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PROCEDURES THAT SUPPORT REPRODUCTIVE MANAGEMENT OF REPLACEMENT BEEF HEIFERS*

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Introduction

Selection and management of replacement beef heifers involve decisions that affect future productivity of an entire cowherd. Programs to develop replacement heifers are focused on the physiological processes that influence puberty. Age at puberty is most important as a production trait when heifers are bred to calve as 2-yr-olds and in systems that impose restricted breeding periods (Ferrell, 1982). The decision to breed heifers as yearlings involves careful consideration of the economics of production and the reproductive status, breed type, or genetic make-up of the heifers involved (Wiltbank, 1978; Morris, 1980; DeRouen and Franke, 1989; Kinder et al., 1990; Marshall et al., 1990; Short et al., 1990). Geographical-region differences in the age at which heifers are first exposed for breeding depend on management systems, forage quality and availability, and adaptation of respective breed types to specific environmental conditions (Short et al., 1990). In some cases, the economic advantage of early breeding and calving is now offset by biological limitations of the animal and management constraints of the environment (Short et al., 1990).

Reproductive performance is the single most important economic trait in a beef cow herd (Trenkle and Willham, 1977; Melton, 1995). Most reproductive loss occurs because cows fail to become pregnant or losses at or near birth are high (Wiltbank, 1990; Bellows and Short, 1990). Reproductive management requires a broad appreciation of technical material and knowledge to minimize reproductive loss, and make decisions that ultimately result in profit (Dziuk and Bellows, 1983). This review is focused on reproductive management practices for developing replacement beef heifers and the current state of the industry concerning utilization of various management procedures.

The Reproduction Cycle of the Cow

The reproductive phase of the beef production to consumption process is characterized by the breeding, conception, birth, and early nurturing of an animal (Melton, 1995). Increased weaning rate represents the greatest time-adjusted economic value to commercial cow-calf producers, simply because without a calf to sell no other characteristic has much meaning (Melton, 1995). Reproductive failure and (or) loss within a herd occurs primarily as a result of cows failing to become pregnant or the loss of calves at or near birth (Wiltbank, 1990; Bellows and Short, 1990). Puberty in the heifer and resumption of estrous cyclicity following calving in the

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postpartum cow are the critical reproductive events that determine if and when pregnancy will occur.

Puberty in the bovine female is determined by an array of identifiable genetic and environmental variables. Ultimate reproductive competence is established as a consequence of a specific program of developmental events leading to organization of functionally competent reproductive tissues and organs (Bartol et al., 1995). Studies designed to determine the sequence of events that occur at puberty gave way to research focused on basic factors that influence the onset of puberty and the interplay of reproduction, growth and metabolism. Reviews of the literature provide answers to questions concerning control of puberty in the heifer and factors influencing its onset. These perspectives include genetics (Martin et al., 1992), nutrition and season (Schillo et al., 1992), reproductive endocrinology (Day and Anderson, 1998), and management (Kinder et al., 1990; Patterson et al., 1992a; Larson, 1998).

Production of forage and the reproductive process in beef cattle are cyclical events (Figure 1; Bellows, 1987). The broad general categories that describe this cycle include: 1) developing the replacement heifer and 2) rebreeding the lactating dam. Growth and weight gains are integral to both reproductive events and attainment of profitable production (Bellows, 1987). Collectively, this suggests life-cycle feeding approaches are needed, in which higher levels of supplemental feeding are used during key periods of growth and development.

Heifers bred to calve as 2-yr-olds should be exposed for breeding before mature herdmates and early calving periods can be used as a means of increasing production efficiency (Wiltbank, 1970). This practice often results in heifers being bred on their pubertal estrus. Fertility of heifers bred at the pubertal estrus was 21% lower than for those bred on their third estrus (Byerley et al., 1987; Perry et al., 1991). This means heifers should reach puberty 1 to 3 mo before the average age at which they are to be bred (Short et al., 1990). Earlier age at puberty in relation to breeding ensures a high percentage of heifers are estrous cycling and the effects of lowered potential fertility at the pubertal estrus are minimized (Short et al., 1990).

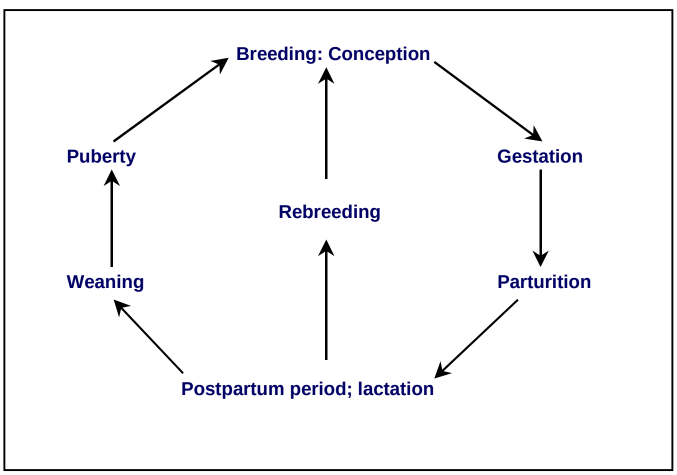

Figure1. Reproduction cycle of the beef female (Bellows, 1985).

The timing of puberty is critical in determining whether a heifer remains in the herd and the extent to which lifetime productivity is achieved. Because most components of fertility that influence calving and subsequent reproductive performance are not highly heritable, it is logical to assume the majority of factors related to reproductive performance in cattle are influenced almost entirely by management. Patterson et al. (1992a) provided a sequential review of the consequences associated with use of various management practices that may be imposed during each phase of the development process, beginning with the suckling phase of the heifer calf and progressing through the first postpartum period.

