Research paper

Is the Famacha© system always the best criterion for targeted selective treatment for the control of haemonchosis in growing lambs?

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ARTICLE INFO	ABSTRACT
	Targeted selective treatment (TST) aims to aid in the control of gastrointestinal nematodes in small ruminants, identifying animals that require treatment with the purpose of preserving the *Refugia* population and delaying the buildup of anthelmintic (AH) resistance. The objective of this study was to evaluate the effectiveness of both productive and clinical indicators in the selective treatment of gastrointestinal parasites in growing lambs. Two experiments were carried out between 2015 and 2016. Experiment 1: lambs (n = 70) exclusively raised on pasture were evaluated from the ages of 60 days to 180 days old. Experiment 2: lambs (n = 48) raised on pasture and fed concentrated commercial supplementation were evaluated from the ages of 60 days to 150 days old. Parasitological (eggs per gram of feces - EPG), productive (average daily weight gain - DWG), and clinical (hematocrit - Ht and FAMACHA© system - F) parameters were measured every 14 days. The lambs were divided into 4 experimental groups with different criteria for AH treatment: the control group (CG), was treated with AH every 30 days; the FAMACHA© group (FG), in which lambs classified as F3, F4, and F5 were treated with AH; Daily weight gain group (DWGG), in which lambs with average DWG ≤ the average DWG of the CG minus one standard deviation were treated with AH; FAMACHA© + daily weight gain group (FDWGG), in which lambs classified as F3, F4 and F5 and/or lambs with average DWG ≤ the average DWG of the CG minus one standard deviation were treated with AH. In experiment 1, no significant differences in the general means of DWG and Ht (p > 0.05) were observed between experimental groups, although the lowest mean EPG was observed in the CG (p < 0.05). In experiment 2, the lowest mean EPG (p < 0.05) was also observed in the CG (1044.5 EPG), and the highest mean (p < 0.05) in the FG (4845.5 EPG). There were differences in the mean DWG of the CG (198.4 g) and FDWGG (200.0 g), which were both higher (p < 0.05) than that of the FG (90.5 g), and similar (p > 0.05) to the DWGG (151.8 g). In both experiments, considering the total mean number of AH treatments, FG had the lowest number of lambs treated with AH (p < 0.05), with the DWG and FDWGG being similar to each other (p > 0.05). Even when *Haemonchus* is the major parasite, it is not recommended to use the FAMACHA© system as an exclusive criterion for TST in growing lambs. The DWG productive criterion can be used effectively in the TST of growing lambs.

1. Introduction

The intensive use of anthelmintics (AH) has caused an increase in parasite resistance, which has become a problem in sheep production reported worldwide (Papadopoulos, 2008; Torres-Acosta et al., 2012; Van den Brom et al., 2015; Salgado and Santos, 2016).

Some alternative countermeasures are commonly adopted to control parasites in small ruminants, including targeted selective treatment (TST). TST consists of diagnosing animals that require treatment with

AH in order to decrease treatment frequency and, consequently, to increase the *Refugia* population and prevent the development of resistance to AH (Van Wyk, 2001; Kenyon et al., 2009).

In TST, clinical, productive, and parasitological indicators can be used in the diagnosis of animals that need treatment, such as the FAMACHA© system, body condition score, diarrhea score, presence of submandibular edema, and decreases in productivity (Bath and Van Wyk, 2009; Cringoli et al., 2009; Stafford et al., 2009; Busin et al., 2014; Cornelius et al., 2014). An ideal indicator for use in TST would be

cost-effective, simple to use, require minimal operator training, and allow treatment decisions to be made "sheep-side" or "pen-side," so that, at the time of evaluation of an animal, a response is obtained regardless of whether or not it needs treatment (Kenyon et al., 2009; Bath and Van Wyk, 2009).

The success of these indicators also depends on their correct use. For example, the FAMACHA© system is used in regions where *Haemonchus contortus* is prevalent and was developed to diagnose anemia in small ruminants. It should not be used as a selective criterion in the diagnosis of non-hematophagous parasites (Van Wyk and Bath, 2002). In contrast, the diarrhea score and body condition score, as well as declines in productivity, can be used to diagnose both hematophagous and non-hematophagous parasites (Bath and Van Wyk, 2009; Greer et al., 2009).

In adult sheep produced in regions where *H. contortus* is the most common parasite, the FAMACHA© system is considered one of the best TST criteria in ewes (Van Wyk et al., 2006; Molento et al., 2009; Leask et al., 2013; Sotomaior and Cintra, 2018). In lambs, however, there is little information on whether the FAMACHA© system would be as effective criterion for TST in lambs as it is in ewes.

