An update on estrus synchronization in goats: A minor species[1]

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ABSTRACT: Estrus synchronization allows for parturition at suitable times to take advantage of niche markets, feed supplies, labor, and rising price trends. In the past, synchronization of estrus in goats has focused primarily on dairy goats to allow for optimal timing of milk production. However, recent interest in meat goat production has resulted in attempts to use dairy goat, sheep, and cattle synchronization regimens in meat goat management systems. Methods of synchronization have included techniques as simple as alteration of light patterns or manipulation of social inputs (i.e., the buck effect) and as complex as varying timed hormonal treatments combined with light alteration and the buck effect. The synchronization of estrus using timed hormonal treatments seems to be more convenient in many meat goat production situations. Examples of hormones used include melatonin, progestogens (administered orally, as an injection, or by using intravaginal releasing devices), gonadotropins/GnRH (or agonists), and PG alone or in combination. As is seen with sheep and cattle, breed and/or breed type, stage of production, and environmental effects can influence synchronization success in goats. The introduction of breeds developed in other countries for rapid growth, such as the Boer goat, and increased consumer and producer interest have added to the impetus for developing cost-efficient and highly effective estrus synchronization regimens. New research is being conducted and various synchronization methods are being attempted in goats, a minor species, and the objective of this paper is to review these efforts.

Key Words: Estrus Synchronization, Meat Goats, Progestogen, Prostaglandin, Season

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Introduction

The expanded popularity of meat goat production has led to increased interest in reliable methods to synchronize/induce estrus in goats. With this technology, producers are able to more efficiently use complementary techniques for reproductive management, including AI and embryo transfer, so that genetic material is more easily obtained or transferred domestically and internationally.

Issues involving estrus synchronization (**SYNCH**) include the fact that new product development and inclusion of goats (and sheep) in labeling for products used in SYNCH has not coincided with user interest. Goat and sheep producers therefore have been forced to use products in an extralabel manner. However, research into SYNCH is essential to provide evidence that user interest merits efforts to provide labeling for minor species on desired pharmaceutical products. In addition, continued SYNCH research is imperative to establish optimal doses and agents to use for favorable synchrony and fertility. With this in mind, manipulation of the estrus cycle in goats was previously reviewed by Amoah and Gelaye (1990) and in goats and sheep by Wildeus (1999). However, the goal of the current review, given the increasing popularity of meat goat production, is to provide an update on SYNCH in the goat as a minor species, with emphasis on research conducted within the past 3 to 4 yr.

Progestogen Use

In efforts to extend the lifespan of the corpus luteum for SYNCH, various forms of progestogens and different methods of administration have been used in cycling does, as well as in seasonally anestrus does, to induce or synchronize estrus (Amoah and Gelaye, 1990; Wildeus, 1999). Progestogen administration is common, especially in seasonally anestrus animals and has been used with or without accompanying treatments such as gonadatropins or prostaglandin analogs.

In the United States, no FDA-approved progestogen product is being manufactured for use in goats. How-

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ever, in Australia and New Zealand, commercially available progestogen sponges formulated for goats, including those containing fluorogestone acetate (**FGA**; Cronogest 45) and methyl acetoxy progesterone (**MAP**; Repromap and Veramix; Rathbone et al., 1998), can be used. Similarly, a controlled internal drug-releasing device (**CIDR**) in the form of a silicone intravaginal progesterone insert is also available for use in goats outside the United States (Rathbone et al., 1998). The CIDR product (**CIDR-G**) has been investigated for potential use in sheep as a minor species in the United States with promising results and may be commercially available within a few years (Knights et al., 2001a,b). Therefore, timely investigation into the procedures necessary to support approval of CIDR use in goats may be advantageous.

Previously, norgestomet, marketed under the name SynchroMate-B (**SMB**), was a progestogen product available for use in sheep in the United States, and thus held promise for approval for use in goats. The successful use of SMB in goats has been reviewed previously (Wildeus, 1999) and has been documented in other countries recently (Mexico, Mellado et al., 1998, 2000; Brazil, Oliveira et al., 2001). However, because the SMB product is no longer being manufactured, other forms of progestins have been more closely studied in recent years and some have been compared to SMB for effectiveness. When three SMB protocols were compared with similar protocols involving CIDR devices in cyclic Saanen does, comparable results were reported at standard doses with new vaginal inserts (Oliveira et al., 2001; Table 1), as well as with previously used inserts, and both were more effective when gonadotropin co-treatments were used at removal (vs. the prostaglandin analog, closprostenol, alone). Norgestomet ear implants (Cooper, UK Ltd., Cambridge, U.K.) were also compared with natural progesterone sponges (both 14-d treatments) in Mashona does, and again, similar results were reported with 92 and 83% bred within 21 d and 64 and 70% kidding for sponges and implants, respectively (Kusina et al., 2000).