A number of factors influence the ability of a cow to calve in a given year and successively over a number of years. Management of replacement heifers during the postweaning to prebreeding period influences to a large extent when puberty, pregnancy, and parturition will occur. Heifers that calve early during their first calving season have higher lifetime calf production than those that calve late (Lesmeister et al., 1973). Because most calves are weaned at a particular time rather than on a weight-constant or age-constant basis, calves born late in the normal calving season are usually lighter than those born early, decreasing lifetime productivity of their dams (Lesmeister et al., 1973).

Reproductive Management Procedures for Replacement Beef Heifers

Long-term survival and prosperity of the U.S. beef cattle industry depends on its economic viability, which is best served by its competitiveness, profitability and economic efficiency (Melton, 1995). Managing an enterprise requires the fundamental ability to make decisions based on information that exists rather than something one imagines. A range of procedures is available to cow/calf producers to aid in reproductive management of replacement beef heifers and determine the outcome of a development program. These procedures, when collectively viewed as a "program", assist producers in more effectively managing reproduction in their herds. Producers that utilize these procedures are able to use data generated on their own farms and with their own heifers to plan, execute, and accomplish reproductive and genetic goals for their herds. These procedures facilitate improvements in breeding performance of replacement beef heifers during the first breeding season and during the subsequent calving and rebreeding period as 2-yr-olds. Adoption of specific procedures for an operation depends on factors including current level of performance, availability of facilities and labor, and economic return.

Table 1 provides a summary from USDA's National Animal Health Monitoring System (NAHMS, 1994a), which reviews the percent of beef cattle operations in the U.S. using selected management procedures on replacement beef heifers. These procedures gained only marginal acceptance, despite their potential impact and resulting contribution to the reproductive integrity of an entire herd, both short and long-term. Collectively, these practices help to ensure heifers entering a herd as raised or purchased replacements will contribute immediately, and cumulatively long-term, to the general performance and productivity of that herd. These procedures provide an objective assessment of the postweaning to prebreeding development phase and a useful means of selecting or culling potential replacements. A sequential review of these practices is required to establish the relative merit of each practice singly, and more importantly, the cumulative contribution of these practices to an improvement in total reproductive management of an entire cowherd.

Table 1. Selected management procedures used on replacement beef heifers[a]

Management practice	% of operations
Feed separately	31.8
Pelvic measurements	3.0
Reproductive tract scores	1.2
Breed prior to the mature herd	12.7
Synchronize estrus	3.0
Artificial insemination	3.3
Body condition score	4.6
Weigh	7.9
Pregnancy diagnosis/palpation	15.9

[a]Adapted from NAHMS, 1994a.

Target Weight. The target weight principle calls for feeding heifers to a prebreeding target weight that represents 65% of the heifer's projected mature weight. Puberty can be expected to occur at a genetically predetermined size among individual animals (Lamond, 1970; Taylor and Fitzhugh, 1971), and only when heifers reach genetically predetermined target weights can high pregnancy rates be obtained. Genotype of the heifer must be considered in the development program (Laster et al., 1976; Brinks et al., 1978; Toelle and Robison, 1985; Cundiff, 1986). Effects of postweaning nutritional development manifest themselves at different points within the reproductive cycle. Furthermore, vulnerability of specific breeds or breed crosses to these effects differs at specific points within this cycle (Patterson et al., 1991, 1992b). Heifers with the genetic potential to reach a heavier mature weight must attain a heavier prebreeding weight before the first breeding season. Using the standard set by the Beef Improvement Federation (BIF, 1990) for nine frame-size classifications for U.S. breeding cattle, producers can estimate body composition and energy requirements per kg of gain at various weights during the feeding period (Fox et al., 1988). Optimum growth rates for replacement females of various body types are also available. These growth rates represent optimums for heifers that vary in mature size and were developed to maximize female lifetime productivity (Table 2; Fox et al., 1988).

Table 2. Optimum growth rate for breeding herd replacement heifers[a]

Frame size	1	3	5	7	9
Optimum weight at first estrus, lb	572	669	761	858	955
Mature weight, lb	880	1027	1173	1320	1467

[a]From Fox et al., 1988.

Although rate of gain is important for heifers to reach puberty at an early age, rapid growth during the prepubertal period can decrease subsequent milk production (Mangus and Brinks, 1971; Kress and Burfening, 1972; Holloway and Totusek, 1973; Beltran, 1978; Martin et al., 1981; Sejrsen et al.,1982; Harrison et al., 1983; Johnsson and Obst, 1984; Laflamme, 1993; Sejrsen, 1994; Sejrsen and Purup, 1997). Stair-step nutritional management regimens were used to limit growth during critical periods of mammary development and to subsequently allow periods of rapid growth to permit heifers to reach puberty at an early age (Park et al., 1989, 1998;

Barash et al., 1994; Choi et al., 1997; Lynch et al., 1997). Grings et al. (1998, 1999) reported little direct effect of either trace mineral supplementation or altering rates of gain from weaning through the beginning of the breeding season on reproductive performance and subsequent milk yield for beef heifers gaining over .6 kg/d. These authors, therefore, suggested some flexibility in gain strategy and diet formulation with subsequent alterations in feed costs (Grings et al., 1999).

