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REGULAR ARTICLES

Feasibility of selective anthelmintic therapy to horses in tropical conditions: the Cuban scenario

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Abstract

For the past several decades, selective anthelmintic therapy (SAT) has been recommended in temperate climate countries for controlling gastrointestinal parasites in horses. However, the feasibility of this approach in tropical climates remains unknown, given the very different parasite transmission patterns and a larger representation of working equids. The aim of this study was to evaluate the bio-economic feasibility of SAT in horses kept under tropical conditions of Camagüey, Cuba. Fecal egg counts were determined from 794 adult horses and used for evaluating three different putative treatment thresholds; > 500 strongylid eggs per gram of feces (EPG); > 1000 EPG; and treatments yielding > 80% of the total herd egg output. These scenarios were evaluated under three treatment frequencies (every 2, 6, and 12 months). The bio-economic feasibility of these nine possible selective anthelmintic therapy scenarios was evaluated taking into account the cost of parasitological tests, and the mean cost of anthelmintic treatment in Camagüey. The majority (96.7%) of the samples tested were positive for strongyle eggs, with a mean of 1549 EPG. The percentage of horses exceeding the cut-off points at the nine scenarios varied between 40.1 and 93.8%. All owners surveyed used extra-label anthelmintic product in their horses on a routine basis. The economic analysis demonstrated that selective therapy generally was much more costly than deworming the entire herd without determining egg counts. However, we consider that the deworming every 6 months of the horses that expel 80% of the eggs in the herd allows a reduction of the treatment intensity without increasing costs, and it can be considered as a viable selective deworming scheme under similar conditions.

Keywords Economy · Horses · Parasitic control · Selective therapy · Tropic

Introduction

Gastrointestinal parasitism in horses is directly related to poverty in developing countries (Perry et al. 2002). Horses may be infected by, at least, 83 nematode species, including *Strongylus* and *Parascaris* genera, and cyathostomins. Frequently, the latter group accounts for 95–100% of the parasitic population (Salas-Romero et al. 2014; Saeed et al. 2019), and their significance is recognized because of the pathogenic potential (Love et al. 1999). Parasite control relies on the systematic use of three major classes of anthelmintics, i.e., benzimidazoles, tetrahydropyrimidines, and macrocyclic lactones. However, drug-resistant populations are now globally diffused and anthelmintic resistance is a major hindrance for the control of cyathostomosis and for the health management of horses (Peregrine et al. 2014).

The principle of selective therapy has been widely recommended for the past decades (Duncan and Love 1991;

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Gomez and Georgi 1991). The idea is to reduce anthelmintic treatment intensity, while still achieving significant herd strongyle fecal egg count reduction. This is achieved by determining fecal egg counts from all horses present, and treating those exceeding a pre-determined threshold (Nielsen et al. 2012). In Europe, regulations are implemented in favor of selective anthelmintic therapy (Nielsen et al. 2006; Becher et al. 2018). It is important to emphasize that selective therapy is focused on the control of one parasite category, the cyathostomins, and assumes a low prevalence or absence of *Strongylus vulgaris* (Nielsen et al. 2014). Several studies have demonstrated the principle of selective therapy in temperate climates (Becher et al. 2010; Francisco et al. 2012; Menzel et al. 2012). The foundation is the overdispersal of parasites among equine populations, with 20% typically excreting 80% of the eggs (Lester et al. 2013; Relf et al. 2013; Nielsen et al. 2018), but as these studies were all done in temperate climates and with sport/leisure horses, it is unclear whether these findings translate to tropical conditions.

The aims with this study were to explore the feasibility of selective anthelmintic therapy under tropical conditions with specific emphasis on strongyle shedding patterns observed and bioeconomic aspects of parasite surveillance and anthelmintic intervention.

Materials and methods

This study was done between February 2014 and June 2018. The local climate is that of tropical savanna, according to the Köppen climate classification, with a rainy season taking place between May and October, and a dry season, between November and April.

