



Effect of Treatment with Equine or Human Chorionic Gonadotropin on Blood Count Values in Early Gestation in Nulliparous Sheep in Northern Mexico

Jesús Armijo-Nájera¹, Ariadna Vanessa Alvarado-Espino²,
Francisco Gerardo Véliz-Deras³, Irene Concepción Chavarría-Neri³,
Gerardo Arellano-Rodríguez³, Jessica Maria Flores-Salas³, Oscar Ángel-García³,
Cayetano Navarrete-Molina³, Francisco Gerardo Véliz-Romero¹, Alan Sebastian Alvarado-Espino³

10.18805/IJAR.BF-2128

ABSTRACT

Background: Hormonal treatments can influence hematological profiles through direct and indirect mechanisms in sheep's. The aim was to evaluate the effect of administering equine or human chorionic gonadotropin (eCG, hCG, respectively) at 7 or 14 days post-mating on blood count values in early pregnancy of nulliparous ewes.

Methods: A total of 63 ewes were used, which were randomly assigned to five experimental groups (EG): EG-eCG7 (300 IU of eCG, 7 days post-mating (DPM)), EG-hCG7 (300 IU of hCG 7 DPM), EG-eCG14 (300 IU of eCG 14 DPM), EG-hCG14 (300 IU of hCG 14 DPM) and; EG-Control (without hormonal treatment). Hematologic variables were determined on days 7, 14 and 28 DPM and included white blood cell count (WBCC), red blood cell count (RBCC), hematocrits (Ht), hemoglobin concentration (HbC), mean corpuscular hemoglobin (MCHb), mean corpuscular hemoglobin concentration (MCHbC) and medium corpuscular volume (MCV). An ANOVA and Pearson correlation were performed on the response variables.

Result: The results showed differences in WBCC on day 7 between the EGs and between days for the EG-Control. The RBCC variable only showed differences between the days of the EG-eCG14. The Ht variable reported differences between the days of the EG-eCG14. Regarding HbC, differences were determined between the EGs for days 14 and 28, as well as between the days of the EG-hCG7. Additionally, positive and negative correlations were evidenced between the variables considered. Based on the above, it is concluded that in the first month of gestation, the variables WBCC, RBCC, Ht, HbC and MCV increase in pregnant ewes. The aforementioned contributes to determining ewes' reproductive performance and improving their productive and reproductive parameters.

Key words: Erythrocytes, Hematocrits, Hemoglobin concentration, Leukocytes, Pregnancy.

INTRODUCTION

One of the main factors affecting the productivity and profitability of sheep herds is reproductive efficiency (Magaña-Monforte *et al.*, 2024). In this context, hormonal synchronization protocols are commonly used to improve reproductive efficiency (Ashour *et al.*, 2018; Murphy, 2012; Sánchez-Ramos *et al.*, 2022). These protocols include the application of equine chorionic gonadotropin (eCG) or human chorionic gonadotropin (hCG) to stimulate follicular development and ovulation (Ashour *et al.*, 2018; Husein and Haddad, 2006; Murphy, 2012). However, hormonal treatments can influence hematological profiles through direct and indirect mechanisms (Bamerny *et al.*, 2022; El-Sayed *et al.*, 2025). This is especially important, as hemograms provide an overview of the physiological and nutritional status of sheep across reproductive stages and facilitate the diagnosis of conditions (Bamerny *et al.*, 2022; Bhat *et al.*, 2017; Mauffré *et al.*, 2016; Porcu *et al.*, 2020; Rabea *et al.*, 2024). In this sense, hematological parameters such as white blood cell count (WBCC) "leukocytes", red blood cell count (RBCC) "erythrocytes", hematocrits (Ht), hemoglobin concentration (HbC), mean corpuscular hemoglobin (MCHb), mean corpuscular hemoglobin concentration (MCHbC) and medium corpuscular volume (MCV) undergo dynamic

¹Graduate Program-Agricultural and Livestock Sciences, Antonio Narro Agrarian Autonomous University, Laguna Unit, Torreon Coahuila 27054, Mexico.

²Faculty of Veterinary Medicine and Animal Science Campus 2, Autonomous University of Chiapas, Tuxtla Gutiérrez, Chiapas 29050, Mexico.

³Regional Division of Animal Science, Antonio Narro Agrarian Autonomous University, Laguna Unit, Torreon, Coahuila 27054, Mexico.

Corresponding Author: Francisco Gerardo Véliz-Deras; Alan Sebastian Alvarado-Espino, Regional Division of Animal Science, Antonio Narro Agrarian Autonomous University, Laguna Unit, Torreon, Coahuila 27054, Mexico.

Email: velizderas@gmail.com; alanalvaes@gmail.com

ORCID: <https://orcid.org/0000-0002-5105-1508>, <https://orcid.org/0000-0003-4590-1673>

How to cite this article: Armijo-Nájera, J., Alvarado-Espino, A.V., Véliz-Deras, F.G., Chavarría-Neri, I.C., Arellano-Rodríguez, G., Flores-Salas, J.M., Ángel-García, O., Navarrete-Molina, C., Véliz-Romero, F.G., Alvarado-Espino, A.S. (2026). Effect of Treatment with Equine or Human Chorionic Gonadotropin on Blood Count Values in Early Gestation in Nulliparous Sheep in Northern Mexico. *Indian Journal of Animal Research*. **60**(10): 1742-1751. doi: 10.18805/IJAR.BF-2128.

Submitted: 01-04-2026 **Accepted:** 29-04-2026 **Online:** 28-05-2026

alterations throughout pregnancy (Rabea *et al.*, 2024). These fluctuations are usually attributed to hemodilution, fetal metabolic demands and changes in plasma volume (Bamerny *et al.*, 2022; Rabea *et al.*, 2024).

Regarding the use of these hormones in hormonal treatments, eCG has a long biological half-life due to glycosylation (Murphy, 2012). And that its application increases twin birth rates, by promoting multiple ovulations through its dual activity, similar to follicle-stimulating hormone (FSH) and luteinizing hormone (LH) (Martínez-Ros and Gonzalez-Bulnes, 2019; Porcu *et al.*, 2020). Although eCG is used for reproductive purposes, its interaction with homeostatic mechanisms justifies the monitoring of the number of leukocytes (Bizjak *et al.*, 2018; Gallagher, 2013). This is important, as fluctuations in MCV, MCHb and MCHbC indicate physiological changes during hormonal protocols (Porcu *et al.*, 2020). In this regard, eCG synchronization doses, ranging from 350 IU to 500 IU, have been reported to induce estrus without altering systemic health (Husein and Haddad, 2006; Sánchez-Ramos *et al.*, 2022). In other research, including studies on glycogenic and eCG formulations, results showed that while high doses of other substances affect HbC and MCV, hormonal treatments typically keep rates within physiological limits (Husein and Haddad, 2006; Porcu *et al.*, 2020; Sánchez-Ramos *et al.*, 2022). This suggests that the use of hormonal reproductive protocols with eCG are physiologically compatible with the health of sheep (Dimauro *et al.*, 2008; Martínez-Ros and González-Bulnes, 2019; Porcu *et al.*, 2020; Wildeus, 2000).

