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Characterization of sheep production systems and their relation with gastrointestinal parasites in four municipalities of Campeche, Mexico

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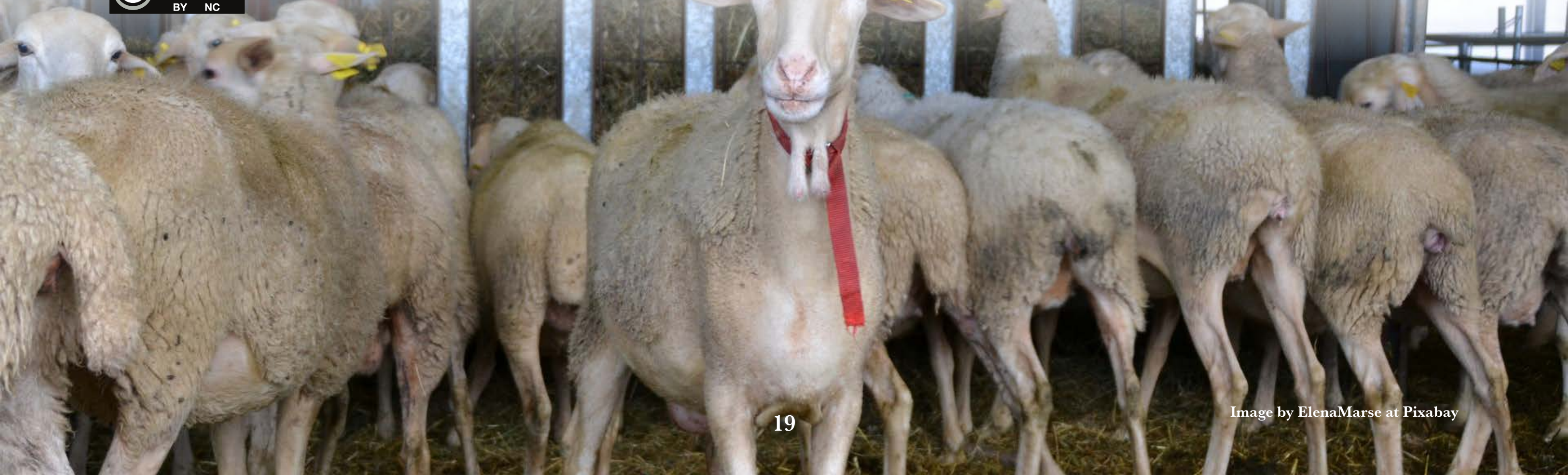
ABSTRACT
Objective: The increase in the number of sheep in herds is accompanied many times by bad practices, which lead to nutritional deficiencies, rises in parasitism and loss of homeostasis. Therefore, gastrointestinal parasites from sheep were characterized from four municipalities of the state of Campeche.
Design/methodology/approach: The number of sheep studied was 243, evaluating the body weight, body condition, coloring of the eye mucosae, age, eggs per grams of feces, and family of parasites. The data were analyzed through an ANOVA and Tukey's means test ($P<0.05$), as well as Spearman's correlation analysis using the statistical package Statistica 7.
Results: Five parasite families were found (*Trichostrongyloidae*, *Strongyloidae*, *Trichuridae*, *Eimeriidae* and *Anoplocephalidae*). In the production systems of the municipality of Calakmul the five families of parasites were found, with a parasite load of 3,571 hpg. The family *Trichostrongyloidae* presented the highest frequency in the municipalities of Champotón and Calakmul with 52 and 75%, respectively. The animals with best body condition, FAMACHA© and lowest parasite load were observed in Hecelchakán.
Limitations on study/implications: It is suggested to carry out a study of anthelmintic resistance, to establish a management of prevention and control of gastrointestinal parasites.
Findings/conclusions: The frequency of gastrointestinal parasites is influenced by the management and the municipality of origin within the sheep production systems in the state of Campeche.