Strongyle egg shedding in adult horses of Camagüey

Prior to the interview, owners gave their written agreement to participate in the study. The equine targeted population consisted of adult horses (4–25 years old) from the Camagüey province. The studied horse herds included large (more than 50 horses) and small farms (less than 50 horses) used in reproduction and horses used by local coachmen offering transportation services in Camagüey City.

Twenty grams of feces was collected rectally or from non-contaminated freshly deposited feces on the ground. Transport and storage of samples was done in refrigerated condition (placed into a cooler containing ice packs). Laboratory analysis of samples occurred within 72 h maximum after collection. Fecal egg counts were determined using the McMaster technique with a detection limit of 25 eggs per gram (EPG), using a dilution of 4 g of feces to 26 mL of saturated sucrose/NaCl solution (specific density of 1.21) (Salas-Romero et al. 2017b). No prior fecal egg count information was known. Only horses, where information about the amount of time elapsed since last anthelmintic deworming was available (< 60 days, 60–120 days, 121–180 days, 180–365 days, > 356 days), were included.

Statistical analyses

The strongyle egg count data were summarized with calculation of mean and standard deviation. The distribution of egg shedding levels was then assessed by calculating the percentage of horses exceeding three chosen thresholds: 500 EPG, 1000 EPG, and the horses contributing 80% of the total strongyle egg output. An assessment of normality was conducted by using a Shapiro–Wilk normality test in which the null hypothesis is that the data follow a normal distribution. Kruskal–Wallis test and Dunn's multiple comparisons were performed to evaluate the effect of the time since last deworming (treatment frequency) on FEC. All statistical analyses were carried out using GraphPad Prism 7.00.

Bio-economic analysis

The economic analysis was based on 2018 conditions and prices in Camagüey, Cuba. A total of 60 horse owners were surveyed in order to identify the mean cost of deworming in the province. These owners represented a subset of the horses enrolled in the strongyle egg shedding study. The questions included in the questionnaire were as follows: (1) How much does it cost you to deworm an adult horse and (2) have you used anthelmintics manufactured and labeled for horses?

Nine hypothetical selective anthelmintic therapy scenarios were considered for 1 year, based on screening sequences with two, six, and 12-month intervals, and the three treatment thresholds mentioned above.

A hypothetical herd of 100 adult horses was conceived with an egg shedding as were determined in adult horses of Camagüey at the first part of the work. The unit cost of coprological tests was determined, according to the prices for veterinary diagnostics made available by the Department of Animal Health, Ministry of Agriculture, Cuba (Rodríguez 2016). The parasitological work consisted in sample collection and delivery, the cost of McMaster test, and the cost of coproculture and larval identification for each animal. The latter was deemed necessary due to the high prevalence of *S. vulgaris* previously reported in Camagüeyan herds (Salas-Romero et al. 2014, 2017b).

The currency exchange rate applied to determine the values in US dollars (USD) was $ 25 Cuban Pesos (CUP) = $ 1 USD.

The unit cost of parasitological tests (CPT) was determined as follows:

CPT = CSCD + CMcM + CC + CL.

where CSCD is the unit cost of sample collection and delivery, CMcM is the unit cost of FEC determination through McMaster, CC is the unit cost of coproculture, and CL is the unit cost of larval identification.

The cost of whole-herd deworming without parasitological tests (WHD) in a hypothetical herd of 100 adult horses was determined as follows:

WHD (100) = MVAT × 100.

MVAT—mean unit value of antiparasitic treatment in Camagüey (obtained by survey).

The total cost of selective anthelmintic therapy (CSAT) was determined as follows:

CSAT (100) = (CTP + MVAT × %HTCoffST) × 100.

where CSAT (100) is the total cost of selective anthelmintic therapy in a hypothetical herd of 100 adult horses, CPT is the unit cost of parasitological tests, MVAT is the mean unit value of antiparasitic treatment in Camagüey, and %HTCutoffST is the percentage of horses that exceed the different thresholds for selective therapy (in three different frequencies of coprological samplings: every 2, 6, or 12 months).

