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GENETIC SELECTION FOR FERTILITY AND PERFORMANCE

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Introduction

Over the last two- to three-decade period, the beef industry has made great use of genetic selection tools to improve economically important traits. Much of that improvement is due to the implementation and use of expected progeny differences (EPD). Since beef producers are paid for their animals on the basis of weight, or in some cases by the merit of animal carcasses, most EPD reported in breed association sire summaries involve growth traits and carcass traits. Often, selection for reproductive traits (male and female) has been overlooked even though reproduction (fertility) is key to a beef operation's bottom line.

Reproductive efficiency (fertility) determines to a great extent the profitability of the beef cattle enterprise. Income from a beef cattle herd comes from the sale of progeny or the sale of salvageable animals in the breeding herd itself. There is no disputing the level of importance reproduction has when compared to other traits. In a commercial beef cow herd, improvements in reproductive traits can be four times more important than improvements in carcass traits (Melton, 1995). More recently, an evaluation of the relative economic weights of various trait categories was conducted on approximately 110,000 records from the American Gelbvieh Association's Gelbvieh Alliance marketing program. The estimated relative importance of reproductive traits, growth traits, and product traits was approximately 4:2:1, respectively (Schiefelbein, 1998). Reproductive efficiency also has an indirect role in determining profit since it is largely responsible for the amount of selection pressure that breeders might exert in their efforts to increase production levels through genetic improvement of their herds.

The aforementioned studies, as well as others, would suggest that selection for reproduction is required to maximize profitability in the beef cattle enterprise. While it is evident that reproductive traits should receive the greatest emphasis in selection programs, producers should be diligent not to overlook reproduction and at least place it on an equal level with production and product traits in selection protocols. Historically, beef producers have found it difficult to select for reproductive traits. There has been little agreement on how reproduction should be described or expressed. Age at first calving, age at puberty, average interval between successive calves, calving date, calving rate, days from first breeding to conception, days open, number of calves born or weaned per 100 cows bred, postpartum interval, pregnancy rate, services per conception, and 60- to 90-day nonreturn rate are just some of the measures that have been, or are currently being used to describe reproductive efficiency. Following is a discussion of the genetic control many of these traits are under and how reproductive traits may be improved through selection.

Level of Genetic Control on Reproductive Traits

Prior to considering the level of genetic control that reproductive traits are under, a discussion of heritability is warranted. Heritability is a population parameter, or statistic, that measures that amount of observed differences in a trait that are caused by genes passed from one generation to another. In other words, heritability is the amount of variation in a trait that is due to genetics. Values of heritabilities range from zero (low) to one (high). Traits that are lowly heritable are under less genetic control, and are affected by the environment (non-genetic factors) to a greater extent, than highly heritable traits. Heritabilities also indicate how a trait will respond to selection. Lowly heritable traits do not respond to selection as well as highly heritable traits.

Early genetic studies of reproductive traits in cattle involved quantitative evaluations of various gross measures of reproductive efficiency. Such studies generally showed these traits to be lowly heritable. Estimates of the heritability of first service conception rate reported by Dunbar and Henderson (1953), Inskeep et al. (1961), and Dearborn et al. (1973) ranged from 0.004 to 0.22. Zero values were obtained as estimates by Dunbar and Henderson (1953) and Legates (1954) for the heritability of calving interval. For services per conception, Legates (1954) reported a heritability estimate of 0.026. Davenport et al. (1965) and Dearborn et al. (1973) estimated the heritability of number of calves born per 100 cows exposed to a bull to be 0.15 and 0.00. More recent studies of gross measures of reproductive efficiency have yielded similar results. Guitiérrez et al. (2002) and Martínez-Velázquez et al. (2003) estimated the heritability of age at first calving to be 0.23 and 0.08. Pregnancy rate heritabilities reported by Toelle and Robison (1985), Evans et al. (1999), Martínez-Velázquez et al. (2003), and Minnick Bormann et al. (2006) ranged from 0.06 to 0.14. Estimates of the heritability of calving date reported by Buddenberg et al. (1990) and MacNeil and Newman (1994) ranged from 0.03 to 0.30. These and many other studies of the heritability of various gross measures of reproductive efficiency have been made and generally suggest that variation in such traits was largely environmental in origin (instead of genetic) and selection response from these traits would be slow. Consequently, at best only very low rates of improvement in these traits could be expected from application of selection pressures on them.

