






Feeding strategies in lactating hair sheep: Effect of bypass fat on the resumption of postpartum ovarian activity

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ABSTRACT

Objective: To evaluate the effect of bypass fat during the postpartum period in Pelibuey ewes synchronized with an intravaginal progesterone-releasing device (CIDR).

Design/methodology/approach: Seventy-six Pelibuey sheep suckling were used during the postpartum period, with an average body condition score of 3. The ewes were randomly assigned to one of four treatments: T1 = cs (continuous suckling; n = 19), T2 = CS (controlled suckling; n = 19), T3 = cs + bypass fat (ac + FAT; n = 19), and T4 = CS + bypass fat (AC + FAT; n = 19). The experimental design was completely randomized with a 2 × 2 factorial arrangement. There were two factors: factor A was suckling, with two respective levels: 1, continuous (c); 2, controlled (C); while factor B was bypass fat supplementation, grouped into two levels: 1, no bypass fat in the diet; 2, bypass fat in the diet. The SAS statistical package (2009) was used for data analysis, performing logistic regression tests (PROC LOGISTIC), Poisson distribution (PROC GENMOD), and survival analysis (PROC LIFEREG) according to each variable.

Results: bypass fat and type of lactation had no effect on the variables of estrus manifestation, time to estrus, return to estrus, pregnancy rate, and birth rate ($p > 0.05$). However, statistical differences ($p < 0.05$) were found in the variables of embryonic loss ($p = 0.0005$), prolificacy ($p = 0.04$), and fertility ($p = 0.03$).

Limitations on study/implications: The results were obtained with a limited number of sheep in each of the treatments.

Findings/conclusions: The interaction of controlled lactation and supplementation with bypass fat is an efficient and cost-effective management strategy that improves reproductive efficiency during the postpartum period by reducing the interval between calving and first ovulation.

Keywords: bypass fat, suckling, postpartum.

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INTRODUCTION

The nutritional status of animals directly influences reproductive activity (Rodríguez *et al.*, 2021), as it can stimulate early onset of puberty, promote cyclicity, and increase ovulation



rates (Halac, 2016). In any animal production system, diets must ensure the inclusion of essential nutrients such as energy, proteins, vitamins, and minerals, as these are necessary for various vital functions in each individual (Campos, 2015). At the physiological level, changes in body condition affect gonadotropin secretion (LH/FSH; Galina *et al.*, 2021).

Reproductive activity is associated with energy availability, which depends on the integration between energy metabolism and the hypothalamic-pituitary-ovarian axis (Alomar, 2012). Forage-based diets implemented in different production systems are often deficient and do not meet nutritional requirements, which is why complementary energy sources have been added (Leal-Isidro, 2020).

As an energy source and due to its structural characteristics, bypass fat is not degraded in the rumen and can be utilised in the small intestine. It is therefore widely used in ruminant diets, as it benefits energy balance, reduces metabolic problems, stimulates milk production and, in terms of reproductive parameters, promotes follicular development, ovulation rate and embryo implantation. In addition, there have been cases in which it increases the conception rate (Osorio-Marín, 2021). Therefore, the objective of this study was to evaluate the effect of including bypass fat to the diet of Pelibuey ewes synchronized with a CIDR during the postpartum period, assessing the following reproductive variables (estrus manifestation, time to estrus, return to estrus, pregnancy rate, embryonic/fetal loss, lambing rate, prolificacy, and fecundity).

The objective of this study was to evaluate the effect in the diet of Pelibuey sheep during the postpartum period to measure the recovery of ovarian activity (oestrus manifestation, oestrus duration, return to oestrus, pregnancy rate, embryonic/foetal loss, lambing rate, prolificacy and fertility).

MATERIALS AND METHODS

Study site

Animal management was conducted in accordance with animal welfare regulations, in line with protocol COBIAN/020/25 and the Regulations for the Use and Care of Animals for Research at the Colegio de Postgraduados.

The experimental period took place from March to November 2024 at the Sheep and Goat Reproduction Laboratory (LaROCa) at the Montecillo Campus of the Colegio de Postgraduados, located in the municipality of Texcoco in the State of Mexico (19° 27' 51" N, 98° 54' 34" W, at an altitude of 2,250 m above sea level).

