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Selective Anthelmintic Treatment at Different Physiological Stages in Hair Sheep Under Humid Tropical Conditions

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ABSTRACT

Ewes' genotype and physiological stage are important factors associated with gastrointestinal nematode infection. The aims were to evaluate the parasitic (fecal eggs count, FEC), health (anemia level, FAMACHA; packed cell volume, PCV; hemoglobin, HGB), and productive response (live weight, LW; body condition score, BCS) of hair ewes managed under a selective deworming program with levamisole (7.5 mg/kg of live weight) at reproductive stages (not pregnant, NPW, n=17; ewes between the first and second third of gestation, 1-3PW, n=22; ewes in the last third of gestation and peripartum, 4-5PWN, n=16) and genotype groups (Pelibuey, PB, n=12; Katahdin, KT, n=12; Pelibuey × Katahdin, F1 PB×KT, n=16; and Pelibuey × Dorper F1 PB×DP, n=15). The effects of treatments were studied using analysis of variance, considering the reproductive stages and genotypes as treatments through 4 evaluation periods (days 20, 48, 76, and 104). FEC values were higher (p<0.01) for ewes at 4-5PW than 1-3PW and NPW. FAMACHA, PCV, LW, and BCS were similar in ewes regardless of the reproductive stage. On day 48 post-deworming (levamisole at 7.5 mg/kg of LW), the proportion of ewes with >800 e/g was higher (13.74%) at 4-5PW than at the peripartum stage. On day 76, the accumulated proportion of ewes that were dewormed was higher (p<0.05) at 4-5PW than at the peripartum stage. The accumulated total proportion revealed that the genotype F1 PB×DP ewes had the highest deworming requirement (p<0.05), being dewormed at least once (32.8%). According to the indicators of LW, BCS, FAMACHA, FEC, PCV, HGB, and proportion of dewormed animals, ewes with the F1 PB×KT genotype showed the best performance. Therefore, reproductive stage-orientated management and the use of the best genotype for grazing conditions combined with a selective deworming program can contribute significantly to the control of gastrointestinal nematodes.

***Keywords:** Hair ewes; humid tropical; selective deworming*

INTRODUCTION

High humidity and temperature in the warm climates of the Mexican tropics favor the reproduction, development, and propagation of sheep internal parasites. Gastrointestinal nematodes (GIN) cause productive losses estimated at 8 g live weight loss per unit increase in eggs per gram of feces (Ilangopathy *et al.*, 2019; Williams *et al.*, 2022). The presence of GIN also impairs reproductive performance, reducing pregnancy rates, fetal development, size, and lamb survival. Changes in metabolism, immune response, and health of the host itself, as well as changes in behavior and animal welfare, are common problems associated with GIN infection (Luna-Palomera *et al.*, 2010; Zaragoza-Vera *et al.*, 2019; Aleuy *et al.*, 2020). GIN control in tropical grazing systems traditionally relies on chemical anthelmintic (AH) use. However, frequent AH use has caused a resistance increase in the main nematode species (Claerebout *et al.*, 2020; Dey *et al.*, 2020), resulting in a high cost for ineffective AH treatments (Santiago-Figueroa *et al.*, 2019; Sepúlveda-Vázquez *et al.*, 2021). The mass use of AH has raised awareness and public health concerns because of the chemical residues of animal products and the damage they cause to the environment (Hodgkinson *et al.*, 2019).

To reduce AH resistance (AR) onset, GIN control requires an integral approach that considers flock management practices based on the knowledge of the factors involved in AR development. Rational and strategic AH use requires methodologies that integrate information on fecal egg count, anemia level (FAMACHA), and body condition score (BCS), in addition to a diarrhea score (Torres-Acosta *et al.*, 2014). However, large-scale field validation of such alternatives has been rather limited.

Genotype resistance is an additional tool that can be employed for GIN control (Ramírez-Rojas *et al.*, 2022). Pelibuey is a hair sheep breed well known for its resistance and phenotypic resilience against GIN (Aguirre-Serrano *et al.*, 2020; Zaragoza-Vera *et al.*, 2022). However, to increase lamb productivity, crossbreeding with heavier breeds, such as Katahdin (KT) and Dorper (DP), is recommended (Hinojosa-Cuéllar *et al.*, 2015). Natural GIN resistance remains to be elucidated in these crossbreeds under tropical management conditions.