Patterson et al. (1992b) reported a significant negative relationship between age at puberty (AAP) and subsequent length of the postpartum interval (PPI) to estrus after parturition. The increase in PPI among heifers that reached puberty at younger ages was associated with weight of the heifer at weaning. Heifers that weighed more at the time they were weaned as calves reached puberty at younger ages and heavier weights. These same heifers, however, experienced longer PPI after calving, and weaned heavier calves at the end of their first year in production as 2-yr-olds. Heifers experienced longer PPI when both weight and condition at calving declined. Ferrell (1982) showed large heifers were younger and heavier at puberty, produced more milk, and had lower body condition scores than did small heifers. Large cows that produce more milk are expected to have higher feed requirements than small cows that produce less milk. Lower condition scores suggest large heifers are less able to meet their feed requirements during lactation than are small heifers (Ferrell, 1982; Buttram and Willham, 1987). These data are supported by more recent studies from Brink and Kniffen (1996), and Frazier et al. (1999). Collectively, these data characterize a common problem in the industry associated with nutritional management of the 2-yr-old cow and demonstrate early management regimens have a significant effect on subsequent reproduction.

Until a better rule of thumb is established, the target weight principle of developing heifers to an optimum prebreeding weight seems to be the most feasible method of ensuring that a relatively high percentage of yearling heifers reach puberty by the breeding season. However, the NAHMS (1994a) data indicate that few operations either weigh (7.9%), body condition score (4.6%), or feed heifers separately from the mature cowherd (31.8%), suggesting in many cases heifers are not being fed adequately in order to meet their unique nutritional needs (Table 1).

Prebreeding Exams: Reproductive Tract Scores (RTS) and Pelvic Measurements.

Reproductive Tract Scores. A practice developed recently (Anderson et al., 1991) can be used to assist beef producers with selection of potential herd replacements and support timing of estrus synchronization programs. A reproductive tract scoring (RTS) system was developed to estimate pubertal status (Table 3). Scores are subjective estimates of sexual maturity, based on ovarian follicular development and palpable size of the uterus. A RTS of 1 is assigned to heifers with infantile tracts, as indicated by small, toneless uterine horns and small ovaries devoid of significant structures. Heifers scored with a RTS of 1 are likely the furthest from puberty at the time of examination. Heifers assigned a RTS of 2 are thought to be closer to puberty than those scoring 1, due primarily to larger uterine horns and ovaries. Those heifers assigned a RTS of 3 are thought to be on the verge of estrous cyclicity based on uterine tone and palpable follicles. Heifers assigned a score of 4 are considered to be estrous cycling as indicated by uterine tone and size, coiling of the uterine horns, as well as presence of a preovulatory size follicle. Heifers assigned a score of 4 do not have an easily distinguished corpus luteum. Heifers with RTS of 5 are similar to those scoring 4, except for the presence of a palpable corpus luteum (Table 3). Prebreeding examinations that include RTS furnish the opportunity to assess reproductive development, but further provide an appraisal of possible aberrant situations that may detract from a heifer’s subsequent reproductive potential.

Table 3. Reproductive tract scores[a]

RTS	Uterine horns	Ovarian length (mm)	Ovarian height (mm)	Ovarian width (mm)	Ovarian structures
1	Immature, < 20 mm diameter, no tone	15	10	8	No palpable follicles
2	20-25 mm diameter, no tone	18	12	10	8 mm follicles
3	20-25 mm diameter, slight tone	22	15	10	8-10 mm follicles
4	30 mm diameter, good tone	30	16	12	10 mm follicles, CL possible
5	> 30 mm diameter	> 32	20	15	CL present

[a]From Anderson et al., 1991.

Figure 2 represents a modified interpretation of the conceptual model for puberty onset in the heifer presented by Day and Anderson (1998). This model combines the associated endocrine and ovarian changes that occur as heifers approach puberty, in addition to the corresponding RTS that would be assigned at respective points in development. A RTS of 1 corresponds to the point in time at which the pattern of LH release is characterized by low-frequency pulses. This is due to the fact that the hypothalamic-pituitary axis is highly responsive to estrogen negative feedback. Reproductive tract scores of 2 and 3 are associated with the peripubertal phase, at which responsiveness to estradiol negative feedback decreases, causing increases in LH pulse frequency, follicle growth, and estradiol secretion. The decline in estradiol negative feedback and increase in LH secretion result in significant increases in follicular growth, and elevated concentrations of estradiol sufficient to induce estrus and the preovulatory LH surge. Reproductive tract scores of 4 and 5 are assigned to heifers that have reached puberty, but differ in stage of the estrous cycle at the time of the prebreeding exam (follicular phase = 4; luteal phase = 5).

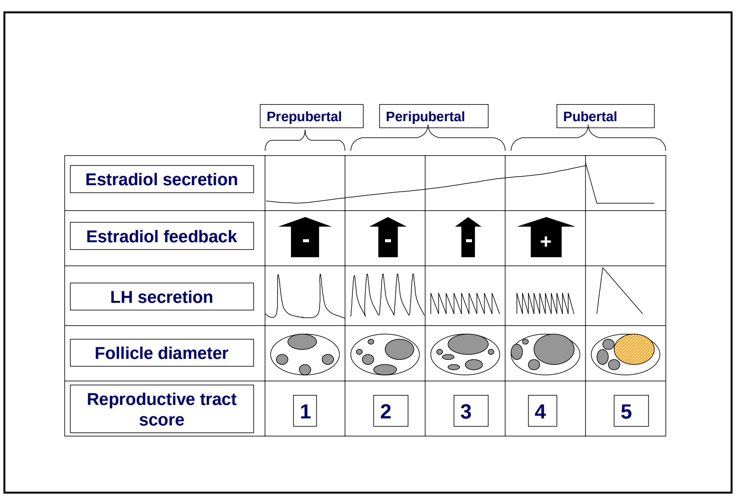

Figure 2. Endocrine and ovarian changes associated with puberty onset in the heifer and associated reproductive tract score (adapted from Day and Anderson, 1998 and Anderson et al., 1991).