Keywords: sheep farming, technologies, gastrointestinal parasites, livestock systems



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INTRODUCTION

In the Mexican tropics, sheep farmers have focused on breeding sheep for meat production (González-Garduño *et al.*, 2013), opting mainly for the short-hair breeds, because of their greater rusticity and adaptability to environmental conditions in these zones (Pérez-Hernández *et al.*, 2011), which are characterized mainly by high temperatures and environmental moisture, and high solar radiation. In these systems, it is common for the productive performance in the herds to be affected by nutritional deficiencies, parasitism, and loss of homeostasis (Whitley *et al.*, 2014). To understand and respond to this quandary, characterizations have been made in sheep production agroecosystems in zones of the Mexican tropics, which reflect the deficient management of nutritional supplementation and sanitary management (Nuncio-Ochoa *et al.*, 2001; Dzib-Can *et al.*, 2006; Candelaria-Martínez *et al.*, 2015; Góngora-Pérez *et al.*, 2010; Pérez-Hernández *et al.*, 2011; Pérez-Bautista *et al.*, 2021), conditions that make herds susceptible to presenting gastrointestinal parasitosis (Herrera *et al.*, 2010; Fthenakis *et al.*, 2015). In Yucatán and Tabasco, Mexico, studies have been conducted on the prevalence and loads of gastrointestinal parasites in sheep (González-Garduño *et al.*, 2011; López-Ruvalcaba *et al.*, 2013), and high prevalence of larvae of *Haemonchus contortus* (68,9%), followed by *Trichostrongylus colubriformis* (30.9%) and *Cooperia curticei* (0.6%) (Zaragoza-Vera *et al.*, 2019) were reported until 2019. Likewise, studies have been conducted for the detection of anthelminthic resistance (Torres-Acosta *et al.*, 2012) through the analysis of immunological parameters (Alvarado-Alvarado *et al.*, 2017) and through the level of social hierarchy on the parasite load (Flota-Bañuelos *et al.*, 2019). Within the strategies of prevention or control, the following have been implemented: use of FAMACHA© (Soto-Barrientos *et al.*, 2018), copper oxide needles (Galindo-Barbosa *et al.*, 2011), selective removal of parasites (Medina-Pérez *et al.*, 2015), use of plants with presence of secondary metabolites (Herrera-Manzanilla *et al.*, 2017; Sepúlveda-Vázquez *et al.*, 2018), or residues of *Coffea arabica* (Ortiz-Campos *et al.*, 2016).

In the state of Campeche, there are reports of the types of sheep production systems and the morphostructural variability of black belly studs (Dzib-Can *et al.*, 2011). However, information about gastrointestinal parasites is scarce, with records about identification and presence of anthelminthic resistance to benzimidazole in gastrointestinal nematodes of cattle (Encalada-Mena *et al.*, 2014), with prevalence of 62.31 and 80.15% in calves younger than four months and from four to seven months old, respectively (Encalada-Mena *et al.*, 2009), and about the frequency of sheep resistant to anthelmintic in nine ranches of Campeche (Sepúlveda-Vázquez *et al.*, 2021), leaving aside the management aspects that impact this problem. Given the importance and relevance of this activity in the state (FIRA, 2010) and the increase in sheep production of 136,000 to 193,501 heads from 2009 to 2020 (SIAP, 2021), the objective set out for this study is to characterize gastrointestinal parasites in sheep production systems in four municipalities of the state of Campeche.

MATERIALS ANDY METHODS

The study was conducted during the months of September 2019 to March 2020, in 19 sheep production systems with cooperating producers in the state of Campeche. The municipalities of study were Champotón, located at 18° 34' and 19° 41' LN and 89° 54' and 91° 11' LW, altitude between 8 and 20 masl, mean annual temperature of 26.5 °C and mean annual precipitation of 1500 mm (INEGI, 2009a); Hecelchakán, located at 19° 54' and 20° 17' LN and 89° 51' and 90° 30' LW, altitude between 0 and 100 masl, mean annual temperature of 27 °C, mean annual precipitation between 800 and 1100 mm (INEGI, 2009b); Campeche, located at 17° 48' and 18° 31' LN and 90° 14' and 91° 20' LW, altitude between 100 and 200 masl, mean annual temperature of 26.5 °C, mean annual precipitation between 1200 and 2000 mm (INEGI, 2009c); and Calakmul located at 17° 49' and 19° 10' LN and 89° 25' and 90° 17' LW, altitude between 100 and 300 m, mean annual temperature of 26 °C, mean annual precipitation of 1500 mm (INEGI, 2009d).

