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Original research

Treatment efficacy of pyrantel, fenbendazole and macrocyclic lactones in equine strongyles in Germany using FECRT and the model *eggCounts*

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ABSTRACT

Background: Reduced anthelmintic efficacy against small strongyles in horses is a widespread problem, yet recent data is scarce.
Aims: This paper aims to investigate the current status of anthelmintic efficacy in the field in Germany, specifically focusing on pyrantel.
Methods: The study included 1670 horses for which a total of 1913 dewormings were analysed. Of these, 1682 were performed with pyrantel, 56 with fenbendazole, 162 with macrocyclic lactones and 13 with other compounds (e.g. herbs). The faecal egg count reduction (FECR) was calculated with two methods, the faecal egg count reduction test (FECRT) and the statistical model *eggCounts*. In interpreting the results, we adhered to the guidelines of the American Association of Equine Practitioners (AAEP) and the World Association for the Advancement of Veterinary Parasitology (WAAVP).
Results: Overall, 1156 dewormings (68.7 %) with pyrantel, 12 (21.4 %) with fenbendazole and 159 (98.1 %) with macrocyclic lactones were scored with a FECR >95 %. Pyrantel is classified as 'low resistant' with both FECRT (UCL/LCL: 91.1/89.5) and *eggCounts* (88.7/88.1), fenbendazole as 'resistant' with FECRT (65.0/49.1) and *eggCounts* (50.4/42.9), and macrocyclic lactones as 'susceptible' with FECRT (100.1/99.0) and as 'low resistant' with *eggCounts* (99.8/99.5).
Conclusion: Whereas treatments with macrocyclic lactones were sufficiently effective, the majority of fenbendazole treatments showed insufficient efficacy. For pyrantel the results confirm reduced treatment efficacy in 31.3 % of the treatments. Nevertheless, most treatments remained effective. Consequently, pyrantel should be continued to be used for treating strongyle infections. A control of treatment efficacy 10–14 days after administration of the anthelmintic should become standard practice.

1. Introduction

Most grazing horses are infected with small strongyles or exposed to infection pressure [1–5]. If the level of egg excretion exceeds a certain threshold, treatment is recommended [6–9]. In Germany, fenbendazole (benzimidazole), pyrantel (tetrahydropyrimidine), ivermectin and moxidectin (macrocyclic lactones) are available for treatment of strongyle infections (https://vetidata.de/; date: 11/19/2023).

Recent literature indicates increasing prevalence of resistance to all classes of anthelmintics in equine populations [10]. While resistance to fenbendazole is known worldwide [1,2,6,7,10–17], resistance to pyrantel has also been reported in most of the countries evaluated [1,2,6,7,10,11,18,19]. First cases of resistance against macrocyclic lactones have been reported in Australia, Brazil, Finland, Italy, the UK, and the US [10,20–26]. Currently, only limited data is available of the situation in Germany, with the most recent study conducted in 2015 [27].

To test treatment efficacy, commonly the classical FECRT formula and the Bayesian models *eggCounts* or *bayescount* are used. The standardised FECRT method estimates the percentage of egg count reduction (FECR) using a simple formula based on eggs per gram (epg) values before and after treatment. Calculating the confidence interval is not possible if all egg counts are zero after treatment. By contrast, *eggCounts* enables estimation of the density distribution in addition to the egg count reduction and the confidence interval [28]. The model considers

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epg values before and after treatment while allowing for the inclusion of multiple covariates that are determined *a priori*.

In general, *eggCounts* provides low bias while maintaining good coverage probability [29]. *EggCounts* is expected to be robust as individual observations are weighted within the Bayesian framework, taking into account both likelihood and prior distributions. This is in contrast to the FECRT, which assigns equal weight to all observations when calculating the mean and variance of the samples. In addition, the ratios used in the variance estimate can cause individual observations to distort the results. Therefore, to enhance the accuracy of the estimation of anthelmintic efficacy, the use of statistical packages such as the *R* package *eggCounts* [30,31] is suggested. For non-statisticians, the use of respective web-based interfaces such as "*shiny eggCounts*" (https://shiny.math.uzh.ch/user/furrer/shinyas/shiny-eggCounts/) is recommended [30,32].