The present study aimed to evaluate the effectiveness of a clinical criterion (FAMACHA© system), a productive criterion (mean daily gain of weight - DWG), and a combination of both, in the selective treatment of gastrointestinal nematodes in growing lambs.

2. Methodology

2.1. Experimental design

The present study was approved by the Ethics Committee on the Use of Animals (CEUA) of the Pontifical Catholic University of Paraná (PUCPR) under number 0993/2015.

Two experiments were carried out between the years of 2015 and 2016. Experiment 1 was carried out on a commercial farm located in the county of Castro, Paraná, between July 2015 and January 2016. We used 42 Ile de France lambs and 28 Texel lambs, each 60 days of age (beginning of the experiment – D60), which were evaluated over a period of 180 days or until they reached slaughter weight (38/40 kg). The ewes and lambs were exclusively grazed on a pasture composed predominantly of ryegrass, at a density of approximately 70 animals/ha, although there was some variation in stocking during the experiment. The lambs were weaned at approximately 90 days of age, when the mothers were removed from the lot and the weaned lambs remained with other lambs and ewes. The suckling lambs received commercial rations from creep-feeders located in the pasture. On rainy days, the animals received no supplementation. The AH used in TST was monepantel (Zolvix®, Novartis Saúde Animal, Brazil) and had never been used at the farm prior to the experiment. The dosage was 2.5 mg/kg, which was delivered orally.

Experiment 2 was carried out in the sheep farming sector of the university farm of the Pontifical Catholic University of Paraná, located in the county of Fazenda Rio Grande, Paraná, between August 2015 and March 2016. Crossbred lambs (n = 48) of the Texel and Ile de France breeds (60 days old, start of the experiment - D60) were monitored for 150 days or until they reached 40 kg, whichever occurred first. The lambs, weaned at a mean age of 60 days, were kept in a semi-intensive system, remaining in paddocks of native pasture during the day (approximately 50 animals/ha) and being housed in collective pens at the end of the day, where they received supplementation (commercial sheep feed) equal to 2% of the average live weight of the lambs. In this herd, the fecal egg count reduction test (FECRT) (Coles et al., 2006) was performed. The active ingredient levamisole, which can produce a 95% reduction in FECRT, was the one applied in TST, subcutaneously, at the dose of 9.4 mg/kg (Ripercol ® ʟ-150 F, Zoetis Indústria de Produtos Veterinários Ltda, Brazil).

Both experiments used the same methodology, and the parasitological, hematological, productive, and clinical evaluations were performed every two weeks.

In order to evaluate the efficiency of TST, we used several analytical parameters: lamb weight was used to assess productivity; EPG was used to assess the extent of parasitic infection; Ht was used as an indication of the health of the animal; and the number of treatments with AH was also recorded, in order to compare the groups.

2.2. Parasitological, hematological, productive, and clinical evaluations

For the parasitological analyzes, the animals were individually contained and feces were collected using plastic gloves directly from the rectal ampulla. Fecal samples were used to obtain the egg per gram of feces (EPG) count, in accordance with the methods of Gordon and Withlock (1939), sensitive to 50 EPG. For the analysis of the results, we considered only eggs of strongylids. The culture and identification of larvae was performed monthly, pooled across all groups, according to the methods of Roberts and O'Sullivan (1950).

To determine the globular volume or hematocrit (Ht), blood samples were collected from the external jugular vein in tubes containing EDTA as an anticoagulant. Samples were homogenized, identified, and sent to the laboratory for routine microhematocrit examination, according to the methods of Jain (1986).

Analysis of productivity consisted of monitoring the weight of the lambs, which were weighed every 14 days. Mean daily weight gain (DWG) was calculated using the formula: DWG = previous weight - day weight / 14.

For the evaluation of the FAMACHA© system (F), the animals were manually contained and evaluated by comparing the color of the conjunctiva of the lower eyelid against the colors on the chart (F1 to F5) as described by Van Wyk and Bath (2002).

2.3. Experimental groups

In both experiments, the lambs were divided into 4 experimental groups according to their gender, breed, and initial weight, ensuring homogeneity between the groups. Treatment with AH (Experiment 1: monepantel - 2.5 mg/kg, orally, Zolvix®, and experiment 2: levamisole - 9.4 mg/kg subcutaneously, Ripercol® ʟ-150 F) was implemented for each group according to the different criteria (productive, clinical, and systematic). The experimental groups, according to treatment criteria established for each group, were:

CG (Control Group): Treatment with AH every 30 days.

FG (FAMACHA© Group): Treatment with AH for the lambs classified as F3, F4, and F5 in evaluations.

DWGG (Daily weight gain Group): Treatment with AH for lambs with average DWG ≤ than the average DWG of the CG minus one standard deviation.