The most commonly used SYNCH protocols include MAP or FGA vaginal sponges. For successful SYNCH during the breeding season (100% in estrus within 4 d), 60-mg MAP sponges (14-d treatment), with or without 500 IU of eCG at sponge withdrawal, were used in Saanen, Nubian, and crosses by Regueiro et al. (1999; Table 1), although a higher percentage of does kidded with MAP alone (64%) compared with with eCG co-treatment (41%). Ten-day MAP (60 mg) treatment was also used during the breeding season in West African Dwarf goats in combination with gondatropin and PG or an additional GnRH treatment (24 h after sponge removal), with the GnRH co-treatment being more successful in inducing estrus by 74 h after sponge removal (5/6 with GnRH vs. 3/6 without GnRH; Pierson et al., 2003). To determine whether a lower-dose MAP sponge could be used for SYNCH during

Table 1. Reproductive variables for does with estrus synchronized with a progestogen during the breeding season

	Variables							
Reference	Progestogen	Dose	Duration, d	Combined treatment	n	Time to estrus, h	Estrus, %	Fertility, %[a]
Oliveira et al. (2001)	Norgestomet (SMB)[b]	2.0 mg	9	2.5 mg of estradiol valerate and 1.5 mg of norgestomet before insertion; 100 IUof eCG and 0.05 mg of cloprostenol at removal	20	Most within 24	100	80.0‡
	CIDR[c]	0.3 g	9	100 IU of eCG and 0.05 mg of cloprostenol at removal	20	Most within 24	100	100 ‡
Requeiro et al. (1999)	MAP[d]	60 mg	14	500 IU of eCG at removal	40	34.5 ± 11.9	100	41.0§
	MAP	60 mg	14	2 mL of saline at removal	40	42.9 ± 19.6	100	64.1§
Motlomeo et al. (2003)	MAP	60 mg	16	300 IU of PMSG at removal	30	32.2 ± 0.50	93.1	51.7⊥
	FGA[e]	40 mg	16	300 IU of PMSG at removal	30	30.9 ± 0.40	96.7	60.0⊥
	CIDR	0.3 g	16	300 IU of PMSG at removal	30	27.2 ± 0.40	100	46.7⊥

[a]Fertility measured as ‡pregnancy rate, §kidding rate, and ⊥conception rate.
[b]SynchroMate B.
[c]Controlled internal drug (progesterone)-releasing device.
[d]Methyl acetoxy progesterone.
[e]Fluorogestone acetate.

the breeding season, Greyling and van der Nest (2000) used whole (60 mg) or halved (±30 mg) MAP sponges in Boer and South African feral indigenous goat does compared with a control group synchronized a cycle earlier using 60-mg MAP sponges inserted for 14 d. The MAP dose did not influence efficiency of SYNCH in either breed, and what the authors (Greyling and van der Nest, 2000) felt were acceptable pregnancy rates were achieved for fixed-time AI in both breeds and at both MAP doses (65 to 80%) when compared with AI at 12 and 24 h after the onset of estrus for control goats (75 to 80%).

As with MAP, the use of FGA for 14 d in combination with PMSG at withdrawal was also successful for SYNCH during the breeding season in goats (Damascus does; Al-Merestani et al., 2003). To compare progestogen sponges, FGA and MAP sponges were administered to cycling Nubian does. Half the animals administered each sponge type had sponges inserted 48 h after the other half and both groups retained sponges for 14 d such that half the animals had sponges removed 48 h subsequent to the first group. Although progestogen treatment did not influence the percentage of does in estrus, does with FGA inserts removed after 48 h had a shorter time to first estrus (26.0 ± 7.1 h) than does that had sponges removed 48 h before (45.3 ± 13.5 h; Romano, 2002). Motlomeo et al. (2002) compared the use of MAP, FGA, and CIDR vaginal inserts in Boer and South African indigenous goats during the breeding season. There was no influence of progestogen treatment on estrus response, but time to the onset of estrus was advanced by 3 to 5 h in the CIDR group compared with the FGA and MAP groups (Table 1). The use of CIDR in combination with estradiol 14 h before CIDR removal was also found to facilitate sexual behavior in ovariectomized French-Alpine does during the breeding season (Billings and Katz, 1999).