Considering the use of hCG, in the hormonal protocols of small ruminants, it has been reported that it works as an analogue of LH (Adeyeye and Ate, 2016; Aiche *et al.*, 2020; Khan *et al.*, 2009) and that its main application consists of the synchronization of estrus and the induction of ovulation in sheep and goats (Quintero *et al.*, 2015). In this respect, the application of hCG stimulates the formation of accessory corpus luteus, which improves the endogenous secretion of progesterone (P4) (Adeyeye and Ate, 2016; Khan *et al.*, 2009; Lashari and Tasawar, 2010). Additionally, it has been reported that hCG administration, on day 12 post-mating, aims to increase P4 concentrations to prevent luteolysis (Quintero *et al.*, 2015). This facilitates embryo growth and favors placentation (Cam and Kuran, 2004), correlating with higher pregnancy and fertility rates in various sheep breeds (Quintero *et al.*, 2015). In addition, research on the impact of hCG on the hemogram provides data for the clinical follow-up of sheep under intensive reproductive management (El-Sherif and Assad, 2001; El-Sayed *et al.*, 2025).

Therefore, the correlation between the administration of eCG or hCG and immediate hematological changes in sheep requires additional research to improve animal health monitoring standards (Mattos *et al.*, 2011; Murphy, 2012). These assessments can clarify how these hormones influence systemic variables beyond the hypothalamic-adenopituitary-ovarian axis (Sánchez-Ramos *et al.*, 2022;

Wei *et al.*, 2016). In small ruminants (*i.e.*, sheep and goats), metabolic adjustments associated with hormonal manipulation and physiological stress can lead to variations in leukocyte and neutrophil counts (Cismaru *et al.*, 2024; Darwish and El-Ebissy, 2019). Therefore, integrating hematological monitoring into routine reproductive management improves the well-being and productivity of sheep herds (Porcu *et al.*, 2020; Wei *et al.*, 2016). Understanding the relationships between hormone application and hematological monitoring is necessary to refine protocols used in global sheep production (Găvan *et al.*, 2010; Greguła-Kania *et al.*, 2020). Therefore, the objective of this study was to evaluate the effect of hCG or eCG administration at 7 or 14 days post-mating on blood count values in early gestation in nulliparous ewes. In order to contribute to improving the reproductive success of sheep, which will improve the income of sheep farming families, while promoting a sustainable vision aligned with the fulfillment of the sustainable development goals of the 2030 Agenda (Autukaitė *et al.*, 2021; Navarrete-Molina *et al.*, 2024; Pampori *et al.*, 2025).

MATERIALS AND METHODS

General

All experimental procedures and animal management used in this study were performed in accordance with international and national standards of ethics, care and animal welfare for research (FASS, 2010; NAM, 2002). The period during which the experiment was conducted included the days between September 15 and December 4, 2025. Additionally, this investigation had institutional approval, with reference number UAAAN-UL-18-3060.

Location and environmental conditions of the study area

The sheep production unit, where the study was carried out, is an intensive farm in the Comarca Lagunera (25°37' N, 103°16' W, 1113 meters above sea level) in north-central Mexico. The region is classified as a semi-arid ecosystem, registering an average annual temperature of 23.8°C, with maximums of 41.0°C in summer and minimums of -1.0°C in winter and an average annual rainfall of 230 mm. Additionally, it registers relative humidity ranging from 12% to 61% and photoperiods ranging from 13 h 41 min during the spring solstice (June) to 10 h 19 min during the winter solstice (December) (CONAGUA, 2025; INEGI, 2010).

Animals and experimental design

In this study, 63 Dorper × Blackbelly and Dorper × Katahdin crossbred nulliparous ewes, 7 to 9 months old, with a live weight of 32.2±4.4 kg, were used. At the beginning of the experiment and to synchronize the onset of estrus and ovulation, all ewes were administered two doses of prostaglandin F_{2α} (75 µg of D-cloprostenol sodium; Estrumate®, Darmstadt, Germany) with an interval of 12 days between applications. After the manifestation of estrus, the ewes were exposed to sexually active Dorper males for

seven days to ensure mating. For this, the males were marked with vegetable paint in the sternal region to easily identify the mounted females. The day on which the painted sheep of the lumbar region was observed for the first time was considered the day of mating.

Based on the above, the ewes were randomly assigned to five experimental groups (EG): EG-eCG7 (n = 14), the ewes in this group received 300 IU of eCG (Folligon®, Darmstadt, Germany) intramuscularly (IM) 7 days post-mating; EG-hCG7 (n = 13) females included in this group received 300 IU via hCG IM (Chorulon®, Darmstadt, Germany) 7 days post-mating; EG-eCG14 (n = 13) received 300 IU of eCG via IM 14 days post-mating; EG-hCG14 (n = 13) received 300 IU via IM of hCG 14 days post-mating and; EG-Control (n = 10) who did not receive post-mating hormonal treatment. In addition, on days 7 and 14 post-mating, all ewes that did not receive hormonal treatment received 1.5 mL of sterile injectable solution (Isosol MDKR, Mediker, Gomez Palacio, Durango, Mexico). The sheep were fed a diet based on food residues from a highly industrialized dairy cattle production system twice a day (1000 and 1800 h). Likewise, all females had ad libitum access to drinking water, mineral salts and shade. To guarantee the physiological status of the females (*i.e.* pregnant), a diagnosis of pregnancy was made at 32 days post-mating by transrectal ultrasonography, which was confirmed by visualization of intrauterine fluid (embryonic vesicle) and the presence of echogenic structures within anechoic cavities compatible with viable embryos, for which an ultrasound (Chison ECO5 Doppler®, Wuxi, Jiangsu, China) and complemented with a rectal transducer (7.5 MHz, Color® Doppler, Wuxi, Jiangsu, China) was used, confirming that 100% of the experimental units that were included in the EGs were pregnant.

Blood sampling and quantification of the values of the blood count to be evaluated

On days 7, 14 and 28 post-mating, blood samples were taken from all ewes (n = 63) to determine blood count values. To this end, at 08:00 h on an empty stomach, samples of 5 mL of blood were obtained by jugular venipuncture with BD Vacutainer® tubes of 9 mL (Franklin Lakes, New Jersey, USA). The tubes contained 7.2 mg of

dehydrated K₂EDTA in their inner walls. This compound acts as an anticoagulant by binding calcium ions and interrupting the blood-clotting process. To continue the analysis of the samples, the hemogram variables considered in the study were quantified. For this, an automated hematological analyzer Hemalyzer HVET 2000 brand HLab (Denver, Colorado, USA), was used. All procedures were performed by a trained technician. The blood response variables considered in the study included: white blood cell count "leukocytes" (WBCC, $\times 10^9$ cells L⁻¹); red blood cell count "erythrocytes" (RBCC, $\times 10^{12}$ cells L⁻¹); hematocrits (Ht, %); hemoglobin concentration (HbC, g dL⁻¹); mean corpuscular hemoglobin (MCHb, pg); mean corpuscular hemoglobin concentration (MCHbC, g dL⁻¹) and medium corpuscular volume (MCV, fL). All analyses were performed in the Bromatology Laboratory of the Antonio Narro Agrarian Autonomous University, Laguna Unit.