FDWGG (FAMACHA© + daily weight gain Group): Treatment with AH for lambs classified as F3, F4, and F5 and/or with DWG ≤ DWG of the CG minus one standard deviation.

In both experiments, lambs belonging to the CG were treated with AH whilst 60 days old (the beginning of the experiment), whereas for the other groups, each one followed the specific treatment criterion.

As the animals in the CG were treated every 30 days with AH, this group was the DWG model for the other groups. Once the mean DWG minus the standard deviation of the CG was calculated, this value was used as the treatment criterion for the DWGG and FDWGG. The DWG of the CG was calculated separately for each breed in experiment 1.

2.4. Analysis of the data

The data from the lambs was grouped by age into the following categories: 60, 75, 90, 105, 120, 135, 150, 165, and 180 days old within each group (CG, FG, DWGG, FDWGG). Following this grouping the data was then analyzed.

In the analysis of the percentage of lambs treated with AH in each

Table 1
Means and standard deviations of live weight (kg) of lambs in each of the experimental groups (CG - control group, FG - FAMACHA[©] group, DWGG - daily weight gain group, FDWGG - FAMACHA[©] + gain of daily weight group), according to age.

Age (days)	CG	FG	DWGG	FDWGG
Experiment 1				
60	19.0 ± 3.9 [aA]	19.3 ± 3.6 [aA]	19.9 ± 3.6 [aA]	19.7 ± 3.6 [aA]
75	21.4 ± 3.5 [aA]	21.2 ± 4.2 [aA]	22.4 ± 3.6 [aA]	21.8 ± 4.3 [aA]
90	23.3 ± 3.6 [aAB]	23.2 ± 4.0 [aA]	24.0 ± 4.1 [aA]	23.8 ± 4.3 [aAB]
105	26.1 ± 4.9 [aABC]	25.4 ± 4.3 [aAB]	25.7 ± 4.3 [aAB]	25.6 ± 5.2 [aABC]
120	27.8 ± 4.4 [aBCD]	28.1 ± 4.7 [aBC]	28.1 ± 4.3 [aBC]	27.6 ± 4.9 [aBCD]
135	29.2 ± 4.4 [aBCD]	29.7 ± 5.0 [aBCD]	30.1 ± 4.3 [aCD]	29.1 ± 5.3 [aCDE]
150	30.9 ± 5.4 [aCD]	30.8 ± 5.3 [aCD]	31.3 ± 4.5 [aCD]	30.3 ± 5.6 [aCDE]
165	31.8 ± 5.2 [aCD]	31.8 ± 5.1 [aCD]	33.0 ± 4.7 [aD]	31.3 ± 5.8 [aDE]
180	34.2 ± 5.9 [aD]	32.9 ± 5.5 [aD]	33.5 ± 3.6 [aD]	33.4 ± 5.1 [aE]
Mean	26.6 ± 6.3 [a]	26.9 ± 6.5 [a]	27.3 ± 6.1 [a]	26.9 ± 6.3 [a]
Experiment 2				
60	24.0 ± 6.0 [aA]	24.6 ± 4.8 [aA]	24.4 ± 5.0 [aA]	26.5 ± 4.7 [aA]
75	26.1 ± 6.7 [aAB]	26.0 ± 5.3 [aA]	26.4 ± 5.2 [aAB]	28.1 ± 4.4 [aAB]
90	28.0 ± 7.1 [aABC]	26.5 ± 6.6 [aA]	27.3 ± 5.8 [aAB]	29.6 ± 5.3 [aAB]
105	31.1 ± 7.4 [aBCD]	27.4 ± 6.8 [aA]	29.5 ± 6.2 [aABC]	32.0 ± 5.2 [aBC]
120	34.3 ± 8.3 [bCD]	27.8 ± 6.1 [aAB]	31.0 ± 6.2 [abBCD]	34.6 ± 4.5 [bCD]
135	35.2 ± 7.8 [aD]	30.0 ± 7.6 [aAB]	34.8 ± 7.5 [aCD]	36.5 ± 5.4 [aDE]
150	38.1 ± 10.1 [aD]	33.5 ± 8.8 [aB]	36.5 ± 8.2 [aD]	39.3 ± 4.8 [aE]
Mean	30.4 ± 8.6 [b]	27.9 ± 7.0 [a]	29.9 ± 7.4 [ab]	32.2 ± 6.4 [b]

Means with different capital letters in the column indicate statistical difference (p < 0.05) by the Tukey test.
Means with different lowercase letters in the row indicate statistical difference (p < 0.05) by the Tukey test.
Groups: Control group (CG) - treatment with anthelminthic (AH) every 30 days; Famacha[©] group (FG) - treatment with AH for lambs classified as F3, F4 and F5; Daily weight gain group (DWGG) - treatment with AH for lambs with mean daily weight gain (DWG) ≤ than the mean DWG minus one standard deviation of the CG; Famacha[©] + DWG group (FDWGG) - treatment with AH for lambs classified as F3, F4, and F5 and/or DWG ≤ than the mean of DWG minus one standard deviation of the CG.

group, the number of animals treated in two evaluations was added (sum of 30 days) to allow proper comparison with the CG, in which the lambs were treated every 30 days.

