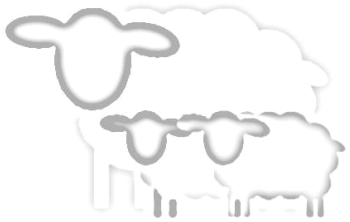
THE USE OF PHOTOPERIOD FOR OUT OF SEASON REPRODUCTION IN THE EWE



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1. Principal Action

It is now well known that the annual variation in daylength is what has the largest effect on the determination of the start or end of the reproductive season in sheep. In general, long days inhibit sexual activity whereas short days stimulate activity.

Many research projects have shown that modifications of natural daylength have made it possible to start reproductive cycles at the time of the year when they are usually inhibited. Thus, thanks to the photoperiod treatment, it is possible to manipulate the circadian rhythm (internal biological clock) of animals. The general principal consists of creating one period of artificial light during all of the year or simply a portion of the year. However, to stimulate sexual activity in ewes it is not sufficient to maintain them in an environment of short days, because after a prolonged exposure to a relatively fixed daylength (short days or long days), the ewes do not respond to the photoperiodic stimulus any more. Thus, to stimulate the ewes, it is necessary to alternate the short days with long days. In other words, to obtain the desired effect with short days, that is the renewal of sexual activity, the subjects must be exposed to a treatment of long days beforehand.

2. Use

There are many lighting programs in existence which aim to achieve various goals: to improve the fertility of ewes out of season, to advance the normal season, to prepare the rams for breeding out of season or to advance puberty in ewe-lambs.

2.1. Ewes

Many photoperiod programs are used to induce the estrous activity of ewes in the spring in Quebec sheep flocks (Demers, 1983; Castonguay et Lepage, 1998). Often, these various programs have been adapted by each producer to function according to specific constraints on each farm. They are all however, based on alternating a block of long days for several months (16 h/day of light for 2 to 3 months) preceded by a block of short days (8 h/day of light for 2-3 months).

2.2. Rams

Since, the spermatic production and quality of the ram semen are influenced by photoperiod, it is necessary to prepare the rams for breeding out of season. Compared to the ewes, rams respond very rapidly to photoperiod treatment. In practice, one would place the rams under the same light treatment as the ewes

(blocks of long days/ short days), taking care however, to totally isolate them from the ewes to be able to take advantage of the ram effect on introduction to the ewes. Another way would be to quickly alternate long days with short days, which eliminates the seasonal variations on the sexual activity of rams. Research has shown that alternating between 16 h/day of light and 8 h/day in all months maintains semen production and the quality of the ram semen for the entire year. This program is used by the Quebec sheep insemination center in La Pocatière.

2.3. Replacement ewe lambs

Changes in photoperiod during the development of puberty are important for the initiation of puberty. For replacement ewe-lambs born in the spring, the photoperiod is naturally decreasing (short days) a convenient period to stimulate puberty. However, for ewe-lambs born in the fall, puberty will generally occur at an older age, towards one year of age, rather than at 7-8 months, because the ewe-lamb finds itself in an out of season period (long days), which delays sexual maturity. To advance the puberty of ewe-lambs born in the fall, it is possible to use a photoperiod treatment.

3. How to use

3.1. Calendar model

Many photoperiod programs can be used according to the specific situation on each farm. The photoperiodic calendar suggested here arises from observations made by several producers who already use photoperiod and from the results and observations obtained thanks to a research project done in Quebec between 1995 et 1998 (Castonguay et Lepage, 1998).

In the model suggested (figure 1), the fall breeding takes place as usual from August 15 until the end of September for a limited period of 45 days. About the first of August, vasectomized rams can be introduced to the ewes for a period of 15 days to profit from the ram effect and also to start the reproductive activity of the ewes still in an anestral period. Breeding should not be done too close to the beginning of the sexual season, in August, in order to avoid the decreased prolificacy generally observed when the ewes are fertilized with the first estrus cycle of the season. From the month of August until November 15, the ewes are under natural daylight. After November 15, the duration of daylength is fixed at 16h/day until February 15. After February 15, daylength is 8 h/day. The breeding rams are introduced on April 15, approximately 8 weeks after the start of the short day photoperiod, for a period of 45 days, just until the end of May. The ewes selected to participate in the short day treatment and that have the best chance of success will have lambed before the first of February in order to respect an interval between the last lambing and the resumption of reproduction of at least 70 days. Weaning of the lambs takes place between age 50 and 60 days and must be done at least a week before the rams are put with the ewes, at the latest by April 8. In this calendar, fall lambings will be especially concentrated in September and will stretch until mid October.