Statistical analysis

The Kolmogorov-Smirnov test at a confidence level of 95% was used to verify the normality of the data. Considering that the response variables RBCC, Ht, MCHbC and MCV did not show a normal distribution, a Box-Cox transformation was performed. Equality of variances was assessed using Levene's test with a 95% confidence level. Subsequently, an analysis of variance was performed, using Fisher's LDS method to compare means, considering a 95% confidence level. Additionally, the mean and standard error were calculated for each response variable. Finally, Pearson's correlation coefficient was computed between the independent variables (*i.e.*, experimental group and day) and the dependent variables (*i.e.*, blood count variables) at the 95% confidence level. All statistical analyses were performed with the statistical software Minitab® version 20.4 (MINITAB, 2021).

RESULTS AND DISCUSSION

Table 1 shows the means $\pm$ standard error for the WBCC response variable ($\times 10^9$ cells L⁻¹) of the blood count. It was observed that only on day 7 were differences ($P < 0.05$) evidenced between the EGs. Among the EGs, only the EG-Control showed differences between days of the experiment

Table 1: Mean $\pm$ standard error of the white blood cell count "leukocytes" ($\times 10^9$ cells L⁻¹) in nulliparous sheep, synchronized with two doses of prostaglandin F₂ α and treated with 300 IU of equine or human chorionic gonadotropin administered on day 7 or 14 post-mating and a control group in northern Mexico (25°N).

Day	Experimental group				
	eCG7 ¹	hCG7 ²	eCG14 ³	hCG14 ⁴	Control
7	88.86 $\pm$ 2.25 ^{a,b A}	92.18 $\pm$ 2.33 ^{a A}	86.98 $\pm$ 2.00 ^{a,b A}	89.84 $\pm$ 2.67 ^{a,b A}	84.61 $\pm$ 2.27 ^{b B}
14	89.48 $\pm$ 2.68 ^{a A}	90.81 $\pm$ 2.25 ^{a A}	90.08 $\pm$ 2.08 ^{a A}	90.53 $\pm$ 2.56 ^{a A}	92.09 $\pm$ 1.99 ^{a A}
28	89.22 $\pm$ 1.65 ^{a A}	89.09 $\pm$ 2.36 ^{a A}	91.50 $\pm$ 1.71 ^{a A}	89.95 $\pm$ 2.13 ^{a A}	85.61 $\pm$ 2.39 ^{a B}

¹eCG7: Equine chorionic gonadotropin (eCG) administered on day 7 post-mating; ²hCG7: Human chorionic gonadotropin (hCG) administered on day 7 post-mating; ³eCG14: eCG administered on day 14 post-mating; ⁴hCG14: hCG administered on day 14 post-mating; ^{a,b}Values with different lowercase letters in the same row represent differences ($P \leq 0.05$) between experimental groups for the same day.

^{A,B}Values with different capital letters in the column represent differences ($P \leq 0.05$) between days for the same experimental group.

($p < 0.05$). The rest of the GA showed no differences ($P > 0.05$) between them, nor between the remaining days considered in this study. In the same sense, the RBCC response variable ($\times 10^{12}$ cells L^{-1}) showed differences ($P < 0.05$) only among the ewes included in the EG-eCG14. For the rest of the GA and days, no differences were observed ($P > 0.05$) in the RBCC response variable (Table 2).

In this context, the WBCC response variable (Table 1) increased throughout the study period, which could be related to an immune response to physiological stress (Aiche *et al.*, 2020). The absence of differences ($P > 0.05$) for this response variable was similar to that reported for other oviparous species, such as cows (Ate *et al.*, 2009) and sows (Žvorc *et al.*, 2006). On the contrary, the results are inconsistent with those reported by Greguła-Kania *et al.* (2020), who found significant differences in this variable. In the same sense, the differences between WBCC values could be related to a characteristic alteration of the gestation stage, in which maternal and fetal cells are reciprocally recognized by their immune systems, resulting in fetal maintenance capacity (Greguła-Kania *et al.*, 2020). Additionally, it has been reported that there is a direct relationship between the leukocyte profile, stress and glucocorticoid levels (Preisler *et al.*, 2000). In the same sense, the results presented in Table 1 were higher than the reference values reported (Stayt, 2022). Similarly, they were high compared with those observed in sheep during

the last stage of gestation in some sheep breeds in Brazil, Colombia, Nigeria and Turkey (Adeyeye and Ate, 2016; Bezerra *et al.*, 2017; Cihan *et al.*, 2016; Plaza-Cuadrado *et al.*, 2019).

Considering the response variable Ht (%), Table 3 presents the mean $\pm$ standard error of the hematocrits. In this sense, no differences ($P > 0.05$) were observed between the EG with respect to the number of days included. Only the EG-eCG14 showed differences ($P < 0.05$) between the values determined for the days of analysis. When analyzing the results of the HbC response variable (g dL^{-1}) (Table 4), it is evident that the EGs reported differences ($P < 0.05$) between them for days 14 and 28, as well as the EG-hCG7, for which differences were determined ($P < 0.05$) between the days considered in the study (Table 4).

In the same sense, Ht levels showed a trend similar to the response variables discussed in the previous paragraphs (Table 3). This is not consistent with what was reported in 2021 by Abdelghany *et al.* (2021), who compared pregnant and non-pregnant ewes, finding that pregnant ewes showed significant reductions for the RBCC, Ht and MVC variables. Similarly, Aiche *et al.* (2020) found reductions in the percentage of Ht as gestation progressed in sheep. Likewise, the results obtained are lower than those reported by El-Malky *et al.* (2019) and Cihan *et al.* (2016) and also lower than the reference values reported by Stayt in 2022, who reported an optimal range of 27 to

Table 2: Mean $\pm$ standard error of the red blood cell count “erythrocytes” ($\times 10^{12}$ cells L^{-1}) in nulliparous sheep, synchronized with two doses of prostaglandin $F_{2\alpha}$ and treated with 300 IU of equine or human chorionic gonadotropin administered on day 7 or 14 post-mating and a control group in northern Mexico (25°N).

Day	Experimental group				
	eCG7 ¹	hCG7 ²	eCG14 ³	hCG14 ⁴	Control
7	2.40 $\pm$ 0.12 ^a ^A	2.38 $\pm$ 0.11 ^a ^A	2.34 $\pm$ 0.14 ^a ^B	2.40 $\pm$ 0.14 ^a ^A	2.40 $\pm$ 0.20 ^a ^A
14	2.63 $\pm$ 0.17 ^a ^A	2.41 $\pm$ 0.16 ^a ^A	2.54 $\pm$ 0.19 ^a ^{A,B}	2.44 $\pm$ 0.15 ^a ^A	2.35 $\pm$ 0.21 ^a ^A
28	2.67 $\pm$ 0.16 ^a ^A	2.66 $\pm$ 0.15 ^a ^A	2.89 $\pm$ 0.24 ^a ^A	2.48 $\pm$ 0.15 ^a ^A	2.65 $\pm$ 0.21 ^a ^A

¹eCG7: Equine chorionic gonadotropin (eCG) administered on day 7 post-mating; ²hCG7: Human chorionic gonadotropin (hCG) administered on day 7 post-mating; ³eCG14: eCG administered on day 14 post-mating; ⁴hCG14: hCG administered on day 14 post-mating; ^aNo differences ($P > 0.05$) were observed between the experimental groups for the same day; ^{A,B}Values with different capital letters in the same column represent differences ($P \leq 0.05$) between days for the same experimental group.

