FACTORS ASSOCIATED TO GASTROINTESTINAL NEMATODES INFECTIONS IN DAIRY GOATS GRAZING ON SEMI-ARID RANGELANDS OF NORTHEASTERN MEXICO†

[FACTORES ASOCIADOS A LAS INFECCIONES DE NEMATODOS GASTROINTESTINALES EN CABRAS LECHERAS PASTOREANDO EN PASTIZALES SEMIÁRIDOS DEL NORESTE DE MÉXICO]

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SUMMARY

There is a lack of information about the epidemiology of gastrointestinal nematode (GIN) infections on dairy goats. The objective of this study was to evaluate factors associated with the prevalence of GIN infection in mixed-breeds dairy goat grazing on semi-arid rangelands of northeastern Mexico. Mixed-breed dairy goats (n = 668) including Boer, Nubian, Alpine, Saanen and Toggenburg in 18 flocks were used. The goats were weighted and sampled of faeces and blood. The egg counts per gram of faeces (EPG) and the percentage of packed cell volume (PCV) was determined. Age, body condition score (BCS), and FAMACHA© were estimated. Environmental temperature, annual rainfall, and altitude were the independent variables. The association between EPG, PCV, BCS, and FAMACHA© was determined. Temperature, rainfall, altitude, and live weight affected the EPG of GIN excretion (P <0.01). Older goats had the highest EPG counts and lower values for BCS, PCV, and FAMACHA© (P <0.05) than young goats. Goats with poor BCS had a higher EPG count and lower values of PCV and FAMACHA© (P <0.05). The correlations between EPG and FAMACHA©; EPG and BCS; EPG and PCV were 0.58, -0.55 and -0.55, respectively (P <0.01). Correlations between FAMACHA© and PCV and BCS were -0.69 and -0.66, respectively (P <0.01). It concluded, that the prevalence of infections with GIN in mixed-breeds dairy goat is high; the BCS, live weight, ambient temperature, rainfall, and altitude were factors that influence the GIN infections on dairy goats grazing on semi-arid rangeland of northeastern Mexico.
Keywords: GIN; EPG; PCV; Goat; Semi-arid Rangeland; México.

RESUMEN

La información sobre la epidemiología de las infecciones con nematodos gastrointestinales (NGI) en las cabras lecheras es limitada. El objetivo del presente estudio fue evaluar los factores asociados con la prevalencia de la infección por NGI en cabras lecheras bajo pastoreo en pastizales de las zonas semi áridas del Noreste de México. Se utilizaron cabras lecheras (n = 668) de razas cruzadas (incluyendo Bóer, nubian, Alpine, Saanen y Toggenburg) de 18 rebaños. Las cabras fueron pesadas y muestreadas de heces y sangre. Se determinó la cuenta de huevos por gramo de heces (HPG) y el Hematocrito (Ht). Se estimó la edad, la condición corporal (CC) y FAMACHA©. La temperatura ambiental, la precipitación pluvial y la altitud fueron las variables independientes. Se determinó la asociación entre HPG, Ht, CC y FAMACHA©. Temperatura, precipitación, altitud, y peso vivo afectaron la cuenta de HPG de los NGI (P < 0,01). Las cabras de mayor edad presentaron altas cargas de HPG, valores más bajos de CC y Ht y valores más altos de FAMACHA© (P< 0,05) que las cabras jóvenes. Las cabras con CC baja tuvieron un recuento más alto de HPG, valores más bajos de Ht y más altos de FAMACHA© (P < 0,05). Las correlaciones entre HPG y FAMACHA©; HPG y CC; HPG y Ht fueron 0,58, -0,55 y -0,55, respectivamente (P< 0,01). Las correlaciones entre FAMACHA© y Ht y CC fueron-0,69 y -0,66, respectivamente (P< 0,01). Se concluye que la prevalencia de infecciones con NGI en razas mixtas de cabras lecheras es alta; la CC, el peso vivo, la temperatura ambiente, la

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precipitación y la altitud son factores que influyen en las infecciones por NGI en cabras lecheras bajo pastoreo en pastizales de zonas semiáridas del Noreste de México.
Palabras Clave: NGI; Ht; HPG; Cabras; Zonas semi áridas; México.