Description of the management in production systems

A questionnaire was applied through direct interviews with those responsible for the sheep production systems, which contained the following information: general description (age and schooling of the person responsible, land tenure, workforce used, importance of sheep production, technical assistance, time devoted and purpose of sheep farming), type of production system, registry of production, number of females, number of studs, offspring, surface devoted to grazing, number of pens, sanitary management (disease control, removal of parasites/product, disease prevention), nutrition (ensilage, use of fodder plants, use of multi-nutritional blocks, supplement), and use of grasslands (grazing/grass/plant) (Dzib-Can *et al.*, 2006; Dzib-Can *et al.*, 2017 and Halimani *et al.*, 2021). After applying the questionnaire, a visit was made to the facilities to verify the conditions of herd management (Pérez-Bautista *et al.*, 2021).

The size of the sample was calculated through the formula of finite populations (Sierra, 1995), with a level of confidence of 95%, error of 5%, and total population size of 650 animals between all the production systems, obtaining a sample size of 243 Pelibuey sheep and their crosses, which are characteristic and representative of the municipalities of Campeche.

Weight and body condition

The animals were managed by the ranch owners (with prior consent) and aligned with the regulations for the use and care of research animals (ColPos, 2019). To measure the weight (BW), all the sheep were fasted for 12 h prior to weighing on a digital Torrey® PCp 500 scale. The body condition (BC) was measured with a comparative morphometric scale established by Russel *et al.* (1969), where 1 is very thin, 2 thin, 3 normal, 4 fat, 5 very fat, based on palpation and observation of different areas of the sheep to determine the level of fat coverage.

Coloring of the ocular mucosae

The degree of anemia was evaluated in function of the coloring of ocular mucosae using the FAMACHA© method, where 1 is intense red coloring, 2 light red, 3 pink, 4 light pink, and 5 very pale (Kaplan *et al.*, 2004).

Parasite load

The number of eggs per gram of feces (hpg) was evaluated through a coproparasitoscopic analysis, collecting 10 g of fresh feces taken directly from the rectum of each sheep selected, which were deposited into previously marked bags. Then, the feces were homogenized and processed individually to quantify the eggs for each gram of feces using the McMaster technique (Sandoval *et al.*, 2011). The eggs were identified at the level of family, genus or species in function of the morphometric characteristics (Figueroa-Castillo *et al.*, 2015).

Analysis of information

The data from the questionnaires were captured in worksheets of the Microsoft Office Excel 2007 software, then codified, classified, and a descriptive analysis of the variables was conducted (Santesmases, 2005). To compare the body weight, body condition, coloring of ocular mucosae (FAMACHA©), and parasite load per municipality, a one-way analysis of variance was carried out to determine statistical differences through Tukey's test ($P<0.05$). Spearman's correlation analysis ($P<0.05$) was conducted with the dependent variables using the statistical package Statistica 7.

RESULTS AND DISCUSSION

Description of the management in production systems

In 95% of the sheep production systems analyzed, the person responsible belonged to the masculine gender and only in 5% the person responsible was of the feminine gender. In this sense, Vázquez-García (2013) mentions that a gender approach is required to help understand the allotment of tasks between women and men, because women are fundamental pieces in this productive process in the rural sphere, by performing feeding activities of animals in the pen, grazing, and sanitary management of the animals (Estevez-Moreno *et al.*, 2019). The sheep under care of women showed lower total parasite load ($F=4.942032$, $P=0.027570$) in contrast with the sheep with only men responsible, with averages of 80.77 and 2,058.86 hpg, respectively. In this sense, Hulela (2010) mentions that women have more experience in the management of diseases and control of parasites in sheep and goats thanks to the association of empirical knowledge; this is the case of women shepherd in Chiapas, Mexico, who have improved the quality of the wool and have decreased the neonatal mortality in their herds (Vázquez-García *et al.*, 2013).