Table 3: Mean $\pm$ standard error of the hematocrits (%) in nulliparous sheep, synchronized with two doses of prostaglandin $F_{2\alpha}$ and treated with 300 IU of equine or human chorionic gonadotropin administered on day 7 or 14 post-mating and a control group in northern Mexico (25°N).

Day	Experimental group				
	eCG7 ¹	hCG7 ²	eCG14 ³	hCG14 ⁴	Control
7	9.77 $\pm$ 0.50 ^a ^A	9.35 $\pm$ 0.43 ^a ^A	9.32 $\pm$ 0.61 ^a ^A	9.42 $\pm$ 0.57 ^a ^A	10.24 $\pm$ 0.87 ^a ^A
14	10.12 $\pm$ 0.62 ^a ^A	9.52 $\pm$ 0.64 ^a ^A	9.86 $\pm$ 0.50 ^a ^{A,B}	9.72 $\pm$ 0.60 ^a ^A	9.40 $\pm$ 0.78 ^a ^A
28	10.60 $\pm$ 0.64 ^a ^A	10.52 $\pm$ 0.58 ^a ^A	11.49 $\pm$ 1.03 ^a ^B	9.82 $\pm$ 0.58 ^a ^A	10.55 $\pm$ 0.88 ^a ^A

¹eCG7: Equine chorionic gonadotropin (eCG) administered on day 7 post-mating; ²hCG7: Human chorionic gonadotropin (hCG) administered on day 7 post-mating; ³eCG14: eCG administered on day 14 post-mating; ⁴hCG14: hCG administered on day 14 post-mating; ^aNo differences ($P > 0.05$) were observed between the experimental groups for the same day; ^{A,B}Values with different capital letters in the same column represent differences ($P \leq 0.05$) between days for the same experimental group.

45% Ht in pregnant ewes. However, increases in Ht and Hb concentrations have also been reported in pregnant ewes (Sharma *et al.*, 2015). In addition, Brito *et al.* (2006) did not observe differences in hematological components between pregnant and non-pregnant ewes, although they reported that Ht decreased as pregnancy progressed.

Additionally, with respect to Ht, Greguła-Kania *et al.*, (2020) observed a dilution of erythrocyte concentration (lower number of erythrocytes, hematocrit and hemoglobin) in pregnant ewes, which is consistent with what was reported in this study (Table 2-4). This could be a physiological response to the decrease in blood viscosity, which improves blood supply to small blood vessels and to the newly formed vascular bed in the uterus and maternal placenta (Greguła-Kania *et al.*, 2020; Habibu *et al.*, 2017). In the same sense, the RBCC values found in this study were lower than those reported by Aiche *et al.*, (2020), as well as those reported by Bezerra *et al.* (2017), El-Malky *et al.* (2019) and Plaza-Cuadrado *et al.* (2019). Additionally, a study by Soliman (2014) in Ossimi sheep showed that physiological state can lead to significant ($p < 0.05$) modifications in hematological parameters, such as RBCC and Hb. However, Brito *et al.*, (2006) found no variation in hematological parameters between pregnant and lactating ewes when well fed. Additionally, the HbC values found are higher than those reported by El-Malky *et al.* (2019) in pregnant sheep and Plaza-Cuadrado *et al.* (2019), but similar to those reported

by Adeyeye and Ate (2016) and Bezerra *et al.* (2017), who recorded higher HbC values in ewes at the end of gestation.

Table 5 and 6 present the means $\pm$ standard errors for the response variables MCHb (pg) and MCHbC (g dL⁻¹), respectively. Considering this, it was determined that there were no differences ($P > 0.05$) in all interactions between the EGs and the days considered in the study.

Regarding RBCC and HbC values, it has been reported that they play an important role in maintaining pregnancy and the survival of the fetus by regulating fetal oxygen supply (Greguła-Kania *et al.*, 2020). However, the variations evidenced for the RBCC (Table 2) and HbC (Table 5) response variables are likely due to hemodilution resulting from increased plasma volume expansion (Rabea *et al.*, 2024). This plays an important role, particularly in pregnant ewes of twin fetuses, by reducing blood viscosity and thus improving blood flow in the vessels located in the uterus and udder (Karaşahin *et al.*, 2023). In the same sense, the values identified in this study are similar to those reported by Antunović *et al.* (2011) in Croatia. The absence of significant differences in the response variables RBCC, Ht and MVC was similar to that reported by Ate *et al.* (2009) in cows, but it contradicts the findings of Žvorc *et al.* (2006) in pigs, probably due to species differences. Additionally, it has been reported that gestational stress may be responsible for this, given that reproductive status is associated with

Table 4: Mean $\pm$ standard error of the hemoglobin concentration (g dL⁻¹) in nulliparous sheep, synchronized with two doses of prostaglandin F₂ α and treated with 300 IU of equine or human chorionic gonadotropin administered on day 7 or 14 post-mating and control group in northern Mexico (25°N).

Day	Experimental group				
	eCG7 ¹	hCG7 ²	eCG14 ³	hCG14 ⁴	Control
7	14.01 $\pm$ 0.24 ^{a A}	14.05 $\pm$ 0.29 ^{a A,B}	13.37 $\pm$ 0.22 ^{a A}	13.87 $\pm$ 0.32 ^{a A}	13.33 $\pm$ 0.45 ^{a A}
14	13.86 $\pm$ 0.28 ^{a A}	13.55 $\pm$ 0.26 ^{a,b B}	13.54 $\pm$ 0.22 ^{a,b A}	13.48 $\pm$ 0.29 ^{a,b A}	13.03 $\pm$ 0.32 ^{b A}
28	14.19 $\pm$ 0.25 ^{a A}	14.42 $\pm$ 0.26 ^{a A}	13.80 $\pm$ 0.35 ^{a,b A}	13.78 $\pm$ 0.24 ^{a,b A}	13.36 $\pm$ 0.27 ^{b A}

¹eCG7: Equine chorionic gonadotropin (eCG) administered on day 7 post-mating; ²hCG7: Human chorionic gonadotropin (hCG) administered on day 7 post-mating; ³eCG14: eCG administered on day 14 post-mating; ⁴hCG14: hCG administered on day 14 post-mating; ^{a,b}Values with different lowercase letters in the same row represent differences ($P \leq 0.05$) between experimental groups for the same day. ^{A,B}Values with different capital letters in the column represent differences ($P \leq 0.05$) between days for the same experimental group.

Table 5: Mean $\pm$ standard error of the mean corpuscular hemoglobin (pg) in nulliparous sheep, synchronized with two doses of prostaglandin F₂ α and treated with 300 IU of equine or human chorionic gonadotropin administered on day 7 or 14 post-mating and a control group in northern Mexico (25°N).

