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Influence of artificial lighting in milk production of dairy cows

Isabel González-Barragán and José Ignacio Hernández Calzada, Cenit Solar, Proyectos e Instalaciones Energéticas S.L.

Abstract

The evolution of global milk production is allowing a higher concentration of livestock, improved its management and the introduction of more sophisticated production systems. Many factors are involved in the optimization of the process to improve yields and one of them is the photoperiod to which lactating cows are exposed.

The lighting directly affects milk production by inhibiting melatonin synthesis in the pineal gland, which results in lower blood levels of the hormone. This hormone reduces the activity of the animal and promotes sleep. It also has the effect of increasing the concentration of others hormones such as IGF-1, whose concentration is believed to play a relevant factor in milk production. Because of this, on dairy farms is observed that the curve of total milk production evolves according to the hours of daylight.

This study analyzes the influence of artificial lighting in order to achieve an increasing in the milk production. To do this, on the farm under study two barns with the same characteristics has been selected. One of them has been equipped with artificial lighting system capable of providing more than 160 lux at all points of the stable. Milk production and food intake data have been collected to analyze the increasing of milk production and their profitability according to the electricity prices.

Keywords: lighting; dairy cow; milk production

1. Introduction

Milk production in the world is evolving towards a model of exploitation where, compared to the traditional scheme based on the extensive livestock, the animals are housed in indoor or outdoor patios in large barns. This evolution is enabling greater concentration of livestock, improved its management systems and the introduction of more sophisticated production systems. This type of farms has allowed the development of the economy of scale and lowering production costs, driven by both the development of the sector as the pressures of the consumer market.

Looking for optimizing production costs, one important factor is the specific production of dairy cows, due to often involving most of the income of a dairy farm. This milk production depends on many variables which can be summarized in three general areas: genetic, feeding and cow comfort.

The term cow comfort is currently used to refer to animal welfare. This involves a large number of aspects related to the management and handling of dairy cattle: bio safety installations, housing, hygiene measures, ventilation, feeding, milking, etc., always with the aim of optimizing animal welfare, and therefore milk production.

1.1 Lactation

The lactation, like a production process, is the expression in time of milk production and it can be studied from a quantitative point of view (amount of milk) and a qualitative point (composition of milk).

In all mammals, the milk production is the result of two consecutive and interdependent physiological and biological processes:

- The milk synthesis and secretion in the alveolar lumen.
- The removal of milk from the mammary gland.

Both processes are influenced by many factors that are divided into two main groups:

a) Intrinsic: they depend on the animal and they cannot be easily modified.
b) Extrinsic or the environment: they are modifiable with management practices.

The average duration of lactation in dairy cows is 10 months: 305 days.

1.2 Lactation curve

It is defined as the evolution over time of the daily milk production of an animal, as well as variations in composition.

Lactation type or standard, in dairy cows, is one that has a production period of 305 days with 60 days of drying, which implies a theoretical calving interval of 365 days.

Graph representing the lactation curve

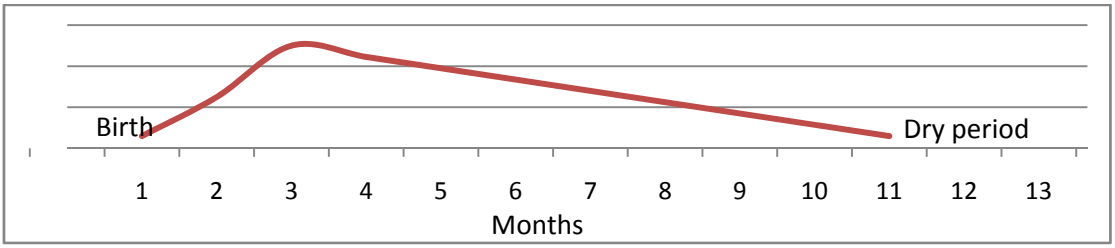

Figure 1: Graph representing the lactation curve

1.3 Extrinsic factors of variation of the lactation curve

1.3.1 Environmental effects

- *Season:* births in autumn or early winter represent a better lactation that births in spring-summer. On the other hand the percentages of fat and protein increase during periods of short days of the year.
- *Weather:* the high or low temperatures decrease the amount of milk and they alter its composition. During the cold months, milk fat, total solids, protein and solids not fat are in a higher quantity. During the warm months, fats and proteins lower.
  The humidity also affects milk production, the milk yield decreases in dry climates.
- *Lighting:* the number of hours of exposure to light influences in a bigger or smaller milk production.
- *Altitude also influences*, decreasing the amount of milk and increasing the fat content in the high mountain areas.

1.3.2 Housing system

Dairy cows in extensive livestock produce milk richer in fat and protein.