Although alternative methods are available during the breeding season, it is commonly accepted that a progestogen is required for induction/SYNCH outside of the normal breeding season. For example, when inducing estrus during the nonbreeding season, 18-d MAP sponge treatment in combination with 150 or 200 IU of PMSG at sponge withdrawal allowed for 100% of indigenous Damascus does to be mated, a 65.8% conception rate, a 64.1% kidding rate, and a 192.2% kid crop compared with buck use alone (no animals expressed estrus or were mated; Zarkawi et al., 1999). Also, Medan et al. (2002) administered 11-d norgestomet implants to two groups of Egyptian Baladi goats outside of the breeding season in combination with a single injection of prostaglandin $F_{2\alpha}$ 24 h before implant removal and GnRH 24 h after implant removal (or no GnRH), whereas a third group remained untreated. The percentage of goats expressing estrus was 77.5, 85, and 10% for the three treatment groups, respectively (Medan et al., 2002).

Although sponges offer a convenient method to administer progestogens, perhaps a more straightforward method might be through oral dosing in feeds. The use of melengestrol acetate (**MGA**) to induce estrus in seasonally anestrus ewes has been documented (Wildeus, 1999; Daniel et al., 2001; Whitley et al., 2003); however, not as many studies have determined its potential value in goats. Jackson and Whitley (2002) reported that MGA decreased days to first mating after buck introduction in seasonally anestrus Boer and Boer-crossbred does when fed in a complete pellet (Southern States 12% Cattle Pellet, MGA; Southern States Cooperative Milling, Gettysburg, PA). However, all animals were mated by d 10. In addition, MGA treatment seemed to lower the percentage mated and thus the percentage of does kidding, even though ultimately the same overall number of kids was produced from both treatment groups (Jackson and Whitley, 2002). Also, in Spanish and Boer crossbred goats, daily feeding of 0.25 mg of MGA per doe outside of the breeding season was compared with the male effect alone or in combination with MGA for 14 d or were not treated/exposed to bucks before mating attempts. As in the previously mentioned study, does that had consumed MGA (alone or in combination with the male effect) had fewer d to estrus than does that did not consume MGA (3.0 ± 0.2 compared with 10 ± 0.7 d, respectively; Lerma and Stanko, 2003). The number of days to first elevated progesterone concentration was greater for untreated does (no MGA and no prior male exposure), even though first elevated progesterone was detected in all does by approximately d 12. However, overall pregnancy rate (approximately 96%) was not influenced by treatment (Lerma and Stanko, 2003).

In contrast to previously discussed research involving MGA, when yearling does were fed 0.25 mg of MGA per doe each day, or a control feed, or MGA in combination with PG600 (Intervet, Millsboro, DE) at the end of feeding (10 d; n = 5/treatment) outside the breeding season, no animals exhibited estrus and only does receiving MGA in addition to PG600 ovulated (Worlds et al., 2003). In a follow-up study, yearling does were treated for 8 d with 0.5 mg of MGA in feed daily (n = 7), or given intravaginal sponges containing progesterone (500 mg; n = 4) or methylhydroxy progesterone acetate (n = 4) with a gondatropin co-treatment (PG600). Only 50% of MGA-treated does exhibited estrus. Ovulation rate (0.4 ovulation site per animal) and pregnancy rate (7%) were lower for MGA-treated animals compared with does with sponges (Wildeus et al., 2003).

Differences in responses to MGA could be due to genetic or age differences in animals used or to environmental differences between the study areas and the study years. For example, in a study conducted with the same herd as that used in a previous study (Jackson and Whitley, 2002), using a nearly identical protocol and starting a year to the day later than the previous study, Boer and Boer crossbred does showed no convincing signs of estrus and no pregnancies were noted. The unusually hot, humid weather during the study period may have been part of the reason neither the MGA treatment (0.25 or 0.125 mg/animal daily) nor the male effect alone was effective in inducing estrus (Jackson et al., 2003). The cited studies in which MGA was not effective or was only partially effective were all conducted in May or June of 2003 in a geographical location with similar weather patterns noted at that time (Petersburg, VA, and Princess Anne, MD). In addition, factors such as a progestogen × environment interaction or specific MGA effects cannot be excluded as partial causes of a lack of response to MGA in these instances.

Thus, these studies and those in previous reviews (Amoah and Gelaye, 1990; Wildeus, 1999) indicate that a progestogen or the male effect alone have been used effectively to synchronize estrus for natural breeding. Future studies could be conducted to determine if, as with cattle (Kojima et al., 2000; Wood et al., 2000; Lucy et al., 2001), MGA, MAP, CIDR, or other progestogen delivery methods could be used during and outside of the breeding in conjunction with GnRH and/or PG to facilitate more consistent or more precise results for procedures such as timed AI.