INTRODUCTION

In Mexico, the major national milk goat and meat goat production came from arid and semi-arid zones (SIAP, 2016), where, goat production systems are mainly under extensive grazing without feed supplementation throughout the year (Salinas-González *et al.,* 2016). A constraint for goat production under grazing/browsing conditions is the infection with gastrointestinal nematodes (GIN) because they negatively affect the health and well-being of animals (Besier *et al.*, 2016). The negative effects of GIN on growing kids has been amply documented (Arsenos *et al.*, 2009; Ceï *et al.*, 2015, 2018; Torres-Acosta *et al.*, 2012, 2014, 2016). However, there is a lack of information on dairy goats (Fthenakis and Papadopoulos 2018). GIN infection reduces milk production in 10% and milk protein content (Alberti *et al.*, 2012) with negative effects on cheese production industry (Alberti *et al.*, 2014). The anthelmintic drugs for GIN control are becoming less effective. So, GIN anthelmintic resistance is a challenge faced by the world's goat producers (Vercruysse *et al.*, 2018). The use of alternative methods such as vaccines, secondary plant metabolites, copper oxide needles, food supplementation, and nematophagous fungi offer alternative means to goat farmers to control GIN infections (Hoste *et al.*, 2016). However, previously, it is necessary to know the epidemiology of GIN infections in goat flocks (Tariq 2015, Besier *et al.*, 2016). It is necessary to determine the factors associated with the diseases in order to develop adequate control strategies and regulate the potential risk of this infection (Besier *et al.,* 2016). Ambient temperature, humidity, rainfall, altitude and vegetation are climatic and environmental factors associated with GIN infections (Ratanapob *et al.*, 2012; Stadalienė *et al.*, 2015; Zvinorova *et al.*, 2016). There are factors associated with animals such as age, body weight, gender and physiological stage (Yusof and Md Isa 2016; Bihaqi *et al.*, 2017). Other indirect measurements such as body condition score (BCS) and FAMACHA© have also been associated with GIN (Soto-Barrientos *et al.*, 2018). A previous study in semi-arid zones of Mexico showed that Mixed-breed dairy goat flocks had a high prevalence (88.8%) of GIN infections (Olivas-Salazar *et al.*, 2018). The most sensitive breed was Alpine-type and the most resistant was Boer and Anglo-Nubian. The predominant nematodes were *Tricostrongylus colubriformis* and *Haemonchus contortus*. However, there is no information on the influence of climatic and environmental factors of GIN infections in grazing dairy goats in Mexico. The objective of this study was to evaluate some factors associated with the prevalence of GIN infection in mixed-breed dairy goats on semi-arid rangelands in northeastern Mexico.

MATERIALS AND METHODS

Farm selection and study area

The study was carried out at 18 goat farms from different agro-ecological regions on semi-arid rangelands of northeastern Mexico from June to November 2016. Altitude ranged from 1390 to 1680 m above sea level, with an extremely dry climate, with an annual average temperature between 14-19°C, irregular rains of 350-450 mm annually, with the major precipitation from June to October.

The vegetation is a forest, desert rangeland and thorny scrub, characteristic of the Chihuahuan desert. According to the precipitation, there are two seasons: the dry season (November to June) and the rainy season (June to October). The winter generally is dry and cold and the vegetation has poor nutritional value (INEGI 2003).

Prior to the start of the study, the farm's owners completed a questionnaire to verify that they met the inclusion criteria. These criteria were flocks with at least 100 adult goats, and not dewormed in the last six months.

The data of environmental temperature, rainfall and altitude were collected at the meteorological stations located closest to the communities where the goats grazed in the period in which the study was developed.

Animals and their management

Adult mixed-breed goats (n = 668), including different degrees of Boer, Nubian, Alpine, Saanen, and Toggenburg were sampled once from June to November 2016.

The goats grazed daily during seven h (10:00-17:00 h) and were night penned in rustic facilities located adjacent to the house´s owners. Most flocks grazed in communal areas where had contact with other animal species such as horses, cattle, and sheep. Additionally, the goats received supplement with stubble (*Zea maíz*), oat straw (*Avena sativa*) or bean straw (*Phaseolus vulgaris*) during extreme drought.