Day	Experimental group				
	eCG7 ¹	hCG7 ²	eCG14 ³	hCG14 ⁴	Control
7	59.28 $\pm$ 2.86 ^{a A}	60.21 $\pm$ 2.56 ^{a A}	59.33 $\pm$ 3.08 ^{a A}	59.43 $\pm$ 3.00 ^{a A}	55.79 $\pm$ 4.90 ^{a A}
14	54.63 $\pm$ 3.22 ^{a A}	58.91 $\pm$ 3.85 ^{a A}	57.29 $\pm$ 2.36 ^{a A}	57.33 $\pm$ 3.25 ^{a A}	58.91 $\pm$ 4.76 ^{a A}
28	55.54 $\pm$ 3.55 ^{a A}	56.41 $\pm$ 3.54 ^{a A}	56.15 $\pm$ 2.42 ^{a A}	57.59 $\pm$ 3.26 ^{a A}	55.42 $\pm$ 4.25 ^{a A}

¹eCG7: Equine chorionic gonadotropin (eCG) administered on day 7 post-mating; ²hCG7: Human chorionic gonadotropin (hCG) administered on day 7 post-mating; ³eCG14: eCG administered on day 14 post-mating; ⁴hCG14: hCG administered on day 14 post-mating; ^aNo differences ($P > 0.05$) were observed between the experimental groups for the same day; ^ANo differences ($P > 0.05$) were observed between the days for the same experimental group.

hormonal changes, particularly steroid hormones, which are known to be immunosuppressive (Adeyeye and Ate, 2016). It has also been suggested that a high rate of red blood cell destruction in mammary cells is responsible for low Ht, along with the mobilization of water to the mammary glands (El-Sherif and Assad, 2001).

Continuing with the discussion of the results of the response variables MCHb and MCHbC showed no differences ($P>0.05$), however, decreases were determined during the period analyzed (Tables 5 and 6). This has been associated with maintaining blood oxygen content (El-Sherif and Assad, 2001; Miglio *et al.*, 2015). From this perspective, the MCHbC values recorded in this study were much higher than those reported by El-Malky *et al.* (2019), as well as Plaza-Cuadrado *et al.* (2019) and the reference values reported by Stayt in 2022. On the other hand, the results obtained were consistent with those reported by Bezerra *et al.* (2017) and Cihan *et al.* (2016). This could be explained by the fact that the body compensates for the decrease in red blood cells in sheep by increasing the concentration of hemoglobin in erythrocytes, whereas MCHbC increases with advancing pregnancy and decreases after calving (Aiche *et al.*, 2020; Bezerra *et al.*, 2017).

The hemogram response variable with the most differences ($P<0.05$) was MCV (fL), where the EGs differed from day 7, as well as the EGs: ECG7, eCG14 and Control,

which showed differences between the days considered in the analysis (Table 7).

The value of the MCV (Table 7) obtained in this study was consistent with what was reported by Bezerra *et al.* (2017); El-Malky *et al.* (2019) and Plaza-Cuadrado *et al.* (2019), as well as within the reference range (*i.e.*, 28-40) reported by Stayt in 2022. The determination of these variables (MCHb, MCHbC and MCV) is very important, as they are essential markers of oxygen transport and necessary for cell survival (Aiche *et al.*, 2020). Additionally, it should be noted that an increase in oxygen demand stimulates an adaptive response in which higher hemoglobin concentrations translate into greater oxygen transport (Gravena *et al.*, 2010).

Pearson's correlation analysis was used to evaluate the relationships between the dependent and independent variables considered in the study. In this context, Table 8 presents Pearson's correlation coefficients and the corresponding significance levels for the relationships among the variables considered. In this regard, low positive correlations of strong to very strong were determined between the variables day and RBCC, HbC and MCHb, day and MCV, WBCC and HbC and HbC and MCV. As well as a very strong moderate positive correlation between the RBCC variable and the MCHbC and MCV variables. Additionally, a high, very strong positive correlation was observed between

Table 6: Mean±standard error of the mean corpuscular hemoglobin concentration (g dL⁻¹) in nulliparous sheep, synchronized with two doses of prostaglandin F₂α and treated with 300 IU of equine or human chorionic gonadotropin administered on day 7 or 14 post-mating and control group in northern Mexico (25°N).

Day	Experimental group				
	eCG7 ¹	hCG7 ²	eCG14 ³	hCG14 ⁴	Control
7	152.60±6.82 ^{a A}	153.41±6.48 ^{a A}	157.55±6.67 ^{a A}	158.98±6.24 ^{a A}	141.90±8.86 ^{a A}
14	142.79±7.54 ^{a A}	155.61±8.13 ^{a A}	146.40±5.83 ^{a A}	153.28±6.89 ^{a A}	158.04±10.92 ^{a A}
28	146.17±8.19 ^{a A}	148.78±8.01 ^{a A}	146.18±6.51 ^{a A}	151.31±6.65 ^{a A}	150.05±8.74 ^{a A}

¹eCG7: Equine chorionic gonadotropin (eCG) administered on day 7 post-mating; ²hCG7: Human chorionic gonadotropin (hCG) administered on day 7 post-mating; ³eCG14: eCG administered on day 14 post-mating; ⁴hCG14: hCG administered on day 14 post-mating; ^aNo differences ($P>0.05$) were observed between the experimental groups for the same day; ^ANo differences ($P>0.05$) were observed between the days for the same experimental group.

Table 7: Mean±standard error of the medium corpuscular volume (fL) in nulliparous sheep, synchronized with two doses of prostaglandin F₂α and treated with 300 IU of equine or human chorionic gonadotropin administered on day 7 or 14 post-mating and a control group in northern Mexico (25°N).

Day	Experimental group				
	eCG7 ¹	hCG7 ²	eCG14 ³	hCG14 ⁴	Control
7	39.41±0.11 ^{a B}	39.45±0.12 ^{a A}	39.35±0.11 ^{a,b B}	39.39±0.10 ^{a A}	38.99±0.15 ^{b B}
14	39.50±0.13 ^{a A,B}	39.51±0.24 ^{a A}	39.45±0.15 ^{a A,B}	39.55±0.12 ^{a A}	39.33±0.11 ^{a B}
28	39.77±0.10 ^{a A}	39.75±0.09 ^{a A}	39.80±0.20 ^{a A}	39.46±0.11 ^{a A}	39.87±0.21 ^{a A}

¹eCG7: Equine chorionic gonadotropin (eCG) administered on day 7 post-mating; ²hCG7: Human chorionic gonadotropin (hCG) administered on day 7 post-mating; ³eCG14: eCG administered on day 14 post-mating; ⁴hCG14: hCG administered on day 14 post-mating; ^aNo differences ($P>0.05$) were observed between the experimental groups for the same day; ^{A,B}Values with different capital letters in the column represent differences ($P\leq 0.05$) between days for the same experimental group.

Table 8: Pearson correlation matrix between groups and response variables analyzed in nulliparous sheep, synchronized with two doses of prostaglandin F₂α and treated with 300 IU of equine or human chorionic gonadotropin administered on day 7 or 14 post-mating and control group in northern Mexico (25°N).

