Management and financial considerations affecting the decision to synchronize estrus in beef females[1]

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Abstract

A beef producer's decision to use estrus synchronization (ES) in an AI breeding program is usually influenced by the potential to positively affect productivity and profitability. Pregnancy rates at synchrony clearly affect profitability and are a major factor in the decision to use ES, but many producers are unaware of the necessary conditions that ensure success. Seedstock producers who use AI to generate offspring with recognized pedigrees are more likely to use ES than commercial producers whose income depends on other production factors such as improved weaning weight, increased carcass quality, desirable maternal value in replacement heifers, and a reduced incidence of dystocia. These changes in productivity are easily accomplished through ES/AI, but there is a lack of research that clearly documents the impact of these technologies on profitability in commercial and seedstock beef herds. Research to fill this information void would help producers make more informed management and financial decisions associated with ES/AI and perhaps increase the incentive to adopt such technologies. There is also a need to increase the number of marketing methods that commercial producers can use to capture potential price premiums for value-added calves generated from ES/AI. Future use of ES by beef producers may depend on the opportunity to receive greater reward for improved value in their calves. A more intensified effort to discover new ways for producers to receive higher financial reward for the improved productivity associated with ES/AI is needed. This should be an interdisciplinary effort involving academicians and other parties with interest in the beef industry.

Key Words: Estrus, Artificial Insemination, Profitability, Beef Cows

Introduction

In a beef AI program, estrus synchronization (**ES**) clearly affords reduced labor associated with estrus detection. With or without ES, a successful AI program can reduce the need for a large bull battery. Bull costs per pregnancy range from $20 to $60 depending on pregnancy rates, salvage value and maintenance costs of the bull, the number of years retained in the herd, and the potential for death of the bull (Sorensen, 1979; Loseke et al., 1990). In a study of 37 commercial Wyoming beef herds, the AI costs per calf were only slightly higher ($1.87) than for natural service but were more than compensated for by the value of increased calf performance due to using superior AI sires (Stevens and Mohr, 1969). Clearly, the opportunity to recover the costs of AI and ES in a commercial beef herd, whether equal to or different from the costs of natural service, is affected dramatically by pregnancy rates to AI, degree of increase in calf performance, and market prices.

This article is not intended to be a literature review, but rather an attempt to describe the current status of ES in the beef industry with respect to its application and utility as affected by the necessary financial and management considerations. The potential impact and use of ES in the future are also discussed.

Discussion

Brief History of Estrus Synchronization

Early efforts at ES in cattle included repetitive injections of progesterone given over a 12- to 14-d period, which allowed for spontaneous regression of corpora lutea (**CL**) while delaying estrus and ovulation. Cessation of injections resulted in cows displaying estrus within 2 to 6 d. Estrus response and the degree of synchrony were variable and dependent on progesterone dose and duration of treatment. Some treatments were often ineffective in regressing CL, the result of which was that some treated cows did not display a synchronous estrus. Fertility was low with certain progesterone/progestin treatments (Ulberg, 1951; Ulberg and Lindley, 1960; Hansel et al., 1961); this was only recently attributed to abnormal follicular growth (Lucy et al., 1990; Sirois and Fortune, 1990). Methods to regress CL were subsequently improved by including estrogen in the treatment regimen to increase the number of females that could display estrus and ovulate (Wiltbank et al., 1961; Wiltbank and Kasson, 1968; Gonzales-Padilla et al., 1975; Roche, 1976; Sprott et al., 1984).

The inconvenience of repetitive injections resulted in the development of various methods of progesterone/progestin delivery by way of short-term feeding, subcutaneous implants, and controlled release devices placed intravaginally. During this same time period, $PGF_{2\alpha}$ and its analogues became available as luteolytic agents and offered an alternative method to effect CL regression.