Another relevant factor that needs to be addressed when analyzing GIN prevalence and infection intensity is the ewes' physiological stage. The last third of gestation, peripartum, and lactation have been largely documented as stages when ewes are prone to infection, with the fecal egg count (FEC) being the highest (Beasley *et al.*, 2012; López-Leyva *et al.*, 2022). A fine understanding of deworming frequency during these physiological stages is crucial for reproductive purposes. Nutrition level and BCS are additional factors involved in the parasitic response that simultaneously affect ewes' fertility (Calvete *et al.*, 2020).

Previous research has focused on one or another of the factors involved in GIN prevalence and infection intensity (Tariq, 2015; Kuma *et al.*, 2019; William *et al.*, 2022; Williams, 2023). In this study, based on the natural infection, physiological stage, and genotype of the animals, a holistic approach was employed to identify strategies to reduce the use of AH and delay AR onset. We hypothesized that regardless of breed, the physiological stage of ewes is the main factor affecting the fecal nematode egg count, and selective deworming is highly recommended.

Based on this hypothesis, the objective of this study was to evaluate the parasitological and productive response of Pelibuey, Katahdin, Pelibuey × Katahdin, and Pelibuey × Dorper ewes at different physiological stages in relation to variables, such as body condition score, FAMACHA system, and deworming frequency, under a selective deworming program.

MATERIALS AND METHODS

All handling and sampling procedures were carried out by a veterinarian in accordance with NOM-051-ZOO-1995 and NOM-062-ZOO-1999 for animal production, care, and welfare in force in Mexico. All experimental procedures were approved by the Institutional Committee on Research Ethics of Universidad Juárez Autónoma de Tabasco, México, with approval number UJAT-CIEI-2024-095.

Study Area Description

The experimental work was carried out at the San Vicente farm located at 1 km from the Jalapa-Villahermosa highway in the municipality of Jalapa, Tabasco, Mexico (17.73842N, -92.813950, 14 masl), from March to June of 2022 (dry season). The climate is classified as humid tropical, with an average temperature of 26.6 °C and an average annual rainfall of 2563 mm (CONAGUA, 2021).

Animal Management

A total of 55 ewes between 1.5 and 5 years of age had a BCS of 2.9 ± 0.5 points and live weight (BW) of 40.0 ± 1.2 kg. The ewes were distributed in a completely random design, in which the BCS and BW were considered to distribute and balance the groups. The treatments consisted of a single factor of 1) Genotype: Pelibuey (n=12), Katahdin (n=12), F1 PBxKT (n=15), and PBxDP (n=16); and 2) Physiological stages: non-pregnant ewes (n=17), second to third of gestation (n=23), and last third of gestation to peripartum (n=15). The ewe was the experimental unit.

The genotype consisting of the Pelibuey (PB, n=12), its cross with Dorper (F1 PB × DP, n=15), Katahdin (KT, n=12), and its cross with Pelibuey (F1 PB × KT, n=16) were included in this study. The reproductive physiological stage was determined using an ultrasound (Chison™ Eco2, China). The ewes were classified into 3 physiological stages: 1) non-pregnant ewes (NPW, n=17), 2) ewes between the first and second third of gestation (1-3PW) (n=22), and 3) ewes in the last third of gestation and peripartum (4-5PW) (n=16). The ewes remained naturally infected with GIN since they were continuously grazing on Alicia grass (*Cynodon dactylon*) for 10 h during the day. All ewes were grazed together in 5 ha paddocks and supplemented with 200 g/ewe of a farm-made mix for 2.8 Mcal/kg of energy, which contained 15% crude protein (NRC, 2007) (Table 1). The minerals (phosphorus : calcium ratio, 1 : 1) and water were offered *ad libitum*.