Live weight, body condition score and FAMACHA©

To determine the goat live weight, the goat was weighed using an electronic scale. The BCS was evaluated according to Honhold *et al*. (1989); goats were classified into five categories (from 1 to 5), where the value 1 is an extremely thin goat with no fat reserves and a BCS of 5 is a very over-conditioned (obese) goat. The FAMACHA© was estimated according to Van Wyk and Bath (2002) by visual examination of the membranes of the ocular mucosa of each goat using a laminated colour chart bearing pictures of goats classified into five categories rank from the normal red, through pink to practically white in severe anaemic animals. Goats were classified into five categories (from 1 to 5), where the value 1 is a mucosa ocular of normal red colour and the value 5 means serious anaemic animals with a pale ocular mucosa.

Faecal egg count, faecal cultures and larvae identification

A faecal sample was taken from the rectum of each goat using a new polyethene bag. The samples were identified and refrigerated until processing. All samples were processed by the McMaster technique to determine the EPG of GIN according to Rodríguez *et al.* (1994) in the Animal Production Laboratory of the Universidad Autonoma Agraria Antonio Narro in Saltillo, Coahuila, Mexico. To identify the GNI genera, a faecal pool copro-culture from each flock was carried out using the Corticelli Lai technique (Corticelli and Lai, 1963), and identification keys described by Van Wyk and Mayhew (2013) were used to identify larvae. The shape of the head and the length of the tail of the larva were the main criteria for identifying the helminths.

Packed cell volume (PCV)

Each goat was blood sampled by jugular venipuncture and collected in tubes with anticoagulant (EDTA) to determine the percentage of packed cell volume (PCV) by means of the microhematocrit technique (Benjamín 1991).

Statistical analysis

Prevalence and 95% confidence intervals were calculated according to Thrusfield (2005) using the frequency procedure of SAS (SAS Proc Freq/binomial; SAS Inst. Inc., Cary, NC, USA). The temperature, rainfall, altitude, BCS, body weight, and age were the independent variables. The response variables were: EPG of GIN, PCV, BCS, and FAMACHA©. The effects of the independent variables on the EPG count and the blood variables were determined using PROC GLM of SAS (SAS 2004). First-level interactions were included in the model. Prior to the analysis, the EPG values were log10 (n+1) transformed. Means were compared with Tuckey´s test and differences were set at P<0.05. The associations between the EPG count of GIN with the PCV, the BCS and the FAMACHA© were determined with Spearman correlations.

RESULTS

Table 1, shows that the prevalence of GIN infections per flock ranged from 64 to 100%. Two herds were free of GIN. The average of EPG of GIN ranged from 305 to 1848 eggs. Table 2, shows that the factors ambient temperature, rainfall, altitude, body weight, and age of goats influenced the EPG, PCV, BCS and FAMACHA© (P<0.05).

The environmental temperature at 14°C resulted in lower excretion of EPG, higher PCV, BCS, and lower FAMACHA© compared to goats raised in places with 16°C and 19°C (P<0.05). Lower annual precipitation (350 mm) was related with a lower EPG, higher PCV, BCS and lower FAMACHA© compared to goats raised in places with higher precipitation (450 mm) (P<0.05). Goats located at altitudes greater than 1560 masl showed lower EPG counts, higher PCV, and lower FAMACHA© compared to goats grazing at altitudes of 1390-1400 masl (P<0.05). There was a negative relationship between live weight and EPG counts (P<0.05). Goats <38kg LW had higher EPG count and lower values of PCV, BCS and higher FAMACHA©. Regarding age, goats >5 years had higher EPG count and lower BCS, PCV and higher FAMACHA© (P<0.05). Table 3 shows that 45% of goats presented <500 EPG and close to 21% had >1000 EPG (considered a GIN serious infection).

The correlations between EPG and FAMACHA©; EPG and BCS; EPG and PCV were 0.58, -0.55 and -0.55, respectively (P<0.01). Correlations between FAMACHA© and PCV and BCS were -0.69 and -0.66, respectively (P<0.01). The increase in the level of infection with GIN (EPG counts) presented a negative association (P<0.01) with BCS and the percentage of PCV and positive with the FAMACHA© (Figure 1). Higher BCS positively influenced PVC and negatively affected EPG (Figure 2).

Table 1. Prevalence of gastrointestinal nematodes infection and eggs per gram of faeces of gastrointestinal nematodes (EPG of GIN) on goat herds under extensive grazing condition in semi-arid zones of northeastern Mexico.