Quantitative evaluations of component measures of reproductive efficiency have been conducted in an attempt to find traits that respond more readily to selection and indirectly affect reproduction. Examples of such studies include research relating dam pelvic measurement/calf birth weight with dystocia (calving difficulty) and scrotal circumference with bull fertility. Results of these studies provided some promise in terms of potential improvements in some aspects of reproductive efficiency.

Reduced reproductive efficiency from dystocia stems from perinatal calf losses and reduced reproductive performance of the dam following a difficult birth. Calf losses at or near birth attributed to calving difficulty range from 20.4% (Laster and Gregory, 1973) to 79.0% (Anderson and Bellows, 1967). An intermediate value of 50.9% was reported by Bellows et al., 1987. In these studies, dystocia is identified as the single most important contributor to perinatal calf losses. Estimates of overall calf mortality in these three studies were, respectively, 8.6%, 4.7%, and 6.7%. Evidence for reduced reproductive performance in females experiencing dystocia is provided by Brinks et al. (1973) and Laster et al. (1973). In the former, heifers experiencing dystocia weaned 14% fewer calves per cow exposed the year following a difficult birth than did contemporaries that had no difficulty at parturition. In the latter, 14.4% fewer cows experiencing dystocia were detected in estrus during a 45-day artificial insemination period than those not experiencing dystocia. Dystocia also resulted in a 15.9% lower conception rate. Clearly, dystocia contributes significantly to the problem of reduced reproductive efficiency in cattle populations.

Numerous studies (Bellows et al., 1971; Rice and Wiltbank, 1972; Price and Wiltbank, 1978; Deutscher, 1985) have shown that the incidence of dystocia increases as the ratio of calf size to dam's pelvic size increases. In these studies and others, a number of factors have been shown to influence calving difficulty but calf birth weight and dam's pelvic size have emerged as playing a primary role. Many estimates of the heritability of calf birth weight have been reported. A summary by Koots et al. (1994) yielded an average weighted value of 0.35. Several studies (Neville et al., 1978; Benyshek and Little, 1982; Nelsen et al., 1986) have provided estimates of the heritability of pelvic size. These are generally high ranging, for pelvic area, pelvic height, and pelvic width, from 0.04 to 0.68, 0.10 to 0.57, and 0.18 to 0.83, respectively. While the average magnitude of these estimates suggests that selection for increased pelvic size would be quite effective, there is evidence (Benyshek and Little, 1982) that benefits from the resultant increased pelvic size might be partially offset by correlated increases in calf birth weights. However, evidence to the contrary is reported by Nelsen et al., (1986). Estimates of genetic correlation between pelvic measures and birth weight were generally moderately negative although two values obtained through a sire-son regression technique were positive.

Testicular measures have been evaluated as possible means to directly improve male reproductive efficiency (semen output, semen quality, age of puberty, etc.) and indirectly improve female reproductive efficiency (age of puberty). Among the testicular measures, scrotal circumference has been shown to be associated with several measures of semen quality. Studies by Almquist et al. (1976), Neely et al. (1982), Knights et al. (1984) and Gipson et al. (1987) have shown the phenotypic correlation between scrotal circumference and spermatozoal output to be high (greater than 0.50). The latter two studies (Knights et al., 1984; Gipson et al., 1987) also show that scrotal circumference is desirably associated, phenotypically and genetically, with percent live sperm, sperm motility and sperm concentration.

Many studies of the heritability of scrotal circumference have been reported and estimates are consistently high. Koots et al. (1994) reported an unadjusted, weighted scrotal circumference heritability of 0.51. Fewer estimates of the heritability of semen quality traits have been published. Available estimates (Neely et al., 1982; Knights et al., 1984; Gipson et al., 1987) generally indicate that semen quality traits show little genetic variance. Heritability estimates for sperm motility, sperm number, and sperm concentration are generally low and range from 0.03 to 0.24. The generally high heritabilities for scrotal circumference and low heritabilities for semen quality traits, and the consistently high desirable genetic correlations between scrotal circumference and those semen quality traits suggest that direct selection for increased scrotal circumference size would be most effective in bringing about improvement in semen quality traits.

In addition to the favorable correlations with semen traits, scrotal circumference is also favorably correlated with several female reproductive traits, including age of puberty. Martínez-Velázquez et al. (2003), estimated the genetic correlation between scrotal circumference and age of puberty to be -0.15. Other literature estimates place the correlation near -0.80. The presence of such a relationship is beneficial to beef producers as they try to improve reproductive efficiency. Improvements in female age of puberty can be made indirectly by selecting sires with greater scrotal circumference. Toelle and Robison (1985) reported several favorable genetic correlations between scrotal circumference and age at first breeding (-0.10), age at first calving (-0.35), pregnancy rate (0.44), and calving interval (-0.33).