In the mid-1990s, a greater understanding of ovarian follicular wave dynamics resulted in the use of gonadotropins in combination with luteolytic compounds to synchronize estrus. Such an approach improves ovulation synchrony and circumvents reduced fertility associated with persistent dominant follicles that occur in females treated during diestrus (Thatcher et al., 1993; Troxel et al., 1993; Pursley et al., 1995). Similar effects can be accomplished by the timely administration of estrogens during certain progesterone/progestin treatments (Bo et al., 1995, 1996; Burke et al., 1997a,b; Fike et al., 1997; Yelich et al., 1997). Methods to refine the management of follicular waves during ES treatments continue to be investigated. Reviews of these methods are given by Beal (1998) and Day (1998). A continual challenge is the development of ES treatments that can induce a fertile estrus in postpartum anestrous females and peripubertal heifers. Numerous successful approaches to this challenge have occurred (Pursley et al., 1995; Fike et al., 1997; Stevenson et al., 1997; Anderson and Day, 1998; Geary et al., 1998a,b; Lammoglia et al., 1998; McDowell et al., 1998).

Economic Value of Estrus Synchronization

The economic incentive in the dairy industry to increase milk production through the use of high-maternal-value sires has made AI popular, but the use of ES/AI in the beef industry remains low. Surveys by the National Animal Health Monitoring System indicate that approximately 4 to 5% of beef producers use AI, and 3 to 4% use ES (USDA, 1994). Four regional surveys of approximately 4,500 Texas producers show that 9 to 15% use AI, and 44 to 65% of those also use ES (Texas Agricultural Extension Service, unpublished data). Some beef producers believe that ES/AI is not economically feasible. For others, off-farm employment limits their time that would otherwise be used to implement ES/AI. Some producers simply do not have adequate working facilities to handle their animals, whereas others are averse to the frequent handling associated with ES/AI, particularly when there are large numbers of females to be treated in a relatively brief period. Realistically, ES/AI may not be an option for some beef producers.

Not only does ES reduce the amount of labor associated with estrus detection, but it also affords at least two chances to inseminate each female in the first 21 to 24 d of breeding, as opposed to 42 to 45 d without ES. The results are earlier conception in a higher proportion of females (Smith et al., 1979). This concentrates the calving period and reduces the age variability in the calf crop, thereby increasing the average market weights. Concentrated calving also affords more focused labor during observations for dystocia. Another benefit of ES is that it often results in higher pregnancy rates at the end of breeding, particularly when accompanied by temporary (48-h) calf removal near the end of progestin-based ES treatments in postpartum females (Smith et al., 1979; Odde and Holland, 1994).

The effect of ES on changing the average day of conception has additional benefits; calves conceived at synchrony are the first to be born during calving and are consequently older and heavier at marketing than are their herdmates conceived after synchrony. In a 4-yr Texas field trial involving 800 synchronized matings in commercial beef females that were time-mated artificially and subsequently exposed for natural mating, the average day of conception in females that conceived at synchrony was 26 d earlier than in females conceiving after synchrony (author's unpublished data). The weight per day of age (adjusted for birth weight) of a 7-mo-old, 204- to 227-kg calf would range from .8 to .93 kg, so the extra 26 d of growth for a calf conceived at synchrony would translate to an extra 20.8 to 24.2 kg of weight at weaning, compared to calves not conceived at synchrony. Using these weight values and synchronized pregnancy rates ranging from 30 to 60% and market prices ranging from $1.32 to $1.98/kg, Table 1 shows the predicted change in gross income per treated female. It is clear that the degree of income change is sensitive to pregnancy rate at synchrony and market prices, but it is likely that in any scenario shown the additional income resulting from calves conceived at synchrony would cover the cost of synchronizing drugs. The use of AI sires with high EPD for weaning/yearling weight would have an additive effect on calf weight above that shown in Table 1.

However, achieving the complete benefits of ES/AI requires that the AI period be extended beyond the synchrony period. The choice to do so in a commercial cow herd depends on several factors, including the costs of labor, semen, and equipment and the length of the AI period. Additionally, the degree of increased calf performance, pregnancy rates, and market prices must be considered. An accurate record or estimate of all costs is necessary, but it is difficult, if not impossible, to predict the change in calf performance as affected by the choice of AI sires. Consequently, to increase the chances of achieving acceptable change in calf weights, sires with the highest EPD for weaning/yearling weight (with allowances for calving ease) should be used for a terminal mating. In other mating systems in which female offspring are to be retained, the sire's EPD for maternal value should also be considered.

For the terminal mating situation, Table 2 shows the maximum affordable cost per commercial female in an ES/AI program as affected by a range of pregnancy rates, four arbitrary levels of calf weight increase due to using superior sires, added production (weaned kilograms of calf) per female, and market prices. As the table illustrates, the need for AI sires with high EPD for weaning/yearling weight increases as pregnancy rates and market prices decrease.