Results

A total of 794 horses were screened. Of all the samples taken, 96.7% tested positive for strongyle eggs ($n = 768$), with a mean of 1549 EPG (median 1300 epg; SD 1115.7 epg; range 0–6450 epg). Of the total strongyle eggs released, 80% was contributed with by 53.4% (424) of the horses. The percentage of horses exceeding the thresholds varied between 40.1 and 93.8% (Table 1). Time since last deworming was significantly associated with egg count level (Table 1).

Table 2 Cost of laboratory tests and mean costs of deworming in Cuba

Item	Unit cost in Cuban pesos (USD)	Cost in herds of 100 adult horses (USD)
Sample collection and delivery to the lab[a]	5.00 (0.20)	500.00 (20.00)
McMaster	3.62 (0.14)	362.00 (14.48)
Coproculture	9.60 (0.38)	960.00 (38.40)
Larval identification	3.78 (0.15)	378.00 (15.12)
All parasitological costs	22.00 (0.88)	2200.00 (88.00)
Mean cost of deworming[b]	47.55 (1.90)	
Cost of whole-herd deworming		4755.00 (190.20)

WHD whole-herd deworming without parasitological tests

[a]According to the price charged by the veterinary clinics and the Veterinary Service in the province of Camagüey

[b]Based on survey of private horse owners

The mean cost of deworming was estimated to $ 47.55 (USD 1.90) ± 12.12 (SD), ranging between $ 25 and $ 80 (USD 1–USD 3.2). The cost of laboratory tests was estimated to $ 22.00 (USD 0.88) (Table 2). All the owners surveyed used extra-label anthelmintic products on a routine basis and 21 owners (35%) declared that they had never used registered products.

The evaluation of different scenarios based on the three thresholds and three treatment intervals revealed that the ratio between the SAT cost and whole-herd deworming varied between 86.4 and 140.1% (Table 3). Costs were reduced by applying SAT every 2 months in horses with FEC higher than 1000 epg, or to the maximum shedders in the herd, with the inconvenience of performing the parasitological study six times in 12 months. On the other hand, by applying the SAT every 6 months using the "High shedders" horses as a cut-off point, the cost is equal to the deworming of the whole herd, but with a low selection pressure.

Table 1 Descriptive data for strongyle egg count and horses exceeding different thresholds under Cuban conditions

Time since last deworming (months)*	*n*	Fecal egg count		Percentage of horses that		
		Mean	Std. Dev	Exceed		Shed 80% of total egg output
				> 500 EPG	> 1000 EPG	
≤ 2[a]	122	1233.4	1209.6	65.6	45.1	40.1
3–4[ab]	110	1340.5	1047.5	77.3	55.5	50.1
5–6[ab]	160	1545.3	1179.3	84.4	60.6	55.0
7–11[b]	176	1772.0	1045.1	93.8	75.0	60.0
≥ 12[b]	226	1650.5	1054.7	90.7	68.1	56.6
Total	794	1549.2	1115.8	84.4	62.8	53.4

*Different letters designate statistical differences between groups ($p < 0.05$)

Table 3 Cost of different selective anthelmintic therapy scenarios in horses, in the tropic areas of Camagüey, Cuba

Threshold	Sampling interval (months) of SAT								
	2			6			12		
	Horses exceed Cut-off (%)	Cost of SAT (USD)	Ratio cost of SAT/WHD (%)	Horses exceed Cut-off (%)	Cost of SAT (USD)	Ratio cost of SAT/WHD (%)	Horses exceed Cut-off (%)	Cost of SAT (USD)	Ratio cost of SAT/WHD(%)
> 500 EPG	65.6	5314.52 (212.58)	111.8	84.4	6213.22 (248.53)	130.7	93.8	6660.19 (266.41)	140.1
> 1000 EPG	45.1	4344.50 (173.78)	91.4	60.6	5081.53 (203.26)	106.9	75.0	5766.25 (230.65)	121.3
High shedders	40.1	4106.75 (164.27)	86.4	55.0	4815.25 (192.61)	101.3	60.0	5053.00 (202.12)	106.3

