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Effects of Photoperiodic Manipulation on Growth Rate and Ability to Breed Fall-born Ewe Lambs in Spring[1]

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Summary

Effects of photoperiod in winter on puberty and growth were examined in fall-born ewe lambs, 44 Dorset (D) in year 1 and 23 D, 14 Suffolk x D (SD) and 12 Texel x D (TD) in year 2. Lambs were randomized within age, weight, breed and type of birth and rearing, to be exposed to either natural photoperiod (controls) or both natural and supplemental light (evening, ~100 lux at lamb eye-level) to produce a photoperiod of 16 h light:8 h dark for 14 weeks. At completion of supplemental lighting, each treated lamb received an ear implant of melatonin (20 mg s.c.). Lambs were weighed at weaning, light completion and insertion of controlled-internal, drug-releasing devices containing progesterone (CIDR) to synchronize estrus. Serum progesterone was measured at light completion, and one week before and at CIDR insertion. CIDRs were removed and fertile rams introduced for 27 days or 33 days. Pregnancy was determined by transrectal ultrasonography. At light completion, treated ewe lambs had gained 4.7 kg ± 1.6 kg more than controls in year 1 ($P < 0.05$), but 3.2 kg ± 2.2 kg less in year 2 ($P > 0.05$). There was a tendency for more treated than control lambs to have progesterone above 0.3 ng/mL one week before or at CIDR insertion ($P < 0.10$). Estrous response (year 1) and pregnancy rate (56 percent year 1 and 31 percent year 2) did not differ with treatment. At ages tested, photoperiodic manipulation did not hasten puberty or response to progesterone and ram introduction in fall-born ewe lambs.

Key Words: Ewe Lambs, Photoperiod, Pregnancy, Puberty, Season

Introduction

Ewe lambs born in autumn typically reach puberty in the next breeding season (Foster, 1981), while winter- or spring-born ewe lambs reach puberty as early as 6 months to 8 months of age. To maximize lifetime productivity in out-of-season breeding programs, fall-born ewe lambs need to conceive in spring. Foster (1981) reported that placing fall-born Suffolk ewe lambs into a photoperiodic environment simulating that which occurs naturally for spring-born lambs hastened puberty. Blocks of long days at 12 to 22 weeks of age led to normal luteal cycles in fall-born ewe lambs beginning at an age equivalent to spring-born lambs (34 weeks; Yellon and Foster, 1985). Decreasing day length is necessary to initiate puberty in spring-born ewe lambs (Ebling and Foster, 1988). Thus, light sequence is the basis for great differences in age at puberty in ewe lambs in relation to season of birth. Slyter et al. (1997) found that April-born, crossbred-ewe lambs exposed to 16 h to 18 h light during December through February gained more weight during the trial, and a greater proportion became pregnant to April-May breeding the following year (84 percent vs. 57 percent of controls).

Melatonin, which is secreted from the pineal gland during darkness, has been shown to be a key component of regulation of the breeding season and timing of puberty in sheep (reviewed by Foster and Hileman, 2015). Supplemental treatments with melatonin have been used to hasten the breeding season (Nett and Niswender, 1982 and others) and were more effective in fall-born ewe lambs when used following 12 weeks of extended light (Stellflug et al., 1989).

Treatment with progesterone for as few as 5 d and ram introduction at progesterone withdrawal induces fertile estrous cycles in anestrous adult ewes (Knights et al., 2001 a, b), but has not been effective during spring in fall-born ewe lambs. However, Knights et al. (2002) observed an estrous response in 82 percent of fall-born ewe lambs in July after treatment with progesterone for 5 d followed by ram introduction at withdrawal and 25 µg estradiol benzoate 24 h later.

The objectives of the present experiment were to determine if an artificial photoperiod of 16 h light and 8 h dark, in the winter after fall birth, followed by implantation with melatonin will: 1) hasten puberty or the response to progesterone and ram introduction in fall-born purebred Dorset, Suffolk x Dorset and Texel x Dorset ewe lambs, 2) increase weight gain in prepubertal fall-born ewe lambs, and 3) lead to an increased proportion that will become pregnant for fall lambing.

Materials and Methods

Animals and Treatments

The effects of an artificial long photoperiod on hastening puberty in fall-born ewe lambs were examined at a cooperating producer's farm in Aurora, West Virginia (latitude 39.58N, longitude 79.34W, elevation 894 m) beginning in December, 2011 and repeated beginning in December, 2012. The flock had been used for fall lambing studies with progesterone and ram introduction in adult ewes since approximately 2000.