However, recovering costs of ES/AI does not always depend on the degree of increased production per female. This is particularly true for seedstock producers who are able to obtain premiums for offspring from valuable sires/dams among their choice of breeds. Similarly, commercial producers who use ES and participate in club calf markets have garnered premiums ranging from $150 to $500 per calf (Sprott et al., 1989a).

Other economically feasible reasons to use ES/AI in commercial beef herds include the production of replacement heifers with specific genetic background for desirable maternal value. Although it is difficult to predict their value, such heifers will certainly have a long-term financial impact on the herd. In other instances, the use of calving ease bulls via ES/AI in replacement heifers has been shown to eliminate dystocia and reduce the associated costs (assistance at parturition, death loss, therapy) by as much as $56 to $64 per heifer when 25 to 33% of the heifers have historically required assistance at parturition (Sprott and Carpenter, 1998). An ES/AI program can easily be implemented at costs below the value of losses in replacement females when they have previously had a 25 to 33% incidence of dystocia.

The current emphasis on carcass quality (marbling and yield grade) and the advent of EPD for various carcass characteristics for some beef breeds offer another avenue to recover costs of ES/AI. In 1996, 46 steers from sires proven for growth and carcass quality were generated from ES/AI and entered in the Texas A&M Ranch to Rail Program. Their performance was compared to that of an equal number of herd contemporaries from unproven sires. Use of proven sires increased the percentage of steers grading USDA Choice by 10 to 50 percentage points. When sold on a quality/yield price grid, carcasses from steers sired by bulls with EPD for increased marbling grossed from $17 to $40 per steer more than carcasses from steers sired by unproven bulls. Fed steers from sires with high EPD for weaning/yearling weight and sold on a live weight basis grossed $70 per steer more than steers from unproven sires. The chance to capture premiums associated with added value in such steers necessitates retained ownership through the feeding or slaughter phase of production and that they be sold on an individual basis or to a buyer willing to pay premiums for groups of animals with a documented history of improved performance. When sold on a traditional "pen basis," which is used in most fed cattle transactions, the potential for premiums is precluded because an average price is assigned to the entire pen of steers.

The economic feasibility of ES/AI in a beef herd depends on the production goals of the individual producer, the type of marketing avenues that can be followed, and the potential for long-term, positive financial impact on the herd. Adding value to beef calves through ES/AI and capturing the justified premiums require planning and a well-executed marketing strategy.

Suggested Management Practices

A robust body of scientific literature exists regarding the development of ES treatments, their application, and the necessary management practices required for success as measured by pregnancy rates to synchronized mating. Control of diseases, particularly those affecting reproduction, is critical. Thorough vaccination programs that are applied in a timely manner (prebreeding) are essential whether using ES or not (Sprott et al., 1998). Adequate nutrition increases pregnancy rates to synchrony (Smith et al., 1979; Odde, 1990), and management for sufficient forage quality and quantity while providing appropriate supplements cannot be ignored during the calving and breeding periods.

Often overlooked are the importance of using high-quality semen from reputable sources and the need for proper semen handling from thawing to insemination (Barth, 1993). Sprott et al. (2000) demonstrated that AI using semen from bulls with a detectable fertility-associated antigen (**FAA**) on sperm improved pregnancy rates by 15 percentage points in synchronized beef heifers and nonsynchronized postpartum cows.

Timed AI in large herds requires experienced technicians. Recently trained technicians and those who infrequently perform inseminations simply do not have the stamina to effectively and correctly inseminate a large number of females presented in the average period (2 to 6 h) characteristic of timed AI. Other seemingly minor considerations that can affect success with ES are the exclusion from treatment of females with a history of low fertility and the ease with which animals can be handled. Working chutes that are in good repair and designed to allow for a smooth flow of animals can reduce the amount of time required to administer treatments and perform inseminations.

Estrus detection during the synchrony period can be confusing and frustrating due to the high degree of repetitive and frequent mounting activities. This limits the ease of quickly identifying estrual females. The use of heat mount detectors during the synchrony period allows observers to quickly sort females with activated detectors away from the remainder of the herd. The result is less confusion and more accurate observation of animals that have not yet displayed estrus.