Cost of SAT cost of selective anthelmintic treatment expressed in Cuban Pesos; *WHD* whole-herd deworming without parasitological tests; *High shedders* horses in the herd that contribute 80% of the strongyle egg output

Discussion

This study has demonstrated some of the challenges with adapting recommendations for equine parasite control to tropical conditions. One main finding is that the overall strongyle egg count levels are substantially higher than reported in temperate climates, and that the distribution between the typical egg count levels is substantially different. Previous research in Camagüey, Cuba, demonstrated that 15.9% of horses showed FEC values below 500 EPG (Salas-Romero et al. 2017b), similar to the results of this study. Hence, based on conventional thresholds recommended in temperate climates (Nielsen et al. 2019), 84% of the animals in the herd needed deworming (Salas-Romero et al. 2017b). Moreover, this is in line with a recent study of Quarter Horses done in Ciego de Avila, Cuba, which showed that only two out of 65 screened animals had FEC below 500 EPG, with a mean of 2479 EPG (Salas-Romero et al. 2017a). In this study, over 60% of the horses exceeded 1000 EPG, and the percentage of horses contributing to 80% of the egg output was over 50%. Thus, the overdispersal of strongyles egg reported elsewhere (Lester et al. 2013; Stratford et al. 2014) clearly do not apply to this population.

Rather than comparing to studies with managed horses, the egg count results reported herein are more comparable to studies done with unmanaged wild/feral horses. A study of wild horses in Australia recorded a mean strongyle FEC of 1443 EPG, and 89% of all the horses studied (257/289) exceeded the 500 EPG cut-off point (Harvey et al. 2019). Other studies performed in tropical herds have shown high FEC as well. For example, mean FEC observed in horses in Lesotho was 950 EPG (Upjohn et al. 2010), 1117 EPG in Nicaragua (Kyvsgaard et al. 2011), and 1438 and 1470 EPG in two studies from Brazil (Ferraro et al. 2008; Costa et al. 2018). Considering the results from these studies, the implementation of SAT in many tropical herds would lead to treatment of most animals present due to the high FEC levels. Even at a 1000 EPG cut-off, more than half the horses in tropical climates would require deworming.

Only two of the SAT schemes evaluated herein turned out to be more economical than deworming the whole herd. This occurred, when the 2-month frequency of parasitological tests was applied using 1000 EPG as the cut-off point for treatment, or when the horses contributing 80% of the egg output were chosen for treatment. However, it is questionable whether horse owners in this area are willing to or can afford six yearly fecal egg counts and associated targeted treatments, as only 122 of the 794 horses (15%) were dewormed this frequently. Although those schemes were economically viable, their biological feasibility would be affected with a risk of accelerating the development of anthelmintic resistance (AR). An increase in deworming frequency is known to cause an exponential increase in the rate of resistance development (Leathwick et al. 2019). Whole-herd deworming is not sustainable either, though it seemingly may be the most cost-effective short-term choice. One theoretic consequence derived from frequent whole-herd deworming is the reduction of parasite population in refugia, and a resulting faster development of anthelmintic resistance (Peregrine et al. 2014; Leathwick et al. 2019). Nevertheless, cyathostomin populations in tropical areas have been documented to have developed resistance even when exposed to a comparatively low treatment intensity (Kumar et al. 2016; Seyoum et al. 2017; Mayaki et al. 2018; Salas-Romero et al. 2018). Computer modeling studies have demonstrated that anthelmintic resistance develops faster in tropical and subtropical areas compared to temperate areas, even after the application of SAT (Nielsen et al. 2019; Sauermann et al. 2019). This can be explained by the existence of climatic conditions that favor strongyle parasite survival and transmission. Year-round transmission will also lead to faster selection of resistant parasites (Leathwick et al. 2019; Nielsen et al. 2019).