1.3.3 Milking

It modifies the production and composition at any given time, but it doesn´t influence the total amount of each component throughout the day. Initially the milk is richer in proteins, salts and lactose, but poorer in fat.

There are also differences between the morning milking and the evening milking: in the morning it produces more quantity and less percentage of fat, while in the evening it produces less quantity and higher percentage of fat.

The interval between milkings affects milk production and composition. If we remove milkings, the milk production gets off and the composition is altered on successive days.

The increase in the number of daily milkings increases the production between 9 and 15%. This is due to a lower intramammary pressure, increased hormonal stimulation (e.g., prolactin) and a lower negative feedback on cellular synthesis.

1.3.4 Feeding

It is one of the most important extrinsic factors affecting the lactation curve. Keep in mind the following considerations:

- Food intake increases during first 8-12 weeks of lactation.
- The mobilization of body reserves allow the animal to maintain milk production in the first few weeks, as there is a lag between the milk production increased and the intake increased.
- A poor energy level increases the percentage of fat and decreases milk production and percentages of protein and lactose.
- Overfeeding increases milk production, protein and not fat solids. The fat and lactose can vary in an irregular form.
- The content of carbohydrates and crude fiber and its digestibility influence in the fat because they alter the rumen volatile fatty acids. The high content of crude fiber acts as a producer of acetic acid which is a precursor of fatty acids with short chains and it causes a higher percentage of fat.
- The shortage of protein in the diet affects negatively to the milk protein.
- The consumption of pastures, forages and concentrates highly digestible and low in fiber increase milk production and decrease fat fraction.
- A food rich in concentrates and cereals (40-65 % of the total ration), favours the propionic fermentation, which is unfavourable to fat production.

1.3.5 Dry period

Its duration depends on the state of the animal body reserves at the time of birth.

At the end of the lactation period, the thin dairy cows need an unproductive period within which they can replenish their body stores.

The udder requires a period for regeneration of secretory tissue.

Duration of 60 days is recommended. Dry periods shorter (40-50 days) and older (70-80 days) give a lower production in next lactation.

1.4 Photoperiod

The duration of the daytime lighting varies by seasons and the animals are sensitive to this variation. It is known as the photoperiod to the response offering both animal and plant to alternating periods of illumination and darkness during the day.

The approximately twelve hours of daylight of Ecuador are increasing in summer and decreasing in winter as we increase the latitude. In Spain the maximum day length reaches 15.5 hours in summer and shorter days in winter reach 9.5 hours.

The animals use day length as an indicator of what time of year they are, because the longer day's entry corresponds to the beginning of spring, which is generally associated with an increase in temperature.

Exposure of animals to these periods of light and dark is the most commonly signal used by animals to predict changes and alter the physiological responses to changes of the environment (Gwinner, 1986). One of the factors which most influence the photoperiod is the seasonal reproductive status of the animals, besides it also influences in other aspects such as growth or changes in body hair.

Cows are not immune to this phenomenon and its daily and nightly rhythm is of fundamental importance. With the presence of light, this impacts on the retina of the cows, inhibiting an enzyme used in the synthesis of melatonin in the pineal gland. Thus, with a longer photoperiod, the duration of high levels of melatonin in the blood is lower. The concentration of melatonin in the blood affects negatively the blood levels of other hormones such as IGF - 1, a hormone that it is believed to play a relevant factor on milk production (Buyserie et al., 2001).

Many studies indicate that milk production increases when the cows are exposed to photoperiods of 16 to 18 hours. However, an increase of daylight hours is not always linked to increased milk production and it also depends on the factors listed above, together with the post-gestation stage, age, etc. By maintaining these other factors constant, an increase in milk production was observed when the light intensity increases, reaching a maximum level which is a point of light saturation. Above this point, the performance of milk production cannot be increased although the brightness is raised.

In this way, it has been shown that exposure to the presence of light 24 hours a day without interruption is not associated with a milk production rise, but milk production of cows under this state of brightness doesn´t show any difference with those animals exposed to natural photoperiod (Marcek and Swandson, 1984). On the other hand, the milk composition isn´t usually affected by photoperiod, although some studies collected slight decreases in the percentage of fat in milk produced with a longer photoperiod (Dahl et al., 2000).

Consequently, we consider a long day photoperiod (LDPP) as one in which continuous exposure to light is 16 to 18 hours, followed by 6-8 hours of complete darkness; while a short-day photoperiod (SDPP) is that which has 8 continuous hours of light followed by 16 hours of darkness. Under natural conditions, the longest day of the year can get to fill with natural light a day of long photoperiod, while on the shortest days of the year we have conditions closer to a SDPP.

To take LDPP days in the barns of animals, several studies suggest that a light level higher than 160 lux at the barns stimulates the enzyme that it inhibits the secretion of melatonin (Buyserie et al., 2001). The 160 lux is the minimum level necessary to search for environments that simulate conditions LDPP days. In the dark period, the luminosity should not exceed 10 lux and it isn´t needed to leave any lights switched on because dairy cows don´t need light to find food and water.