Producer satisfaction with ES is understandably related to subsequent pregnancy rates and usually affects the decision to include the technique in future breeding efforts. Estimation of the potential for success prior to administering treatments is prudent. This is especially important in herds with an unknown or questionable reproductive history and in herds owned by producers who are inexperienced in ES. Consider the body condition of each lactating female and the number of days since parturition. Pregnancy rates will be low in thin, early postpartum (< 40 d) females (Smith et al., 1979; Carpenter et al., 1991). For replacement heifers, nutrition that provides acceptable growth prior to first breeding at 14 to 16 mo of age will ensure that a high percentage are pubertal, which will increase response to treatment and subsequent pregnancy rates (Brown et al., 1988).

The proportion of females that can conceive is, of course, affected by the number that are cycling prior to treatment. This number can be estimated by several methods. Five days of estrus detection before treatments are given will reveal the expected number of estrual females in the herd. The number of females in estrus during this 5-d period should be mathematically converted to a percentage of the herd and then multiplied by 4. The product approximates the percentage of the herd that is cycling. Multiplying the expected percentage that are cycling by a value ranging from .45 to .6 (expected range in proportion that will conceive) will approximate the percentage of females that will conceive during synchrony. An alternative that precludes the need for estrus detection but necessitates an extra processing of the herd through the working facilities is to place heat-mount detectors on the animals during this 5-d period. Instead, the use of spotter/gomer animals with chin ball markers during the period offers a less labor-intensive, but perhaps more expensive, approach.

If pretreatment estimations of response are not possible in herds of potentially marginal management status, choosing ES treatments that require estrus detection during synchrony will reveal whether enough females are responding to justify continuance of the program. If treatments requiring estrus detection in such herds are not possible and techniques allowing for timed AI are the only option, one may place heat-mount detectors on all females when treatments are completed. At subsequent timed AI, only those animals that are found with activated detectors should be inseminated. This approach avoids semen waste in cows that cannot respond and significantly reduces semen cost, especially if the price per unit of semen is high.

Choosing Synchronization Techniques

The specific protocols for various ES treatments are continually changing; this subject warrants a brief comparison of management considerations associated with different techniques. Table 3 compares the following techniques and their specific characteristics that should be considered in planning an ES program. Refinement of these techniques is a dynamic research subject, and recent protocol modifications are excluded for brevity.

The norgestomet/estradiol valerate protocol involves placement of a subcutaneous ear implant containing 6 mg of norgestomet coupled with an injection of 5 mg of estradiol valerate and 3 mg of norgestomet at the time of implant placement. The implant is removed 9 d later, and AI is performed at 48 to 54 h after implant removal. Treated dams should remain temporarily (48 h) separated from their calves beginning at the time of implant removal (Smith et al., 1979). Calves are returned to their dams when timed AI is completed.

Three options are available for the use of prostaglandins. First, two 25-mg injections of $PGF_{2\alpha}$ are given 11 to 14 d apart, followed by 5 d of estrus detection and AI. Second, estrus detection and AI are performed for 5 d, then one injection of $PGF_{2\alpha}$ is given to females not inseminated in the first 5 d and estrus detection and AI are continued for 5 d. Third, following one injection of $PGF_{2\alpha}$ and 5 d of estrus detection and AI, one injection of $PGF_{2\alpha}$ is given at d 6 to females not inseminated in the first 5 d, then estrus detection and AI are continued for 5 d.

The following protocols are used for prostaglandin/GnRH combinations. Select Synch involves injection of GnRH followed 7 d later with an injection of $PGF_{2\alpha}$ and 5 d of estrus detection and AI; Ov Synch involves injection of GnRH (d 0), $PGF_{2\alpha}$ on d 7, a second injection of GnRH at 24 to 30 h after $PGF_{2\alpha}$, and timed AI at 20 to 24 h after the second injection of GnRH; CO Synch involves injection of GnRH (d 0), $PGF_{2\alpha}$ on d 7, and a second injection of GnRH plus timed AI at 48 h after $PGF_{2\alpha}$. For the Ov Synch and CO Synch options, calves should be removed from their dams at the time of prostaglandin injection and returned after timed AI is completed (Geary et al., 1998a).