Several articles emphasize the epidemiological importance of the so-called 20/80 ratio of fecal egg shedding, with 20% of the horses shedding 80% of the egg output (Kaplan and Nielsen 2010; Wood et al. 2012; Lester et al. 2013; Relf et al. 2013). However, this 20:80 rule has not been previously suggested as a decision-making element (threshold) in a SAT scheme (Becher et al. 2010; Nielsen et al. 2014), though it might be due to adjusted threshold to the conditions and characteristics of each herd. In tropical conditions, deworming the horses that shed 80% of FEC could be economically acceptable, and would leave a larger parasitic population *in refugia* than when using the 500 or 1000 EPG thresholds.

The thresholds used for SAT in horses are empirical, following the recommendations of veterinary parasitologists and tradition (Uhlinger 1993). According to Kaplan and Nielsen (2010), the utilization of a cut-off of 200 EPG allows for a reduction of 50% anthelmintic treatments, while still achieving over 95% overall reduction of the strongylid egg output. Moreover, a study conducted in Kentucky, based on the necropsy of 693 horses, showed that animals with fecal counts higher than 500 EPG had significantly higher total worm counts, and recommended this value as the maximum cut-off point for selective therapy in equids (Nielsen et al. 2010). However, as demonstrated herein, under the conditions of Camagüey, a choice of cut-offs below 1000 EPG results in a large proportion of horses receiving treatment without any economic advantages.

The exclusive use of FEC has been accepted as the basis of treatments (Nielsen 2012; Lester et al. 2013). For instance, there is a possibility that "low-shedders" horses become affected by others parasites as roundworms, tapeworms, bots, or juvenile stages of highly pathogenic strongyle species, like *S. vulgaris*. Therefore, the proportion of horses to be dewormed can be higher than the proportion of horses that is over the chosen cut-off point. Besides, the relation between the parasitic burden of equines in the tropic and their clinical repercussions must be determined.

In Cuba, the prevalence of *S. vulgaris* is reported between 5 and 50% (Salas-Romero et al. 2014), and it has been observed in 95–100% of the herds studied (Salas-Romero et al. 2017b, 2018; Gómez-Cabrera et al. 2019). In Nicaragua, the prevalence of the parasite has been reported above 35% (Kyvsgaard et al. 2011), whereas in wild horses in Australia, it neared 100% (Harvey et al. 2019). Considering the pathogenicity of the species, its presence is considered a good reason for deworming positive animals (Duncan 1973, 1974). Because of the widespread presence of large strongyles in Cuban herds, animals would require individual diagnostic workup. Although there are currently other tools for the diagnosis of this species (Kaspar et al. 2017; Cain et al. 2018), coproculture continues to be the most widely used method (Buzatu et al. 2017; Salas-Romero et al. 2017b). However, it is time-consuming, requiring 10–14 days to perform coproculture (Nielsen et al. 2008), which increases cost and therefore hinders the implementation of SAT.

In conclusion, there is an urgent need for implementation of control methods that allow proper management of parasitic diseases, and delay resistance. The rates at which eggs are released in feces, and the prevalence of *S. vulgaris* in Camagüey, as in other tropical herds, differ from the current situation observed in well-managed herds in Europe and North America (Osterman Lind et al. 1999; Lyons et al. 2006; Wood et al. 2012). As a result, the application of SAT in horses (as has been proposed in equine herds in temperate climates) does not seem to be economically feasible under Camagüeyan conditions. However, the deworming every 6 months of the horses that expel 80% of the eggs in the herd allows a reduction of the treatment intensity without increasing costs. Further studies are required in order to determine SAT feasibility in other tropical areas.

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Author contribution Concept and design JSR and KGC; acquisition of parasitological data KGC, JAS, and JES; analysis or interpretation of parasitological data JSR, KGC, and MKN; economic analysis RC, JES, and JSR; drafting of the manuscript JSR and KGC; critical revision of the manuscript MKN. All authors read and approved the final manuscript.

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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate Following the recommendations of the Cuban Legislation No 180/07 (Gaceta Oficial 084, 19/12/2007), this field study on working horses did not require ethical approval. Prior to the interview, horse owners gave their agreement to participate in the study.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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