2.5. Statistical analyses

For the statistical analysis of the quantitative data, analysis of variance (ANOVA) was performed, when homogeneity of variance was observed by mean of Levene's test, followed by the Tukey test, with a significance level of 5%. Qualitative analyses were evaluated using the chi-square test (p = 0.05). Both analyses were performed using the statistical software Statgraphics[©] 4.1.

3. Results

In experiment 1, the initial mean body weight of lambs (60 days old) was 19.5 kg, and by the end of the experiment (180 days old) the mean weight was 33.5 kg. There was no difference in mean weight over time between the groups (p > 0.05), however, as time passed, significant (p < 0.05) increases in weight were observed within each group (Table 1). The mean DWG of these lambs was 113.7 g.

In experiment 2, the lambs started the experiment (60 days old) with a mean weight of 24.9 kg (p > 0.05) and ended with a mean weight of 36.9 kg when 150 days old. However, weights differed between groups. The FDWGG and CG had higher weight values (p < 0.05) than the FG, in which weight was similar to that in the DWGG (p > 0.05), as shown in Table 1. The mean DWG of all lambs was 160.1 g.

In experiments 1 and 2, when EPG values were compared between groups in the first evaluation, there was no difference (p > 0.05), except in the FG in experiment 1, which had a lower mean EPG when compared to the CG. Since the CG was treated on day 60, there was a significant decrease (p < 0.05) in the EPG on day 75 in both experiments (Table 2). Based on these results, it was possible to calculate that the rate of EPG count reduction in animals treated with monepantel in experiment 1 was 95.5%. Similarly, in experiment 2 following treatment with levamisole, the rate of reduction was 94.9%.

During experiment 1, there was some variation in mean EPG within the groups, however, this variation was not significant (p > 0.05). Comparing groups, there were some differences throughout the experiment, and the overall mean in the CG was similar (p > 0.05) to the FG and DWGG but lower (p < 0.05) than that of the FDWGG (Table 2).

In experiment 2, there were significant differences in the EPG both within and between groups (p < 0.05) (Table 2). Lambs from the CG had the smallest parasitic load based on overall mean EPG (p < 0.05), whilst the DWGG and FDWGG had similar means (p > 0.05) which were lower than the mean for the FG (p < 0.05).

In both experiments, the results of Ht analyses were inversely proportional to the EPG results in most cases. The groups started the experiments with similar Ht values between all groups (p > 0.05). The general mean of all evaluations in experiment 1 showed no significant difference in Ht values between groups (p > 0.05). In contrast, in experiment 2, the FDWGG and CG had the highest Ht averages, with mean values in the FG being the lowest (p < 0.05) (Table 3).

For evaluations of the FAMACHA[©] system, in experiment 1, no lambs were found which could be classified as F4 or F5. The highest proportion of F1 lambs was found in the CG, although this proportion was statistically similar to those of the other groups (p > 0.05). However, the proportion of F2 in the CG was lower (p < 0.05) than in other groups. Few lambs were diagnosed as anemic (F3), and anemia was only observed in the FG and FDWGG (Table 4).

In experiment 2, only one F4 lamb was found in the FG. In the same group, a higher percentage (p < 0.05) of lambs diagnosed with F2 and F3 (Table 4) was observed when compared to the CG and FDWGG. The CG had a higher percentage of F1 lambs in relation to the FG (p < 0.05), which was statistically equal (p > 0.05) to the percentage of F1 lambs in the DWGG and FDWGG.

In both experiments, the CG had more lambs requiring treatment with AH than any other group (p < 0.05) in all periods evaluated, since all the lambs in this group were treated monthly. In experiment 2, fewer lambs were treated with AH in the FG than in the other groups (p < 0.05). In the total percentage, the groups that had DWG criteria for treatment were equal (p > 0.05) in the number of treatments, but higher (p < 0.05) to FG and lower than CG (p < 0.05) (Table 5).

Table 2
Means and standard deviations of the number of strongylid eggs per gram (EPG) for lambs in each of the experimental groups (CG - control group, FG - FAMACHA© group, DWGG - daily weight gain group, FDWGG - FAMACHA© + daily weight gain group), according to age.