Variables Evaluated

A selective deworming system was established, considering a minimum count of 800 eggs per gram of feces (EPG) as a decision criterion for deworming (Soto-Barrientos *et al.*, 2018). Prior to the start of the study, a coproparasitoscopic study was carried out using the McMaster technique with a sensitivity of 50 EPG (Cringoli *et al.*, 2004), and all ewes were dewormed with levamisole at a dose of 7.5 mg/kg of live weight (LW). Twenty days after deworming, the first sampling

Table 1. Composition of the supplement (NRC, 2007) provided to ewes grazing Alicia grass (*Cynodon dactylon*)

Feedstuff	Dry matter basis, %
Maize silage	4
Sugar cane molasses	5
Vegetable oil	5
Soybean meal	13
Grass hay	41
Sorghum grain, ground	32
Total	100
Metabolizable energy (Mcal/kg)	2.8
Crude protein, (%)	15

was carried out and later samplings were carried out every 28 days (days 20, 48, 76, and 104). Feces were sampled randomly without discrimination between diarrheic or formed feces. On each sampling date, the ewes were weighed with a digital hanging scale (Torrey, model CRS-300) with a ±50 g sensitivity. The BCS was evaluated on a scale from 1 (thin) to 5 (obese) (Russel, 1991), and the coloration of the palpebral mucosa was recorded using the FAMACHA scale (1=red to 5=white) (Leask *et al.*, 2013). Blood samples were collected from each ewe in 5-mL tubes with anticoagulant (EDTA) every 28 days (days 20, 48, 76, and 104) to perform a blood analysis with ABAXIS VetScan HM2™ equipment based on impedance. Hematic analysis consisted of packed cell volume (PCV), hemoglobin (HGB), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), white blood cell (WBC), red blood cell (RBC), red cell blood distribution width (RDW), and platelets (PLT).

Statistical Analysis

Data were analyzed considering a completely randomized design. The variables BW, BCS, FAMACHA, FEC, PCV, HGB, MCV, MCH, MCHC, WBC, RBC, RDW, PLT, and MCV were evaluated by analysis of variance using the SAS PROC GLM procedure (SAS, 2017) with repeated measurements over time (days 20, 48, 76, and 104), considering the initial reproductive physiological stage of the ewes as treatment (NPW, 1-3PW, 4-5PW) and its interaction with the sampling time. However, the effect of the genotype as a treatment (PB; KT; F1 PB×KT, F1 PB×DP) and its interaction with the sampling period were also analyzed. Because of the limited number of observations within each category, the interaction between the genotype and physiological stage was not considered for analysis. The deworming frequencies of ewes in each category were analyzed using contingency tables and Chi-square tests. All analyses were performed considering a significance level of $p<0.05$.

RESULTS

The main effects and the second-order interactions with the sampling period that were statistically significant are described below.

Reproductive Physiological Stage

At the beginning of the study, ewes that were in the last third of pregnancy and peripartum (4-5PW) presented the highest FEC ($p<0.01$). At commencement, no statistical differences were detected between the non-pregnant ewes (NPW) and those at the first and second thirds of gestation (1-3PW) (Table 2). Neither LW nor BCS showed differences between the physiological stages. Similarly, variables of the red formula (PCV, HGB, MCV, MCH, and MCHC) and the FAMACHA scale were not affected by the initial physiological stage of ewes. The number of white blood cells was similar between non-pregnant ewes and those in the last third of pregnancy (Table 2).

After 20 days of study commencement, the proportion of ewes dewormed because they exceeded the predetermined threshold (FEC≥800) was low in all three categories, and it was not higher than 2.5% (NPW=1.67%, 1-3PW=2.27%, and 4-5PW=2.27%) (Figure 1). The proportion of dewormed ewes increased in the following periods. On day 48, NPW (0%) and 1-3PW (3.41%) were significantly different ($p<0.05$) from 4-5PW (13.73%). The proportion of ewes that required deworming at 76 days was higher ($p<0.05$) in the 4-5PW group (15.29%) compared to the non-pregnant group (5.0%) and similar to the 1-3PW group (10.23%). The highest cumulative proportion of ewes that required deworming corresponded to ewes that were at the end