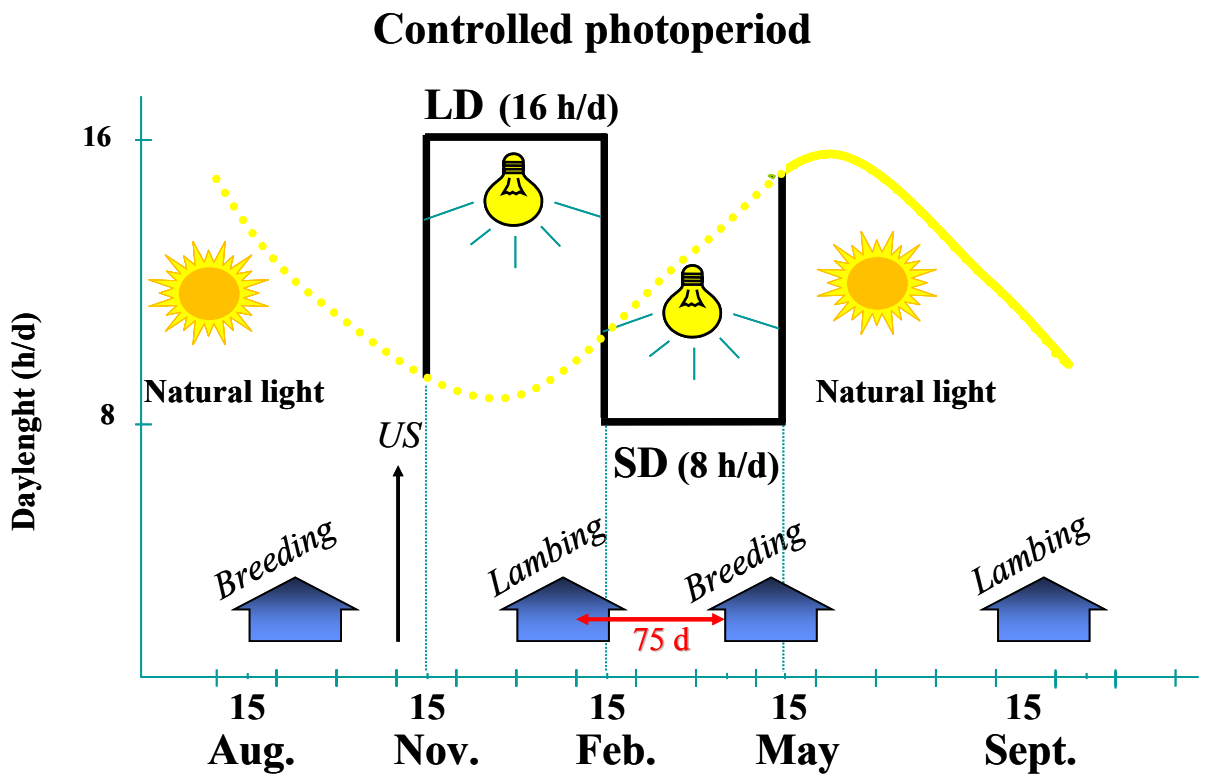

Figure 1. Proposed photoperiod calendar

The ewes and the rams undergo the same photoperiod treatment. To obtain the best ram effect, isolate the rams from the ewes at least one month prior to the breeding period. When it is possible, the best solution is to have a location solely for rams under photoperiod treatment.

This calendar has several advantages: 1) The majority of winter lambings should take place during the period of maximum daylength 16 h/day; 2) a period of light of 8 h/day for the short day treatment is long enough to allow regular farm activities; 3) When the breeding period finishes, at the end of May, the ewes are ready to go to pasture; 4) fall lambings occurring at the beginning of September, avoid the decreased growth rate of lambs born in August, a period when the hot temperatures negatively affect the feeding of lambs. In order for this calendar to function well, it is necessary that the great majority of fertilization takes place in the first two weeks of September at the latest. When pregnancy tested at the beginning of November, the lambs in utero should therefore be approximately 60 to 70 days of age to respect the proposed calendar. If the majority of lambs are too young, it will be necessary to delay the beginning of the calendar.

Of course, the exact dates of events on the proposed calendar should be adapted to meet the specific conditions of each producer. It is important to respect certain basic principles.

3.2. Basic principals to respect

Several photoperiod programs are valid and can be applied successfully. It is most

important to above all know and respect the basic principles of the technique.

