Induction of estrus as a strategy to improve the economic efficiency of the sheep flock

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Citation: Cadena-Villegas, S., Cigarroa-Vázquez, F. A., Hernández-Marín, J. A., Flores-Santiago, E. del J., Cortez-Romero, C., & Sosa-Pérez, G. (2023). Induction of estrus as a strategy to improve the economic efficiency of the sheep flock. *Agro Productividad*. https://doi.org/10.32854/agrop.v16i12.2780

Academic Editors: Jorge Cadena Iñiguez and Lucero del Mar Ruiz Posadas

Received: July 12, 2023.
Accepted: November 30, 2023.
Published on-line: January 24, 2024.

Agro Productividad, 16(12) suplemento. December. 2023. pp: 137-145.

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ABSTRACT

Productivity and profitability in sheep production systems are strongly influenced by the reproductive capacity of the flock.

Objective: To evaluate the use of reproductive biotechnologies (*e.g.*, the induction of estrus) and its impact on the economic efficiency and the productive and reproductive performance of technified sheep production systems, during the seasonal anestrus.

Design/Methodology/Approach: Four-hundred recently weaned (60 days postpartum) ewes of the Katahdin breed were randomly divided into two treatments: T1=natural mating (n=200) and T2=induction of estrus (n=200). Estrus was induced through the application of intravaginal sponges, impregnated with 20 mg of chronolone, plus the injection of 400 IU of Equine Chorionic Gonadotropin. The aim was to evaluate the reproductive and economic efficiency of the flock.

Results: The induction of estrus during the seasonal anestrus recorded increases ($p<0.001$) in prolificacy (32%), fertility (86%), and kilograms of lamb weaned per year per ewe (48%), while decreases ($p<0.05$) were recorded in the number of open days (25%), calving interval (11%), cost per open days (23%), and the kilograms of lamb required per ewe per year (10%).

Study Limitations/Implications: The constant variations in the price of supplies and services caused changes in the economic indicators.

Findings/Conclusions: The use of reproductive biotechnologies (such as estrus induction) has a positive impact on production units, improving their profitability.

Keywords: sheep, reproductive biotechnologies, profitability, fertility, costs.

INTRODUCTION

In 2020, sheep stock in Mexico amounted to 8,708,246 heads (SIAP, 2022). Nevertheless, the market fails to meet the domestic meat demand and, consequently, lamb meat is mainly imported from New Zealand and Australia (FOASTAT, 2020). The low productivity of the sheep production systems is mainly the result of poor nutrition, lack of health management, and low efficiency (Gastelum-Delgado *et al.*, 2015; Martínez-González *et al.*, 2017). Increasing the reproductive capacity of the flock can be an alternative to improve the productivity and profitability of the flocks. The reduction of the unproductive period of the sheep can diminish fixed production costs and variables and increase production, obtaining three births per ewe in two years (Hinojosa-Benavides *et al.*, 2019).

The use of biotechnologies is one of the reproductive management strategies that improves flock performance. The synchronization and induction of estrus are two biotechnologies that use effective and easily applied pharmacological methods. These methods facilitate the manipulation of the reproductive physiology of ewes, consequently homogenizing lamb production, reducing the open days, and directly improving the productive and economic aspects of sheep production (Lozano-González *et al.*, 2012).

In view of this situation, the hypothesis of this study was that the implementation of reproductive biotechnologies (*e.g.*, the induction of estrus) can reduce production costs and improve the productive and reproductive performance of technified sheep production systems. Therefore, the objective of this study was to evaluate the technical and economic feasibility of implementing a protocol for the induction of ewe estrus in a commercial production system.

MATERIALS AND METHODS

Study area location

The study was carried out from March to July, 2020 (seasonal anestrus) in a Commercial Flock, located in the Texcoco municipality, State of Mexico, at 19° 29’ N and 98° 53’ W, at 2,240 m.a.s.l. The area has a subhumid warm weather, with summer rains. Its climatic formula is Cb(w0)(w)(i’) (García, 2004).

Animals and feeding

Four-hundred recently weaned (60 days postpartum; 1.28 prolificity) and multiparous ewes of the Katahdin breed were used; they had a 55.7±4.8 kg average weight and a 2.5 average body mass index in the scale proposed by Russel *et al.* (1969). The specimens were placed in pens with automatic feeders and water dispensers (20 ewes per pen). The ewes consumed a 2.5-kg integral portion (13% crude protein; 2.4 Mcal of metabolizable energy; and 20% crude fiber), made up of 70% corn silage and 30% concentrated feed and prepared in the production unit.