Table 2. Target selective treatment on productive behavior, FAMACHA, FEC, PCV, and hematological response (Means ± SE) from hair ewes in different reproductive stages

Variables	Reproductive stages			p-Value
	Non-Pregnant (n=17)	1-3PW (n=23)	4-5PW (n=15)	
LW, kg	38.2±1.1	37.5±0.97	40.6±1.1	0.12
BCS (1-5)	2.9±0.08	2.9±0.07	3.0±0.08	0.99
FAMACHA (1-5)	1.5±0.09	1.7±0.07	1.5±.08	0.06
FEC, epg	970±131[b]	846±106[b]	1310±118[a]	0.004
PCV, %	19.21±1.1	18.6±0.9	17.6±1.1	0.61
HGB, mg/dL	7.94±0.37	7.33±0.35	7.56±0.42	0.25
MCV, fL	35.17±0.45	35.28±0.75	35.26±0.51	0.94
MCH, pg	15.49±0.55	17.11±0.89	16.22±0.62	0.40
MCHC, %	44.60±2.20	50.25±3.5	46.62±2.50	0.52
WBC $x10^9$/mL	43.51±5.46[a]	26.24±4.91[b]	33.44±5.84[a,b]	0.05
RBC $x10^9$/mL	5.19±0.37	4.66±0.36	4.77±0.42	0.39
RDW-SD, %	14.46±0.25	14.61±0.24	14.39±0.28	0.93
PLT $x10^9$/mL	277.4±58.52	227.75±62.25	272.37±63.58	0.76

Note: 1-3PW= ewes between the first and second third of gestation; 4-5PW= ewes in the last third of gestation and peripartum; LW= live weight, BCS= body condition score, FAMACHA= anemia level, FEC= fecal egg count, PCV= packed cell volume; HGB= hemoglobin, WBC= white blood cell, RBC= red blood cell, RDW= red cell blood distribution width, PLT= platelet. a,b Means in the same row with different superscripts differ significantly at p<0.05.

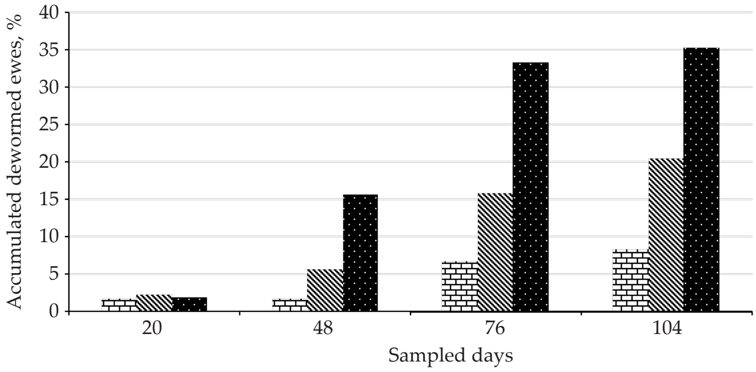

Figure 1. Phenotypic dewormed proportions of hair ewes by reproductive stages under a target selective treatment. NPW (▤) = non-pregnant ewes; 1-3PW (▧) = ewes between the first and second third of gestation; 4-5PW (■)= ewes in the last third of gestation and peripartum.