	EG ¹	Day	WBCC ²	RBCC ³	Ht ⁴	HbC ⁵	MCHb ⁶	MCHbC ⁷	MCV ⁸
EG	1								
Day	0.000 ns	1							
WBCC	-0.058 ns	0.011 ns	1						
RBCC	-0.073 ns	0.200 **	0.101 ns	1					
Ht	0.047 ns	-0.179 *	-0.129 ns	-0.896 ***	1				
HbC	-0.242 ***	0.102 ns	0.246 ***	0.007 ns	-0.040 ns	1			
MCHb	0.008 ns	-0.091 ns	-0.052 ns	-0.797 ***	0.787 ***	0.198 **	1		
MCHbC	-0.050 ns	0.085 ns	-0.071 ns	0.458 ***	-0.502 ***	-0.104 ns	-0.663 ***	1	
MCV	-0.125 ns	0.324 ***	0.118 ns	0.436 ***	-0.435 ***	0.368 ***	-0.113 ns	-0.127 ns	1

¹EG: Experimental group; ²WBCC: White blood cell count "leukocytes" ($\times 10^9$ cells L⁻¹); ³RBCC: Red blood cell count "erythrocytes" ($\times 10^{12}$ cells L⁻¹); ⁴Ht: Hematocrits (%); ⁵HbC: Hemoglobin concentration (g dL⁻¹); ⁶MCHb: Mean corpuscular hemoglobin (pg); ⁷MCHbC: Mean corpuscular hemoglobin concentration (g dL⁻¹); ⁸MCV: Medium corpuscular volume (fL); ns: not significant; *: P≤0.05; **: P≤0.01; ***: P≤0.001.

the variables Ht and MCHb. However, a series of negative correlations was observed, such as the one between the day and Ht variables, which was very low in magnitude and of moderate significance. Another example of negative correlation was determined between the EG and HbC variables, which was low but very strong. Very strong moderate negative correlations were determined between the Ht variable and the MCHbC and MCV variables, as well as between the MCHb and MCHbC variables. Finally, a high, very strong negative correlation was observed between the RBCC variable and the Ht and MCHb variables (Table 8).

The correlations observed among the different response variables analyzed (Table 8) support the hypothesis of a close relationship among blood components in sheep. This provides valuable information on dynamic changes in hematological parameters during the first month of sheep gestation, which are consistent with the findings of Abdelghany *et al.* (2021) and Antunović *et al.* (2013). However, they do not align with others research, such as that reported by Bezerra *et al.* (2017).

Considering the above, the results obtained indicate that the objective of this study was met by evaluating the effects of hCG or eCG administration at 7 or 14 days post-mating on blood counts in early gestation in nulliparous ewes. This is important because it has been reported that analysis of hematological parameters is a reliable method for evaluating the health status of animals, contributing to accurate diagnosis, prognosis and treatment to improve

the production and reproduction of sheep (Cetin *et al.*, 2009; Roubies *et al.*, 2006). In this sense, Tables 1 to 7 show the results for various hematological parameters measured at different EGs during the first month post-mating. It could be noted that the variations identified for all hematological response variables in sheep blood during the first month of gestation were within physiological ranges (Table 1-7) (Brooks *et al.*, 2022).

CONCLUSION

Considering that a complete hematological analysis provides reliable information on animal health, it is also an important means of evaluating the production, reproduction and adaptability of animals to different stressful conditions. It was found that the values of the hematological profile of the ewes in the first month of gestation increased for the variables WBCC, RBCC, Ht, HbC and MCV; however, most of the increases were not significant. Highlighting the physiological adjustments developed by the ewes to achieve adequate fetal development, as well as their ability to adapt to the demands of pregnancy. Based on the results obtained, it is recommended to expand the study to determine reference values applicable to the study area and to include additional biochemical parameters. Therefore, future research in this area could deepen understanding of the interrelationships involved to improve the general welfare and reproductive outcomes of sheep.

ACKNOWLEDGEMENT

The authors acknowledge the Antonio Narro Agrarian Autonomous University - Laguna Unit for all the support provided for the completion of this study.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

Informed consent was obtained from the owner of the animals involved in this study. All experimental procedures and animal management used in this study were performed in accordance with international and national standards of ethics, care and animal welfare for research. Additionally, this investigation had institutional approval, with reference number UAAAN-UL-18-3060.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

- Abdelghany, A.H., Akraeim, A. and Saad, S.E.S. (2021). Evaluation the impact of the transition period on some hemato-biochemical and hormonal parameters in Native sheep in Algabal Alakhdar governorate in Libya. *Benha Veterinary Medical Journal*. **40(2)**: 19-23. doi: 10.21608/bvmj.2021.71045.1390.
- Adeyeye, A.A. and Ate, I.U. (2016). Blood profile of ewes during third trimester of pregnancy and lactation. *Bulletin of Animal Health and Production in Africa*. **64(4)**: 475-482.
- Aiche, S., Smail, F., Chikhaoui, M. and Abdelhadi, S.A. (2020). Factors influencing the hematological parameters in ewes of the rembi breed during late pregnancy in Tiaret Region, West of Algeria. *Alexandria Journal of Veterinary Sciences*. **66(1)**: 97679. doi: 10.5455/ajvs.97679.
- Antunović, Z., Novoselec, J., Klir, Ž. and Pidara, M. (2013). Hematological parameters in the alpine goats during lactation. *Poljoprivreda*. **19(2)**: 40-43.
- Antunović, Z., Novoselec, J., Sauerwein, H., Šperanda, M., Vegara, M. and Pavić, V. (2011). Blood metabolic profile and some of hormones concentration in ewes during different physiological status. *Bulgarian Journal of Agricultural Science*. **17(5)**: 687-691.
- Ashour, G., El-Bassiony, M.F., Dessouki, S.M. and El-Wakeel, M.A. (2018). Application of different hormonal protocols for improving reproductive performance of Barki ewes. *World's Veterinary Journal*. **8(3)**: 55-64.
- Ate, I.U., Rekwt, P.I., Nok, A.J. and Tekdek, L.B. (2009). Haematological values of cows during third trimester of pregnancy and early lactation in settled cattle herds in Zaria, Northern Nigeria. *African Journal of Biomedical Research*. **12(3)**: 225-231.
- Autukaitė, J., Počkienė, I., Juozaitienė, V., Antanaitis, R., Baumgartner, W. and Žilinskas, H. (2021). The influence of thermal stress on serum biochemical profile in sheep. *Indian Journal of Animal Research*. **55(6)**: 647-651. doi: 10.18805/IJAR.B-1349.
- Bamerny, A.O., Barwary, M.S. and Alkass, J.E. (2022). Changes in some haematological and biochemical parameters in local black goats during pregnancy. *Iraqi Journal of Agricultural Sciences*. **53(2)**: 378-384.
- Bezerra, L.R., Oliveira, W.D.C., Silva, T.P.D., Torreão, J.N.C., Marques, C.A.T., Araújo, M.J. and Oliveira, R.L. (2017). Comparative hematological analysis of Morada Nova and Santa Inês ewes in all reproductive stages. *Pesquisa Veterinária Brasileira*. **37(4)**: 408-414. doi: 10.1590/S0100-736X201700400017.
- Bhat, A.R., Ishfaq, A., Ganai, A.M., Beigh, Y.A., Sheikh, G.G. and Masood, D. (2017). Effect of *Artemisia absinthium* (Titween) on nutrient intake, digestibility, nutrient balance and blood biochemical of sheep. *Indian Journal of Animal Research*. **52(7)**: 1010-1013. doi: 10.18805/ijar.B-3321.
- Bizjak, D.A., Jungen, P., Bloch, W. and Grau, M. (2018). Cryopreservation of red blood cells: Effect on rheologic properties and associated metabolic and nitric oxide related parameters. *Cryobiology*. **84**: 59-68. doi: 10.1016/j.cryobiol.2018.08.001.
- Brito, M.A., González, F.D., Ribeiro, L.A., Campos, R., Lacerda, L., Barbosa, P.R. and Bergmann, G. (2006). Blood and milk composition in dairy ewes from southern Brazil: Variations during pregnancy and lactation. *Ciência Rural*. **36(3)**: 942-948. doi: 10.1590/S0103-84782006000300033.
- Brooks, M.B., Harr, K.E., Seelig, D.M., Wardrop, K.J. and Weiss, D.J. (2022). *Schalm's Veterinary Hematology* (7th ed.). John Wiley and Sons, Inc. New Jersey, USA. pp. 1393. doi: 10.1002/9781119500537.
- Cam, M.A. and Kuran, M. (2004). Effects of a single injection of hCG or GnRH agonist on day 12 post mating on fetal growth and reproductive performance of sheep. *Animal Reproduction Science*. **80(1-2)**: 81-90. doi: 10.1016/S0378-4320(03)00158-1.
- Cetin, N., Bekyürek, T. and Cetin, E. (2009). Effects of sex, pregnancy and season on some haematological and biochemical blood values in angora rabbits. *Scandinavian Journal of Laboratory Animal Science*. **36(2)**: 155-162.
- Cihan, H., Temizel, E.M., Yilmaz, Z. and Ozarda, Y. (2016). Serum iron status and its relation with haematological indexes before and after parturition in sheep. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi*. **22(5)**: 679-683. doi: 10.9775/kvfd.2016.15103.
- Cismaru, C.A., Tomuleasa, C., Jurj, A., Chira, S., Isachekcu, E., Cismaru, G., Gherman, L.M., Gulei, D., Munteanu, R. and Neagoe, I.B. (2024). Synergistic effect of human chorionic gonadotropin and granulocyte colony stimulating factor in the mobilization of HSPCs improves overall survival after PBSCT in a preclinical murine model. Are we far enough for therapy? *Stem Cell Reviews and Reports*. **20(1)**: 206-217. doi: 10.1007/s12015-023-10648-5.