In recent years, efforts have been made to develop evaluations and identify traits that are more directly related to reproduction than many of the previously mentioned traits. Two such traits are heifer pregnancy and stayability. Heifer pregnancy is defined as the probability of a beef female becoming pregnant by the end of her first breeding season. A heritability estimate for heifer pregnancy of 0.14 was reported by Evans et al. (1999). Stayability is currently defined as the probability that a beef female will remain productive in the herd until the age of six. In reality, the age end point could be changed, but six years of age is currently the standard in the industry. Snelling et al. (1995) reported estimates of heritability for stayability ranging from 0.02 to 0.23.

Tools to Improve Reproduction

Expected progeny differences (EPD) represent the beef industry’s most powerful source of information for selection and genetic improvement. EPD are the best estimate of an animal’s genetic worth. EPD are calculated by breed associations and presented in the breed associations’ sire summaries. Before implementing a selection protocol, producers should define their production goals, set minimum performance standards for each trait of interest, and evaluate their herd. After the directions are set, producers should select breeding animals that are superior for the traits of interest and animals that will allow productions goals to be met. Listed below are EPD that producers can use to affect the reproductive performance in their breeding herd.

Birth weight – birth weight EPD is expressed in pounds and represents the sire's ability to transmit birth weight to his offspring compared to other sires. Larger values indicate greater birth weights. Birth weight EPD may be used to keep birth weights in check in a breeding herd and alleviate calving difficulties.

Calving ease (direct) – calving ease (direct) EPD is expressed as a difference in percentage of unassisted births and predicts the difference in ease which a sire's calves will be born when he is mated to first-calf heifers. Larger values indicate greater calving ease (larger percentage of unassisted births) in first-calf heifers. Calving ease (direct) EPD may be used to assist in preventing and diminishing calving difficulties in a breeding herd.

Calving ease (maternal) – calving ease (maternal) EPD is expressed as a difference in percentage of unassisted births and predicts the difference in ease which a sire's daughters will calve as first-calf heifers. Larger values indicate greater caving ease (larger percentage of unassisted births) in a sire's daughters. Calving ease (maternal) EPD may be used to assist in preventing and diminishing calving difficulties in a breeding herd.

Heifer pregnancy – heifer pregnancy EPD is expressed as a difference in percentage of a sire's daughters conceiving to calve at two years of age. Larger values indicate greater numbers of pregnant heifers. Heifer pregnancy EPD may be used to improve reproductive efficiency in a breeding herd.

Scrotal circumference – scrotal circumference EPD is expressed in centimeters and represents the sire's ability to transmit scrotal growth to his offspring compared to other sires. Larger values indicate greater scrotal circumferences. Scrotal circumference EPD may be used to improve reproduction in breeding herds through improved semen traits (males) and decreased age of puberty (males and females).

Stayabilty – stayability EPD is expressed as a difference in percentage of a sire's daughters remaining in the breeding herd until at least six years of age. Larger values indicate greater numbers of cows remaining in the breeding herd for longer periods. Stayability EPD may be used to improve reproductive efficiency in a breeding herd.

Crossbreeding to Improve Reproduction

It is a well know fact that crossbreeding beef cattle offers two primary advantages compared to the use of only one breed. The first advantage that crossbreeding offers is the opportunity to combine the desirable characteristics of more than one breed which allows for an overall higher level of performance among crossbred animals. This is generally referred to as breed complementarity, which occurs when the strong points of one breed mask the weak points of another. The second advantage of crossbreeding is heterosis. Heterosis refers to the phenomenon that causes crossbred animals to have an increased level of performance for certain traits over and above the performance of their purebred parents. As we consider improving reproduction, it should be noted that heterosis and heritability have an inverse relationship. In other words, traits that are lowly heritable and respond poorly to selection generally exhibit greater levels of heterosis.