Growth-promoting implants are used extensively in the nursing, growing, and finishing phases of the beef cattle production cycle (Hargrove, 1990; Simpson and Moore, 1990; Deutscher, 1991). Growth promoting or anabolic agents are compounds containing estrogen and (or) progesterone, nonsteroidal compounds that have estrogenic activity (zeranol), or potent synthetic androgens (trenbolone acetate). Bartol et al. (1995) designed a study to determine 1) if exposure of neonatal heifer calves to progesterone or estradiol, delivered from a commercial growth-promoting implant (Synovex-C®) would affect adult uterine structure or function evidenced by changes in gross morphology, histoarchitecture, or uterine luminal protein content; and 2) whether such effects would be related to the neonatal age at which steroid exposure first occurred. The results from Bartol's study are shown in Table 4. Results from this study (Bartol et al., 1995) clearly indicate chronic exposure of heifer calves to progesterone or estradiol, beginning on or before postnatal d 45, reduced uterocervical wet weights and altered uterine wall histology. It is especially important to note these effects were observed in heifers 15 mo after the first steroid exposure. Regardless of the neonatal age at which treatment began, chronic administration of progesterone and estrogen was ultimately reflected in the adult uterine wall by significant reductions in cross-sectional areas for both myometrium and endometrium and by reduced uterine gland density. In some cases, developmental loss of adult endometrial parenchyma was reflected by reductions in both endometrial area and glandularity, in some cases approaching 75%. Although this study was not designed to evaluate implant effects on bovine fertility, the changes that occurred cannot be considered desirable effects, because both maternal uterine tissues and uterine secretions are recognized to play critical roles in support of conceptus development (Bartol et al., 1995).

Table 4. Effects of neonatal exposure to progesterone and estradiol on reproductive tract development of adult beef heifers[a]

	Neonatal age at treatment[c]			
Response[b]	Birth	Day 21	Day 45	Control
Uterocervical weight[d] (g)	113.7[e]	123.5[e]	101.3[e]	173.9[f]
Myometrial area (mm^2)	123.7[h]	141.8[h]	111.3[h]	162.8[I]
Endometrial area (mm^2)	29.9[j]	32.4[j]	37.7[j]	45.4[k]
Gland density (hits/mm^2)	172.2[e]	380.3[f]	328.2[f]	486.9[g]
Uterine luminal protein content (mg/flush)	2.8[e]	2.9[e]	2.3[e]	4.9[f]

[a]Adapted from Bartol et al., (1995).
[b]Data were collected from cyclic adult heifers on d 12 of an induced estrous cycle.
[c]Treated heifers received a single Synovex-C® implant containing progesterone (100 mg) and estradiol benzoate (10 mg). Implants were placed (sc) on the designated day of neonatal life. Control heifers were untreated.
[d,e,f,g,h,i,j]Means within a row with different superscripts differ ($P < .05$).

The significance of these findings as they relate to RTS pertain to situations involving heifers in which the management history of the heifer is unknown at the time the prebreeding exam is performed. The changes that occur in uterine morphology as a result of implant administration are in many cases palpable per rectum at the time the RTS is performed. These observations are made in heifers that are examined up to 15 mo after the first steroid exposure, as noted by the 75 % reduction in endometrial area and glandularity (Bartol et al., 1995).

The reproductive tract scoring system can be used to select heifers that are "reproductively ready" for the breeding season and thus minimize carrying costs of heifers that will very likely fail to cycle and conceive. Reproductive tract scores, when timed appropriately, serve as a useful indicator in determining whether heifers are ready to be placed on an estrus synchronization treatment and are useful too, in determining the most appropriate method of estrus synchronization to use. However, just over 1 % of producers use this relatively new management tool (Table 1).

Pelvic Measurements. Pelvic measurements should be used in addition to, not in place of, selection for size, weight, and above all fertility (Bellows and Staigmiller, 1990). Producers should be aware selection for pelvic area will not likely result in increased pelvic dimensions alone, but will result in increased size of the entire skeleton and animal (Morrison et al., 1986). Increased skeletal size of the dam will be reflected in higher birth weights and dimensions of the calf. Pelvic measurements, on the other hand, can be used successfully to identify abnormally small or abnormally shaped pelvises. These situations, left unidentified, often are associated with extreme dystocia, resulting in Cesarean delivery and even death of the calf or dam (Patterson et al., 1992a).

Recent estimates indicate nearly 20% of beef heifers require some degree of calving assistance (NAHMS, 1994b). The NAHMS (1994b) survey indicates over half of producers (57.2%) only check their heifers one to two times per 24-hr period during the calving season. Furthermore, recent statistics indicate that calf losses due to dystocia may run as high as 20%. Selection of sires with low BW-EPD mated to heifers screened for pelvic area could contribute to a decrease in the incidence and (or) severity of calving problems and minimize calf losses from dystocia.