Age (days)	CG	FG	DWGG	FDWGG
Experiment 1				
60	2830.0 ± 3088.7 [bB]	911.9 ± 888.6 [aA]	1258.6 ± 1188.4 [abA]	1490.4 ± 1668.7 [abA]
75	127.2 ± 287.5 [aA]	902.2 ± 1550.1 [aA]	800.0 ± 952.9 [aA]	934.7 ± 1329.3 [aA]
90	263.6 ± 347.9 [bA]	679.5 ± 685.8 [abA]	635.4 ± 670.8 [abA]	888.6 ± 1094.8 [aA]
105	50.0 ± 74.1 [bA]	975.0 ± 906.6 [aA]	604.5 ± 780.2 [abA]	1077.2 ± 1956.4 [aA]
120	272.7 ± 350.2 [bA]	928.2 ± 1108.1 [aA]	447.8 ± 398.7 [abA]	795.4 ± 934.8 [abA]
135	188.8 ± 362.9 [bA]	1066.6 ± 1319.0 [aA]	634.0 ± 899.9 [abA]	682.6 ± 797.0 [abA]
150	366.6 ± 360.5 [aA]	833.3 ± 687.4 [aA]	1059.0 ± 1986.6 [aA]	615.0 ± 717.1 [aA]
165	187.5 ± 356.3 [aA]	1264.2 ± 1410.7 [aA]	390.9 ± 661.1 [aA]	1109.0 ± 2206.0 [aA]
180	221.4 ± 282.6 [aA]	710.0 ± 473.1 [aA]	847.3 ± 1844.6 [aA]	1197.7 ± 1759.5 [aA]
Mean	508.0 ± 1311.0 [a]	919.1 ± 1055.8 [ab]	800.2 ± 1338.7 [ab]	976.7 ± 1467.7 [b]
Experiment 2				
60	3137.5 ± 3298.9 [aB]	2333.3 ± 3048.4 [aA]	2733.3 ± 4086.4 [aA]	4479.1 ± 5314.1 [aAB]
75	159.9 ± 1443.5 [aA]	6195.8 ± 5851.0 [bAB]	3191.6 ± 3033.2 [abA]	3237.5 ± 4570.8 [abAB]
90	1554.1 ± 2170.2 [aA]	9925.0 ± 7620.8 [bB]	4937.5 ± 6995.8 [abA]	5837.5 ± 7268.0 [abB]
105	16.6 ± 32.5 [aA]	3995.8 ± 5534.7 [aA]	3258.3 ± 5961.0 [aA]	2877.2 ± 4862.4 [aAB]
120	1131.8 ± 921.7 [aA]	3631.8 ± 4188.5 [bA]	854.5 ± 1051.3 [aA]	845.0 ± 914.8 [aA]
135	55.5 ± 113.0 [aA]	5255.0 ± 7245.8 [bAB]	2786.3 ± 4642.5 [abA]	571.0 ± 770.0 [aA]
150	841.6 ± 923.2 [aA]	2090.0 ± 2562.2 [aA]	2795.0 ± 3753.9 [aA]	1083.3 ± 1671.8 [aA]
Mean	1044.5 ± 1983.7 [a]	4845.5 ± 5852.2 [c]	2968.1 ± 4592.4 [b]	2871.1 ± 4696.3 [b]

Means with different capital letters in the column indicate statistical difference ($p < 0.05$) by the Tukey test.
Means with different lowercase letters in the row indicate statistical difference ($p < 0.05$) by the Tukey test.
Groups: Control group (CG) - treatment with anthelminthic (AH) every 30 days; Famacha© group (FG) - treatment with AH for lambs classified as F3, F4 and F5; Daily weight gain group (DWGG) - treatment with AH for lambs with mean daily weight gain (DWG) ≤ than the mean DWG minus one standard deviation of the CG; Famacha© + DWG group (FDWGG) - treatment with AH for lambs classified as F3, F4, and F5 and/or DWG ≤ than the mean of DWG minus one standard deviation of the CG.

The highest percentage of larvae found in the coprocultures was *Haemonchus* spp. larvae in both farms. Other larvae found were *Trichostrongylus* spp. and *Oesophagostomum* spp. (Fig. 1).

4. Discussion

The main objective of TST is to preserve the *Refugia* population in order to retard the buildup of AH resistance and to control verminosis (Bath and Van Wyk, 2009). TST uses different criteria to identify the animals that should be treated with anthelminthic. As criteria become easier and more practical to assess, the more viable for use they become (Van Wyk et al., 2006; Bath and Van Wyk, 2009; Kenyon et al., 2009).