Flock number	Goat					EPG of GIN		
	Population	Sampled	Positive	Prevalence	95% IC	Mean±SD	Median	Range
1	220	54	48	88.9	77.4-95.8	1165.7±1674.4	750	0-9900
2	205	50	40	80.0	66.3-96.0	593.0±578.6	450	0-2150
3	175	43	43	100.0	91.8-100	1208.1±1018.9	1000	50-3700
4	122	30	25	83.3	65.3-94.4	480.0±661.1	150	0-2600
5	128	31	30	96.8	83.3-99.9	814.5±684.0	550	0-2350
6	160	40	37	92.5	79.6-98.9	366.3±361.7	300	0-1700
7	165	40	35	87.5	73.2-95.8	470.0±468.1	375	0-2000
8	108	28	23	82.1	63.9-93.9	346.4±369.4	200	0-1300
9	120	30	29	96.7	82.8-99.9	553.3±415.8	450	0-1600
10	92	25	24	96.0	79.6-99.9	1848.0±2802.4	650	0-11600
11	110	27	26	96.3	81.6-99.9	401.9±281.6	300	0-1150
12	122	30	30	100.0	88.4-100	485.0±393.1	475	50-1250
13	159	42	37	88.1	74.4-96.0	364.3±369.8	200	0-1350
14	205	50	32	64.0	49.2-77.1	305.0±398.5	125	0-1350
15	190	48	44	91.7	80.0-97.7	908.3±831.7	725	0-3450
16	212	50	50	100.0	92.9-100	740.0±967.4	425	50-5400
17	98	25	0	0.0	-	0.0	0	0
18	108	25	0	0.0	-	0.0	0	0
Total	2699	668	553	82.8	79.7-85.6		350	0-11600

Table 2. Influence of climatic (temperature, rainfall, altitude) and animal (weight and age) factors on the count of eggs per gram of faeces (EPG), packed cell volume (PCV), body condition score (BCS) and FAMACHA© (FAM) in goats under extensive grazing condition in semi-arid areas of northeastern Mexico.

		EPG				PCV		BCS		FAM	
FACTOR	N	Media±SD		Median	Range	Media±SD		Media±SD		Media±SD	
Temperature											
14ºC	80	418.12±418.87	ab	350	0-2000	31.99±5.20	a	2.51±0.55	a	2.76±0.69	b
16ºC	258	713.95±1053.07	b	350	0-9900	25.54±6.05	b	2.17±0.80	b	2.99±0.70	a
19ºC	330	633.48±1030.83	a	325	0-11600	25.09 ± 6.05	b	1.96±0.73	c	3.10±0.72	a
Rainfall (mm)											
350	133	545.11±1391.50	b	100	0-11600	29.06±7.04	b	2.17±0.75	b	2.84±0.72	b
390-400	455	704.95±911.65	a	400	0-9900	24.19±5.25	c	2.01±0.76	b	3.11±0.70	a
450	80	418.13±418.88	b	350	0-2000	31.99 ± 5.20	a	2.51±0.55	a	2.76±0.69	b
Altitude (masl)											
1390-1400	133	885.57±1106.39	a	250	0-11600	29.06±7.04	a	2.17±0.75	a	2.84±0.72	b
1560-1600	208	519.87±622.65	b	550	0-9900	24.94±5.91	b	2.00±0.78	a	3.08±0.69	a
1655-1680	327	545.11±1391.50	b	300	0-2000	25.62±5.94	b	2.14±0.73	a	3.05±0.73	a
Weight											
<38 kg	221	1055.65±1373.43	a	350	0-11600	24.02±6.74	c	1.69±0.73	c	3.38±0.70	a
38-44 kg	221	543.21±667.04	b	350	0-9900	26.26±5.97	b	2.13±0.69	b	2.96±0.65	b
>44 kg	226	324.55±589.58	c	250	0-6250	27.96±5.66	a	2.49±0.62	a	2.73±0.64	c
Age											
1-2 años	144	648.95±1075.93	b	375	0-9900	27.59±7.20	a	2.15±0.77	a	2.93±0.80	b
3 años	170	597.05±886.14	b	300	0-7500	26.53±6.14	ab	2.17±0.75	a	2.95±0.70	b
4 años	268	597.94±769.16	b	300	0-5400	25.27±5.81	b	2.11±0.74	a	3.05±0.70	ab
>5 años	86	831.39±1509.46	a	450	0-11600	25.27±6.33	b	1.88±0.74	b	3.19±0.62	ab

a,b Means with the same literal in the column do not differ ($P < 0.05$).