Bullock and Patterson (1995) reported puberty exerts a positive influence on pelvic width and resulting pelvic area in yearling heifers, however, differences seen among heifers as yearlings did not carry through to calving as 2-yr-olds. Therefore selection (culling) decisions based on pelvic measurements and contemporary grouping for genetic analysis of pelvic measurements should include consideration of pubertal status at the time of the examination. The data suggest that puberty plays a role in pelvic size as yearlings, but once heifers reach puberty the effects may no longer be present. An independent culling level for pelvic size on heifers that are at different stages in their reproductive development appears to be more restrictive for those heifers that are peripubertal at the time of the exam. Despite the fact pelvic measurements can be a useful management tool to eliminate heifers with a higher potential for calving difficulty, only 3% of producers reported using this technique in their herds (Table 1).

Estrus Synchronization and Artificial Insemination. The percentage of beef cattle inseminated artificially is predicted to increase substantially with the advent of sexed semen (Seidel, 1998). Currently, however, only 3.3% of the beef cattle operations in the U.S. practice AI on their heifers and only 3% of total operations use estrus synchronization to facilitate their AI programs (Table 1).

Although hormonal treatment of heifers and cows to group estrous periods has been a commercial reality now for years, producers have been slow to adopt this management practice. Perhaps this is because of past failures, which resulted when females placed on estrus synchronization treatments failed to reach puberty or to resume normal estrous cycles following calving. Estrus synchronization and artificial insemination remain however, the most important and widely applicable reproductive biotechnologies available (Seidel, 1995).

Estrus synchronization and artificial insemination contribute to a total heifer development program in several ways. Estrus synchronization improves time management for producers that use AI by concentrating the breeding and resulting calving periods. Managers are able to spend more time observing heifers as they calve because calving occurs over a shorter time period. Calf losses in many cases are reduced because of improved management during the calving period. Artificial insemination provides the opportunity to breed heifers to bulls selected for low BW-EPD with high accuracy. This practice minimizes the incidence and severity of calving difficulty and decreases calf loss that results from dystocia. In addition, heifers that conceive during a synchronized period typically wean calves that are older and heavier at weaning time (Schafer et al., 1990). Finally, heifer calves that result from AI can be an excellent source of future replacements facilitating more rapid improvement in the genetic makeup of an entire herd.

Methods of synchronizing estrus were reviewed by Patterson et al. (1989), Odde (1990), Larson and Ball (1992), Beal (1998), and Patterson (1999). The development of methods to control the estrous cycle of the cow has occurred in five distinct phases (Patterson, 1999). Phase I included efforts to prolong the luteal phase of the estrous cycle or to establish an artificial luteal phase by administering exogenous progesterone. Later, progestational agents were combined with estrogens or gonadotropins in Phase II; whereas Phase III involved prostaglandin $F_{2\alpha}$ (PG) and its analogs as luteolytic agents. Treatments that combined progestational agents with PG characterized Phase IV.

Precise monitoring of ovarian follicles and corpora lutea over time by transrectal ultrasonography expanded our understanding of the bovine estrous cycle and particularly the changes that occur during a follicular wave. Growth of follicles in cattle occurs in distinct wave-like patterns, with new follicular waves occurring approximately every 10 d (range 6-15 d). We now know (Phase V) precise control of estrous cycles requires the manipulation of both follicular waves and luteal lifespan. A single injection of gonadotropin-releasing hormone (GnRH) to cows at random stages of their estrous cycles causes release of luteinizing hormone leading to synchronized ovulation or luteinization of most large dominant follicles. Consequently, a new follicular wave is initiated in most cows within 2 to 3 d of GnRH administration. Luteal tissue that forms after GnRH administration is capable of undergoing PG-induced luteolysis 6 or 7 d later (Twagiramungu et al., 1995). The GnRH-PG protocol increased estrus synchronization rate in beef (Twagiramungu et al., 1992a,b) and dairy cattle (Thatcher et al., 1993). However, a drawback of this method is approximately 5 to 15% of the cows are detected in estrus on or before the day of PG injection, thus reducing the proportion of females detected in estrus and inseminated during the synchronized period. Furthermore, this system has not been effective when administered to heifers.

In recent years, the 14-17 d melengestrol acetate (MGA)-PG treatment has become a widely used method of synchronizing estrus in replacement beef heifers (Brown et al., 1988). Melengestrol acetate is an orally active progestational steroid (Zimbelman and Smith, 1966) capable of inhibiting estrus and ovulation in heifers when consumed (0.5 mg) on a daily basis. Melengestrol acetate is fed for 14 d in a supplement carrier. Heifers exhibit estrus beginning 48 h after MGA withdrawal from the feed, but should not be inseminated or exposed for natural service at this time. Prostaglandin $F_{2\alpha}$ should be administered 17 d after MGA withdrawal with insemination based on detected estrus. This treatment avoids problems with reduced conception and offers advantages compared with untreated controls (Brown et al., 1988;Patterson and Corah, 1992). The advantages of MGA for synchronization of estrus are ease of administration and cost. Furthermore, MGA recently received clearance (Federal Register, 1997) for use in reproductive classes of beef and dairy females. Although, this treatment works effectively to synchronize estrus, growth in the use of estrus synchronization and artificial insemination depends upon the development of methods that shorten the time period required to detect heat and (or) facilitate use of fixed-time insemination.

Wood et al. (1999) evaluated a modified MGA-PG protocol for inducing and synchronizing a fertile estrus in yearling beef heifers. The first modification changed the day of PG injection from d 31 to d 33 of treatment. The second modification was the addition of a GnRH injection on d 26 of treatment (MGA feeding d 1 to 14, GnRH on d 26, and PG on d 33; MGA-GnRH-PG). Injection of GnRH on d 26 of this protocol successfully induced luteal tissue formation and initiated a new follicular wave on approximately d 28. This modification resulted in a significant increase in the proportion of animals with synchronized follicular waves on d 33 and an associated improvement in the degree of synchrony after PG. This sequential approach to estrous cycle control (progestin-GnRH-PG) appears to offer significant potential to more effectively synchronize estrus with resulting high fertility (Wood et al., 1999; Kojima et al., 2000; Patterson et al., 1999).