Of the total of survey respondents, 36.8% studied primary school, 31.6% studied secondary school, and 31.6% undergraduate university studies; the producers from Hecelchakán and Calakmul have more schooling with 14 years on average, compared to the producers from Campeche and Champotón, who have 9 years on average ($F=14.690$, $P=0.0001$), with values higher than those reported by Estevez-Moreno *et al.* (2019) in sheep producers from Zinacantepec, Mexico, with incomplete primary school (5.16 years of schooling) and in Yucatán, where 61% of the sheep producers have complete primary school (Góngora-Pérez *et al.*, 2010). Concerning age, the producers were in the range of 26 to 65 years old, with those from the municipality of Champotón being older ($F=79.695$, $P=0.0001$) with 56 years on average (Table 1), and age ranges are similar to those registered in sheep production systems from Campeche and Yucatán (Pérez-Bautista *et al*., 2021; Candelaria *et al*., 2015).

For 36.8% of the producers, sheep farming is a very relevant activity, because it generates important economic resources, and 63.2% indicate that it is moderately relevant to date, because they are in the phase of starting the activity, the sales are scarce because the objective of the business is to increase the size of the herd (Table 1). The producers

Table 1. Characteristics of the sheep production systems in Campeche, Mexico.

Variables	**Municipality**			
	Hecelchakán	**Champotón**	**Campeche**	**Calakmul**
Age of the person responsible (years)	47 ± 0.89^{b}	56 ± 11.95^{a}	42 ± 0.42^{b}	30 ± 8.42^{c}
Schooling of the person responsible (years)	14 ± 3.12^{a}	9 ± 4.89^{b}	9^{b}	13 ± 4.43^{a}
Time devoted to sheep production (months)	7^{c}	67 ± 50.26^{a}	33 ± 48.55^{bc}	36 ± 50.11^{b}
% Gender of the person responsible	100 masculines	100 masculines	95 masculines 5 feminine	100 masculines
Land tenure	Private property	*Ejido* property	Private and/or *ejido* property	Private and/or *ejido* property
Workforce used	Hired with payment	Family without payment and hired	Family without payment and/or hired	Family without payment and/or hired
Importance of sheep production	Medium	High	Medium	Medium
Purpose of sheep production	Consumption and sale	Sale	Sale, consumption, and sale	Sale
Number of females (>1 year)	10.5*	70*	42.8*	50*
Number of studs (>1 year)	3*	2*	1.3*	4*
Offspring (birth to 1 year)	25*	48*	10.7*	26*
Type of production system	Confined and grazing	Confined and grazing	Confined and grazing	Grazing
Surface devoted to grazing (ha)	7*	8*	3*	8*
Number of pens	4*	5*	2.1*	3*
Supplement	Yes	No	Yes	No
Disease control	Yes	Yes	No	Yes
Registry of production	Yes	No	No	Occasional
Removal of gastrointestinal parasites / product	4 months / Ivermectin	2 months/ Ivermectin, fenbendazole	3 months / Ivermectin	3 months / Ivermectin
Disease prevention	Yes	No	No	No
Ensilage	Yes	No	No	No
Use of fodder plants	Yes	No	No	No
Use of multi-nutritional blocks	Yes	No	No	Yes
Grazing/grass/plant	Yes / *B. decumbens*, *A. gayanus*, *M oleifera*, *B. alicastrum*	Yes / native grasses	Yes / native grasses	Yes / native grasses
Technical assistance	No	Yes	No	Occasional

[a,b,c] Different letters in the same line indicate significant differences $P\leq0.05$. The values indicate average ± standard deviation. *It refers to the average.

from Champotón had greater experience in the management of sheep (F=11.33414, P=0.000001) with more than 6 years in the activity. Both schooling and experience are relevant factors for success in the productivity of the systems (Herrera-Haro *et al.*, 2019), because in some cases, the null or minimum experience and the low schooling in those responsible lead to failure (Martínez-González *et al.*, 2011).

