other literature (13, 17) reports the incidence of placental retention to range between 3 to 12% following normal parturition; however, this rate increases dramatically to 20 to 50% following abnormal births or when the reproductive tract was infected (17). Lech et al. (16) reported that placental retention in dairy cattle occurs in approximately 8% of normal births but increases to 30 to 50% in births 1 to 2 wk premature and to 45 to 70% in twin births. Calculated averages from the NAHMS pilot studies (29–47) indicate placental retention occurring at a rate of 23 per 1,000 dairy cows and 8 per 1,000 beef cows.

Costs of treatment of retained placentas in Georgia herds totaled $0.03 per cow inventory in beef operations and $0.40 per cow inventory in dairy farms (39). However, retained placentas also may cause related costs including decreased subsequent fertility, longer postpartum intervals, and decreased milk production, as well as increased risk of metritis or pyometra (16). Data from a study in the Netherlands with dairy cattle showed that when placentas were retained for periods >6 h, an increase of 17 d to first service and 26 additional d open resulted (48). This study also reported a reduction in 100-d milk production of 237 kg per cow for cows with placentas retained for >12 h compared with cows not experiencing retained placentas. Assuming the same milk loss for the U.S. and the 7.8% rate of retained placentas as estimated by NAHMS Dairy '96 (23), we estimate average annual U.S. milk loss would be 18.5 kg per cow for a total loss of 168 million kg milk or $54 million per year.

Metritis and Pyometra. Metritis is defined as inflammation caused by mild infection of the uterus, and pyometra is severe uterine infection. The two conditions differ in pathology and treatment, but have been grouped together to facilitate more accurate estimates of incidence rate and economic impact. Metritis and pyometra can lead to greatly reduced fertility, prolong the interval to uterine involution and first ovulation by 20 or more d (which may increase calving interval 16 to 36 d), and delay conception after ovulation by causing direct damage to the ova or sperm by bacterial or fungal toxins produced by the infection (16). Lech et al. (16) reported that metritis incidence rates may range from 90 to 260 cases per 1,000 cows and that pyometra may range in incidence

from 20 to 60 cases per 1,000 cows in all postpartum dairy cows. In the NAHMS pilot projects, yearly metritis in dairy herds ranged from 81 cases per 1,000 cows in Ohio (44) to 138 cases per 1,000 cows yearly in Georgia (39). Most data indicate the problem is more prevalent in dairy cattle, but, again, the authors suggest that because of operation nature, some degree of difference in incidence could be attributed to greater detection in dairy herds, which would also lead to higher per cow treatment costs.

Prevention and treatment of metritis in dairy cattle was reported to cost producers $1.30 per cow inventory in Georgia (39); Ohio dairy farmers spent an average of $8.00 per cow inventory (46). In Iowa beef operations, however, treatment costs were just $0.04 per cow inventory (40). Again, inadequately standardized cost data makes it difficult to determine true national estimates, but, based on the Ohio and Georgia studies, we estimate metritis and pyometra cost approximately $4.70 per dairy cow inventory.

Failure to Conceive upon First Breeding. Cows and heifers that do not become pregnant to first service contribute largely unknown but substantial costs to both dairy and beef industries. Considering a normal 285-d gestation length, 60-d postpartum anestrous interval, and a 20-d estrous cycle, a cow must become pregnant in her first estrous cycle after the postpartum anestrous interval to maintain an annual calving interval and high productivity. If a cow does not conceive during this time, the producer incurs losses in the form of decreased weaning BW, decreased milk production, and increased overall cost per productive unit (kilograms of calf or milk). These losses, although significant, could not be quantified in this study.

Total Reproductive Condition and Disease Costs. When summed across the different reproductive diseases and conditions, our estimated cost to beef cow-calf producers is $14.90 per cow, and, for dairy producers, the cost estimate is $53.20 per cow. An alternative approach is to average the total cost of reproduction conditions and diseases from individual state pilot studies. The advantage of this approach is that it allows more state estimates to be used as some states reported totals only.