Potential for Induced Estrous Cyclicity with Progestins. Progestins were used to induce estrus in peripubertal heifers (Gonzalez-Padilla et al., 1975) and are often combined with estrogen to mimic changes that occur in concentrations of blood hormones around the time of puberty. Increased progesterone is thought to be a prerequisite for the development of normal estrous cycles. Progesterone increases during the initiation of puberty in the heifer (Berardinelli et al., 1979), and before resumption of normal ovarian cyclicity in postpartum suckled beef cows (Prybil and Butler, 1978; Rawlings et al., 1980). Progestins stimulate an increase in follicular growth that results subsequently in increased production of estrogen by ovarian follicles (Henricks et al., 1973; Wetteman and Hafs, 1973; Sheffel et al., 1982; Garcia-Winder et al., 1986). Melengestrol acetate initiates estrous cyclicity in peripubertal beef heifers (Patterson et al., 1990) and is associated with increased LH pulse frequency during the treatment period (Smith and Day, 1990; Imwalle et al., 1998). Recent studies suggest the stimulatory effects of progestins on LH secretion are greatest after removal of the steroid (Hall et al., 1997; Imwalle et al., 1998). Furthermore, improvements in observed pubertal induction response following treatment with a progestin occur with an increase in age (Hall et al., 1997). The increase in pulsatile release of LH that occurs in response to progestin treatment in peripubertal heifers results in a decrease in estrogen receptors within neuronal systems that mediate negative feedback actions of estradiol on GnRH secretion (Anderson et al., 1996).

Burfening (1979) suggested because puberty is a heritable trait, induced puberty in replacement heifers over several generations might result in situations in which attainment of puberty would be difficult without hormone treatment. This consideration cannot be overlooked. However, there is a need to explore treatments to induce puberty in breeds of cattle that are late-maturing but of sufficient age and weight at the time of treatment to permit successful application (Patterson et al., 1990). The decision to utilize this practice within a herd perhaps differs with various types of beef operations. For instance, the common goal of most managers of commercial cow-calf herds is to maximize weaning rate. In other words, the investment in time and resources in a heifer from weaning to breeding requires management efforts be made to facilitate puberty onset and maximize the likelihood of early pregnancy. In this scenario, a method to induce puberty in heifers could serve as a valuable tool to improve reproductive performance of heifers retained for breeding purposes. On the other hand, seedstock managers should weigh the economic importance of puberty onset in their herds, as well as their customers', and the associated potential and resulting implication of masking its true genetic expression.

Early Pregnancy Diagnosis. Determining pregnancy rates and accurately evaluating their distribution by period within a breeding season requires pregnancy diagnosis be performed at a fixed time. To accurately determine conception date and resulting calving date, this time point should represent a maximum number of days from when breeding began. This information can then be used to determine the success of an estrus synchronization and AI program, project subsequent calving dates and cull late-bred or non-pregnant replacements.

Diagnostic ultrasonography provides a non-invasive form of visual access to the cervix, uterus and ovaries for evaluating normal, morphologic changes in cattle (Pierson and Ginther, 1988; Kastelic et al., 1988; Griffin and Ginther, 1992). The potential advantages of using ultrasonography for pregnancy diagnosis are that the presence of an embryo can be detected earlier than by palpation per rectum. Use of ultrasonography rather than manual palpation of the reproductive tract may improve consistency of early (< d 45) pregnancy diagnosis by reducing variation in accuracy among technicians (Beal et al., 1992). In addition, fetal sexing using ultrasonography may be an effective management and marketing tool (Muller and Wittkowski, 1986). Knowing the sex of the developing fetus can provide valuable information to the breeder and (or) purchaser of bred replacement heifers. Pregnancy diagnosis is one of the more widely used reproductive procedures, however, only 15.9 % of the beef cattle operations in the U.S. routinely determine pregnancy status of their heifers (NAHMS, 1994a).

Interpreting Data Obtained from Various Reproductive Procedures to Make Management Decisions

Collectively, prebreeding weight, reproductive tract score, pelvic height, pelvic width, and total pelvic area can be used to evaluate success of a development program. Timing these procedures is critical in determining whether heifers are ready to be placed on an estrus synchronization treatment, the type of treatment to be used, and the anticipated outcome of a particular treatment regarding estrus response and subsequent pregnancy. Table 5 summarizes prebreeding data collected on 2,664 heifers (Patterson and Bullock, 1995). Measurements were obtained within 2 wk prior to administration of a 14-17 d MGA-PG treatment. Reproductive tract score was correlated with prebreeding weight (r=.39), pelvic height (r=.30) pelvic width (r=.34) and total pelvic area (r=.39). Poor reproductive performance of heifers with RTS of 1 points to the importance of identifying and culling these heifers before the breeding season begins (Table 5).

In situations where heifers are scheduled to begin an estrus synchronization treatment with MGA, we recommend RTS be performed within 2 wk prior to the initiation of treatment. We further recommend heifers are ready to begin treatment with MGA if 50 % of the heifers within a group are assigned RTS of 4 or 5. This indicates these heifers have reached puberty and are estrous cycling. Based on the age and weight of prepubertal or peripubertal contemporaries, up to 70 % of these heifers can be expected to exhibit estrus and ovulate after MGA withdrawal, so the potential estrus response during the synchronized period is up to 80 % (Table 5). Estrus response among heifers that were assigned scores of 2 or 3 was lower than for those assigned scores of 4 or 5. However, as RTS increased, estrus response improved.