Using MGA/prostaglandin, 14 d of MGA feeding (.5 $mg \cdot animal^{-1} \cdot d^{-1}$) is followed 17 d later with one injection of prostaglandin, then 5 d of estrus detection and AI.

Even though they are not widely used in ES/AI programs, progesterone-releasing intravaginal devices (PRID) and controlled internal drug release (CIDR) devices are included in Table 3 for comparison purposes, and it is assumed that estrus detection during synchrony is required. Research in the application of PRID and CIDR devices continues, and it is likely that the addition of various hormone (estrogens, $PGF_{2\alpha}$, and gonadotropins) injections are needed to achieve an acceptable degree of ovulation synchrony that allows for timed AI (Day, 1998).

Except for melengestrol acetate and norgestomet implants with the associated injectable solution, acquisition of drugs requires veterinary prescription, and some are not yet approved by the U.S. Food and Drug Administration. An equally important consideration in treatments requiring estrus detection is the availability of experienced personnel. Producers with a limited number of personnel or lack of time to commit to estrus detection should choose techniques that allow for timed AI. Personnel unfamiliar with certain application techniques (placement of ear implants or intravaginal devices) should seek training or professional assistance.

There are differences among treatments for frequency of animal handling, the option to use timed AI or to detect estrus, and the total time required to complete application procedures and inseminations. Potential differences in pregnancy rates exist among ES techniques, particularly when one uses treatments designed to alter follicular wave dynamics or to eliminate persistent dominant follicles (Thatcher et al., 1993; Troxel et al., 1993; Pursley et al., 1995; Stevenson et al., 1997; Day, 1998), but in many cases low pregnancy rates to synchrony using progestin treatments are a result of inadequate nutrition (Smith et al., 1979), insufficient days postpartum (Carpenter et al., 1991), and, in the case of replacement heifers, a low percentage that are sexually mature (Brown et al., 1988).

A final consideration is the need for temporary (48-h) calf removal from treated dams when using techniques allowing for timed AI. Some producers are hesitant to employ calf removal for fear of causing lowered calf performance and udder problems in their dams. Nevertheless, calf removal increases pregnancy rates (Smith et al., 1979; Geary et al., 1998a) to timed AI and does not affect subsequent calf and dam performance (Beck et al., 1979; Odde et al., 1981; Wettemann et al., 1986; Makarechian and Arthur, 1990; Fanning et al., 1995).

Alternative Uses of Estrus Synchronization

Because ES can increase the proportion of females conceiving early in the breeding season, it may be used to shorten the subsequent calving period, which has positive effects on profitability. However, to accomplish this in a poorly managed herd is a challenge requiring simultaneous attention to disease control, improved nutrition, and removal of females with low fertility (Sprott et al., 1989b; Fanning et al., 1992). In herds with breeding season durations of 100 d or more, there may be a need to treat parturient females in groups of similar postpartum lengths to avoid poor response in females with very young (< 40-d-old) calves.

There is also the potential to use ES with natural mating. This practice retains the advantage of early conception during the breeding period but excludes the opportunity to use AI sires with proven genetic background. Choosing an appropriate bull:cow ratio is also a problem because bulls vary greatly in serving capacity (Blockey, 1976; Lunstra et al., 1978; Carpenter et al., 1992) and sperm characteristics that affect fertility (DeJarnette et al., 1992; Bellin et al., 1994, 1998; Saacke et al., 1994). This suggests that bulls should be intensely screened for all aspects of fertility before exposing them to the heavy breeding pressure associated with estrus-synchronized females. Even then, there is no assurance that bulls can service as many females as can be artificially inseminated. Other complications arise from injuries due to fighting among bulls as they compete for estrual females.

The Future for Estrus Synchronization

In the late 1970s and early 1980s, ES received enormous attention from progressive beef producers. Many were justifiably excited about the prospect of inseminating a large proportion of their breeding females in a 1- to 5-d period but were unaware of the factors affecting success. Some had unrealistic expectations that 70 to 100% of the herd would become pregnant. In many cases, their inexperience and lack of attention to details resulted in failure, and subsequent disappointment caused these producers to abandon further efforts at ES. Consequently, the level of future interest by producers likely depends on several factors, all of which may be positively influenced by both academicians and various parties with financial interests in the beef industry.