Incidence rates of reproductive conditions and diseases in beef cow-calf herds ranged from a low of 30 per 1,000 cows in California to a high of 78 per 1,000 cows in Tennessee and averaged 55 per 1,000 cows across five states: California (30), Colorado (32, 33, 34), Georgia (37, 38), Ohio (44, 45), and Tennessee (47). Annual cost estimates from these five states ranged from a low of $7.80 per cow inventory in Georgia to a high of $16.90 in California, with an average of $13.10 per cow inventory.

For dairy cows, incidence rates of reproductive conditions and disease occurrence ranged from a low of 205 per 1,000 cows in Ohio to a high of 574 per 1,000 cows in Michigan and averaged 350 per 1,000 cows across four states: California (29, 31), Michigan (42, 43), Ohio (45, 46), and Tennessee (47). Estimates of total cost for dairy herds ranged from a low of $28.20 per cow inventory in Tennessee to a high of $62.80 per cow inventory in Ohio, with a four-state average cost of $52.00 per cow inventory.

With reproductive diseases and conditions estimated to annually cost beef cow-calf producers $13.10 to $14.90 per cow inventory, aggregate industry losses to reproductive diseases would range from $441 to $502 million annually. For dairy producers, annual costs of reproductive conditions and diseases range from $52.00 to $53.20 per cow inventory. Total annual dairy industry losses associated with reproductive diseases and conditions would range from $473 to $484 million.

Discussion

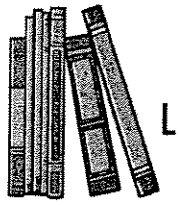
Clearly, infertility and dystocia are the two most costly reproductive conditions, as they account for almost three-fourths of the costs in dairy herds and over four-fifths of the costs in beef cow-calf herds. In dairy herds, dystocia is the most costly reproductive condition with more than one-half of its cost resulting from lost milk production. Lost milk production is not directly measured in beef cow-calf herds and, thus, was not quantified as a cost in our study, although the cost of weaning lighter BW calves is also a cost of dystocia. Even with lost milk production not accounted for, dystocia was the second most costly reproductive condition in beef herds; the most costly reproductive condition for beef cow-calf herds is infertility. Infertility ranked as the second most costly reproductive disease condition for dairy cows. Infertility is costly because producers usually cull infertile females. Thus, the producer has incurred the cost of raising or purchasing the animal that does not generate revenue (other than salvage value) as well as the additional expense of replacing the animal.

Because observed reproductive disease and condition occurrences are seven times greater in dairy cows than in beef cows, it is not surprising that the per head costs are three to five times greater in dairy herds than in beef herds. Part of the differential in occurrences can be explained by the fact that dairy cows are observed every day, but beef cows are not; thus, producers are more aware of reproductive problems in dairy cows. In addition to a greater incidence rate, dairy cows have greater reproductive costs than beef cows because of the associated measurable milk losses. Milk losses associated with dystocia and retained placenta account for one-third of the cost of reproductive diseases and conditions in dairy cattle.

To help put the cost of reproductive disease conditions into perspective, it can be compared with other diseases. From the NAHMS pilot studies used in this study, respiratory diseases in cattle cost the beef industry $101 million and the dairy industry $55 million annually (28–47). In dairies, mastitis (both clinical and subclinical) costs between $1.5 to $2.0 billion (49) and Johne's disease costs $200 to $250 million (19) yearly. Another way to put the cost of reproductive disease and conditions into perspective is to compare costs with the value of production generated by the beef cow-calf and dairy industries. During 1999, beef cow-calf herds generated $13.0 billion in value of production (value of weight gains), and dairy herds generated $26.2 billion [value of weight gains plus milk; (22)]. On a percentage basis, reproductive conditions and diseases cost 3.4 to 3.9% of beef cow-calf value of production and 1.8% of dairy value of production.