Health management

The ewes were subcutaneously dewormed with 10 mg of ivermectin (Iverfull®, Aranda); additionally, 10.95 mg of sodium selenite and 50 mg of vitamin E were applied through an intramuscular injection (MUSE®, MSD).

Induction of estrus protocol

The induction of estrus was carried out using progestogens. The method consisted of the application of an intravaginal sponge, impregnated with 20 mg of chronolone (Chronogest®, MSD). A speculum was used to introduce the sponges in the fundus of the vagina, where they remained for 12 days. Forty-eight hours before the removal of the sponge, 400 UI of Equine Chorionic Gonadotropin were applied through an intramuscular injection (eCG, Novormon®, VIRBAC).

Treatments and description

The sheep were randomly divided into two treatments: T1=natural mating (n=200), and T2=induction of estrus (n=200).

Natural mating: The ewes were kept in a mating stage for 60 days (three 17-days estrus cycles), with 20 ewes per ram. Suitable rams were subjected to a physical and semen evaluation to determine their reproductive characteristics. During this period, rams used nylon marking harnesses. Ewes with a color mark between their coxal tuberosities were considered to have been mounted by the ram. The ewes mounted by the rams were registered in the daily 8:00 am tour. The color of the males' marking harnesses was changed every 14 days to control the mating. Ewes stained with two different colors were considered as non-pregnant after the first mating and, consequently, they returned to the estrus stage.

Induction of estrus

The detection of estrus was carried out for 120 minutes, every 6 hours, with the help of a ram. This process started 24 hours after the removal of the sponge. Ewes with signs of estrus were separated and inseminated twice by natural mating, at the start and at the end of a twelve-hour period. This procedure was carried out 48 h after the starting of the mating. Ewes that did not respond to the treatment were included in a natural mating group for 43 days, in order to restart their reproductive activity.

Gestation diagnosis

The gestation diagnosis was carried out 47 days after the induction of estrus. In the case of natural mating, the diagnosis was carried out 90 days after it started. The diagnosis consisted of a real-time ultrasound carried out with a MINDRAY® DP 10 Veterinary micro-convex array transducer, calibrated at 5 mHz. The ewes were classified as positive or negative, depending on whether or not they had a well-formed fetus.

Costs

Variable costs. This indicator was the sum of the costs of labor plus feeding, animal health, hormonal treatments, and other costs paid during the period of the analysis.

Fixed costs. These costs included depreciation, which is related to the investment in assets and management expenses.

Total costs. They were calculated as the sum of the variable costs plus the fixed costs of the company, during the analysis period.

Evaluated variables

The study variables included: fertility, prolificity, and open days. The first divides the number of pregnant sheep by the number of inseminated sheep and expresses it as percentages. The second is the number of lambs born divided by the number of sheep that gave birth. Both variables were determined at birth, counting the number of lambs born per ewe. Finally, the third variable takes into account the number of days from the moment of the birth to the moment when the next gestation takes place.

The feeding and production records and the financial data of the production unit were used to determine the costs of open days and the Interval between births for the two strategies in question. Additionally, the components of the fixed, variable, and total costs were determined as a whole. Subsequently, the annual weight (kg) of weaned lambs per sheep (KCDA) and the cost:benefit ratio of the induction of estrus technique were calculated. Finally, the annual break-even point of lamb weight (kg) produced per sheep that the production unit (KNDA) requires to be profitable was also calculated.

Fixed costs were calculated based on the information included in the documents of the ranch. After consulting the bills and receipts of the ranch, the costs paid for each heading were divided by the number of animals in which they were spent, in order to obtain a daily cost per sheep. The fixed costs taken into account for this study were: feed consumption, water consumption, labor, and drug administration; however, the depreciation of the infrastructure was not included, given the lack of information about the facility costs.

A cost of $9.086 Mexican pesos per feeding and per sheep was obtained, based on a 30% concentrate feed and 70% silage corn. Each sheep voluntarily consumed 2.0 kg of feed per day. Daily water consumption was estimated at 4.5 liters per sheep per day, reaching a cost of $0.225 Mexican pesos per day. The ranch had four employees, who were paid a weekly wage of $1,500 Mexican pesos each. The cost of labor amounted to $1.7 Mexican pesos per sheep per day. The monthly cost of the drugs for the basic first-aid kit was divided by 400 animals. The drug cost amounted to $0.1 Mexican pesos. Finally, the monthly fuel bills were divided by 400 animals, resulting in a daily cost per sheep of $0.4 Mexican pesos.