- CONAGUA-Comision Nacional del Agua-National Water Commission. *Normales Climatológicas por Estado: Coahuila de Zaragoza*. Ciudad de México: Servicio Meteorológico Nacional, Comisión Nacional del Agua. 2025. México. (in Spanish). Available online: <https://smn.conagua.gob.mx/es/climatologia/informacion-climatologica/normales-climatologicas-por-estado?estado=coah>.
- Darwish, A.A. and El-Ebissy, I.A. (2019). The diagnostic value of acute phase proteins in barki ewes with pregnancy toxemia. *Alexandria Journal of Veterinary Sciences*. **62(1)**: 27-37. doi: 10.5455/ajvs.26377.
- Dimauro, C., Bonelli, P., Nicolussi, P., Rassu, S.P., Cappio-Borlino, A. and Pulina, G. (2008). Estimating clinical chemistry reference values based on an existing data set of unselected animals. *The Veterinary Journal*. **178(2)**: 278-281. doi: 10.1016/j.tvjl.2007.08.002.
- El-Malky, O.M., Mostafa, T.H., Ibrahim, N.H., Younis, F.E., Abd El-Salaam, A.M. and Tag El-Din, H.A. (2019). Comparison between productive and reproductive performance of Barki and Ossimi ewes under Egyptian conditions. *Egyptian Journal of Sheep and Goats Sciences*. **14(1)**: 61-82.
- El-Sayed, A., Marzok, M., Alqahtani, H.A., Tahoun, A., Almubarak, A.I., Elkhidr, R.Y., Mohamed, Z.A., Abdelnaby, E.A., Babiker, H., Alharbi, H.M., Alwutayd, K.M. and Ateya, A. (2025). Genomic variants, transcriptomic profile, ultrasonographic findings and antioxidant and immunological biomarkers linked to pregnancy toxemia susceptibility in goats. *Veterinary Sciences*. **12(9)**: 891. doi: 10.3390/vetsci12090891.
- El-Sherif, M.M.A. and Assad, F. (2001). Changes in some blood constituents of Barki ewes during pregnancy and lactation under semi arid conditions. *Small Ruminant Research*. **40(3)**: 269-277.
- FASS-Federation Animal Science Society. (2010). Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching, 3rd ed.; Federation Animal Science Society: Champaign, IL, USA. pp. 177.
- Gallagher, P.G. (2013). Disorders of red cell volume regulation. *Current Opinion in Hematology*. **20(3)**: 201-207. doi: 10.1097/MOH.0b013e32835f6870.
- Gyvan, C., Retea, C. and Motorga, V. (2010). Changes in the hematological profile of Holstein primiparous in periparturient period and in early to mid lactation. *Scientific Papers Animal Science and Biotechnologies*. **43(2)**: 244-244.
- Gravena, K., Sampaio, R.C.L., Martins, C.B., Dias, D.P.M., Orozco, C.A.G., Oliveira, J.V. and Lacerda-Neto, J.C. (2010). Hematological parameters of pregnant donkeys in different periods. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*. **62(6)**: 1514-1516. (in Portuguese).
- Greguła Kania, M., Kosior Korzecka, U., Patkowski, K., Juszczyk Kubiak, E., Plewik, M. and Gruszecki, T.M. (2020). Acute phase proteins, cortisol and haematological parameters in ewes during the periparturient period. *Reproduction in Domestic Animals*. **55(3)**: 393-400. doi: 10.1111/rda.13628.
- Habibu, B., Makun, H.J., Yaqub, L.S., Buhari, H.U., Aluwong, T. and Kawu, M.U. (2017). Comparative evaluation of haematological parameters and erythrocyte membrane stability in pregnant and lactating goats in different seasons of tropical Savannah. *Theriogenology*. **99(1)**: 30-35. doi: 10.1016/j.theriogenology.2017.05.004.
- Husein, M.Q. and Haddad, S.G. (2006). A new approach to enhance reproductive performance in sheep using royal jelly in comparison with equine chorionic gonadotropin. *Animal Reproduction Science*. **93(1-2)**: 24-33. doi: 10.1016/j.anireprosci.2005.06.012.
- INEGI-Instituto Nacional de Estadística y Geografía-National Institute of Statistics and Geography. (2010). Compendio de Información Geográfica Municipal de los Estados Unidos Mexicanos 2010. *Coahuila de Zaragoza*. México. (in Spanish). https://www.inegi.org.mx/contenidos/productos/prod_serv/contenidos/espanol/bvinegi/productos/geografia/prontuarios/Coahuila_de_Zaragoza/702825292911.zip.
- Karaşahin, T., Dursun, Ş., Aksoy, N.H., İpek, H. and Şentürk, G. (2023). Hematological parameters in hair goats during and out of breeding season hair goats seasonal hematological parameters. *Iranian Journal of Veterinary Medicine*. **17(2)**: 113-118. doi: 10.32598/ijvm.17.2.1005334.
- Khan, T.H., Beck, N.F.G. and Khalid, M. (2009). The effect of hCG treatment on Day 12 post-mating on ovarian function and reproductive performance of ewes and ewe lambs. *Animal Reproduction Science*. **116(1-2)**: 162-168. doi: 10.1016/j.anireprosci.2009.01.010.
- Lashari, M.H. and Tasawar, Z. (2010). The effect of hCG given on day 12 post-mating on ovarian function and embryo survival in Beetal goats in southern Punjab, Pakistan. *Turkish Journal of Veterinary and Animal Sciences*. **34(6)**: 513-517. doi: 10.3906/vet-0808-29.
- Magaña-Monforte, J.G., Tec-Canche, J.E., Segura-Correa, J.C., Aké-Villanueva, J.R. and Parra-Bracamonte, G.M. (2024). Reproductive and productive performance of hair sheep in a semi-intensive system in southeastern Mexico. *Veterinaria México OA*. **11**: 2-16. doi: 10.22201/fmvz.24486760e.2024.124.
- Martinez-Ros, P. and Gonzalez-Bulnes, A. (2019). Efficiency of CIDR-based protocols including GnRH instead of eCG for estrus synchronization in sheep. *Animals*. **9(4)**: 146. doi: 10.3390/ani9040146.
- Mattos, M.C.C., Bastos, M.R., Guardieiro, M.M., Carvalho, J.O., Franco, M.M., Mourão, G.B., Barros, C.M. and Sartori, R. (2011). Improvement of embryo production by the replacement of the last two doses of porcine follicle-stimulating hormone with equine chorionic gonadotropin in Sindhi donors. *Animal Reproduction Science*. **125(1-4)**: 119-123.
- Maufré, V., Grimard, B., Eozenou, C., Inghels, S., Silva, L., Giraud-Delville, C., Capo, D., Sandra, O. and Constant, F. (2016). Interferon stimulated genes as peripheral diagnostic markers of early pregnancy in sheep: A critical assessment. *Animal*. **10(11)**: 1856-1863. doi: 10.1017/S175173111600077X.
- Miglio, A., Antognoni, M.T., Maresca, C., Moncada, C., Riondato, F., Scoccia, E. and Mangili, V. (2015). Serum protein concentration and protein fractions in clinically healthy Lacaune and Sarda sheep using agarose gel electrophoresis. *Veterinary Clinical Pathology*. **44(4)**: 564-569. doi: 10.1111/vcp.12302.
- MINITAB (2021). *Minitab*, LLC. <https://www.minitab.com>.
- Murphy, B.D. (2012). Equine chorionic gonadotropin: An enigmatic but essential tool. *Animal Reproduction*. **9(3)**: 223-230.