The study included 76 lactating hair sheep during the postpartum period, with an average weight of 55 ± 8 kg and an average body condition score of 3.0 on a scale of 1 to 5, where 1 indicates a very thin ewe and 5 a very fat ewe. The sheep were randomly assigned to one of four treatments at the time of lambing. A completely randomized experimental design with a 2×2 factorial arrangement was used, where the study factors were: A) type of suckling, grouped into two levels; 1, continuous suckling (c; the lambs remained with their mothers 24 hours a day); 2, controlled suckling (C; the lambs were nursed in two 30-minute periods per day, the first at 8:00 a.m. and the second at 4:00 p.m.; after suckling, the lambs were separated from their mothers) and B) bypass fat supplementation in the diet, with two levels: 1) without bypass fat and 2) with bypass fat, resulting in four

treatments: T1=continuous suckling (cs), T2=controlled suckling (CS), T3=cs with bypass fat (cs+FAT), and T4=CS with bypass fat (CS+FAT), with 19 sheep per treatment.

Before the experiment began, the facilities were thoroughly inspected, and a preventive sanitation protocol was implemented. The ewes were dewormed and had their hooves trimmed. They also received a single 1.90 mg kg⁻¹ dose of vitamin concentrates (Vigantol[®], Elanco) to prevent deficiencies in vitamins A, D and E.

At birth, the lambs received care, including navel disinfection and the application of a healing, disinfectant aerosol spray (Aluspray[®], Vétoquinol). They also received an intramuscular injection of 0.02 mg kg⁻¹ of Vigantol[®] and 0.3 mL of selenium (Mu-Se[®], Intervet), as well as an oral dose of Nutri-Drench[®] to strengthen their immune systems.

The ewes received a total mixed ration balanced according to NRC requirements (2007; Tables 3 and 4) and had free access to water prior to the initiation of the synchronization protocol. In treatments supplemented with bypass fat, a modified diet containing 2.5% bypass fat was offered for nine days, starting simultaneously with the synchronization protocol (Tables 1 and 2). The protocol began at 45 days postpartum with the insertion of an intravaginal device (CIDR; 0.3 g progesterone). Seven days later, 1.5 mL of PGF₂α (Lutalyse[®]) and 300 IU of eCG (Novormon[®]) were administered intramuscularly. Two days later, the CIDR was removed and estrus detection began every four hours for 72 consecutive hours using teaser males fitted with aprons to prevent mating.

Pregnancy diagnosis was performed transrectally at 37 and 50 days after mating using a portable ultrasound device (UMS900 Neo) with a ventral transducer (Figure 1).

The variables evaluated were estrus expression, time to estrus, return to estrus, embryonic/fetal loss, pregnancy rate, lambing rate, prolificacy, and fecundity. Data was analyzed using SAS statistical software version 9.0. Binomial variables (estrus expression, return to estrus, pregnancy, and lambing) were analyzed using logistic regression (PROC LOGISTIC), while numerical variables (prolificacy and fecundity) were adjusted to a Poisson distribution using the GENMOD procedure (PROC GENMOD), applying the

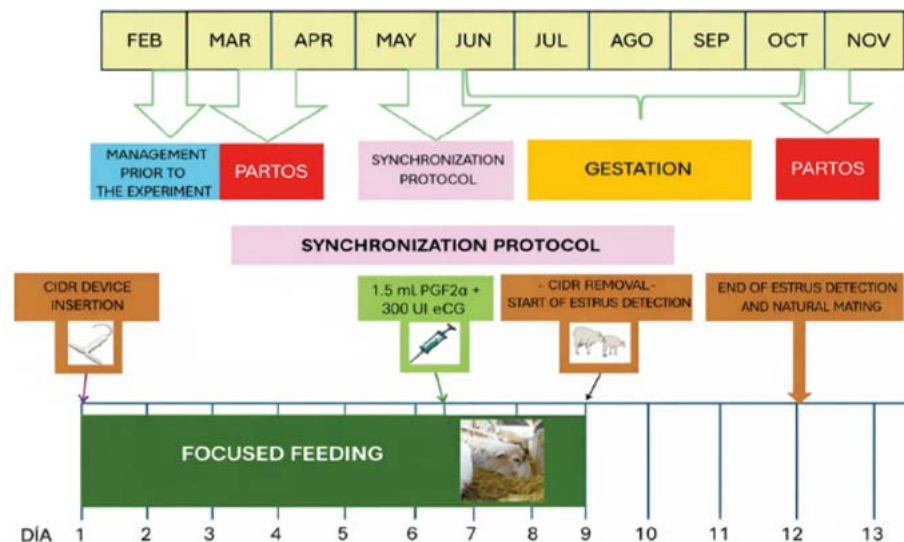


Figure 1. Flow diagram showing the experimental timeline.

Table 1. Diet offered to animals during the experimental period, adjusting the amount of bypass fat (FAT) for cs+FAT and CS+FAT treatments.