Plan the use of photoperiod at the time of fall breeding

To ensure the success of the technique, the producer must group the fall breeding of ewes that he wishes to place under light control for breeding in the spring. This concentration of fall breedings will result in a concentrated lambing and will ensure that there will be a sufficient number of ewes that are physiologically ready to undergo photoperiod treatment at the same time. To obtain the best chance of success, the results of tests carried out in Quebec show that interval between lambing and breeding during treatment with short days must be at least 70 days (Castonguay et Lepage, 1998). It is especially necessary to avoid putting ewes that are being dried up in breeding. One key to success is definitely in the planning.

Modify the barn to eliminate or control the entry of external light

It is important to eliminate or control all of the sources of external light in order to have perfect control of the level of lighting inside the barn. Thus, one needs to block all of the windows and limit the entry of light by the entrances and exits of the ventilation system.

Pregnancy testing before fall breeding to evaluate the age of fetuses

The beginning and the end of the photoperiod blocks depend on the time of the breeding that took place in the fall. The calendar proposed in section 3.1 supposes that the majority of breeding will have taken place at the beginning of September. It is obvious that one can control when the rams are put with the ewes, but the success of the photoperiodic calendar depends on the fertilization, those that produce the lambs. If for different reasons, fertilization takes place later than envisioned in the calendar, the winter lambings of the ewes will be delayed and in the spring one will find oneself putting rams with ewes in lactation or those whose postpartum interval is not optimal. By evaluating the average age of fetuses with an ultrasound scanning machine, approximately 75 days after putting the rams in, it is possible to know when fertilization took place and to delay if necessary, the beginning of the photoperiod calendar. Thus, on November 1, the fetuses should be 60 days old on average (from 45-75 days) if the rams went in on August 15. If they are younger, it will be necessary to delay the beginning of the photoperiodic calendar.

Always precede the treatment of short days with a treatment of long days

The ewe will react to short days only if she is exposed to a period of long days beforehand. It is essential, that the principle of alternating long days and short days is respected.

The "blocks" of photoperiod (short days and long days) should be the same duration ranging between 8 and 12 weeks

The choice of the duration of the "blocks" will depend especially on the genotype of the ewe. Thus, for breeds or crossbreds that are more seasonal (terminal breeds), it is necessary to envision 12 weeks, whereas, 8 weeks may be sufficient for breeds or crossbreds that are less seasonal (maternal and prolific breeds). However, for producers that are experimenting with the technique for the

first time, it is always prudent to validate these recommendations under the conditions specific to their farm. In the beginning, it is thus preferable to "play safe" and stick to the recommendations of two 12 week blocks. Moreover, when breeding is planned in the middle of the anestrus season (June), it is preferable to use the two blocks of 12 weeks regardless of the genotype.

The difference in illumination between short days and long days should be between 6 and 8 hours

The duration of illumination that defines one day as short or a day as long is a function of the "photoperiodic past" of the animal. Thus, for subjects exposed to 20 h/day of light, one duration of 14 h/day will be interpreted as a short day, but the same 14 h/day will be interpreted like a long day if the animals were placed in 8 h/day of light prior to this exposure. It is important to be sure that there is a significant change in illumination between the two blocks of photoperiod.

Scrupulously respect the periods of illumination

To obtain the effect of "short days" desired, it is necessary to refrain from turning on the lights during the dark period. French studies showed that in a program of 8 h/day illumination a "flash" of light in the evening will be perceived as an hour of light by the animal and will result in the animal perceiving the day as a long day. The animal doesn't perceive the period of darkness between the end of the illuminated period of 8 hours and the hour of the "flash". Thus, the effect of the short day is completely inhibited, which compromises the technique. It is therefore necessary to organize all handling of ewes whose photoperiod is limited to 8 h/day so that all things (feeding, shearing, injection etc.) are done during the period of illumination.

Changing the illumination period without transition

The first photoperiod programs used gradual changes of photoperiod, as those which take place in nature. However, abrupt changes in photoperiod (16h/day of light one day, 8h/day of light the following day) are easier to manage for the producers and this does not affect the success of the technique.

The interval between the start of short days and putting in the rams should be 6 to 8 weeks

The time between the start of short days and putting in the rams must be long enough to obtain the desired effect. This time will vary according to the genotype used (longer for less seasonal breeds) and the body condition of the ewes.