Forty-four prepubertal Dorset ewe lambs born in October and November (year 1; n = 22 control and 22 treated) or 52 prepubertal Dorset, Suffolk x Dorset and Texel x Dorset ewe lambs born in late September through early December (year 2; n = 26 control and 26 treated) were randomized within breed type, age, and type of birth and rearing to one of two groups, control or treated. These ewes were sired by 2 Dorset rams in year 1 and 5 rams (2 Dorset, 1 Suffolk and 2 Texel) in year 2. In year 1, one control and two treated ewe lambs died from apparent enterotoxaemia, and one ewe lamb was found to possess a small vagina, so that proper insertion of a CIDR was not possible. At slaughter, she had a malformed reproductive tract and was therefore removed from the experiment. In year 2, one ewe lamb drowned and two died from probable enterotoxaemia. Forty lambs in year 1 and 49 in year 2 (23 Dorset, 14 Suffolk x Dorset and 12 Texel x Dorset) completed the study.

Control ewe lambs were housed in a 3.7 meter x 18.5 meter section of a barn with exposure to natural photoperiod for a 14-week period. Treated ewe lambs were housed in an 5.5 meter x 18.5 meter section of the same barn, but exposed to an artificial photoperiod consisting of 16 h light:8 h dark for a period of 14 weeks. Treatments were implemented from December 16, 2011 until March 24, 2012, or from December 17, 2012 until March 25, 2013. Mean ages at onset of treatment were 51.6 d ± 1.5 d (7 weeks) and 42.6 d ± 3.5 d (6 weeks) in year 1 and year 2, respectively, and did not differ with treatment. In year 2, breeds differed in average age at beginning of treatment (Dorset 59.2 d ± 5.2 d, Suffolk x Dorset 31.5 d ± 2.7 d, and Texel x Dorset 24.0 d ± 2.8 d). At completion of artificial light treatment, each treated ewe lamb received a silastic implant containing 20 mg of melatonin (Melovine®), subcutaneously in the ear.

The barn was divided by black plastic sheeting (4 mil, Blue Hawk, Poly-America, Grand Prairie, Texas) to prevent control lambs from being exposed to the supplemental light provided to the treated lambs. Light intensity during the supplemental lighting period for the treated group was measured at random intervals throughout the experiment and averaged ~100 lux at ewe lamb eye level, as measured by a Digital Light Meter (LX1010B, Mastech Holdings, Inc., Pittsburgh, Penn.). The farm owner made a change in the barn between years, adding a row of windows on the east side of the barn, which contained the control group. Thus the control group received morning sunlight more intensely during the second than the first year. After the change, light intensity at midday averaged 643 lux in the control section and 600 lux in the treated section of the barn, compared to 600 lux in the middle of each section in year 1.

In the first 5 weeks of the treatment periods, ewe lambs were housed with their dams and wether siblings. Wether lambs were marketed at various times shortly before ewe lambs were weaned. All lambs had *ad libitum* access to a supplemental creep ration (Table 1), and to the second cutting grass hay that was provided to their dams, beginning prior to initiation of the study and continued throughout the light treatment phase. All ewe lambs were weaned from the ewes on January 28, 2012 (year 1; mean age 95 d ± 1.5 d) or on February 16, 2013 (year 2; mean age 104 d ± 3.5 d). After completion of light supplementation, ewe lambs were comingled and received the creep ration daily at a maintenance

Table 1. Creep ration provided to lambs during experiments.

Ingredients Composition	Percent of ration
Corn	64.92
Soy Hulls	16.00
Soybean Meal	14.82
Southern States Sheep Mineral	2.5
Limestone	1.24
Salt	0.45
Sodium Bicarbonate	0.045
TDN	85.1
Cr. Prot.	16.5
Ca++	0.55
P	0.36

level of 0.45 kg, along with free access to native grass pastures.

Growth was monitored, as both weight and age are integral components of puberty (Dyrmundsson, 1981). All ewe lambs were weighed at four time points, including onset of light treatment, weaning, light completion and CIDR insertion (EAZI-BREED CIDR®, Pfizer Animal Health, now Zoetis Animal Health, Kalamazoo, Mich.). Weights were collected on a single day at each point, without alteration of the *ad libitum* access to feed and water.