Producers and animal science students need more educational programs and materials that emphasize the management skills and herd conditions necessary to make ES successful. Too many are unaware of the steps required for adequate herd response to ES treatments and have little understanding of the associated economic and production implications.

Interest level in any management technique and its eventual adoption by producers is often affected by the technique's potential economic impact. Unfortunately, there are few studies that clearly document the change in herd productivity and profitability associated with ES in commercial and registered beef herds. Research to fill this information void would help producers make more informed production and financial management decisions.

Research in product efficacy and development should continue. More work is needed in refining the manipulation of ovarian follicular waves, eliminating persistent dominant follicles, and inducing estrus with a high degree of fertility in a greater percentage of anestrous females. Because of the labor requirements and frequency of animal handling associated with most ES treatments, research to develop less time-consuming and less invasive application techniques is warranted.

The financial incentive to use ES/AI in a commercial beef herd is often affected by expected changes in market prices. When feeder calf prices are low, marketing through traditional outlets makes it difficult to justify ES/AI for commercial producers who expect costs to be recovered by increased weaning weight of AI calves. Regardless of market prices, added calf weight from mature females is easier to achieve by using terminal sires with the highest EPD for weaning/yearling weight. Such an approach maximizes the chances of creating sufficient production changes to recover costs of ES/AI. Using calving ease bulls will also help reduce losses associated with dystocia.

Added value can be achieved in other ways by using sires with desirable maternal value or those with improved carcass merit. Usually, there are no price premiums for such calves if they are sold through traditional markets. This suggests that producers who use ES/AI to add value to their calves should use more sophisticated marketing techniques when it is economically appropriate.

The incentive for commercial beef producers to use sophisticated marketing techniques is obviously affected by the degree of associated financial risks and the potential to participate in markets that recognize or specialize in value-added products with price premiums. The emphasis in the beef industry for quality assurance and value-based marketing has generated such markets. Examples are marketing alliances that include cow/calf operators, feedlots, and meat packers. Other examples are markets for products from recognized breeds, branded beef products, and the brand-like initiative being promoted by the National Cattleman's Beef Association. Initial efforts among these groups to merchandize superiorly performing animals and those with specific management histories have resulted in moderate price premiums. Other parties that could potentially participate in marketing alliances for value-added calves are pharmaceutical companies and suppliers of frozen semen. These two groups supply the technology and genetics by which value can be added to cattle through ES/AI, and some degree of company involvement in either ownership or marketing of these calves could be financially rewarding to all parties. If these new markets and alliances continue to be successful, there should be greater financial incentive for beef producers to use ES/AI.

Economics will continue to influence the use of ES, but technologies such as sexed semen add new considerations that affect production and profitability. The opportunity to select gender in the calf crop will not only affect productivity but also offer greater chances to create value-added calves with predictable performance. Estrus synchronization will continue to facilitate such breeding programs.

The future of ES will also be affected by the kinds and availability of marketing systems that producers can use to their economic advantage. The technologies and genetic base to produce superiorly performing offspring are clearly available, but more marketing systems that consistently reward such productivity are needed.

Implications

Estrus synchronization reduces the labor and costs required to implement artificial insemination. Successful synchronization, as measured by pregnancy rate during the synchrony period, requires timely disease-control practices, adequate nutrition, acceptable weight and age of heifers, sufficient postpartum recovery in dams, experienced technicians using correct techniques with high-quality semen, and strict attention to application procedures of the synchronizing compounds. The economic value of synchronization can be enhanced by using semen from sires with proven performance in traits of economic importance (e.g., growth rate, carcass quality, maternal value, and calving ease). Receiving additional income from the resulting offspring depends on the producer's opportunity to participate in marketing systems that recognize and reward superior performance. Such systems exist, but they should be expanded.

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Notes

1. Mention of products and trade names does not imply endorsement or warranty by the Department of Animal Science or the author.