Good preparation of the rams

It is necessary to use a ram:ewe ratio of about 1:20 or 1:25. It should not be forgotten that the ram plays a very important role in the results of fertility, even more so out of season. Since a large proportion of the ewes come into heat between 10 and 30 days after the introduction of the ram, it is necessary to ensure that there are a sufficient number of rams to respond to the "demand" of the ewes.

The preparation of rams is often neglected when planning out of season breeding. To be effective, the rams must undergo the same photoperiodic treatment as the ewes and be prepared in the same way that they would normally be

prepared for a breeding period beginning in the month of August.

It is wise to prepare a specific group of rams for spring breeding. The photoperiod treatment that they will undergo during the winter and spring will delay the resumption of their sexual activity in the fall until October or November according to breed. One will have to abstain from reusing them before this period. Moreover, rams like this, or others, would normally be given long days towards mid November for the next spring breeding, so the period for which they can be used is relatively short (October and November). It is for this reason that it is ideally recommended to plan to use two groups of rams, one for the fall and another for the spring.

To spring breed ewes should be in good condition and dried up for at least a week

Research on out of season breeding has shown that it is necessary to dry up the ewes to improve their fertility out of season. Lactation has a significant negative impact on the resumption of sexual activity in this period. Moreover, in an accelerated lambing system the condition of the ewes is particularly important to ensure good reproductive performance and also not to compromise the productive lifespan of the ewes. It is necessary to aim to use ewes whose body condition score is between 3.0 and 3.5.

Limit the period of spring breeding to 45 days and stop the short day treatment as soon as the rams are removed

It is important to limit the duration of the breeding period and thus of the short day photoperiod to permit the ewes to find their "natural" reproduction rhythm as quickly as possible. This practice will result in a quick resumption of sexual activity in the fall for the ewes that were not fertilized to the spring breeding.

3.3. Illumination intensity

Goat research in France showed that illumination intensity of 10 luxes is sufficient to inhibit the endogenous melatonin, the natural substance which is the hormonal messenger for the perception of photoperiod by the animal. Thus, one can think that this intensity would be undoubtedly sufficient to control the function of reproduction, although there is not specific research on the ewe. Practically, one recommends an intensity of about 100 luxes for the day period and less than 10 luxes for the night period. Now, how to calculate the number of lights necessary to produce an illumination intensity of 100 luxes? It is a simple question but the response is relatively complex. It is first of all necessary to understand the units of measure that are necessary to use in the calculation. The first unit is *Watt/m*^{2}. The unit of measure *Watt* (W) measures the power of a light, like an incandescent bulb of 100 W for example. W/m^2, which expresses a density of power, represents the total power of the lights installed in the building as a function of the surface of this one. Thus, for a sheep barn measuring 9 m x 15 m, or 135 m^2, equipped with 15 100 W bulbs, or 1500 W in total, that represents an illumination power of about 11 W/m^2 (1500W/135 m^2). But, this measurement does not inform us what luminous intensity will be perceived by the animals on their level. The illumination intensity, of which the unit is the lux (lx), is measured with an apparatus called a luxmeter. It is easy to understand that the illumination intensity at the level of the

animals will vary according to several factors :

-distance of lights compared to the eyes of the sheep ;

-degree of surface reflection, wall and ceiling ;

-position of lights, distribution on the ceiling ;

-type of lights, incandescent or fluorescent ;

-age of the lights, aging diminishes the effectiveness of up to 30% in some cases ;

-cleanliness of the lights and surfaces.

Thus, taking into account the number of factors which influence the level of illumination, its value must be measured at the level of the eyes of the animals and should be evaluated in the environment specific to each barn.

Now, to answer specifically the question concerning the calculation of the number of lights necessary to produce an illumination intensity of 100 luxes, let us mention that for a barn of approximately 9 m x 15 m x 3 m in height, it is recommended that incandescent bulbs of 100 W be placed every 3 m in the two directions, which is equivalent to a power of approximately 11 W/m^2. For fluorescent lights (type T12 48''), they should be laid out very 2.5 m center in the center on 3 lines spaced every 3 m. The fluorescent ones have the advantage of being less expensive to use but their installation and purchase price is higher.

As underlined previously, there are many factors that vary the output of lighting installations. To illustrate this point, let us mention that, in a study done by MAPAQ, the lighting power to produce the equivalent of 100 luxes was estimated in each sheep barn. There was a variation of 6 to 15 W/m^2, as a result of the influence of various factors specific to each building. It is therefore understood, that the theoretical estimate of lighting needs is not easy to make and that the results presented here are only an indication and illustrate the complexity of the calculation. For these reasons, it is strongly recommended that a specialist be consulted before undertaking changes or modifications on your building.