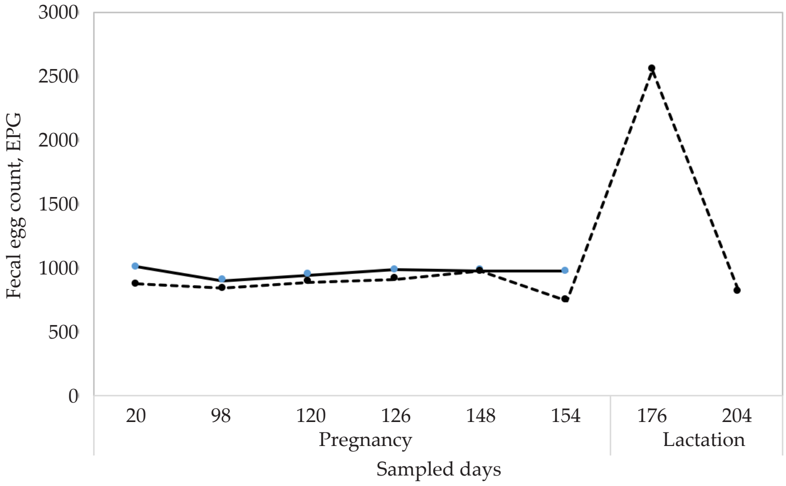

Figure 2. Progression of phenotypic fecal egg count (EPG= eggs per gram of feces) by reproductive stages under a target selective treatment, —●— No pregnant, - -●- - Pregnant.

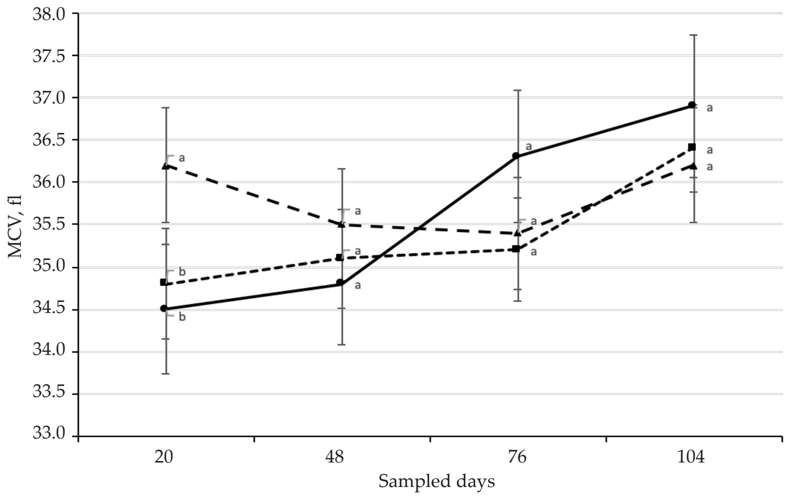

Figure 3. Mean cell volume (MCV) of hair ewes by reproductive stages under a target selective treatment. NPW (—▲—)= non pregnant ewes; 1-3PW (- -■- -)= ewes between the first and second third of gestation; 4-5PW (—●—)= ewes in the last third of gestation and peripartum. [a,b]Means for MCV with different superscripts differ significantly at p<0.05.

of gestation and peripartum (35.3%; Figure 1) and to a lesser extent to those ewes in the 1-3PW gestation group (20.5%) and not pregnant (8.3%). The proportion of ewes dewormed in the 1-3PW group was higher (20.46%) than in the non-pregnant group (8.34%) (Figure 1).

Similar to the deworming proportion trend, FEC showed an increase from early to late gestation to lactation (Figure 2). At 20 and 48 days after the general deworming, the FEC remained relatively low when all the ewes were still pregnant (<1000 EPG). In contrast, ewes in the last third of gestation recorded a significant increase on day 76 (>2500 EPG), which was identified as the peripartal rise and coincided with ewes in lactation.

Within 20 days of general deworming, the MCV levels in pregnant ewes (1-3PW and 4-5PW) were lower on average than in non-pregnant ewes (Figure 3). Ewes in the last third of gestation and peripartum (4-5PW) showed increased MCV levels that remained similar (p> 0.05) to non-pregnant ewes and ewes between the first and second third of gestation (Figure 3).

Effect of Genotype

No significant differences were found for the variables LW or FAMACHA in the PB, KT, F1 PB×DP, and F1 PB×KT genotypes (p>0.05). However, significant differences were recorded for BCS (p<0.05), where the PB ewes registered the lowest score compared to the KT, F1 PB×KT, and F1 PB×DP ewes (Table 3).

The FEC values were significantly higher for ewes of the PB and F1 PB×DP breed groups than for the KT and F1 PB×KT ewes (Table 2). PB and F1 PB×KT ewes showed significantly higher PCV levels compared to KT and F1 PB×DP ewes (Table 3). However, HGB levels and other hematological values were similar between the evaluated genotypes (Table 3).