The variable costs were those used in the protocol for the induction: initial gestation diagnosis ($15.0); induction of estrus treatment ($250.0); and a corn grain-based supplementation ($1.5).

Statistical analysis

The fertility and prolificity variables were analyzed using the χ^2 and the Kruskal–Wallis tests. The rest of the variables were subjected to an analysis of variables (ANOVA). Meanwhile, Tukey's test ($p<0.05$) was used to determine the mean differences between the effects of the protocol type (induced or natural mating) on the reproductive and economic parameters. The data was analyzed using the PROC GLM of the SAS statistical package (SAS Institute Inc., Cary, NC, 2008).

RESULTS AND DISCUSSION

Reproductive variables

Table 1 shows that the prolificity and fertility reproductive variables recorded higher results (32 and 86%, respectively) with the induction of estrus treatment ($p<0.001$). Meanwhile, the group of animals subjected to the induction of estrus recorded 25% and 11% less ($p<0.05$) open days (25%) and shorter intervals between births (11%) than the group subjected to a natural mating. These improvements in the reproductive behavior of the group of sheep subjected to the induction of estrus treatment during the seasonal anestrus can be the result of the use of pharmacological methods that enable the manipulation of the luteal and follicle phases of the estrus cycle). These methods include the insertion of intravaginal devices with progesterone and similar drugs, the intramuscular injection of Equine Chorionic Gonadotropin, and the use of prostaglandins and similar drugs. The resulting changes in the functions of the hypothalamus-pituitary-ovary axis helps to intensify animal production, improving fertility and prolificity (Lozano-González *et al.*, 2012). The productivity of sheep production systems mainly depends on the number of births, which is related to fertility and prolificity. Both fundamental indicators influence the profits of the production unit, because the fixed cost per womb is the same, regardless of its productive level. Consequently, the increase of these indicators determines the feasibility of a production system (Macedo and Castellanos, 2004).

The reduction on the number of open days is important, because this is the period when the sheep consume feed, outside their reproductive stage. Even more importantly, its improvement of the energy balance of the diet allows animals to recover their body condition. On this matter, Alvarado *et al.* (2021) pointed out that those sheep that recover their body condition sooner have a shorter first birth-estrus interval. This parameter is determinant for the profitability of a production unit. Under intensive conditions, the reduction of open days is fundamental to reincorporate the sheep into the productive system and to obtain enough lambs to guarantee the profitability of the system. González-Reyna *et al.* (2020) define productivity as the relationship between the outputs and the inputs of a production period or cycle. Therefore, a minimum-cost production involves a

Table 1. Means and standard deviation of the reproductive variables of Katahdin sheep, during the seasonal anestrus, with natural mating and induction of estrus.

Variable	Protocol type (Mean ± S.D.)		P>F
	Induced (n=185)	Natural mating (n=151)	
Fertility (%)	73.1	39.7	***
Prolificacy (lambs)	1.5±0.6	1.1±0.3	***
Days Open (Days)	79.5±9.2b	104.2±18.6a	***
Lambing interval (days)	225.9±9.6a	250.7±18.1b	***
Birth per year	1.6±0.0a	1.4±0.1b	***

a, b: Values with different literals in the row are different ($P<0.05$). S.D. Standard deviation. ***: $P<0.0001$.

maximum efficiency in the use of the inputs to achieve a point of balance, where a positive cost:benefit ratio and other economic variables can be achieved. Reproductive seasonality is a very important factor, because most ewes need an almost 7-month birth-conception interval; the reproductive seasonality of a high percentage of the specimens includes a 5-month sexual repose (De Lucas *et al.*, 1997). This situation increases the feeding and maintenance costs of the sheep.

Economic variables

Regarding the economic variables, Table 2 shows a reduction (P≤0.0001) in the cost of the open days and the interval between births (23%). In the case of the group subjected to an induction of estrus, the annual lamb weight (kg) required per ewe to guarantee the profitability of a company (10%) likewise recorded a decrease, compared with the group subjected to natural mating. Meanwhile, the annual weaned lamb weight (kg) per ewe increased by 48% (P≤0.0001).

The economic profitability of the sheep production units directly depends on reproductive efficiency and, consequently, on the productivity of every sheep (Gonzáles-Reyna *et al.*, 2003). Since the use of hormonal treatments during the seasonal anestrus reduces the unproductive period (open days), the group of sheep subjected to the induction of estrus protocol had a better profitability in the production unit. Since food accounts for 60% of the total costs of livestock production systems, the feeding expenses diminished, favoring the profitability of the production (Herd *et al.*, 2003). In addition, 70% of the food required for sheep production is consumed by ewes (Hogue, 1987).