Lactating dairy cows should be subjected to a LDPP period immediately after the birth, although the effects on increasing milk production are not fully evident until 3 or 4 weeks later (Buyserie et al., 2001).

Objective

The aim of this work is to study the influence on milk production with the incorporation of artificial lighting in a barn of dairy cows.

For this, we have proposed the installation of a lighting system in one of the barns of the farm "Granja Conchita".

2. Materials and methods

2.1 Dairy farm

The exploitation of this study is a dairy farm called “Granja Conchita“. It is dedicated to milk production and, in a minor way, to heifer’s sale. This farm is in the municipality of La Cistérniga, in the province of Valladolid (Spain).

The farm has about a thousand heads of cows, with 450 as lactating cows. The cows are located in various buildings and courtyards due to the different stages: calves, heifers, lactating, dry...

The present study was performed in the production barns, where there are the lactating cows (productive phase).

2.2 Climate study

At first, we have taken in account the number of hours of artificial light that it will be needed for the dimensioning of the lighting system. The farm is located in the province of Valladolid (Spain) and we have obtained the daily hours of natural light from data from the National Meteorological Agency, considering as daylight hours the interval between the time of sunrise and sunset. In the Figure 4 we can observe that in the month of June (days 151-181) we are above the 14 hours of daylight, while in the months of December and January it is not reached at 10 hours. In our case study, it is considered a necessity 16 daylight hours, so the dotted curve represents the hours of artificial light required for each day of the year, resulting a total of 1,383 hours.

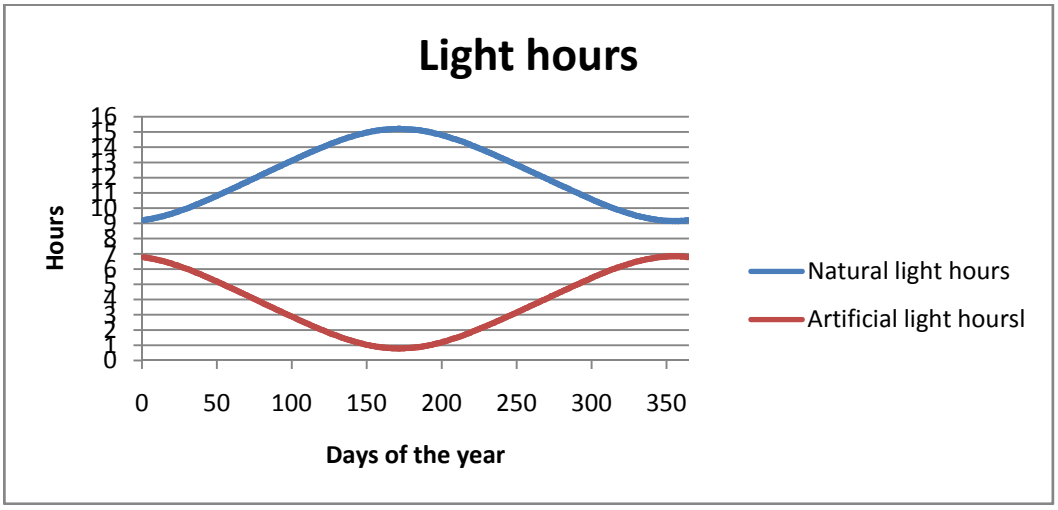

Figure 2: Natural and artificial light hours

2.3 Artificial brightness

To realize the study, we have carried out the installation of a lighting system in one of the barns (patios 3 and 4) of the farm where the dairy cows in production state are located.

To determine the hours of artificial lighting, we have taken the light period of the longest day of the year increased to 16.5 hours (extending the time at both sides equally at dusk and at dawn) and we have replicated it every day of the year. These 16.5 hours provide to the animals a LDPP lighting regime. To determine the time zone, the time of sunrise on the longest day of the year is at 5:44 and the time of sunset is at 20:57 (taken as reference the winter time), which means a period of 15 hours and 13 minutes of daylight. Accordingly, it was established that the period of illumination would be from 5:15 to 21:15 according to the winter schedule that does not change throughout the year (the time change in Spain is artificial), giving the 16,5 hours desired. In Figure 4 the dotted line shows the daily hours of artificial light needed during the year.

We have automated the lighting system by incorporating a clock and a photocell with a cascade configuration. The clock only allows switch on the lighting system in a period of time, being in charge of enforcing the dark period. When the clock allows the system activation (daylight brightness range), the photocell is the responsible to switch on or off the system depending on the presence of natural light. Because of the sensor could give the signal to switch on the system before the dusk or the signal to switch off it after the dawn, we have considered a light additional 15 minutes in both cases, resulting in 1565 hours of artificial light per year.