Table 5. Prebreeding weights, measurements, and subsequent estrus response after synchronization of estrus with MGA-PG[a]

RTS	n	Weight (lb)	Pelvic height (cm)	Pelvic width (cm)	Pelvic area (cm^2)	Estrous response (%)
1	61	594[b]	13.9[b]	10.9[b]	152[b]	54[b]
2	278	620[c]	14.1[b]	11.2[b]	158[b]	66[c]
3	1103	697[d]	14.5[c]	11.4[c]	166[c]	76[d]
4	494	733[e]	14.7[d]	11.7[d]	172[d]	83[e]
5	728	755[e]	14.7[d]	11.7[d]	172[d]	86[e]

[a]Adapted from Patterson and Bullock, 1995. Weights and measurements were taken within 2 wk prior to the first day of MGA. Estrous response is the %age of heifers that exhibited estrus and were inseminated within 144 h after PG.
[b,c,d,e]Means within a column with different superscripts differ ($P < .05$).

Inadequacies in nutritional development programs often are associated with situations in which the desired degree of estrous cyclicity has not been achieved. This necessitates reevaluation of the nutritional development program and in many cases a postponement of the breeding season. The results obtained from a prebreeding exam provide an objective assessment of the success or failure of a development program and are useful in determining the appropriate timing of estrus synchronization treatments (Anderson et al., 1991; Patterson and Bullock, 1995; Randle, 1999).

Reasons for Failure to Utilize Reproductive Procedures

Producers are often restricted in their operations from implementing production-enhancing technologies. Figure 3 provides a summary of the most common reasons for not using specific procedures (NAHMS, 1998). The reason cited most for not utilizing these practices is “lack of time and labor”. Some “other” reason was the next most common explanation followed by “too complicated” or “costly”. In some cases, respondents believed that benefits of incorporating these improved technologies into their management schemes outweigh the costs. Not only can these practices ameliorate profitability by improving production, some can also decrease costs (NAHMS, 1998).

Modern-day production agriculture is an increasingly competitive arena. In many cases technology can help increase production while maintaining or decreasing costs. However, low adoption rates of these and other management practices leads one to question the future competitive position of the U.S. beef cattle industry, when compared with change in technology adoption occurring in other parts of the world. For instance, the United States and Brazil are world leaders in total numbers of beef cows in production. Table 6 summarizes the change in use of AI that occurred over a 5-yr period in these two countries. Growth in the use of artificial insemination in Brazil outpaced that of the U.S. by 93% (ASBIA, 1998; NAAB, 1998). Beef producers in Brazil are inseminating 3.5 times more cows annually compared with producers in the U.S., based on the sale of import and domestic beef semen. Furthermore, nearly one half of the semen used in Brazil is imported, a large portion of which comes from the U.S. Given this scenario, it is likely to assume in the years ahead, elite seedstock herds in the U.S. will provide a sizeable %age of the germ plasm used worldwide. However, unless owners of commercial cowherds in the U. S. begin to aggressively approach reproductive and genetic improvement within their herds, one could argue this country would lose its competitive advantage in the production of high quality beef. International players that are more technically astute and competitively advantaged will position themselves to dominate the production and sale of beef worldwide.

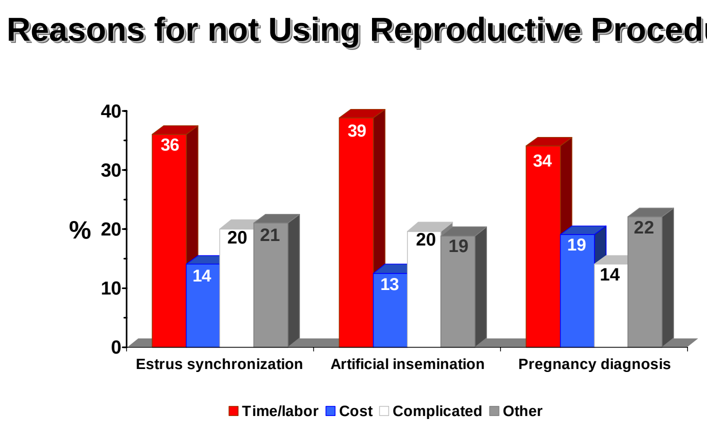

Figure 3. Reasons for not using reproductive procedures (adapted from NAHMS, 1998).

Table 6. Import and domestic beef semen sales in Brazil and the U.S. over a 5-year period

	Import and domestic beef semen sales (units sold)		
Country	1993	1998	% change
Brazil[a]	1,874,996	3,256,259	+74
United States[b]	1,117,798	906,923	-19

Export sales in the U.S. rose from 393,365 units in 1993 to 848,677 units in 1998 (+ 46 %, NAAB, 1998).
[a]ASBIA, 1998.
[b]NAAB, 1998.

Replacement Heifer Programs that Utilize Reproductive Procedures in Development and Marketing

The advent of coordinated on-farm heifer development and marketing programs (e.g., the Bourbon County Kentucky Elite Heifer Program and the Missouri Show-Me-Select Replacement Heifer Program and Sales), and commercial heifer development facilities that focus on the procedures presented here, remove much of the risk of developing replacement beef heifers compared with situations in which replacements are raised or purchased without these criteria being taken into consideration (Patterson, 1998; Randle, 1999).