Table 3. Effect of eggs per gram of faeces of gastrointestinal nematodes (EPG of GIN) on packed cell volume (PCV), body condition score (BCS) and FAMACHA© (FAM) on goats under extensive grazing in semi-arid areas of northeastern Mexico.

	Goats		EPG of GIN			PCV	BCS	FAM
FACTOR	N	%	Mean±SD	Median	Range	Mean±SD	Mean±SD	Mean±SD
EPG								
0	115	17.28	-	-	-	29.17±5.88 a	2.66±0.54 a	2.58±0.57 d
50-500	295	44.16	-	-	-	28.55±5.73 a	2.32±0.63 b	2.74±0.59 c
501-1000	116	17.36	-	-	-	23.75±5.13 b	1.81±0.70 c	3.35±0.63 b
>1000	142	21.25	-	-	-	20.40±3.83 c	1.45±0.63 d	3.67±0.53 a
FAMACHA©								
1-2	167	25.0	190.41±292.0 c	100	0-1700	31.75±5.37 a	2.90±0.66 a	-
3	319	47.75	443.88±582.1 b	250	0-5000	26.60±4.98 b	2.25±0.66 b	-
4-5	182	27.24	1391.75±1454.7 a	1100	0-11600	20.01±3.51 c	1.34±0.58 c	-
BCS								
1	160	23.95	1426.56±1561.27 a	1100	0-11600	20.64±4.59 d	-	3.78±0.53 a
2	275	41.16	524.18±579.63 b	350	0-3700	26.72±6.07 c	-	3.01±0.60 b
3	193	28.89	258.80±389.94 c	100	0-2750	28.78±5.07 b	-	2.45±0.67 c
4	40	5.98	108.75±277.09 d	100	0-2000	30.59±5.83 a	-	2.15±0.76 d

a,b Means with the same literal in the column do not differ (P <0.05).

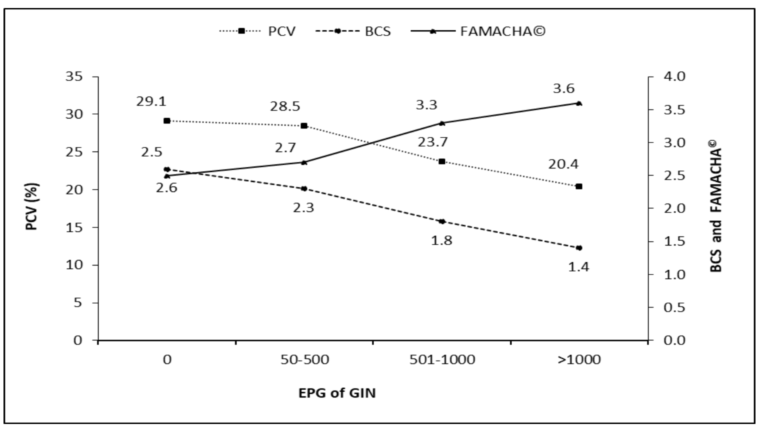

Figure 1. The relationship between eggs per gram of faeces of gastrointestinal nematodes (EPG of GIN) with package cell volume (PCV), body condition score (BCS) and FAMACHA© on dairy goats under extensive grazing in semi-arid areas of Northeastern Mexico (P<0.01).