3.4. Calculation of building needs

To facilitate the realization of the technique, it is necessary to envision a building or a section of a building which will be completely reserved for photoperiod. How do you estimate the size of building that will be required to practice photoperiod for a given breeding? The response to this question is not easy and obviously depends on the number of animals that the producer wants to breed with this out of season technique. Obviously, since the use of photoperiod requires the use of a relatively rigid calendar, inevitably, a certain number of ewes in the flock will not fit the selection criteria or will simply be too unsynchronized compared to the rest of the group to be included in the photoperiod treatment. This is the case for ewes that lamb in March and April for example. By experience, one estimates that approximately one third to one half of the ewes in the flock can be bred out of season with the photoperiod technique. The best estimate is to count the number

of ewes which were bred in April and May in previous years. Also, it is necessary to add the number of rams needed to equal one ram for every 20 ewes. It is thus necessary to envisage a building large enough to hold the number of subjects estimated by allocating approximately 2 m^2/head.

4. Effectiveness

4.1. In the short term

In ewes subjected to a treatment of 90 days alternating long days and short days, the start of ovulatory activity is produced 40 to 60 days (6 to 8 weeks) after the period of long days/short days. After 70 days of sexual activity, the ewes no longer respond to the stimulus of the short days and enter a refractory state from the short days which corresponds to the end of the sexual period. It is important to point out that the interval of time between the beginning of the short days and the sexual activity depends to a large degree on the breed of the ewe and the time of the year in which treatment begins.

In a research project done in Quebec, 10 producers evaluated the photoperiod calendar proposed in section 3.1 to induce sexual activity in the spring. This project comprised of three phases which consisted of repeating the protocol of photoperiod over three consecutive years (1995 à 1998) with at least 50 ewes in the flock. The detailed results from the first two years were presented in 1998 at the 2nd International Sheep Industry Symposium held in (Castonguay et Lepage, 1998).

Briefly, let me mention that the results varied from 50% to more than 95% fertility (table 1). One notes that in general, the producers that follow the guiding principles obtain repeated results of more than 85%.

Table 1. Three year average results of the project

	Year 1	Year 2	Year 3	Total average
Number of ewes	625	616	436	1677
Fertility (%)	70.4¶ (51 - 90%)	86.3 (63 - 97%)	70.6 (55 - 85%)	75.8
Prolificacy	1.8	1.9	1.7	1.8

¶ Average (Minimum-Maximum)

The principle factor affecting the success in certain breedings is the breeding of ewes whose interval between lambing and the start of spring breeding was less than 70 days, the normally recommended interval (table 2).

Table 2. Fertility rate (%) as a function of the number of days between the last lambing and putting to the rams in the spring.

	< 61 days	61 to 70 days	71 to 80 days	> 80 days
Year 1	47.7	63.0	81.6	78.5
Year 2	69.7	85.8	85.6	89.4
Year 3	52.6	75.9	80.4	85.7

This situation can be explained by a lack of planning in the fall breeding (delay in putting in the rams) or by a delay in fertilization during the fall breeding. Since the remainder of the calendar was fixed, the delay of winter lambing caused the spring breeding of ewes which were in the best physiological condition for reproduction (post-partum interval <70 days).

4.2. Long-term

The longterm effect of using a photoperiod program like the one proposed has never really been studied. One of the more nebulous aspects and one which requires that one waits in future years, is that generally, the non gestating ewes following the spring breeding are slower to resume their "natural" sexual activity the following fall. It is noticed however, that this effect is related to the genotype of the ewes used like there is in other cases, furthermore for almost all of the characteristics of reproduction. For example, in the project carried out in Quebec, a producer possessing Arcott Canadian, a terminal breed, of the 18 non pregnant ewes after the spring breeding that were rebred from the month of August until mid October, only 28% lambed by March. All of the other ewes lambed in May and June, after being exposed to the ram in December. One can think that for this breed, the resumption of reproductive activities in the fall in the ewes that are non pregnant after the photoperiod treatment in the spring began in October and November. Another breeder possessing ewes that are primarily ½Romanov or ¼Romanov, recognized to have good natural out of season breeding, the situation proved to be different. Seventy-five percent (75%, 15/20) of the non pregnant ewes from the spring breeding and re-exposed in the month of August after the photoperiod treatment lambed in January-February. Of the other 25%, the lambings were only delayed until May, which implies breedings only in December. Thus, if there exists an effect of breed or important genotype, that should be contemplated, it is apparent that there is always a certain number of ewes whose resumption of sexual activity will be delayed in the natural breeding season following the end of a photoperiod treatment. To minimize the impact of this phenomenon on the total performance of the flock, it is necessary to obtain excellent fertility results to the spring breeding under photoperiod treatment. The number of ewes that will be delayed

will be reduced and therefore, the impact on breeding performance will also be reduced. In fact, the impact will be null if one chooses to cull the ewes that do not follow the production rhythm of the rest of the flock!