Implications

Based on updated cost estimates from previous NAHMS and other studies, reproductive diseases and conditions cost producers $52.00 to $53.20 per dairy cow per year and $13.10 to $14.90 per beef cow per year. The margin of error in these findings is probably larger than that for estimates from traditional national NAHMS studies. Thus, instead of focusing on actual value, it becomes more realistic to focus on relative magnitude and ranking of causes. Clearly, for both beef and dairy cattle, infertility and dystocia are the major costs associated with reproductive problems. On a percentage basis, reproductive conditions and diseases costs approximate 3.6 and 1.8% of value of production in beef and dairy, respectively. Thus, focusing on strategies to improve the probability of conception and the production of a healthy calf that experiences minimal dystocia and survives beyond the first 24 h of birth should receive major attention.



Literature Cited

1. Azzam, S. M., J. E. Kinder, M. K. Nielsen, L. A. Werth, K. E. Gregory, L. V. Cundiff, and R. M. Koch. 1993. Environmental effects on neonatal mortality of beef calves. J. Anim. Sci. 71:282.

2. Barkema, H. W., Y. H. Schukken, C. L. Guard, A. Brand, and G. C. Weyden. 1992. Cesarean section in dairy cattle: A study of risk factors. Theriogenology 37:489.

3. Bellows, R. A., D. J. Patterson, P. J. Burfening, and D. A. Phelps. 1987. Occurrence of neonatal and postnatal mortality in range beef cattle. II. Factors contributing to calf death. Theriogenology 28:573.

4. Bellows, R. A., and R. E. Short. 1978. Effects of precalving feed level on birth weight, calving difficulty, and subsequent fertility. J. Anim. Sci. 46:1522.

5. Bellows, R. A., and R. E. Short. 1994. Reproductive losses in the beef industry. In Factors Affecting Calf Crop. M. J. Fields and R. S. Sands (Ed.). p 109. CRC Press, Boca Raton, FL.

6. Bellows, R. A., R. E. Short, R. B. Staigmiller, and W. L. Milmine. 1988. Effects of induced parturition and early obstetrical assistance in beef cattle. J. Anim. Sci. 66:1073.

7. Brinks, J. S., J. E. Olson, and E. J. Carroll. 1973. Calving difficulty and its association with subsequent productivity in Herefords. J. Anim. Sci. 36:11.

8. Dematawewa, C. M. B., and P. J. Berger. 1997. Effects of dystocia on yield, fertility, and cow losses and an economic evaluation of dystocia scores for Holsteins. J. Dairy Sci. 80:754.

9. Djemali, M., A. E. Freeman, and P. J. Berger. 1987. Reporting of dystocia scores and effects of dystocia on production, days open, and days dry from dairy herd improvement data. J. Dairy Sci. 70:2127.

10. Doornbos, D. E., R. A. Bellows, P. J. Burfening, and B. W. Knapp. 1984. Effects of dam age, prepartum nutrition and duration of labor on productivity and postpartum reproduction in beef females. J. Anim. Sci. 59:1.

11. Food Animal Disease Monitoring, Iowa 1984-1989. Iowa State University, College of Veterinary Medicine, Ames, Iowa. W. J. Owen, Project Director.

12. Gardner, I. A., D. W. Hird, W. W. Utterback, C. Danaye-Elmi, B. R. Heron, K. H. Christiansen, and W. M. Sischo. 1986-1987. Mortality, morbidity, case-fatality and culling rates for California dairy cattle as evaluated by the National Animal Health Monitoring System, 1986-1987.

13. Greer, R. C., R. W. Whitman, and R. R. Woodward. 1980. Estimation of probability of beef cows being culled and calculation of expected herd life. J. Anim. Sci. 51:10.

14. Laster, D. B., H. A. Glimp, L. V. Cundiff, and K. E. Gregory. 1973. Factors affecting dystocia and the effects of dystocia on subsequent reproduction in beef cattle. J. Anim. Sci. 36:695.

15. Laster, D. B., and K. E. Gregory. 1973. Factors influencing peri- and early postnatal calf mortality. J. Anim. Sci. 37:1092.

16. Lech, M. E., L. A. Horstman, and C. J. Callahan. 1988. Reproduction of dairy cattle: Postpartum disorders. AS-Coop-Ext-Purdue-Univ., West Lafayette, IN.