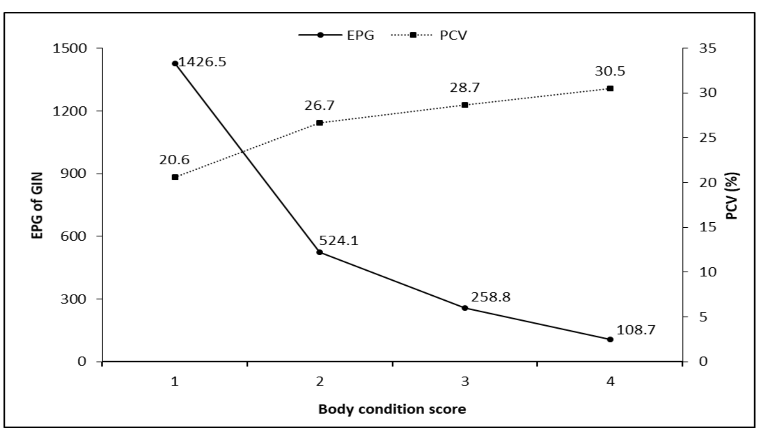

Figure 2. The relationship between body condition score with the eggs per gram of faeces of gastrointestinal nematodes (EPG of GIN) and packed cell volume (PCV) on dairy goats under extensive grazing condition in semi-arid areas of Northeastern Mexico (P<0.01).

DISCUSSION

This is the first survey assessing the effect of climatic and animal factors on the prevalence of GIN infections in mixed-breed dairy goat grazing in semi-arid rangelands of northern Mexico. This is useful to characterize the GIN epidemiology in this type of production system in grazing goats (Kyrianova *et al.*, 2017; Charlier *et al.*, 2018; Olivas-Salazar *et al.*, 2018; Fthenakis and Papadopoulos 2018). The results showed that 88.9% of the flocks were infected with GIN. The 82.8% of the goats harbour at least one parasite (*Tricrostrongylus spp* and *Haemonchus spp*). Other studies in dairy goat herds in Italy, Argentina, France, Slovakia and Austria have shown GIN infections prevalence of 42 to 100% with EPG counts similar to the present study (Alberti *et al.*, 2012, 2014; Zanzani *et al.*, 2014; Babják *et al.*, 2017; Suarez *et al.*, 2017; Lambertz *et al.*, 2018). Kyriánová *et al.* (2017) reported GIN infection prevalence of 99% in dairy goats with counts of 9900 EPG. In Thailand, Ratanapob *et al.* (2012), reported a prevalence of 79.4% in meat goat with 1176 EPG. The present study showed a higher EPG count compared to previous studies. The explanation of present results could be for the continuous exposure of goats to parasites in this region and the intermingling of goats while grazing or drinking water, as well as the closeness of goats with equines, cattle and sheep with which share the rangeland. Farmers in semi-arid zones of Mexico have low economic resources (Salinas-González *et al.*, 2016). The use of anthelminthic drugs to control GIN infections in these farms is limited, so, it is important to identify the factors associated with GIN infections in each flock, where the interaction of climatic condition, the parasites and host immunity are crucial (Besier *et al.*, 2016; Greer and Hamie 2016; Sweeney *et al.*, 2016).

Climatic and soil conditions

The temperature in the region fluctuated from 14 to 19°C around the year. The EPG counts were lower at temperatures of 14 and 19ºC compared to 16ºC. Both temperature and moisture are important factors influencing the growth of the free-living stages of GIN of ruminants. There is a relationship between ambient temperature and *trichostrogylide* present in the grass (O'Connor *et al.*, 2006; Molento *et al.*, 2016). Regarding annual rainfall, in this study, the highest excretion of EPG occurred in goats grazing in areas with higher rainfall. The interaction between the moisture with temperature generated an environment that enhances the development of GIN larvae and sustains the survival of infective larvae, leading to high contamination of the grasses. However, this association varies according to the parasitic species (Molento *et al.*, 2016). For the larvae L3 of *H. contortus* development, it is necessary high temperatures and high relative humidity (30-40°C and 80-90%), respectively, while for *T. colubriformis spp.* temperatures of 24°C or less are required (Molento *et al.*, 2016). Temperatures in the communities of the present study were below 24°C, which explains the high prevalence of larvae of *Trichostrongylus* and to a lesser extent of *Hemonchus spp*. The altitude influenced significantly the parasitic load in the goat herds of this study. At higher altitudes (above 1655 masl), the EPG count was significantly low with a better percentage of PCV and better BCS compared to the values shown in goats raised at altitudes below 1400 masl (P <0.05). These results could be explained for the differences in rainfall, the availability of nutrients, and the vegetation type present in the rangelands (Molento *et al.*, 2016). At high altitude, the flock have less pasture contaminated with GIN larvae because of with the rains there is a runoff of water that drags the faces towards the lower altitude zones. This condition increases the pasture infestation with GIN and consequently the goats load more GIN larvae.