- NAM-National Academy of Medicine (2002). Guide for The Care and Use of Laboratory Animals, 1st ed.; Co-Produced by the National Academy of Medicine-Mexico and the Association for Assessment and Accreditation of Laboratory Animal Care International: Harlan, KY, USA; Mexico City, Mexico.
- Navarrete-Molina, C., Meza-Herrera, C.A., De Santiago-Miramontes, A., Valenzuela-Núñez, L.M., Marín-Tinoco, R.I., Soto-Cardenas, M.A. and Sariñana-Navarrete, M.A. (2024). Dairy goat production: Socioeconomic, environmental and cultural importance across time (1970-2022) and possible scenarios (2050). *Resources*. **13**(12): 177. doi: 10.3390/resources 13120177.
- Pampori, Z.A., Aarif, O., Aasif, S., Hasin, D. and Shah, F. (2025). Housing effect on growth, physiological and blood indices in crossbred sheep during winter. *Indian Journal of Animal Research*. **59**(7): 1224-1229. doi: 10.18805/IJAR.B-4827.
- Plaza-Cuadrado, A., Hernández-Padilla, E., Rugeles-Pinto, C., Vergara-Garay, O. and Herrera-Benavides, Y. (2019). Hematological profile during the gestation of Creole hair sheep in the department of Córdoba, Colombia. *Revista Colombiana de Ciencia Animal*. **11**(1): 42-50. doi: 10.24188/recia.v11.n1.2019.657.
- Porcu, C., Sotgiu, F.D., Pasciu, V., Cappai, M.G., Barbero-Fernández, A., Gonzalez-Bulnes, A. and Berlinguer, F. (2020). Administration of glycerol-based formulations in sheep results in similar ovulation rate to eCG but red blood cell indices may be affected. *BMC Veterinary Research*. **16**(1): 207. doi: 10.1186/s12917-020-02418-z.
- Preisler, M.T., Weber, P.S., Tempelman, R.J., Erskine, R.J., Hunt, H. and Burton, J.L. (2000). Glucocorticoid receptor expression profiles in mononuclear leukocytes of periparturient Holstein cows. *Journal of Dairy Science*. **83**(1): 38-47. doi: 10.3168/jds.S0022-0302(00)74852-1.
- Quintero, J., Olguín, H., Quezada, A., Janacua, H., Rivas, R. and Macías, U. (2015). Effect of hCG application on day 12 post-mating on the reproductive efficiency and plasmatic concentrations of progesterone in hair ewes. *Cuban Journal of Agricultural Science*. **49**(4): 487-490.
- Rabea, A., Abdelraof, Y.M., El-Khaiat, H.M., Kamal, M.A.M. and Helal, M.A.Y. (2024). Dynamics of hematobiochemical and clinical patterns in ewes in different reproductive stages under controlled environmental conditions. *Agrobiological Records*. **15**: 41-51. doi: 10.47278/journal.abr/2023.047.
- Roubies, N., Panousis, N., Fytianou, A., Katsoulos, P.D., Giadinis, N. and Karatzias, H. (2006). Effects of age and reproductive stage on certain serum biochemical parameters of Chios sheep under Greek rearing conditions. *Journal of Veterinary Medicine Series A*. **53**(6): 277-281. doi: 10.1111/j.1439-0442.2006.00832.x.
- Sánchez-Ramos, R., Hernández-Marín, J.A., Ortiz-Salazar, J.A., Olmos-Oropeza, G. and Cortez-Romero, C. (2022). Effects of equine chorionic gonadotropin and GDF9 gene on the reproductive performance of Katahdin sheep. *Revista MVZ Córdoba*. **27**(s): e2888. doi: 10.21897/rmvz.2888.
- Sharma, A., Kumar, P., Singh, M. and Vasishta, N.K. (2015). Haemato-biochemical and endocrine profiling of north western Himalayan Gaddi s heep during various physiological/ reproductive phases. *Open Veterinary Journal*. **5**(2): 103-107.
- Soliman, E.B. (2014). Effect of physiological status on some hemato-logical and biochemical parameters of Ossimi sheep. *Egyptian Journal of Sheep and Goats Sciences*. **9**(2): 33-42.
- Stayt, J. (2022). Chapter 112: Hematology of Sheep and Goats. In *Schalm's veterinary hematology*, [Brooks, M.B., Harr, K.E., Seelig, D.M., Wardrop, K.J. and Weiss, D.J. (Eds).] 7th ed. John Wiley and Sons, Inc. New Jersey, USA. pp. 1012-1018. doi: 10.1002/9781119500537.ch112.
- Wei, S.C., Gong, Z.D., Zhao, H.W., Liang, H.Q., Lai, L.J. and Deng, Y.Y. (2016). Equine chorionic gonadotropin influence on sheep oocyte *in vitro* maturation, apoptosis and follicle-stimulating hormone receptor and luteinizing hormone receptor expression. *Genetics and Molecular Research*. **15**(4): gmr15049162. doi: 10.4238/gmr15049162.
- Wildeus, S. (2000). Current concepts in synchronization of estrus: Sheep and goats. *Journal of Animal Science*. **77**(1): 47-53.
- Žvorc, Z., Mrjak, V., Sušić, V. and Pompe Gotal, J. (2006). Haemato-logical and biochemical parameters during pregnancy and lactation in sows. *Veterinarski Arhiv*. **76**(3): 245-253.