The use of the FAMACHA© system as a clinical criterion in TST is well elucidated and used in adult animals (Van Wyk et al., 2006; Molento et al., 2009; Leask et al., 2013; Sotomaior and Cintra, 2018). The method is widely known for its ease of use (it is useable by any

Table 3
Means and standard deviations of the hematocrit (Ht) values for lambs in each of the experimental groups (CG - control group, FG - FAMACHA© group, DWGG - daily weight gain group, FDWGG - FAMACHA© + daily weight gain group), according to age.

Age (days)	CG	FG	DWGG	FDWGG
Experiment1				
60	25.5 ± 3.8 [aA]	27.4 ± 3.2 [aA]	26.8 ± 4.0 [aA]	27.1 ± 3.6 [aA]
75	27.8 ± 3.6 [aA]	27.3 ± 3.2 [aA]	28.0 ± 3.1 [aA]	26.9 ± 3.3 [aA]
90	27.2 ± 3.5 [aA]	26.8 ± 3.5 [aA]	27.4 ± 3.6 [aA]	26.5 ± 3.2 [aA]
105	27.8 ± 2.3 [aA]	26.3 ± 3.4 [aA]	26.6 ± 3.1 [aA]	25.7 ± 3.8 [aA]
120	28.0 ± 3.5 [aA]	26.9 ± 2.7 [aA]	27.7 ± 1.9 [aA]	26.8 ± 3.9 [aA]
135	26.3 ± 2.4 [aA]	25.6 ± 3.0 [aA]	25.8 ± 3.2 [aA]	26.1 ± 3.2 [aA]
150	26.3 ± 3.8 [aA]	26.1 ± 3.5 [aA]	24.8 ± 3.3 [aA]	25.2 ± 3.4 [aA]
165	26.6 ± 2.3 [aA]	27.2 ± 2.5 [aA]	26.6 ± 3.7 [aA]	26.1 ± 3.4 [aA]
180	26.2 ± 3.3 [aA]	25.5 ± 2.8 [aA]	26.5 ± 3.4 [aA]	25.2 ± 3.7 [aA]
Mean	26.9 ± 3.2 [a]	26.6 ± 3.1 [a]	26.7 ± 3.3 [a]	26.2 ± 3.5 [a]
Experiment 2				
60	25.6 ± 3.0 [aA]	26.0 ± 3.3 [aC]	25.8 ± 3.5 [aAB]	25.3 ± 3.8 [aB]
75	28.0 ± 2.4 [cA]	20.9 ± 2.7 [aAB]	24.6 ± 5.0 [bAB]	26.0 ± 2.7 [bcAB]
90	25.0 ± 5.2 [bA]	18.3 ± 6.0 [aA]	22.2 ± 5.4 [abA]	23.5 ± 6.0 [bA]
105	27.6 ± 2.4 [bA]	21.4 ± 4.7 [aAB]	23.4 ± 6.2 [abAB]	24.7 ± 4.6 [abAB]
120	25.8 ± 3.1 [bA]	22.1 ± 4.5 [aABC]	26.2 ± 4.1 [bAB]	27.9 ± 2.1 [bB]
135	28.1 ± 1.9 [bA]	23.1 ± 4.4 [aBC]	25.5 ± 3.3 [abAB]	25.7 ± 4.6 [abAB]
150	25.5 ± 5.6 [aA]	25.6 ± 4.2 [aC]	27.0 ± 4.3 [aB]	28.0 ± 2.2 [aB]
Mean	26.5 ± 3.5 [c]	22.4 ± 4.9 [a]	24.9 ± 4.8 [b]	25.7 ± 4.2 [bc]

Means with different capital letters in the column indicate statistical difference ($p < 0.05$) by the Tukey test.
Means with different lowercase letters in the row indicate statistical difference ($p < 0.05$) by the Tukey test.
Groups: Control group (CG) - treatment with anthelminthic (AH) every 30 days; Famacha© group (FG) - treatment with AH for lambs classified as F3, F4 and F5; Daily weight gain group (DWGG) - treatment with AH for lambs with mean daily weight gain (DWG) ≤ than the mean DWG minus one standard deviation of the CG; Famacha© + DWG group (FDWGG) - treatment with AH for lambs classified as F3, F4, and F5 and/or DWG ≤ than the mean of DWG minus one standard deviation of the CG.

Table 4
Total percentage (%) of lambs classified as FAMACHA[©] 1, 2, 3, and 4, according to the experimental groups (CG - control group, FG - FAMACHA[©] group, DWGG - daily weight gain group, FDWGG - FAMACHA[©] + daily weight gain group).