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Table 1. Effects of pregnancy rates to synchrony, calf weight advantage, and market prices on added income per treated female in commercial beef herds

Pregnancy rate to synchrony, %	Calf [a] weight advantage, kg	Extra[b] kg of calf per treated female	Added income based on calf weight at four market prices, $/kg [c]			
			$1.32	$1.54	$1.76	$1.98
30	20.8	6.24	$8.23	$9.61	$10.98	$12.35
40	20.8	8.32	$10.98	$12.81	$14.64	$16.47
50	20.8	10.40	$13.73	$16.01	$18.30	$20.59
60	20.8	12.48	$16.47	$19.22	$21.96	$24.70
30	24.2	7.26	$9.58	$11.18	$12.78	$14.37
40	24.2	9.68	$12.78	$14.91	$17.04	$19.17
50	24.2	12.10	$15.97	$18.63	$21.29	$23.96
60	24.2	14.52	$19.17	$22.36	$25.56	$28.75

[a]Weight advantage of calves conceived at synchrony compared to their herdmates.
[b]Percentage pregnant × weight advantage = extra kg of calf per treated female.
[c]Extra kg of calf per treated female × market value ($/kg) = added income based on calf weight.

Table 2. Maximum affordable costs of ES/AI per female at various pregnancy rates, changes in calf performance, and market prices in a terminal mating system

Pregnancy rate, %	Average improvement in weaning weight, kg	Extra kg [a] of calf per female	Max. affordable cost per female at four market prices[b]			
			$1.32/kg	$1.54/kg	$1.76/kg	$1.98/kg
80	13.6	10.88	$14.36	$16.75	$19.15	$21.54
	22.7	18.16	$23.97	$27.96	$31.96	$35.96
	31.8	25.44	$33.58	$39.17	$44.77	$50.37
	40.9	32.72	$43.19	$50.39	$57.59	$64.79
85	13.6	11.56	$15.26	$17.80	$20.34	$22.89
	22.7	19.29	$25.46	$29.71	$33.95	$38.19
	31.8	27.03	$35.68	$41.63	$45.57	$53.52
	40.9	34.76	$45.88	$53.53	$61.18	$68.82
90	13.6	12.24	$16.16	$18.85	$21.54	$24.23
	22.7	20.43	$26.96	$31.46	$35.96	$40.45
	31.8	28.62	$37.78	$44.07	$50.37	$56.67
	40.9	36.81	$48.59	$56.69	$64.79	$72.88
95	13.6	12.92	$17.05	$19.90	$22.74	$25.58
	22.7	21.57	$28.47	$33.22	$37.96	$42.71
	31.8	30.21	$39.87	$46.52	$53.17	$59.82
	40.9	38.85	$51.28	$59.83	$68.38	$76.92

[a]Pregnancy rate × average improvement in weaning weight = extra kg of calf per female.
[b]Market price/kg × extra kg of calf per female = maximum affordable cost per female.

Table 3. Management considerations for various synchronization techniques

Technique	Application procedures [a]	Frequency of animal handling [b]	Time mate or estrus detection [c]	Estimated time for estrus detection, h	Estimated time for total labor, h [d]
Norgestomet/ estradiol valerate	I, DP, DR	3	TM	0	3–7
Prostaglandin options					
1 [e]	I	3	ED	10–15 [f]	22–35
2	I	1–2	ED	22–33 [g]	31–47
3	I	2–3	ED	22–33 [g]	31–47
Prostaglandin/GnRH options					
Select Synch	I	3	ED	10–15 [f]	22–35
Ov Synch	I	4	TM	0	4–8
CO Synch	I	3	TM	0	3–7
MGA/ prostaglandin	SF, I	2	ED	10–15 [f]	22–35
PRID	I, DP, DR	3–4	ED	6–12 [h]	20–26
CIDR	I, DP, DR	3–4	ED	6–12 [h]	20–26

[a]I = injection(s); SF = short-term feeding: DP = device placement: DR = device removal.
[b]Number of times through the working facilities.
[c]TM = time of mating; ED = estrus detection.
[d]Includes time required for application of procedures, estrus detection, and AI.
[e]Option 1= two injections 11 d apart with 5 d ED/AI; Option 2 = ED/AI for 5 d, one injection on d 6 to those not inseminated in first 5 d, continue ED/AI for 5 d ; Option 3 = one injection, 5 d ED/AI, one injection on d 6 to those not inseminated in first 5 d, continue ED for 5 d.
[f]2× or 3× daily observation (1 h each time) for 5 d.
[g]2× or 3× daily observation (1 h each time) for 11 d.
[h]2× or 3× daily observation (1 h each time) for 3 to 4 d.