Of the production systems, 50% are developed in lands with private property tenure and 50% are *ejido*, differing from what is reported by Candelaria *et al.* (2015) in the eastern part of the state of Yucatán, where 89% of the sheep production systems are developed in private properties and 11% in *ejido* lands (Table 1). Access to lands is important to develop the activity and influences the possibility of expanding for pasturelands or fodder crops (Herrera-Haro *et al.*, 2019), although being in *ejido* presents shortages in rights that make agriculture and livestock production more difficult (Morett-Sánchez and Cosío-Ruiz, 2017), in contrast with private property where there are rights for control and of land transference (FAO, 2003).

Of the producers, 95% uses family workforce without payment and hired with payment, while 5% uses only hired workforce (Table 1). In this sense, Candelaria *et al.* (2015) reported a similar finding in sheep breeding systems in eastern Yucatán for which they mention that 100% use family workforce and 82% use hired or occasional labor.

From the production systems evaluated, only the municipality of Hecelchakán conducts supplementation, production records, disease prevention, removal of parasites from animals every 4 months, and they use fodder plants (*M. oleifera* and *B. alicastrum*) as well as improved grasses and multi-nutritional blocks (Table 1). The results are similar to those reported by Dzib-Can *et al.* (2006) and Dzib-Can *et al.* (2017) for the state of Campeche; however, in their studies they had not reported the use of forest shepherding or silo elaboration. In Yucatán, the sheep graze on secondary vegetation or introduced pastures, and only 30.4% of the producers supplement with concentrated commercial feed. In some cases, they use *B. alicastrum* and agroindustrial wastes (Góngora-Pérez *et al.*, 2010).

All of the producers (100%) mentioned that the main problem are the gastrointestinal parasites, and to combat them they eliminate parasites with ivermectin at a frequency of 2 to 4 months, the same as in sheep production systems of the state of Yucatán, where gastrointestinal parasitosis is the disease with highest frequency followed by respiratory diseases, and in 98% of the systems they use chemical anti-parasite drugs, with monthly, bi-monthly, tri-monthly and even annual applications (Candelaria-Martínez *et al.*, 2015); this disease can cause mortality rates of 41.18% (Muñoz-Osorio *et al.*, 2015).

Prevalence of gastrointestinal parasites in sheep

From the 243 sheep studied, 65.8% were positive to gastrointestinal parasites, showing a greater prevalence of the family Trichostrongylidae in the herds from the municipalities of Champotón and Calakmul, with 52 and 75%, respectively, followed by the family Eimeriidae, with 40% for Calakmul and less than 15% for the rest of the municipalities. The family Strongylidae had a prevalence of 23% in Calakmul, while the family Trichuridae showed the lowest prevalence (5%) recorded for Calakmul and Campeche. Likewise, the family Anoplocephalidae was found only for Calakmul with 30% (Figure 1). Similar results were reported in Pelibuey sheep from San Pedro Lagunillas, Nayarit, where the family Trichostrongylidade predominated, followed by the families Eimeriidae and Anoplocephalida (Salgado-Moreno *et al.*, 2017), and in the central region of the state of Tabasco, the family Trichostrongylidae dominated with the genera *Haemonchus* spp., *Trichostongylus* spp. and *Oesophagostomun* spp. (Herrera-Manzanilla *et al.*, 2017). However, in sheep from Bocayá, Colombia, the prevalence was higher with 89.4%, where the main families were Eimeriidae with 63%, followed by Trichostrongylidae (47.7%), Dyctiocaulidae (38.1%) and Strongylidae (21.5%) (Díaz-Anaya *et al.*, 2017).