Marketing heifers developed according to established guidelines has been shown to be a viable means of rural economic development in specific regions of the U.S. (Patterson and Bullock, 1995). Programs in Kentucky and Missouri were designed to: 1) improve existing efforts through a total quality management approach to heifer development; 2) increase marketing opportunities for and add value to the heifer portion of the calf crop; and 3) provide reliable sources of quality replacement females concerning genetics and management.

These programs require compliance with specific guidelines, and provisions for various management and reproductive practices and (or) procedures. These guidelines include provisions for ownership; health and vaccination schedules; parasite control; implant use; weight, pelvic measurement and reproductive tract score; estrus synchronization and artificial insemination; service-sire requirements for BW-EPD; early pregnancy diagnosis, and body condition score (Patterson, 1998).

Statistics that Warrant Change. Table 7 provides a summary of the distribution of the over 900,000 beef operations in the U.S. with regard to herd size (NAHMS, 1998). These statistics indicate that 91.7% of beef operations in the U.S. are involved with herds of < 100 cows. However, the cumulative number of cows on these operations accounts for 50.3 % of the total number of cows in production nationwide.

Table 7. Number of beef cow operations and herd size (NAHMS, 1997)[a]

Number of head	1-49	50-99	100-499	__ 500
% of U.S. beef operations by herd size	79.8	11.9	7.7	0.6
% of U.S. beef cow inventory by herd size	30.8	19.5	35.7	14

[a]%ages represent beef operations in the U.S. for 1996.

Larger size herds make use of more of the technologies currently available (NAHMS, 1997a). There is also indication of regional differences in use of reproductive technologies in cow-calf herds. In general, operations in the Southeast and Southcentral regions are less likely to use any of the reproductive procedures listed. Only 35.4 and and 58.3% of operations in the Southeast and Southcentral regions, respectively, used any of the reproductive procedures currently available (i.e., estrus synchronization, artificial insemination, pregnancy diagnosis, pelvic measurement, body condition scoring, semen evaluation). This compares with 77.7% of operations in the West, 77.3% in the Northcentral, and 67.1% in the Central regions.

According to the NAHMS (1997b) survey, only 46.4% of beef operations in the U.S. maintain restricted breeding and calving seasons. Furthermore, up to 40% of heifers nationwide that become pregnant as yearlings fail to conceive in their second breeding season, or lose calves by the end of their second calving period (Bellows and Short, 1990; Wiltbank, 1990). The demographics of U.S. beef production include large numbers of operations with small numbers of cows in production, low adoption rate of technology, and failure to adopt technology because of limited time and labor, point to an industry destined to concede its competitive position worldwide.

Sources of Information and Implementing Change

Veterinarians serve as a key information source for U.S. beef producers and will be essential in facilitating the adoption of various reproductive procedures (NAHMS, 1997c). Nearly two-thirds (60.8%) of cow-calf producers cited their veterinarian as a “very important” source of information for their cow-calf operation including health, nutrition, or questions pertaining to production or management. Differences in importance of various information sources based on size of the cowherd are illustrated in Figure 4.

On-farm development programs that involve local veterinarians, state, regional, or county livestock specialists, and individual farm operators provide the structure from which change can occur. Organized on-farm programs such as Kentucky’s Bourbon County Elite Heifer Program and Missouri’s Show-Me-Select Replacement Heifer Program are examples that draw on the fundamental basis upon which extension and the Land Grant System were founded: the use and application of what we know to create knowledge (Patterson, 1998). In these programs evaluation has an impact in itself, because meaningful assessment of these programs builds in evaluation as part of the design. Data collection is part of the delivery process and reinforces the development of sound management practices on individual farms regardless of their size (Randle, 1999). Farmers use data generated on their own farms. The focus of these programs centers on action alternatives based on data generated. Methods flow from issues with a negotiated participatory process that involves veterinarians, livestock specialists, and farmers.

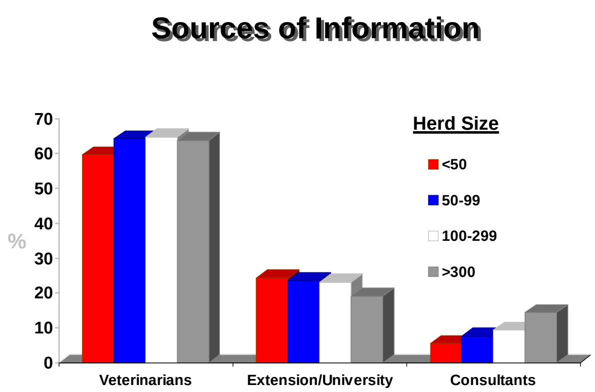

Figure 4. Sources of information (adapted from NAHMS, 1997c).

Implications

During the years 1993-1997 roughly 6 million beef replacement heifers entered the U. S. cowherd annually, and of these approximately 12 % (720,000) were purchased as bred replacements on an annual basis (NAHMS, 1998). It is safe to assume a very small percentage of these heifers were “programmed” per se in terms of reproductive procedures currently available. The expertise to develop and market programmed heifers exists, but requires a team approach to managing heifers in terms of nutrition, reproduction, genetics, health and emerging management practices. Effecting change in reproductive management of the U.S. cowherd will require a fundamental change in the approach to management procedures and development practices being used on heifers retained for breeding purposes. We have reached a point concerning reproductive management of our nation's beef cowherd at which the tasks of transfer and development of technology must be equally emphasized and must progress together for the U.S. to maintain a strong beef cattle sector in our economy. Unless efforts are taken to implement change in the U.S. beef cattle industry, the products of our research and technology may be exported to more competitive international markets.

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