The phenotypic proportions of ewes that required at least one deworming between days 20 and 48 of the evaluation period were relatively low (0% and 6%, Figure 4). By day 76, a higher proportion of dewormed ewes was recorded, especially in the F1 PB×DP genotype (17.24%).

The total accumulated proportion revealed that the F1 PB×DP ewes had the highest deworming requirements, being dewormed at least once (32.8%, Figure 4). No significant differences were found in the accumulated proportion of ewes that needed to be dewormed between the PB, KT, and F1 PB×KT genotypes (Figure 4).

Table 3. Target selective treatment on biometric measure, FAMACHA®, FEC, PCV, and hematological items (Means ± SE) from hair ewes in different genotypes

Variables	Different genotypes				p-Value
	PB (n=12)	KT (n=12)	F1 PBxKT (n=15)	F1 PBxDP (n=16)	
LW, kg	37.9±1.2	37.7±1.4	39.7±1.0	39.5±1.0	0.48
BCS (1-5)	2.7±0.09[b]	3.0±0.1[a]	3.0±0.07[a]	3.0±0.07	0.02
FAMACHA (1-5)	1.6±0.1	1.6±0.1	1.5±0.08	1.6±0.08	0.89
FEC, epg	1475.3±179.5[a]	669.8±175.9[b]	856.0±136.5[b]	1116.0±111.2[a]	0.006
PCV, %	21.1±1.2[a]	16.6±1.4[b]	19.4±1.0[a]	16.8±1.0[b]	0.01
HGB, mg/dL	8.7±0.4	8.0±0.4	8.2±0.3	7.9±0.3	0.37
MCV, fL	35.7±0.5[a]	33.6±0.5[b]	36.0±0.4[a]	35.7±0.5[a]	0.04
MCH, pg	14.5±0.6[a]	18.7±0.5[b]	15.8±0.5[a]	15.4±0.6[a]	0.004
MCHC, %	41.0±2.6[a]	56.3±2.7[b]	44.9±2.1[a]	43.9±2.4[a]	0.07
WBC x10^9/mL	37.79±10.58	35.37±10.41	39.83±8.74	37.36±8.49	0.92
RBC x10^9/mL	5.14±0.76	4.39±0.81	4.95±0.69	5.10±0.61	0.31
RDW-SD, %	14.52±0.52	14.47±0.61	14.36±0.46	14.53±0.44	0.55
PLT x10^9/mL	250.0±113.0	313.9±140.5	252.4±103.5	243.0±102.4	0.72

Note: LW= live weight, BCS= body condition score, FAMACHA= anemia level, FEC= fecal egg count, PCV= packed cell volume; HGB= hemoglobin, WBC= white blood cell, RBC= red blood cell, RDW= red cell blood distribution width, PLT= platelet. Genotypes: PB= Pelibuey, KT= Katahdin, F1 PBxKT= Pelibuey x Katahdin, F1 PBxDP= Pelibuey x Dorper genotypes. [a,b] Means in the same row with different superscripts differ significantly at p<0.05.