The regions with altitudes higher than 1655 masl of the present study, the predominant type of vegetation are the pine forest, which is characterized by having quite varied vegetation. The main tree species of the pine forest are *Pinus cembroides*, *P. greggii*, *Juniperus flaccida* and *J. deppeana*, and *Arbutus xalapensis*. It is often associated with species such as *Yucca carnerosana*, *Yucca filifera*, *Agave spp.* and diverse bushes. While at altitudes of less than 1400 masl, the predominant type of vegetation is the unarm parvifolio scrub where there are abundant shrub species one to two meters high, generally devoid of thorns and with small leaves and leaflets. Among the most important plant species are: *Larrea tridentata, Flourencia cernua, Yucca filifera;* grassland such as *Trichachne californica* and *Hilaria mutica*; Shrubs of *Atriplex canescens, Castela texana, Acacia farnesiana, Prosopis juliflora, Agave lecheguilla, Parthenium incanum, Fouquieria splendens, Acacia constricta, Porliera angustifolia, Opuntia spp., O. imbricata, Jatropha spathulata, Buddleia marrubifoliá, Acacia greggii, Agave asperrima* and others.

The low availability of resources can lead to less food for the goat and the parasite (Kyriazakis *et al.,*, 1998), which could alter the physiological and behavioural mechanisms related to goat defences against parasites. Cotter *et al.* (2011) indicated that immune traits are influenced by the macronutrient content of the diet. Host resistance and the tolerance of parasitic worms depend on the availability of food resources. In general, the high availability of resources increases the resistance to infection and the tolerance once infected, but the cost will be a reduced resistance to the establishment of parasites (Knutie *et al.*, 2017).

Animal factors

This study revealed that the heavier goats showed lower excretion of EPG and higher values of PCV, BCS and lower FAMACHA©. A similar result was reported for Dilgasa *et al.* (2015), who found that well-fed animals develop good immunity that reduces the fecundity of GIN. Yimer and Birhan (2016), observed a significant difference in GIN infection prevalence associated with BCS. They reported that EPG counts were higher in goats with poor BCS (37%) compared to animals with medium (30.5%) and good BCS (3.4%).

Age is a factor associated with GIN infections. In the present study, the older goats had a significantly higher EPG count. Similar results were reported for Bihaqi *et al.* (2017). They found higher GIN prevalence in adult goats (72.63%) than young one (64.19%). Likewise, Yusof and Md Isa (2016) had similar GIN prevalence results by age groups, with 53.1, 87.8 and 86.4% for goats under one year, between one and two years and older than 2 years, respectively. Similarly, Torres-Acosta *et al.* (2014) in the tropics, obtained values of EPG by age as follows: <1 year, 234, 2-3 years, 776, 3-4 years, 295, and >4 years, 331. In contrary, Dilgasa *et al.* (2015) showed that goats under 2 years had a higher incidence of GIN (77.1%) compared to 4-years-old goats (36.3%). Older animals become susceptible to diseases because of the reduction of the immune response against pathogens present in the herd as reported in goats and sheep (Greer and Hamie 2016)

Correlations EPG/PCV/BCS/FAMACHA©

In the present study, a negative correlation between EPG with PCV and BCS; and a positive correlation with FAMACHA© were obtained Under tropical conditions, Torres-Acosta *et al.* (2014) recommend the combined use of EPG, BCS and FAMACHA© as a screening procedure to identify animals at risk of severe GIN infections. The evaluation of EPG helps to reduce the number of goats treated with anthelmintic per year, without negative consequences in goat productivity. The results in semiarid zones of Mexico show the opportunity to establish the same methodology to control GIN infection in the mixed-breed goat flocks.

CONCLUSIONS

According to the study, the prevalence of infections with GIN in mixed-breeds dairy goat was high. The BCS, live weight, ambient temperature, rainfall, and altitude were factors that influenced the GIN infections on goats grazing on semi-arid rangeland of northeastern Mexico.
Goat producers would benefit identifying to discard or treat old goats and goats with poor body condition score, as these animals are more susceptible to present higher GIN loads.

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Conflict of interest
The authors declare that they have no competing interests.

Ethical approval
The Bioethics Committee of the Faculty of Veterinary Medicine of the Autonomous University of Sinaloa, Mexico, approved the present study for its development. This article does not contain any studies performed with human subjects.

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