FAMACHA[©]	CG	FG	DWGG	FDWGG
Experiment 1				
1	91.4[a]	71.2[a]	74.9[a]	75.4[a]
2	8.5[a]	24.3[b]	25.0[b]	22.2[b]
3	0.0	4.4[a]	0.0	2.3[a]
Experiment 2				
1	78.6[a]	45.5[b]	67.7[a]	78.2[a]
2	20.2[a]	42.9[b]	27.3[ab]	19.5[a]
3	1.2[a]	11.6[b]	5.1[b]	2.3[a]
4	0.0	3.3	0.0	0.0

In the evaluations in which no treatment was obtained (= 0), it was not possible to perform the statistical analysis.
Percentages with different lowercase letters in the row indicate statistical difference (p < 0.05) by the chi-square test.
Groups: Control group (CG) - treatment with anthelminthic (AH) every 30 days; Famacha[©] group (FG) - treatment with AH for lambs classified as F3, F4 and F5; Daily weight gain group (DWGG) - treatment with AH for lambs with mean daily weight gain (DWG) ≤ than the mean DWG minus one standard deviation of the CG; Famacha[©] + DWG group (FDWGG) - treatment with AH for lambs classified as F3, F4 and F5 and/or DWG ≤ than the mean of DWG minus one standard deviation of the CG.

Table 5
Percentage (%) of lambs treated with anthelmintic every 30 days (60/75, 90/105, 120/135, 150/165, 150, 180 days of life) and in the total period of the experiment (Total), according to the experimental groups (CG - control group, FG - FAMACHA[©] group, DWGG - daily weight gain group, FDWGG - FAMACHA[©] + daily weight gain group).

Days of life	CG	FG	DWGG	FDWGG
Experiment 1				
60/75	100.0[a]	50.0[b]	60.4[b]	59.5[b]
90/105	100.0[a]	2.1[c]	12.9[c]	15.7[b]
120/135	100.0[a]	2.1[c]	22.9[b]	26.0[b]
150/165	100.0[a]	2.1[c]	21.7[b]	26.6[b]
180	100.0[a]	4.4[c]	21.9[b]	22.7[b]
Total	100.0[a]	23.1[b]	22.4[b]	24.3[b]
Experiment 2				
60/75	100.0[a]	4.2[c]	33.3[b]	37.5[b]
90/105	100.0[a]	37.5[b]	37.5[b]	41.6[b]
120/135	100.0[a]	16.6[b]	19.0[b]	31.8[c]
150	100.0[a]	0.0	30.0[b]	33.3[b]
Total	100.0[a]	11.2[c]	30.3[b]	34.1[b]

In the evaluations in which no treatment was obtained (= 0), it was not possible to perform the statistical analysis.
Percentages with different lowercase letters in the row indicate statistical difference (p < 0.05) by the chi-square test.
Groups: Control group (CG) - treatment with anthelminthic (AH) every 30 days; Famacha[©] group (FG) - treatment with AH for lambs classified as F3, F4 and F5; Daily weight gain group (DWGG) - treatment with AH for lambs with mean daily weight gain (DWG) ≤ than the mean DWG minus one standard deviation of the CG; Famacha[©] + DWG group (FDWGG) - treatment with AH for lambs classified as F3, F4 and F5 and/or DWG ≤ than the mean of DWG minus one standard deviation of the CG.

trained person) and its pen-side applicability (Van Wyk and Bath, 2002; Kenyon et al., 2009; Maia et al., 2014). In the present study, however, the use of this method in lambs as the only criterion to determine AH treatment was less effective when parasitic infection was high. This conclusion is supported by the results of experiment 2, in which the FG exhibited the lowest mean weight and Ht and the highest mean EPG relative to the other experimental groups. The low efficiency of the FAMACHA[©] system as a TST criterion could be explained by the low sensitivity of the system in growing lambs. The sensitivity of lambs is typically low, but as lambs age, sensitivity steadily increases (Cintra

et al., 2018). Another important explanation for the better performance of the group where FAMACHA plus a weight gain index was used is due to the pathogenic effect of non-*Haemonchus* species (especially *Trichostrongylus*), which are a significant cause of poor weight gain (Barker and Titchen, 1982; Roeber et al., 2013).

In experiment 1, the fact that the weight, EPG, and Ht of FG lambs was similar to that of lambs from the CG could be explained by lower levels of parasitic infection since, in herds where parasitic infection is low, animals can express their productive potential without any loss, even when there is no effective control of gastrointestinal nematodes (Bishop and Morris, 2007; Kenyon et al., 2009).

DWG is another criterion that can be used in TST in growing lambs. The groups in which this criterion was used (DWGG and FDWGG) produced the best results, although variations were observed within experimental groups and throughout evaluations. Busin et al. (2014) compared two criteria, one clinical (diarrhea score) and one productive (weight gain) in the TST of lambs and obtained similar results to those presented here. Lambs treated with AH diagnosed by the productive criterion had a better performance in terms of weight gain when compared to the clinical criterion. However, some authors suggest that the viability and applicability of this criterion could be a problem, especially in large and extensive herds (Greer et al., 2009; Gaba et al., 2010; Busin et al., 2014). In the region where this study was conducted, this was not a problem, since most meat farms implement weight control of lambs to achieve better production indexes.