Meanwhile, in the Mexican sheep production systems, 75.7% of the income comes from the sale of lambs, whether as animals with market weight or as weaned lambs (Góngora-Pérez *et al.*, 2010). Consequently, the increase of prolificity and the reduction of the interval between births among sheep subjected to the induction of estrus treatment, during the seasonal anestrus, could increase the efficiency of lamb production (Gonzáles-Reyna *et al.*, 2003) and distribute the maintenance and production cost of the ewes among a larger number of born lambs, increasing the number of sold lambs (Dickerson, 1970).

Table 2. Means and standard deviation of the economic variables used to evaluate the induction of estrus protocol and natural mating of Katahdin sheep, during the seasonal anestrus.

Variable	Protocol type (Mean ± S.D.)		P>F
	Induced (n=185)	Natural mating (n=151)	
Cost Days Open ($)	916±109	1,200±210	***
Cost LI ($)	2,601±115	2,886±211	***
KWLEY (kg)	49±21	33±12	***
KLREY (kg)	52±2.3	58±4.2	NS
Difference	-2.39±22	-24.3±14	***

KWLEY: Kilograms of weaned lamb/ewe/year, KLREY: Kilograms of lamb required/ewe/year. S.D. Standard deviation; T: Synchronization protocol type; ***: P<0.0001.

The increase on the productivity of the sheep from the group subjected to the induction of estrus treatment —defined as the weaned lamb weight (kg) per sheep— is a parameter that includes lamb productivity, along with the reproductive characteristics and the maternal ability of the ewe (Snowder and Fogarty, 2009). In this regard, the increase in profitability and the reduction of the interval between the births reported in this study enabled an increase in the productivity per ewe and guaranteed the profitability of the production unit. This situation takes place, always supposing that the number of lambs born per birth does not exceed the capacity of the ewe. The number of lambs born per birth can vary according to the different production systems, animals, weather, and quantity and quality of available food. The increase in profitability can have a negative impact on the growth and survival of the lamb; in addition, it can make the births harder for the ewes, increasing the mortality rate of the lambs (Gootwine *et al*., 2007; Gootwine *et al*., 2008).

The annual weaned lamb weight (kg) per sheep is the most important production indicator, as a result of its multifactorial nature. It includes the open days, fertility, prolificity, mortality, and weight gain of the lambs. In addition, the production subsystem must fulfill this parameter to be profitable. In most cases, this subsystem is subsidized by the feedlot subsystem, which is more profitable. However, lamb production takes up most of the costs and risks, because it involves the daily feeding of the ewes and the loss or death of the ewes and lambs. It also includes most of the fixed costs of the production unit. Therefore, determining the annual kilograms of produced and weaned lambs per ewe is fundamental to determine how much they must pay for their maintenance in the production unit.

In this study, this indicator was determined based on the sum of fixed and variable costs. The total was divided between the cost per lamb kilogram at the moment of this study to determine the KCDA. A higher value was observed in the induction of estrus treatment, as a result of the cost of the pharmacological products. Table 2 shows that the use of the induction of estrus protocol increased the annual weaned lamb kilograms per sheep by 48.5%. The use of induction estrus treatments did not allow the ewes to achieve the lamb kilograms required to pay for their stay in the farm. Using this method, 2.39 kilograms more were still required to reach a point of balance. For its part, the natural mating treatment group required 24.3 more kilograms to achieve a balance. This difference will be the result of an efficient intensive fattening of lambs and the increase of the sale prices. Guzmán *et al*. (2022) pointed out that a lower weight per litter at the moment of the weaning has a positive relation with the weight of the lambs at the moment of the sale. Consequently, increasing the kilograms of weaned lambs per sheep can increase the kilograms of lamb sold, improving the profitability of the production unit. Ponce *et al*. (2013) evaluated the technical and economic efficiency of two estrus synchronization protocols in Pelibuey sheep and determined that these pharmacological control techniques —used to manipulate the reproductive activity of sheep— increased the production costs. These results match the findings of this study. However, the protocols also increased lamb production and the income of the production unit.

CONCLUSIONS

The use of a protocol for the induction of estrus in Katahdin sheep increases prolificity and fertility and decreases the number of open days. These changes have a positive impact on the production unit, reducing the expenses generated by the open days and the intervals between births. Additionally, it also decreases the lamb kilograms required per sheep to reach a point of balance between the production costs and the product, improving the profitability of the production unit, through a yearly increase in the weaned lamb kilograms per sheep.

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