Ingredient	Fat-supplemented	Non-fat-supplemented
Ground maize	25.20	34.00
Oat straw	23.00	17.30
Chopped alfalfa hay	20.00	20.00
Wheat bran	10.00	10.00
Molasses	7.00	7.00
Soybean meal	5.60	5.50
Corn gluten meal	4.10	3.50
Protected vegetable fat	2.50	0.00
Mineral-vitamin premix (sheep)	2.00	2.00
Sodium chloride	0.50	0.50
Calcium carbonate	0.10	0.20

Table 2. Nutritional composition of diets with and without bypass fat (FAT) offered during the synchronization protocol as a feeding strategy.

Nutrient	Treatments	
	With FAT	Without FAT
DM (%)	88.35	87.75
ME (Mcal)	2.50	2.50
CP (%)	14.04	14.02
RDP (%)	9.00	9.00
UDP (%)	5.04	5.02
E.E. (%)	5.68	3.12
CF(%)	17.18	15.04
Ash (%)	8.37	8.13

Table 3. Ingredients of the general diet offered to ewes prior to the synchronization protocol and focused nutrition.

Ingredient	Amount (%)
Oat hay	50.0
Alfalfa hay	35.0
Commercial concentrate (Reproductive sheep: Purina®)	7.0
Molasses	5.0
Mineral premix (Oveja plus)	2.0
Total	100.0

Bootstrap resampling method to improve confidence interval estimation. Time to estrus was analyzed using parametric survival models (PROC LIFEREG), and survival curves were generated using PROC LIFETEST for graphical comparison among treatments. Means were compared using Tukeys test ($p \leq 0.05$).

Table 4. Nutritional composition of the general diet offered to ewes prior to the synchronization protocol and focused nutrition.

Nutrient	Amount (BTO)
Moisture (H), %	13.81
Dry Matter (DM)	86.19
Ash (C), %	9.29
Organic Matter (OM), %	76.90
Crude Protein (CP), %	11.79
Ether Extract (EE), %	2.73
Crude Fiber (CF), %	16.90
Nitrogen Free Extract (NFE), %	45.48
Total, %	100

RESULTS AND DISCUSSION

After data analysis using the respective statistical methods, results for estrus expression, time to estrus, return to estrus, pregnancy rate, embryonic/fetal losses, lambing rate, prolificacy, and fecundity are presented (Tables 5 and 6).

Estrus expression

No differences were found for estrus expression ($p=0.31$). However, in the CS+FAT treatment, 100% of the ewes expressed estrus. Similar results were reported by Ali (2017) and Urviola *et al.* (2020), who observed 100% estrus expression when synchronization protocols using fluorogestone acetate (8-12 days with 500 IU of eCG) combined with bypass fat supplementation were applied. Bypass fat improves steroid hormone synthesis, particularly estradiol, which is essential for estrus expression. Likewise, the progestogen exerted the expected effect (Morales-Terán *et al.*, 2010). Additionally, controlled suckling directly accelerates the resumption of ovarian activity by temporarily inhibiting suckling stimulus, favoring hormonal recovery of the reproductive axis and increasing pulsatile GnRH secretion (Delgadillo *et al.*, 2008).

Table 5. Results for estrus expression, time to estrus, return to estrus, and pregnancy rate.

Treatment	n	Estrus expression n (%)	Time to estrus (h)	Return to estrus n (%)	Pregnancy rate n (%)
cs	19	16 (84.21)	22.95	3 (15.78)	11 (57.89)
CS	19	18 (94.73)	23.98	4 (21.05)	11 (57.89)
cs+FAT	19	17 (89.47)	24.22	2 (10.52)	13 (68.42)
CS+FAT	19	19 (100.00)	22.40	3 (15.78)	16 (84.21)
Total	76	70 (92.10)	22.40±2.08	12 (15.79)	51 (67.10)

Different letters within rows indicate differences among treatments ($P<0.05$).

cs=continuous suckling, CS=controlled suckling, cs+FAT=continuous suckling+bypass fat, CS+FAT=controlled suckling+bypass fat.

Table 6. Results for lambing, embryonic/fetal losses, prolificacy, and fecundity.

Treatment	N	Lambing n (%)	Embryonic/fetal losses n (%)	Prolificacy	Fecundity
cs	19	11 (57.89)	2 (10.52)	15/11 (1.35)	15/19 (0.78)
CS	19	12 (63.15)	2 (10.52)	19/12 (1.58)	19/19 (1.0)
cs+FAT	19	13 (68.42)	2 (10.52)	24/13 (1.84)	24/19 (1.26)
CS+FAT	19	16 (84.21)	0 (0)	29/16 (1.81)	29/19 (1.52)
Total	76	52 (68.42)	6 (7.89)	87/52 (1.67)	87/76 (1.14)

Different letters within rows indicate differences among treatments ($P < 0.05$).

cs=continuous suckling, CS=controlled suckling, cs+FAT=continuous suckling+bypass fat, CS+FAT=controlled suckling+bypass fat.