The weights of sheep ranged from 26 to 34 kg on average, finding higher weights (P=3.1341, P=0.27127) in the sheep from Hecelchakán and lower in Champotón. The herds showed animals with ages from 12 to 30 months on average, with younger sheep in Calakmul and older in Campeche. The body condition of the sheep from the four municipalities did not present significant differences (Table 2).

The oldest sheep were found in herds from the municipality of Campeche with an average of 30.11 months (F=26.6507, P=0.00001) (Table 2), in these herds a lower total count of parasites was observed, while the youngest sheep were found in the municipality of Calakmul with 12.83 months, which presented a higher number of hpg (r=−0.254926, P=0.05); in this sense, it has been suggested that young animals are more susceptible to infestation from gastrointestinal parasites, compared to older animals (González-Garduño *et al.*, 2018).

In the herds from the municipality of Hecelchakán there was coloring of the mucosae (FAMACHA®) with 2.5 (between light red and pink) (F=8.758, P=0.000016) (Table 2); meanwhile, in the herds of the rest of the municipalities studied, the coloring of the mucosae is closer to the range 3 (pink) or limit (light pink), considered as intermediate value where the animal can be considered both anemic and non-anemic (Zárate *et al.*, 2017).

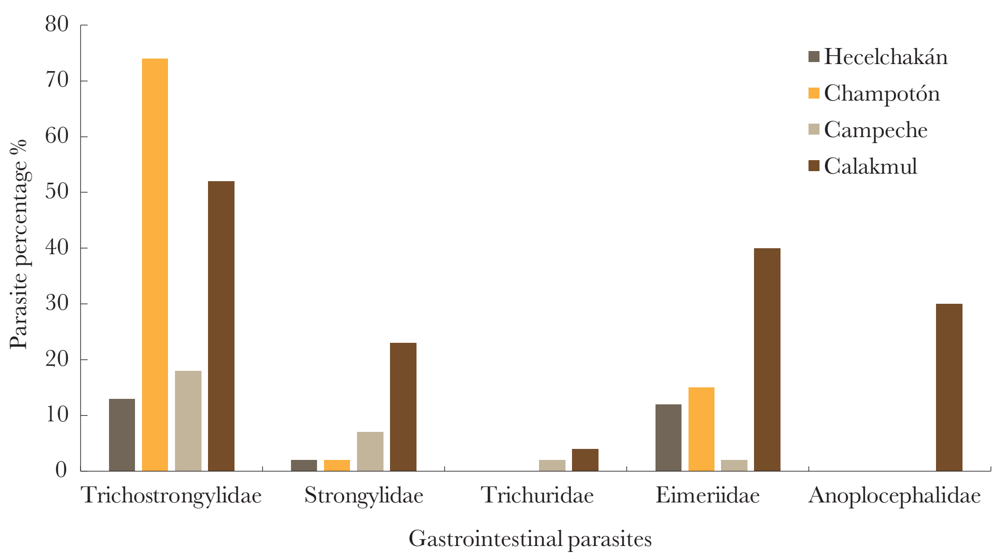

Figure 1. Prevalence of gastrointestinal parasites in municipalities of Campeche

Table 2. Composition of sheep and gastrointestinal parasites in sheep production systems of Campeche, Mexico.

Variables	Municipality			
	Hecelchakán	**Champotón**	**Campeche**	**Calakmul**
Weight (kg)	33.77±14.66[a]	26.11±9.56[b]	33.03±12.01[ab]	28.24±12.24[ab]
Age (month)	22.22±9.23[b]	17.88±5.94[b]	30.11±12.81[a]	12.83±7.93[c]
Body condition	2.46±1.67[a]	2.28±1.09[a]	2.30±1.11[a]	2.02±0.84[a]
FAMACHA	2.55±0.80[a]	3.09±0.92[b]	2.96±0.92[ab]	2.77±0.79[ab]
Trichostrongyloidae (hpg)	727.77±1066.92[a]	560.37±874.38[a]	207.69±313.59[a]	559.83±1248.59[a]
Strongyloidae (hpg)	1.85±9.62[b]	0.94±6.86[b]	11.53±32.58[b]	182.78±326.32[a]
Trichuridae (hpg)	0	0	0	4.09±21
Eimeriidae (hpg)	512.96±679.16[ab]	97.17±217.59[b]	15.38±78.44[b]	2373.77±5967.03[a]
Anoplocephalidae (hpg)	0	0	0	450.81±1208.01[a]
Total of parasites (hpg)	1242.59±1684.52[ab]	658.49±135.41[b]	234.61±62.98[b]	3571.311±1919.88[a]