With the daylight hours needed calculated, we designed the dimensioning of the lighting system of the barn under study. The barn have a central hall for the distribution of feed and two side halls where are the animals. In search of enlightenment in the area of activity of the animals, the light spots will be located in these side halls (Figure 5) along its 70 meters long with a height of light points of 5 meters.

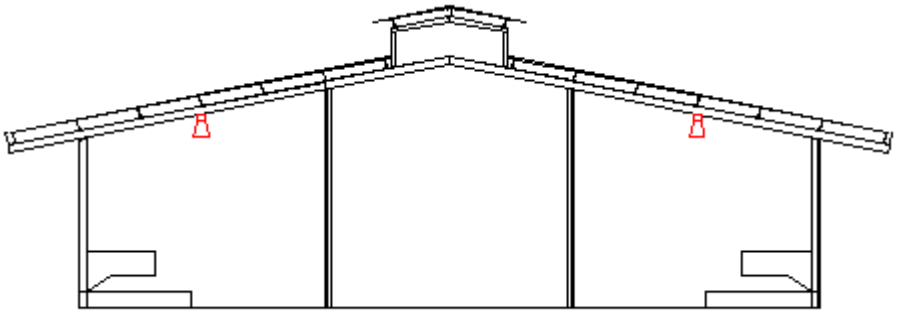

Figure 3: Barn portico

After the study of the different types of lighting systems, we have chosen a configuration of metal halide light with 9 points in each hall. While it isn´t the lowest cost option, it is the best option that provides a better price-coverage ratio relationship.

The coverage ratio is defined as the percentage of the surface illuminated where the brightness is greater than 160 lux. The few hours of operation per year makes that more efficient solutions such as light bulbs or LED lighting are not profitable due to its installation cost is not supplied by the energy savings involved. The configuration chosen covers properly the needs as we can see in Figure 7, where only the corners have the points where the degree of desired brightness is not reached.

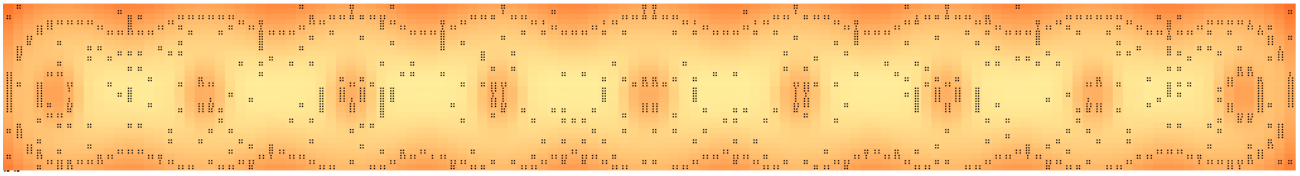

Figure 4: light intensity distribution

The lights installed are bells FIREPLACE BJC F17540HC model with bulbs OSRAM HQI-E 400 / D PRO E40 model, which were fixed to the metal straps of the barn by a threaded rod. They also have as a security measure two additional holding strings. The normal installation of these bells is carried by the suspension by a chain, but we have chosen a fixed anchor method to prevent oscillations, due to the barns are in outdoor conditions and the bells are susceptible to strong winds.

Once the lighting system is installed, his operation started the 24/10/2013, with an operating time from 7:15 to 20:15 (clock time). It was progressively increased half hour every 7 days (7:00 to 20:30, 6:45 to 20:45 ...) until the final schedule 5:15 to 21:15, which took place on 19/12/2013. This progressive increase was made to adapt the animals to the new schedule without causing an abrupt change in the hours of light to which the animals are exposed.

2.4 Record test data

Once installed the lighting system, the study was made taking data from halls 3, 4, 5 and 6. All these halls have lactating cows with similar features, so we can see the effect of lighting on the 3 and 4 halls in contrast to the halls 5 and 6, which are taken as a pattern.

Milk production data are taken three times a day for the three daily milkings.

3. Results and Discussions

The realized study does not throw for the present time conclusive results. Nevertheless, it can be said that in the analyzed data is observed that the dairy cows that they find in the first part of the lactation curve (between 3º and 76º days after the birth), they do not show significant differences as for the supplement of lighting (artificial light).

Nevertheless, in the dairy cows that already have spent the peak in production curve, and are diminishing this milk production, a significant increase of the production is detected when they are complemented by artificial light.

It is important bear in mind that this study has been realized in the increasing days, in which the dairy cows are stimulated by these natural conditions. It will be important and decisive to see the effects of the artificial lighting throughout a complete year. This study will extend up to having results during all the stations of the year.

4. Conclusions

-The results obtained during the first three months of the year (January, February and March) are not conclusive for this study.

- We have seen the importance of analyzing the information of production throughout a complete year.

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