Prostaglandin Use

Early studies with few animal numbers have shown that PG and its analogs (as with cattle and sheep) can be used for SYNCH in cycling females. In Black Bengal goats (n = 6 or 8 per treatment), Ishwar and Pandey (1992) compared 15-mg PG injections i.m. given 11 d apart with treatments that included progesterone injections for 16 d with or without PMSG. Overall, PG resulted in maximum fertility compared with the other treatments, with estrus and ovulation in 4/6 and kidding (per doe mated) in 3/4 of treated does. In addition, using five West African Dwarf does per treatment, Akusu and Egbunike (1984) administered two i.m. injections of 0, 5, or 10 mg of dinoprost tromethamine (Lutalyse; Pharmacia and Upjohn Co., Kalamazoo, MI), 11 d apart (0 dose was administered sterile water only). Dinoprost tromethamine treatment synchronized estrus by decreasing average time to first estrus by approximately 2 wk without influencing other reproductive parameters measured in that study (376.7 ± 187.4, 43.2 ± 10.7, and 59.0 ± 15.3 h for 0, 5, or 10 mg of dinoprost tromethamine, respectively).

In Boer goats, it was previously shown that two injections of cloprostenol at 62.5, 125, or 250 μg, administered 14 d apart, were effective in synchronizing does during the breeding season (Greyling and Van Niekerk, 1986). Although the highest dose given (250 μg) apparently increased the percentage of does in estrus (100% vs. 87.5% for 125 μg and 93.8% for 62.5 μg), overall fertility appeared to decrease with increasing dose, with seemingly lower conception rates and number born per doe bred (not significantly different; Greyling and van Niekerk, 1986).

Romano (1998) found that single doses of 62.5 and 125 μg of cloprostenol administered i.m. were effective in SYNCH at the end of the natural breeding season, with 100% of Nubian does exhibiting estrus at approximately 60.5 h after treatment and a 75% pregnancy rate (6/8; two does, one in each treatment, experienced short cycles), with no difference between the two doses. Also, comparing several synchronization schemes, Kusina et al. (2000) found that two i.m. injections of 125 μg of cloprostenol administered 10 d apart were as effective as the progestogen treatments tested.

To determine whether PG could be used to effectively shorten the breeding period in cyclic does naturally mated in a pasture system, we administered dinoprost tromethamine (Lutalyse; Pharmacia and Upjohn; 19 Boer and Boer-crossbred does; unpublished data). Well into the breeding season, cycling does with visual and olfactory access to 2 mature bucks were injected i.m. with 7.5 mg of dinoprost tromethamine the d of (n = 8) or 4 d after (n = 11) introduction of bucks (d 0) wearing marking harnesses. Number marked by d 4 was recorded and all does not mated were administered 7.5 mg dinoprost tromethamine i.m. There was no difference in the number of does mated by d 4 (averaged 79 ± 9.6%), and all does were mated by d 8 of the study. In addition, there were no differences in kidding rate or number of kids born, indicating that both treatments were effective. Thus, a first injection was not necessary because the male effect was suitable for SYNCH of many of the does, resulting in a "combination" treatment that would be more cost effective for producers than treating all animals twice.

Only effective during the breeding season, PG use (in combination with the male effect) may still offer a flexible, economical method for SYNCH to shorten the breeding season in a natural mating situation. Prostaglandin has also been used as a co-treatment in effective progestogen-based SYNCH protocols in goats (Kusina et al., 2000; Pierson et al., 2001, 2003; Medan et al., 2002), sheep (Husein and Kridli, 2003), and cattle (Kojima et al., 2000; Wood et al., 2000; Lucy et al., 2001) for both natural mating and AI/timed AI situations.

Other Treatments

Light treatment to alter photoperiod response is a well-known SYNCH method for out-of-season breeding in the dairy goat industry. However, time and housing constraints may be impractical for commercial meat goat producers. Administration of melatonin to mimic altered photoperiod may be an effective alternative. Spanish does administered melatonin orally or as an implant for approximately 3 mo (January to

April) were exposed to light- and melatonin-treated bucks or does were not treated. Although there was no difference in the number of does bred, melatonin-treated does had higher pregnancy rates than untreated does (Wuliji et al., 2003). To enhance the effectiveness of a shorter light treatment, a combination treatment might be an option. In Saanen and crossbred dairy does administered melatonin in addition to light treatment for 37 d or treated with light only (in a natural breeding system), all melatonin-treated does had higher conception rates and more Saanen (but not crossbred) does became pregnant and kidded in the melatonin plus light groups when compared with alteration in the light only groups (du Preez et al., 2001).