Jugular venous blood samples were collected at three time points: 1) light completion; 2) 1 week prior to CIDR insertion; and 3) CIDR insertion. Each sample was centrifuged at 4 °C for 20 min at 1,000 x g and the serum was drawn off, placed in a glass vial and frozen at -15 °C. Progesterone was assayed by the RIA method described by Sheffel et al. (1982). The limit of detection was 0.1 ng per mL.

Each ewe lamb was treated to synchronize estrus with a CIDR-G, inserted on May 18 of each year. On May 23, CIDR inserts were removed and intact fertile rams were introduced. Rams had passed a breeding soundness exam prior to introduction. Prior to synchronization, on May 7, 2012 or April 18 or 24, 2013, ewe lambs were shorn and treated for internal parasites. All ewe lambs and four rams were pastured together, thus ewe-to-ram ratio was 10:1 in year 1 and 12.5:1 in year 2. Rams were equipped with marking harnesses bearing crayons to monitor mating (estrous) activity. Rump marks on ewe lambs were recorded for 7 d post ram introduction, only in year 1. Rams were removed on June 19, 2012 or June 25, 2013, thus allowing a breeding period of two opportunities for behavioral estrus (Knights et al., 2001a). Pregnancy was determined by transrectal ultrasonography (Aloka 500 console, 7.5 MHz linear probe; Hitachi Aloka Medical America, Inc., 10 Fairfield Boulevard Wallingford, CT 06492) 25 d after removal of the rams.

Statistical analyses

Lamb weights at each weigh period, within year, were compared between treatments by Students t-test. Concentrations of progesterone at CIDR insertion were classified as above or below the threshold of 0.3 ng/mL reported by Keisler et al. (1983) as an indicator of first ovulation during puberty, and compared by Chi-square with Fisher's exact test (PROC FREQ, SAS Version 9.3). Likewise, proportional data for estrous activity and for pregnancy were examined by Chi-square. Upon inspection of the data, ages and weights varied with breed in year 2. Therefore effects of age and weight groups (less than the mean vs equal to or greater than the mean) on pregnancy rate were examined by Chi square, both within breed and overall. Differences were considered significant at $P < 0.05$.

Results

Growth

Average weights for each treatment at each stage are reported in Table 2. At onset of light treatment, weights averaged 17.8 kg ± 1.1 kg at an average age of 53 d ± 1.5 d in year 1 and 15.3 kg ± 1.7 kg at 43 d ± 3.5 d of age in year 2. Weights differed with treatment only at light termination in year 1, when treated ewes weighed an average of 52.9 kg ± 1.6 kg compared to 48.1 kg ± 1.6 kg for control ewes ($P < 0.05$).

Reproductive performance

Proportions of ewe lambs with progesterone greater than 0.3 ng/mL 1 week before, or at, CIDR insertion did not differ between treated (11/21) and control (14/18) animals ($P = 0.18$) in year 1. However in year 2, more treated ewe lambs (20 /26) had progesterone greater than 0.3 ng/mL 1 week before, or at, CIDR insertion than control lambs (11/24; $P < 0.03$). Data for estrous activ-

Table 2. Weights of ewe lambs (kg) during and after extended light or control treatments.

	Year 1		Year 2	
Stage at weighing	Treated	Control	Treated	Control
Onset of treatment	17.8 ± 1.0	17.7 ± 1.1	15.6 ± 1.8	15.0 ± 1.6
Weaning	35.4 ± 1.2	33.6 ± 1.9	32.4 ± 2.0	34.6 ± 2.1
End of extended light	52.9 ± 1.6[a]	48.1 ± 1.6	46.0 ± 2.1	48.6 ± 2.2
At CIDR insertion	50.5 ± 3.0	47.9 ± 3.2	53.9 ± 9.2	51.6 ± 8.3

[a] Differed from control ewes within year 1 ($P < 0.05$).

Table 3. Estrous response [n (%)] in year 1[a]

Treatment	N	Heavy	Mild	Light	None
Control	21	12 (57)	1 (5)	4 (19)	4 (19)
Treated	18	14 (78)	1 (5)	3 (17)	0 (0)
Overall	39	26 (67)	2 (5)	7 (18)	4 (10)

[a] $P = 0.23$ for differences between control and treated groups.

ity in year 1 were classified based upon the degree of marking on the rumps of the ewes. Treated and control ewes displayed similar responses ($P = 0.23$; Table 3).