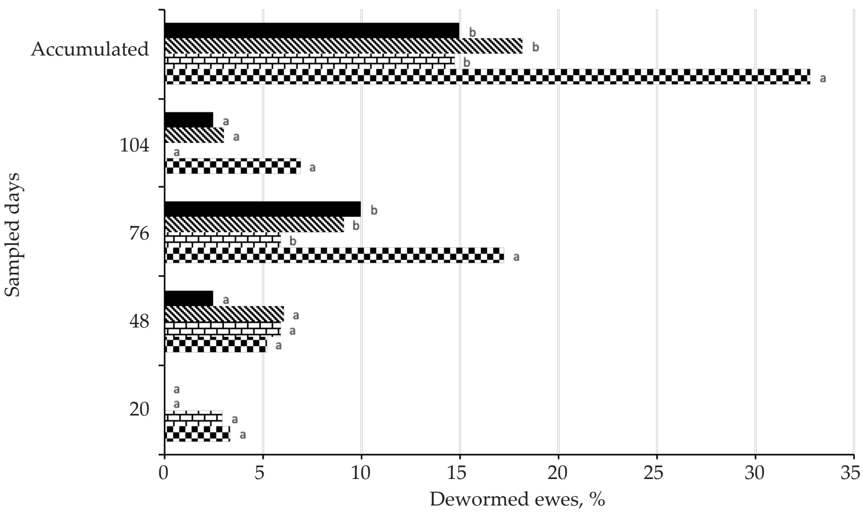

Figure 4. Phenotypic dewormed proportions of grazing ewes by genotype under a target selective treatment. Genotypes: PB (■)= Pelibuey, KT (▨)= Katahdin, F1 PBxKT (▤)= Pelibuey x Katahdin, F1 PBxDP (▦)= Pelibuey x Dorper. [a,b] Means for genotypes in sampled days with different superscripts differ significantly at p<0.05.

DISCUSSION

Reproductive Physiological Stage

GIN infection affects the health and productivity of susceptible ewes, which can lead to animal death when the parasite load is very high (Westers *et al.*, 2017). Although the determination of the EPG count is not a common practice among sheep farmers, it can be a useful tool in the diagnosis and identification of animals susceptible and resistant to GIN (Palomo-Couoh *et al.*, 2017; Romero-Escobedo *et al.*, 2018). Therefore, validating the application of these types of tools under field conditions is a relevant task for technicians and breeders, as they must consider the factors affecting the responses of ewes susceptible and resistant to GIN.

During pregnancy and lactation, specifically in the peripartum stage (peripartal rise) (Gasparina *et al.*, 2019; González-Garduño *et al.*, 2021), ewes were more susceptible, and the FEC increased significantly, as demonstrated in the present study. During the peripartal period, there is a weakening of the immune system associated with hormonal changes, the stress of lambing, and lactation that causes favorable conditions for GIN proliferation and development (González-Garduño *et al.*, 2018; Pereira *et al.*, 2020). A high nematode burden in susceptible ewes affects grazing behavior, reducing the voluntary consumption of food and increasing the risk of damage to animal health.

The peripartal rise phenomenon has been largely reported in wool sheep at other latitudes (Pereira *et al.*, 2020), including Santa Inés (David *et al.*, 2020), Pelibuey (Vásquez-Hernández *et al.*, 2006), and Katahdin (Notter *et al.*, 2017). The peripartal rise occurs in the last two weeks before lambing and persists up to 12 weeks postpartum. The results of the present study agree with those found in the Pelibuey × Katahdin breed (González-Garduño *et al.*, 2014), in which significant EPG count increases, weight loss, and PCV decreases were recorded during early lactation. In the present study, no significant loss of LW, BCS, or FAMACHA levels were observed, and healthy ranges were maintained. Hematological parameters of PCV and HGB were below those reported by Torres-Chablé *et al.* (2020); however, evidence of adverse effects from the blood-sucking habits of GINs was not observed.

The similarity found in the health, body, and hematological variables evaluated between the physiological categories (NPW, 1-3PW, 4-5PW) may be due to the ewes being provided with grass and energy and protein supplementation mixed with mineral salts *ad libitum*. Atiba *et al.* (2020) and López-Leyva *et al.* (2022) showed decreases in FEC and higher PCV values in ewes that received protein supplementation, indicating that proper nutrition levels are crucial for reducing the health impact of GIN.

The present study was carried out during the dry season, which is characterized by lower FEC values in sheep compared to the wet season (Sieuchand *et al.*, 2020), regardless of the breed. Therefore, it is convenient to conduct studies during the rainy season and elucidate the impact of protein supplementation in pregnant ewes through seasons with the highest parasitic burden in sheep. The content of condensed tannins in tropical grasses should also be considered. Condensed tannins are recognized for reducing protein degradation to ammonia in the rumen, increasing the supply of digestible protein and indirectly affecting parasite resistance (Min *et al.*, 2015).