[a,b,c] Different letters in the same line indicate significant differences P≤0.05. The values indicate average ± standard deviation.

The sheep with best coloring of the ocular mucosae presented better body condition (r=0.323408, P=0.05); this situation is because the sheep from the production units of the municipality of Hecelchakán are supplemented with commercial concentrate feed and fodder from shrub and tree species, which allow varying the diet, covering their requirements (Provenza, 1996), and in addition they promote the capacity to resist high parasite loads (Flota-Bañuelos *et al.*, 2019).

For their part, the sheep from production systems in the municipality of Calakmul presented the highest amount of parasites (F=8.40576, P=0.000025) with a value of 3571.31 eggs, and they had higher presence of Strongylidae (F=12.29291, P=0.00001), Eimeriidae (F=6.727639, P=0.000025) and Anoplocephalida (F=6.268243, P=0000413), with 182.78; 2373.77 and 450.81 hpg, respectively (Table 2). The families and frequency of parasites agreed with the reports in sheep from the municipalities of Teapa, Centro and Huimanguillo, Tabasco, where the families that were mainly found were Trichostrongylidae (*H. contortus*, with 1448, 1191 and 800 hpg) (González-Garduño *et al.*, 2011) and *H. contortus*, *Cooperia* spp., *Ostertagia* spp., *Chabertia* spp., and *Moniezia* spp. (Rivero-Pérez *et al.*, 2019). Likewise, in sheep production systems of Colombia, under three systems (confinement, semi-confinement and grazing), the highest frequency of Trichostrongylidae was found with *H. contortus*, *Teladotargia circumcincta* and *Trichostrongylus* spp., with 76, 61.3 and 25.5% (Zapata-Salas *et al.*, 2016), and in temperate zones of Mexico, *Cooperia* spp. and *Trichostrongylus colubriformis* (Mondragón-Ancelmo *et al.*, 2019).

From the four municipalities evaluated, the sheep from the production systems of the municipality of Calakmul presented all the families of parasites and the highest total amount of parasites, influenced mainly by the climate characteristics, with a warm humid climate (AW2), compared to Hecelchakán, Campeche and Champotón (García, 2004), and humidity being one of the main factors that favor the proliferation of gastrointestinal parasites (Quiroz *et al.*, 2011). Other factors that favor the frequency of parasites are the extensive grazing system in native grasses during 24 h, increasing the exposure to parasite re-infestations; in addition, the sheep do not have access to supplementation, which reduces the sheep's capacity to respond against gastrointestinal parasites (Aguilar-Caballero *et al.*, 2002). Likewise, the low recruitment of technical assistance with trained staff, for the prevention and control of diseases promotes bad sanitary practices for sheep management.

CONCLUSIONS

The parasite loads present in sheep from the different production systems evaluated in the state of Campeche depend on the producer's schooling and experience in the activity, which impact directly on the use and management of the herd, removal of parasites, and control of diseases; these characteristics are reflected in the systems of Champotón, with sheep with parasite loads lower than 700 hpg, and in sheep from production systems that belong to the municipality of Calakmul and Hecelchakán with loads higher than 1200 and 3500 hpg, as well as the presence of the five and three families of parasites, respectively (Trichostrongylidae, Strongylidae, Eimeriidae, Trichuridae and Anoplocephalidae). It is proposed to conduct a study of anthelmintic resistance in these systems, to later establish management of prevention and control of gastrointestinal parasites.

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AGRO
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