As mentioned previously, reproductive traits are lowly heritable with heritability estimates around 0.10 (Koots et al. 1994). These estimates would indicate that selection to improve reproductive traits would be difficult and the desired response could take a fair amount of time. However, crossbreeding may offer opportunities to improve reproductive traits and shorten the time required to reach a particular goal. Numerous studies have shown the superiority crossbred cows have over purebred cows in terms of reproduction. Martin et al. (1992) reported the percentage of heifers that reach puberty at a given age is greater for crossbreds than for purebreds. Increased pregnancy rates in beef cattle were reported by Winder et al. (1992) and Olson et al. (1993). Long (1980) reported an average heterosis estimate for calving rate of 8%. In a study examining the lifetime production of crossbred beef cows, Cundiff et al. (1992) found levels of heterosis of 4.9% and 3.8% for survival and growth in crossbred calves. The crossbred cows in the study exhibited maternal heterosis levels of 6.2%, 5.8%, and 16.2% for reproductive rate, weaning weight of progeny, and longevity, respectively. In total, as a cumulative effect of heterosis, lifetime production of weight of calves weaned increased approximately 36% from crossbreeding.

There is no question that a high level of reproductive efficiency is vital to the profitability of a beef cattle enterprise. However, the majority of the traits that are used to describe and evaluate reproductive efficiency are lowly heritable and do not respond well to selection. Considering the results of the cited studies showing the superiority of crossbred cows, and numerous studies that can be found in the literature, all commercial beef cattle operations should take the necessary steps and implement a crossbreeding program.

Summary

Due to the impact that reproductive efficiency (fertility) has on a beef cattle enterprise's profitability, it warrants accurate evaluation and careful consideration in beef cattle selection. Even though producers face challenges (numerous traits, lack of uniformity in describing and evaluating traits, lack of genetic control in various traits, etc.) in selecting for improved reproduction, tools (EPD, etc.) are available to assist them along the way. Depending on the traits that producers are seeking to improve, some favorable correlations may exist to allow for indirect selection of more lowly heritable traits. And finally, if direct and indirect selection methods are not providing the needed selection response, crossbreeding programs are available and can be implemented to take advantage of breed complementarity and heterosis.

References

Almquist, J.O., R.J. Branas, and K.A. Barker. 1976. Postpuberal changes in semen production of Charolais bulls ejaculated at high frequency and the relation between testicular measurements and sperm output. J. Anim. Sci. 42:670-676.

Anderson, D.C. and R.A. Bellows. 1967. Some causes of neonatal and postnatal calf losses. J. Anim. Sci. 26:941(Abstr.).

Bellows, R.A., R.B. Gibson, D.C. Anderson, and R.E. Short. 1971. Precalving body size and pelvic area relationships in Hereford heifers. J. Anim. Sci. 33:455-457.

Bellows, R.A., D.J Patterson, P.J. Burfeing, and D.A. Phelps. 1987. Occurance of neonatal and postnatal mortality in range beef cattle. II. Factors contributing to calf death. Theriogenology 28:573-586.

Benyshek, L.L., and D.E. Little. 1982. Estimates of genetic and phenotypic parameters associated with pelvic area in Simmental cattle. J. Anim. Sci. 54:258-263.

Brinks, J.S., J.E. Olson, and E.J. Carroll. 1973. Calving difficulty and its association with subsequent productivity in Herefords. J. Anim. Sci. 36:11-17.

Cundiff, L.V., R. Nunez-Dominguez, G.E. Dickerson, K.E. Gregory, and R.M. Koch. 1992. Heterosis for lifetime production in Hereford, Angus, Shorthorn, and crossbred cows. J.Anim. Sci. 70:2397-2410.

Davenport, R.L., H.H Stonaker, K. Riddle, and T.M. Sutherland. 1965. Heritability of reproductive performance in inbred and linecross beef cows. J. Anim. Sci. 24:434-437.

Dearborn, D.D., R.M. Koch, L.V. Cundiff, K.E. Gregory, and G.E. Dickerson. 1973. An analysis of reproductive traits in beef cattle. J. Anim. Sci. 36:1032-1040.

Deutscher, G.H. 1985. Using pelvic measurements to reduce dystocia in heifers. Mod. Vet. Pract. 66:751-755.

Dunbar, R.S., and C.R. Henderson. 1953. Heritability of fertility in dairy cattle. J. Dairy Sci. 36:1063-1071.

Evans, J.L., B.L. Golden, R.M. Bourdon, and K.L. Long. 1999. Additive genetic relationships between heifer pregnancy and scrotal circumference in Hereford cattle. J. Anim. Sci. 77:2621-2628.

Gipson, T.A., D.W. Vogt, J.W. Massey, and M.R. Ellersieck. 1987. Associations of scrotal circumference with semen traits in young beef bulls. Theriogenology 24:217-225.