Exposure to males after a period of isolation can be used for induction and SYNCH during the breeding and nonbreeding season without additional treatments in goats. Does lactating in the fall due to summer breeding were used to compare the effect of no treatment (buck exposure during breeding period only) to temporary kid removal (48 h) after approximately 28 d of lactation. Although temporary kid removal decreased days to first mating compared with does still nursing kids, all does were bred within 10 d after introduction of bucks and there was no influence of treatment on kidding rate (79.0 ± 0.1%), average birth weight (3.3 ± 0.2 kg), or weaning weight of removed or subsequent born kids (Fletcher et al., 2002). Hence, kid removal was not necessary to synchronize lactating does during the breeding season.

Comparing several SYNCH regimens, 75% of untreated does (exposed to males during mating) were bred within the 21-d breeding period in one study (Kusina et al., 2000), and 50% were mated in a different study (Ishwar and Pandey, 1992), indicating that the male effect can induce at least partial SYNCH during the breeding season, although both studies indicated that progesterone treatments improved SYNCH. In addition, compared with SMB treatments alone or in combination with the buck effect (teasing), the buck effect was equally effective in inducing estrus and mating during the transitional period, although SYNCH was better with SMB. However, teasing alone was not effective in inducing estrus in young, postpubertal females (Mellado et al., 2000). Nonetheless, to most efficiently use the male effect, a sexually active male is vital. For example, Creole goat males treated with light to simulate the breeding season were more effective in inducing out-of-season reproductive activity in does than in untreated males, (Delgadillo et al., 2002).

Influences on Synchronization

The efficacy of SYNCH depends on many factors, including season, exposure to males, breed, and age among others. For example, Pierson et al. (2001) detected a seasonal shift in the intervals to onset of estrus, LH surge, and ovulation after MAP sponge removal in West African Dwarf goats treated in November, July, or March, whereas the intervals between onset of estrus and the LH surge and between the LH surge and ovulation were not influenced by season. However, in a follow-up study using MAP sponges singly or in combination with GnRH, season had a significant effect on the timing and synchrony of estrus with and without GnRH treatment, and a seasonal shift was observed in the timing of the LH surge only in the absence of GnRH treatment (Pierson et al., 2003). Also, in seasonally anestrus Boer and Boer crossbred does at approximately 30 d lactation, temporary kid removal and/or male exposure (both of which were effective in SYNCH previously) failed to induce estrus in any does (our unpublished observations). The unusually hot, humid summer was noted as a possible causative agent because after weaning, does remained in anestrus even after MGA treatment (Jackson et al., 2003), which had been successful the previous summer in this same herd (Jackson and Whitley, 2002).

Exposure to bucks before implant removal in combination with SMB treatment decreased time to first estrus in prepuberal Crillo × dairy crossbred does when compared with teasing alone (31.6 vs. 60.0 h), and increased percentage in estrus (91.6%) compared with teasing (16.6%) or comparable SMB treatment alone (66.6%; Mellado et al., 2000). Similarly, exposure to bucks (during heat detection) and does in proestrus/estrus also hastened time to first estrus in FGA- and MAP-treated does with sponges removed 48 h after contemporaries (Romano, 2002).

Breed is known to influence the response of seasonal breeders to estrus induction treatments out of season. Less seasonal breeders may respond better to progestin priming than breeds that experience a more pronounced seasonality of reproduction. When Boer, Spanish, and Myotonic does were administered CIDR-G vaginal inserts and an injection of dinoprost tromethamine upon removal 12 d later or dinoprost tromethamine only, the Myotonic breed was the only breed to respond with a higher pregnancy rate compared with untreated animals (11/25, 44% vs. 1/32, 3% for CIDR-G compared with dinoprost tromethamine only; Nuti et al., 2003). Also, a study on reproductive data for goats in Georgia (over a 3-yr period) revealed that for most breeds, the animals were seasonal breeders, and breeding peaked in September to November, except for Pygmy goats, which had an unusual peak in breeding activity in July (Amoah et al., 1996). Age of the females could also influence response to SYNCH in that MGA fed to adult Black Bengal with accompanying PMSG only resulted in superovulation in younger goats (Sanwal et al., 1983), and teasing was effective for SYNCH in multiparous but not young, postpubertal females (Mellado et al., 2000).

Implications

As the popularity of goat production continues to increase, pressure to develop efficient and cost-effective methods for estrus synchronization in goats becomes more important. In addition, reproductive technologies such as artificial insemination and embryo transfer are advanced in some areas of goat production (dairy goat industry, meat goat breeding stock production), making the need for discovery, standardization and eventual Food and Drug Administration approval of optimal products and protocols essential.

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