Perhaps surprisingly, 11/21 (52 percent) control ewe lambs were pregnant to first service compared to 6/18 (33 percent) in the treated group ($P = 0.33$) in year 1. After a second service period, overall pregnancy rates were 14/21 (67 percent) control and 8/18 (44 percent) treated females ($P = 0.21$). Lambing data for year 1 showed that two treated ewes and no controls lost pregnancy due to fetal death. In year 2, only 4/23 (17 percent) controls and 5/26 (19 percent) in the treated group were pregnant to first service. After a second service period, overall pregnancy rates were 7/23 (30 percent) control and 8/26 (31 percent) treated ewes ($P > 0.05$). Overall pregnancy rates were lower in year 2 than in year 1, but varied with breed ($P < 0.001$), with 13 of 23 Dorsets, 2 of 14 Suffolk crosses (both treated) and none of 12 Texel crosses becoming pregnant. Thus the results for Dorsets (57 percent) were similar overall to year 1 (56 percent), and did not differ with treatment.

Upon inspection of ages of the lambs when they went on treatment, Dorset ewes averaged 51.6 d ± 3.1 d in year 1 and 59.2 d ± 5.2 d in year 2, while the Suffolk x Dorset ewes averaged 31.5 d ± 2.7 d and the Texel x Dorset ewes averaged only 24.0 d ± 2.8 d in year 2. Thus the ages at ram introduction also varied with breed in year 2. When Dorset ewes were divided into those 220 d to 250 d of age (31 weeks to 36 weeks) and those only 170 d to 197 d (24 weeks to 28 weeks) at ram introduction, pregnancy rates for the older group were 7/16 at first service period and 5/9 at second service period for a total pregnancy rate of 75 percent, whereas none of the seven younger Dorsets conceived. The Suffolk x Dorset ewes averaged 190 d of age at ram introduction and the two treated ewes that became pregnant were 181 (first service) and 170 (second service) d of age at ram introduction. The Texel crosses averaged only 182 d (26 weeks) of age at ram introduction.

Weights at CIDR insertion varied with breed in year 2, as would be expected, given the age differences noted above. Dorset lambs averaged 58.5 kg ± 3.0 kg, while Suffolk x Dorset crosses weighed 50.8 kg ± 2.3 kg and Texel x Dorset crosses averaged 45.0 kg ± 2.2 kg. Therefore all ewe lambs, regardless of treatment were divided by weight at CIDR insertion into those equal-to or greater-than the overall mean (49 kg in year 1 and 52 kg in year 2) and those less than the mean. In year 1, 62 percent of the heavy group and 47 percent of the light group of Dorset ewe lambs became pregnant ($P = 0.35$). In year 2, including all three breed groups, 57 percent of the heavier group and only 7 percent of the lighter group ($P < 0.001$) became pregnant after two service opportunities. Within the Dorsets, 61 percent of 18 ewes heavier than 52 kg conceived, compared to 20 percent of 5 lighter weight ewes ($P = 0.13$).

Discussion

Results showed that some fall-born Dorset ewe lambs will breed out-of-season without the aid of artificial photoperiods. However, treatment with 16 h light:8 h dark for 14 weeks, followed by melatonin implants during the period that the lambs were on pasture after the light treatment (March 24 or 25 to end of the study) did not enhance the response of these fall-born ewe lambs to treatment with progesterone for 5 d and introduction of rams on May 23. Breeds that experience a longer breeding season, such as Dorset and Finnsheep, reach puberty at an earlier age than Suffolk or Hampshire breeds (Dickerson and Laster, 1975). As reviewed by Notter (2002, 2012), the Dorset breed is less seasonal than many others and both rams and ewes performed better than other breeds in use of the "ram effect" in May. For a complete discussion of factors that influence the ram effect, see Delgadillo et al. (2009), Hawken and Martin (2012) or Jorre de St. Jorre et al. (2014).

Initial analyses showed a breed-type difference in pregnancy rate in response to progesterone and ram introduction in these fall-born ewe lambs in year 2. Despite the use of an estrous synchronization technique that induced estrus and ovulation in a portion of Dorset-ewe lambs (56 percent to 57 percent became pregnant), only two of the ewes sired by Suffolk rams and none sired by Texel rams from Dorset ewes became pregnant. In several studies, treatments with progesterone and ram introduction, including those that used melatonin feeding to simulate short days (T. Holler and E. K. Inskeep, unpublished) have not been adequate to induce puberty during spring months in blackfaced or crossbred fall-born ewe lambs, although Knights et al. (2002) induced an estrous response in 82 percent of fall-born ewe lambs in July. The Suffolk and Texel breeds are known for shorter breeding seasons that may impact their likelihood of expressing ability to breed out-of-season.