Gutiérrez, J.P., I. Alvarez, I. Fernández, L.J. Royo, J. Díez, and F. Goyache. 2002. Genetic relationships between calving date, calving interval, age at first calving and type traits in beef cattle. Livest. Prod. Sci. 78:215-222.

Inskeep, E.K., W.J. Tyler, and L.E. Casida. 1961. Heredity variation in conception rate in Holstein-Friesian cattle. J. Dairy Sci. 44:1857-1862.

Knights, S.A., R.L. Baker, D. Gianola, and J.B. Gibb. 1984. Estimates of heritabilities and of genetic and phenotypic correlations among growth and reproductive traits inyearling Angus bull. J. Anim. Sci. 58:887-893.

Koots, K.R., J.P. Gibson, C. Smith, and J.W. Wilton. 1994. Analyses of published genetic parameter estimates for beef production traits. I. Heritability. Anim. Breed. Abstr. 62:309-338.

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. 36:696-705.

Laster, D.B., and K.E. Gregory. 1973. Factors influencing peri- and early post-natal calf mortality. J. Anim. Sci. 37:1092-1097.

Legates, J.E. 1954. Genetic variation in services per conception and calving interval in dairy cattle. J. Anim. Sci. 13:81-88.

Long, C.R. 1980. Crossbreeding for beef production: Experimental results. J. Anim. Sci. 51:1197-1223.

Martin, L.C., J.S. Brinks, R.M. Bourdon, and L.V. Cundiff. 1992. Genetic effects on beef heifer puberty and subsequent reproduction. J. Anim. Sci. 70:4006-4017.

Martínez-Velázquez, G., K.E. Gregory, G.L. Bennett, and L.D. Van Vleck. 2003. Genetic relationships between scrotal circumference and female reproductive traits. J. Anim. Sci. 81:395-401.

Melton, B.E. 1995. Conception to consumption: The economics of genetic improvement. p. 40 in Proc. 27th Beef Improvement Federation Research Symposium and Annual Meeting, Sheridan, WY. Beef Improvement Federation, Manhattan, KS.

Minnick Bormann, J., L.R. Totir, S.D. Kachman, R.L. Fernando, and D.E. Wilson. 2006. Pregnancy rate and first-service conception rate in Angus heifers. J. Anim. Sci. 84:2022-2025.

Neely, J.D., B.H. Johnson, E.U. Dillard, and O.W. Robison. 1982. Genetic parameters for testes size and sperm number in Hereford bulls. J. Anim. Sci. 55:1033-1040.

Nelsen, T.C., R.E. Short, J.J. Urick, and W. L Reynolds. 1986. Heritabilities and genetic correlations of growth and reproductive measures in Hereford bulls. J. Anim. Sci. 63:409-417.

Neville, W.E. Jr., J.B. Smith, B.G. Mullinix Jr., and W.C. McCormick. 1978. Relationship between pelvic dimensions, between pelvic dimensions and hip height and estimates of heritabilities. J. Anim. Sci. 47:1089-1094.

Olson, T.A., F.M. Peacock, and M. Koger. 1993. Reproductive and maternal performance of rotational three-breed, and inter se crossbred cows n Florida. J. Anim. Sci. 71:2322-2329.

Price, T.D. and J.N. Wiltbank. 1978. Predicting dystocia in heifers. Theriogenology 9:221-249.

Rice, L.E. and J.N. Wiltbank. 1972. Factors affecting dystocia in beef heifers. J. Amer. Vet. Med. Assoc. 161:1348-1358.

Schiefelbein, D. 1998. Back to the basics: A real world strategy for improving the quality and consistency of beef. p. 74 in Proc. 30th Beef Improvement Federation Research Symposium and Annual Meeting. Calgary, AB, Canada. Beef Improvement Federation, Manhattan, KS.

Snelling, W.M., B.L. Golden, and R. M. Bourdon. 1995. Within-herd genetic analysis of stayability of beef females. J. Anim. Sci. 73:993-1002.

Toelle, V.D., and O.W. Robison. 1985. Estimates of genetic correlations between testicular measurements and female reproductive traits in cattle. J. Anim. Sci. 60:89-100.

Winder, J.A., B.J. Rankin, and C.C Bailey. 1992. Maternal performance of Herford, Brangus, and reciprocal crossbred cows under semi desert conditions. J. Anim. Sci. 1032-1038.