Another difficulty of using DWG as a criterion in TST is defining the cutoff point. The challenge lies in defining the exact point where the animal needs the treatment, since changes in weight gain can vary based on breed, gender, type of nutritional management, production system, degree of parasitic infection, and year (Greer et al., 2009; Gaba et al., 2010; Kenyon et al., 2013; Busin et al., 2014). There is also a lack of programs, including specific softwares, which are able to calculate DWG and determine the need for AH treatment immediately after lamb weighing (Gaba et al., 2010; Kenyon et al., 2013; Busin et al., 2014). New studies should thus aim to determine a baseline level for changes in DWG through studying the growth curves and physiological properties of growing lambs in the time from birth until they are sent to slaughter. It is also important to consider that technological development, such as the use of electronic systems and data transmission, can change the agricultural working environment. Smart farming, for instance, relies on the combination and analysis of various farm data to provide decision-making information (Pivoto et al., 2018). This could help in TST strategies, since technologies underpinning smart farms offer an opportunity for enabling the construction and application of farm-specific models (O'Grady and O'Hare, 2017).

One of the main goals of TST is to decrease the number of AH treatments. Kenyon et al. (2009) emphasize that the proportion of animals that need to be left untreated to ensure that an effective parasite population remains in refugia is the subject of much debate. The FG, DWGG, and FDWGG exhibited a reduction in AH treatments when compared to the CG, which represented methods of systematic treatment that are still used in the control of verminosis on many farms (Bath and Van Wyk, 2009; Kenyon et al., 2013). Despite this, the CG did not achieve higher DWG values when compared to groups based on DWG, similar to the results of a study in the United Kingdom on commercial farms where lambs treated with AH achieved the same productive performance (DWG) as lambs not treated with AH (Stafford et al., 2009). This suggests that there is little reason for treating every lamb in most cases. Conversely, the FG had the lowest number of lambs requiring treatment. In this experiment, perhaps because the FAMACHA[©] system has a low sensitivity in lambs (Cintra et al., 2018) and, although *H. contortus* was the main parasite with more than 75% of the larvae recovered, other pathogenic non-*Haemonchus* species (Fig. 1) were present, the number of treated animals was lower than the necessary amount. When lambs were treated based on DWG, although the number of treated animals increased, the proportion of animals treated
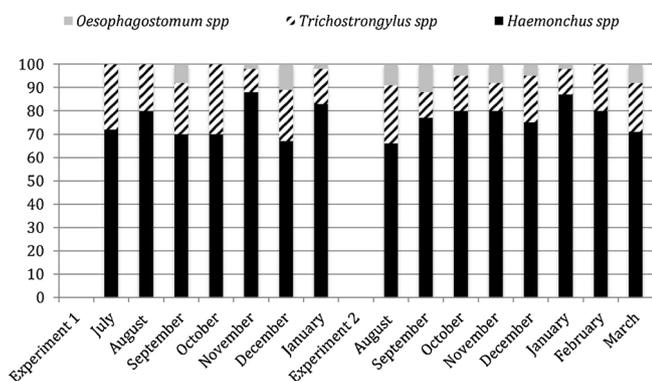
Fig. 1. Total percentage of L3 larvae recovered from the coprocultures carried out monthly in two commercial sheep farms in the State of Paraná, Brazil.

facilitated the better overall performance of the group.

It is important that people involved in sheep production are aware of the need to re-evaluate parasite control. For many years, when parasite control mainly focused on maximizing animal production, farmers were encouraged to regularly treat all their animals. The need to consider the impact of *Refugia* on the development of AH resistance has resulted in advisory changes, with farmers now being encouraged to leave some animals untreated to maintain populations of susceptible parasites on their farms. For this reason, it is imperative that education is made available to both farmers and their advisors to ensure that the complexity of new strategies designed to prevent the development of AH resistance are fully understood. It is useless for these criteria to be elucidated and made feasible if there are no skilled technicians who can apply this newfound knowledge about TST in real-life sheep-production (Kenyon et al., 2009).

5. Conclusion

Even when *Haemonchus* is the major parasite, it is not recommended to use the FAMACHA© system as an exclusive criterion for TST in growing lambs. The productive criterion of weight gain (DWG) in lambs can be effectively used in TST for the control of gastrointestinal nematodes without productive losses, regardless of any association with the FAMACHA© system.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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