Selective deworming is important because there is a significant decrease in the use of AH drugs, confirming the results reported by González-Garduño *et al.* (2014), who found that 37% of pregnant ewes required a higher frequency of deworming compared to non-pregnant ewes, which also aligns with the results of Arece-García *et al.* (2014). Selective deworming combined with the determination of the FAMCHA level and BCS might be valuable tools to reduce the selection pressure toward GIN populations resistant to AH drugs (Torres-Acosta *et al.*, 2014).

Effect of Genotype

Regardless of the breed, the BCS has been shown to be an easy-to-apply tool that assesses animal fat reserves. In addition, the BCS is one of the parameters that has been associated with GIN burden (Torres-Acosta *et al.*, 2014). In this study, the racial group that had the lowest BCS also showed the highest GIN infection levels. Although good body condition scores might be associated with optimal health standards, they are not always associated with a lower parasitic burden (Liddell *et al.*, 2020), as observed in F1 PB×DP ewes in the present study. Torres-Chable *et al.* (2020) reported that BCS was positively associated with indicators evaluating the parasitism degree, such as PCV (r=0.39), HGB (r=0.20), RDW-SD (r=0.45), and FAMACHA level (r=0.26), in Pelibuey ewes.

The levels of PCV and HGB observed in the present study among PB, KT, F1 PB×KT, and F1 PB×DP ewes are below those reported in Pelibuey (Torres-Chable *et al.*, 2020), Santa Inés (David *et al.*, 2020), and Awassi ewes (Ql-Jbory & Al-Samarai, 2016). However, these PCV values are similar (19%–38%) to those reported by Sotomaior *et al.* (2012).

RDW values are related to circulating erythrocyte size variability. This value can be used to diagnose anemia after changes in MCV are evident (Torres-Chable *et al.*, 2020). The MCH and MCHC values were higher for KT ewes but within the parameters reported for other breeds (Al-Samarai, 2016; David *et al.*, 2020), indicating that there were no pronounced anemia symptoms among genotype groups during the study. The same trend was observed for the other analyzed hematological parameters (WBC, RBC, and PLT). A possible explanation for the results among the genotype groups might be due to the nutritional condition of the animals throughout the study since they had free access to a protein and energy source mixed with mineral salts, as evidenced by the BCS and health condition, which showed an adequate nutritional status (López-Leyva *et al.*, 2022).

The sensitivity and specificity of a deworming system that combines several criteria, such as those addressed in this study (FEC, PCV, HGB, FAMACHA, BCS), is associated with factors such as physiological stage, breed, management, and technicians' skills in the use of these tools (Ferreira *et al*., 2019). The genotype plays a preponderant role since breeds and animals within them may be resistant, resilient, or susceptible to GIN (Cunha *et al*., 2024). In this study, the sheep of the F1 PB×DP breed group required more frequent deworming compared to the PB, KT, and F1 PB×KT ewes, which could be due to the selection for a greater rusticity and immune response to high parasite loads observed in PB (Zaragoza-Vera *et al*., 2023) and KT ewes (Notter *et al*., 2017). The hybrid vigor effect resulting in a new allelic combination in F1 PB×KT ewes may be a sustainable control strategy, similar to that observed in other genotypes (Zvinorova *et al*., 2016; Weaver, 2017), as they may not have the susceptible DP genotype (Thorne, 2023). The PB×DP genotype showed the highest proportion of ewes that required at least one deworming from 20 to 104 d. However, the highest FEC was found in PB and PB×DP ewes. According to the indicators of LW, BCS, FAMACHA anemia level, FEC, PCV, HGB, and proportion of dewormed animals during the evaluated period, the sheep of the PB×KT breed group observed the best behavior.

CONCLUSION

Based on the results of this study, appropriate genotype selection for grazing conditions combined with a selective deworming program can significantly contribute to GIN control, ensuring health maintenance and better productive performance of sheep in the tropics. In general, ewes transitioning from the last third of gestation to early postpartum represented the highest proportion requiring deworming. A selective deworming program can significantly contribute to GIN control by paying more attention to more susceptible physiological states, such as the last third of pregnancy and early postpartum, based on the HPG count.

CONFLICT OF INTERESTS

The authors declare no conflicts of interest.

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