17. The Merck Veterinary Manual. 7th ed. Merck & Co., Inc. Rahway, NJ.

18. Mickelson, W. D. 1990. Investigating the causes of low pregnancy rates in beef cattle herds. Veterinary Medicine Publishing Company, Lenexa, Kansas.

19. Ott, S. L., S. J. Wells, and B. A. Wagner. 1999. Herd-level economic losses associated with Johne's disease on U.S. Dairy operations. Prev. Vet. Med. 40:179.

20. Patterson, D. J., R. A. Bellows, P. J. Burfening, and J. B. Carr. 1987. Occurrence of neonatal and postnatal mortality in range beef cattle. I. Calf loss incidence from birth to weaning, backward and breech presentations and effects of calf loss on subsequent pregnancy rate of dams. Theriogenology 28:557.

21. Smith, R. D., H. N. Erb, and P. A. Oltenacu. 1985. Health disorders: Their effect on herd reproduction. Cornell Animal Science Mimeo Service No. 87.

22. United States Department of Agriculture--Animal and Plant Health Inspection Service, National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 2000. U.S. Livestock and Poultry Commodity Values, 1999.

23. United States Department of Agriculture--Animal Plant Health Inspection Service, National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1996. Part I: Reference of 1996 Dairy Management Practices.

24. United States Department of Agriculture--Animal Plant Health Inspection Service, National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1998. Part III: Reference of 1997 Beef Cow-Calf Production Management and Disease Control.

25. United States Department of Agriculture--National Agricultural Statistics Service. 1995. Agricultural Prices, 1994 Summary. Washington, D.C.

26. United States Department of Agriculture--National Agricultural Statistics Service. 2000. Agricultural Prices, 1999 Summary. Washington, D.C.

27. United States Department of Agriculture--National Agricultural Statistics Service. 2000. Cattle. January 2000 Cattle Rept. Washington, D.C.

28. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1998. California Report, Summary of Round One, May 1984-December 1985, p 12.

29. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1988. California Report, Summary of Round Two, March 1986-July 1987, p 17.

30. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1990. California Report, Summary of Round Two Beef, March 1988-September 1989, p 12.

31. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1990. California Report, Summary of Round Three Dairy, March 1988-July 1989, p 16.

32. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1988. Colorado Report, Summary of Round One, p 16.

33. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1988. Colorado Report, Summary of Round Two, October 1986-September 1987, p 18.

34. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1989. Colorado Report, Summary of Round Three, October 1987-September 1988, p 20.

35. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. Colorado Technical Report, Round Two, October 1986-September 1987.

36. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1989. Colorado Technical Report, Round Three, October 1987-September 1988, p 123.

37. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1988. Georgia Report, Summary Round One, July 1985-June 1986, p 20.

38. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1988. Georgia Report, Summary of Round Two, May 1987-April 1988, p 20.

39. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1988. Georgia Technical Report Round One Beef, July 1985-June 1986, p 98.

40. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1987. Iowa Technical Report, Round One, August 1984-October 1985, p 148.

41. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1990. Iowa Report, Summary of Round Two, May 1986-April 1987, p 14.

42. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1988. Michigan Report, Summary of Round One, July 1986-June 1987, p 21.

43. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1990. Michigan Report, Summary of Round Two, January 1988-March 1989, p 31.

44. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1988. Ohio Report, Summary of Round One, November 1983-October 1984, p 25.

45. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1989. Ohio Report, Summary of Round Two, January 1986-March 1987, p 20.

46. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1990. Ohio Report, Summary of Round Three, March 1988-May 1989, p 16.

47. United States Department of Agriculture--National Animal Health Monitoring System, Center for Epidemiology and Animal Health, Fort Collins, CO. 1988. Tennessee Report, Summary of Round One, October 1983-January 1985, p 24.

48. Van Werven, T., Y. H. Shukken, J. Lloyd, A. Brand, H. Tj. Heeringa, and M. Shea. 1992. The effects of duration of retained placenta on reproduction, milk production, postpartum disease and culling rate. Theriogenology 37:1191.

49. Wells, S. J., S. L. Ott, and A. Hillberg Seitzinger. 1998. Key health issues for dairy cattle--New and old. J. Dairy Sci. 81:3029.