Further analyses of the data revealed that breed was confounded with both age and weight at the time of CIDR insertion. The Dorset ewe lambs that exceeded 220 d of age at CIDR insertion had a 75 percent pregnancy rate in year 2. That age is comparable to the 227-d mean at first estrus observed by Keisler et al. (1983) in spring-born-crossbred, white-faced lambs. In all except two Dorset in year 1 and one Dorset and two Texel x Dorset in year 2, weights at CIDR insertion exceeded the 39 kg at first estrus observed by Keisler et al. (1983). However, lambs that weighed less than the overall mean of 52 kg at CIDR insertion had a lower pregnancy rate in year 2; the effect of weight was not significant in Dorset ewe lambs in either year.

Results in this study did not indicate a value of extended light treatment for 14 weeks, followed by melatonin implants, to improve the response of fall-born ewe lambs to progesterone and ram introduction in May. The equal pregnancy rates in control and treated Dorset ewe lambs contrasts with the conclusion by Foster (1981), based on data in fall-born Suffolk ewe lambs, that ewes must be exposed to a set minimum period of long days before they are able to respond to short days by early pubertal development. Lack of effect of treatments in any breed-type may be a function of the ages of these ewe lambs at treatment. Except for seven Dorset ewes in year 2, lambs in both years were younger than 12-weeks of age when the 16-h light period was initiated.

Yellon and Foster (1985) determined that blocks of long days followed by short days, at 3 weeks to 13 weeks of age, resulted in only a few cyclic animals, but when the block of long days occurred at 12 weeks to 22 weeks of age, normal luteal cycles began at a "normal" age, equivalent to spring-born lambs (34 weeks). Exposure to 16 h to 18 h light during December to February increased the proportion of April-born crossbred ewe lambs raised under range conditions that became pregnant after exposure the following year to teaser rams beginning on April 1 and intact rams on April 15 (for 35 d; Slyter et al., 1997). In the latter study, lambs sired by Hampshire rams from Finn-Dorset-Targhee ewes did not respond as well as Finn-Dorset-Targhee lambs, which fits with the shorter breeding season in the Hampshire breed (Hafez, 1952). Thus one can conclude that both breed-type and age are key variables in determining whether fall-born ewe lambs will respond to extended light in winter or breed in response to progesterone and ram introduction in a given spring month.

There was limited evidence that extended light increased weight gain during the light treatment, based upon greater weights in the treated group of fall-born Dorset ewe lambs at the end of light treatment in year 1. The decrease in weight from light termination to CIDR insertion in year 1 was likely due to the change from confinement to pasture along with a reduction in feed from *ad libitum* to a maintenance ration. Weight was not increased during light treatment compared to controls in year 2, which might be due to the increased morning light seen by the control group in the second year.

Note on alternative marketing

To evaluate alternative marketing of fall-born ewe lambs, those from year 1 were sold at the West Virginia Ram Lamb Performance Test Sale in July, 2012. Prices averaged $341 for ewe lambs pregnant to first service, $350 for those pregnant to second service, and $315 for non-pregnant ewe lambs, ready to be bred in August or September. These sale prices minus added expenses, including feed and transportation, resulted in an estimated net gain of $56.65 per ewe over prices that would have been received from sale for slaughter at earlier ages (prices received for their wether siblings at weaning time).

Conclusion

A majority of fall-born Dorset ewe lambs aged 31 weeks to 36 weeks became pregnant in their first spring season in response to progesterone followed by ram introduction, without the aid of an artificial photoperiod. An extended light treatment during winter, followed by melatonin implants to simulate shorter day length, did not advance puberty or enhance response to progesterone and ram introduction. That failure may have been due to age of the lambs at initiation of treatment, but also may be influenced by the breed composition, compared to reports on Suffolk ewe lambs in the literature. Younger Dorset-, Suffolk-, and Texel-sired, fall-born ewe lambs from Dorset ewes did not have the ability to breed in May seen in older purebred Dorset ewe lambs.

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