Time to estrus

No differences were detected among treatments for time to estrus ($p=0.98$). These results may be attributed to the metabolic status of the ewes, as bypass fat provides high energy availability, favoring follicular maturation and a faster response to eCG stimulation (Zarazaga *et al.*, 2010; Abecia *et al.*, 2012). Moreover, the results suggest that all females were under adequate physiological and environmental conditions, which allowed similar estrus onset times (22.40 ± 2.07 h).

Return to estrus

No differences were observed for return to estrus ($p=0.85$); however, the cs+FAT treatment showed a lower percentage of ewes returning to estrus (10.52%). This indicates that bypass fat inclusion reduces the risk of embryonic loss, as energy imbalances can affect oocyte quality and lead to embryo loss (Meza-Herrera *et al.*, 2011).

Pregnancy rate

No significant differences were observed in pregnancy rate; however, ewes in the CS+FAT treatment showed the highest pregnancy rate (84.21%). Adequate energy availability during the breeding period favors the maintenance of early pregnancy (Jiménez-Pérez *et al.*, 2012). Controlled suckling facilitates ovarian activity recovery by reducing the negative effect of estradiol on pulsatile GnRH secretion. The combination of controlled suckling and bypass fat supplementation resulted in higher pregnancy rates (Vargas and Jaramillo, 2013).

Lambing rate

The average lambing rate was 68.42%, with no differences among treatments ($p=0.33$). Ewes subjected to controlled suckling with bypass fat supplementation numerically showed the highest lambing rate (84.21%). These results may be explained by improved progesterone secretion from the corpus luteum due to fat supplementation, which enhances steroid synthesis by increasing cholesterol availability, a progesterone precursor essential for pregnancy maintenance (Rahbar *et al.*, 2014). Polyunsaturated fatty acids, particularly omega-3 and omega-6, regulate uterine prostaglandin production

and improve maternal-embryonic communication, reducing embryonic/fetal losses (Hidalgo *et al.*, 2020).

Embryonic/fetal losses

Significant differences were observed in embryonic/fetal losses ($p=0.0005$). The CS+FAT treatment showed no losses, indicating that appropriate nutritional and reproductive management ensures fetal survival. Lipids enhance *corpus luteum* function (Hughes *et al.*, 2019). Additionally, bypass fat contains polyunsaturated fatty acids (n^{-6} and n^{-3}), which act as immunomodulatory and anti-inflammatory agents by modifying endometrial cell membrane composition, reducing $PGF_2\alpha$ synthesis, and increasing PGE release (Cheng *et al.*, 2004). Lipid supplementation also alters the expression of genes associated with implantation (IGF1, VEGFA, SPP1, and LIF), facilitating angiogenesis and blastocyst adhesion, thereby reducing embryonic loss (Contreras-Solís *et al.*, 2025).

Prolificacy

Prolificacy differed among treatments ($p=0.04$), with higher values in cs+FAT and CS+FAT treatments (1.81 and 1.84, respectively). These results suggest that suckling management improves physiological response (Akbarinejad and Cushman, 2024) and that bypass fat reduces the negative effects of lactation on reproduction (Toalombo Vargas *et al.*, 2022). Controlled suckling partially improves prolificacy by restoring the hypothalamic-pituitary-ovarian axis (Calik-Ksepka *et al.*, 2022). The combined use of nutritional strategies and suckling management increased prolificacy, indicating its usefulness for improving reproductive efficiency.

Fecundity

Differences were found for fecundity ($p=0.03$), with higher fecundity indices observed in the CS+FAT treatment. Controlled suckling reduces suckling stimulus frequency, allowing ovarian activity recovery and restoration of pulsatile GnRH/LH secretion. Bypass fat supplementation provides energy and cholesterol, a precursor for progesterone and estradiol synthesis. These results contrast with those reported by Muñoz-García *et al.* (2015) possibly due to the inclusion of bypass fat, which may have increased steroid hormone secretion.

CONCLUSIONS

Including bypass fat in the diet and controlled suckling in synchronized hair sheep during the postpartum period reduces embryonic and fetal losses and improves prolificacy and fertility. Including bypass fat and controlled suckling in the diet of synchronized hair sheep during the postpartum period reduces embryonic and fetal losses and improves prolificacy and fertility.

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