In this trait in rams, the same phenomenon is observed. In fact, the rams used in spring breeding under light control are generally unable to work well at the start of the fall breeding season. Their sexual activity should improve in October and November, just like the ewes. It is thus essential to take into account this phenomenon when choosing rams to use in each breeding period. As mentioned previously, it is preferable to keep two groups of rams, the first utilized in the fall and the other in the spring. Of course the effect of the delay of the start of sexual activity in the fall will largely be influenced by the breed of ram, as is the case for ewes.

5. Cost

For a 300 m^2 sheep barn, the total cost of electricity for duration of the 90 day treatment period of short days (8 h/day of lighting) was estimated at approximately $144 (Castonguay et Lepage, 1988). For the block of long days of 16 h/day illumination which also lasts 90 days, the cost doubles to $288. The total cost of photoperiod treatment is therefore around $432. In a 300 m^2 sheep barn, approximately 150 animals can be housed allowing 2 m^2/head, with the result that the cost of the photoperiod technique in terms of electrical consumption is approximately $2.88/head.

For the cost of electricity, it is necessary to add the purchase and installation of a timer (approximately $250) and that if the lighting intensity is not sufficient, there will be additional expenses to improve the lighting system. There are also possible costs for the obstruction of the existing windows and ventilation, in the case that the darkness is deficient. The cost of pregnancy testing must also be considered.

6. Advantages and disadvantages

The primary advantage of this technique is to allow intense sexual activity out of season for one relatively prolonged period, which increases the chances of fecundity in the ewes and the total fertility rate in this period of the year. If this technique is done well, fertility rates equal to rates in season can be obtained. This is not the case with other out of season breeding techniques (sponge or MGA). It is relatively simple and inexpensive if the buildings are already adapted or easily modifiable.

In addition, the technique requires good flock management to carry out the illumination changes at the appropriate times. Another significant point, it requires the planning and grouping of fall breedings in order to obtain the necessary number of ewes that can begin the photoperiod treatment at the proper time. One of the primary obstacles in its use is that it generally requires the isolation of part of the flock, which often proves problematic in large sheep barns. It is thus necessary to take account of this element in new construction projects, which enlarge or renovate the sheep barns. In fact, it requires an adapted building, where the entrance of external light can be easily controlled or completely eliminated and whose system of lighting is controlled by a timer. Another fundamental aspect is to ensure that there is good ventilation to control

the increase of temperature and humidity in the interior of barns that result when exterior temperatures are too hot in spring and from the accumulation of litter in this period of the year.

It is a fact that non pregnant ewes following spring breeding have a delayed resumption of sexual activity the following fall can result in a significant loss of productivity if the fertility rate in the spring is very low. It is therefore very important to have a good plan for the photoperiod protocol to maximize fertility.

The proposed calendar has another disadvantage, it is that the majority of ewes will be in lactation in the short day treatment period. Ewes raising lambs under a period of short days has disadvantages. Indeed, several studies have shown that lambs exposed to 8 h/day of illumination have growth rates lower than those under 16h/day of lighting. In general, this reduction is about 5 to 15% according to the studies. This negative effect can be decreased by placing the weaned lambs in another section of the barn where the lighting is at 16h/day.

7. Conclusion

The induction of heat out of season by modifying the photoperiod is an interesting alternative for sheep producers. It gives excellent fertility results when all of the stages of the protocol and guiding principles are scrupulously respected. The investment necessary to adapt buildings for the use of this technique are generally small, given that in our climatic conditions, producers obliged to house their sheep in buildings protected from bad weather and thus, most of the time, it is easy to modify to meet the requirements of the photoperiod treatment.

Finally, it should not be forgotten that the use of photoperiod as an out of season breeding technique is not possible for part of the flock. To ensure out of season breeding of all of the ewes in the flock, it is generally necessary to resort to other techniques to induce heat out of season (vaginal sponge or MGA). Photoperiod is included in our "arsenal" of technical tools, which can be used to produce lamb all year in an economic and profitable way.

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