In practical veterinary work, the use of standardised FECRTs is not very common and mostly only rudimentary knowledge of the status of anthelmintic efficacy is present. Pyrantel is considered to be 'old and ineffective' and is therefore largely neglected by veterinarians [33–37]. The overall aim of this study is to provide an overview of the treatment efficacy of anthelmintics in Germany under field conditions, with a focus on samples of horses treated with pyrantel.

2. Material and methods

2.1. Horses

Horses from all German federal states except Saxony were examined, with a majority of horses coming from southern and western Germany (Appendix 1). We considered treatments that took place between 1 January 2015 and 16 June 2023. The period until 1 June 2022 was considered retrospectively, using data from samples sent to laboratories for routine testing. In addition, the dataset was subdivided into the periods 2015–2019 and 2020–2023. A total of 1670 horses were studied. Several horses were included in the study multiple times, or follow-up treatments were necessary in cases of insufficient reductions. In total, 1913 anthelmintic treatments were evaluated. The distribution of the treatments per year is given in Appendix 2. Table 1 shows the data of sex and age of the horses.

2.2. Inclusion criteria

The study only included horses that excreted at least 200 epg at the initial examination, consistent with the established treatment threshold for strongyle infection cited in multiple publications [9,18,38,39]. There should not have been more than 35 days between the laboratory report dates of the initial examinations before deworming and the report dates of the control examinations after anthelmintic administration. The horse owners and veterinarians were requested to retrieve the control sample 14 days after deworming.

A written declaration of consent for the anonymized data analysis for study purposes was provided for all retrospective examinations. For all samplings later than 1 June 2022, dedicated investigation requests were provided, including a declaration of consent by commissioning the examination.

Table 1
Sex and age of horses (n_{total} = 1670).

sex	number of horses (n)	age	number of horses (n)
female	743	≥6a	1557
male	137	<6a	100
male neutered	790	unknown	13

2.3. Examinations

All examinations were performed using a modified McMaster method with a multiplication factor of 20 epg. If strongyle egg counts were 200 epg or more, deworming was recommended. For horses included in the study, pyrantel (152.3 mg/g, oral, paste) in a single dose was suggested for treatment if suitable (considering the potential presence of other parasites, such as tapeworms; for the treatment of Anoplocephala spp. pyrantel is used in the double of the normal dosage), with the final treatment decision determined by the attending veterinarian. Therefore, treatments with other drugs were not excluded a priori. As the data was collected under field conditions, the weighing of the horses as well as the dosing and application of the anthelmintic was carried out by the local veterinarian or horse owner.

2.4. Active compounds

The collection of samples was conducted with a focus on pyrantel treatment (Table 2). Therefore, it was by far the most frequently used active compound in both initial treatments and retreatments. Retreatments are follow-up treatments that were administered whenever the initial treatment did not result in a sufficient reduction. The distribution of active compounds (pyrantel, fenbendazole, macrocyclic lactones and others) between initial and retreatment is reported in Table 2. The category "others" includes double doses of pyrantel, homeopathic deworming herbs, unknown active compounds, and praziquantel as a single active compound.

2.5. Data analysis

As customary in veterinary practice, the classical formula for the FECRT according to Coles et al. [40] was used first. These calculations were carried out using Microsoft Office LTSC Professional Plus 2021 (Excel). Here, the individual FECR for each horse was determined by using epg before and after deworming. Using these reductions, the mean value was calculated to estimate the FECR of the entire study group. This makes it possible to obtain a complete overview together with the FECR of each individual, which is of great importance for veterinary practice. The 90 % confidence interval was estimated with a Wald-type approach (function confidence.norm). Due to the study design, with the lack of a control group under field study conditions, and in order to follow the recently updated WAAVP guidelines, the paired design was applied [30]. Second, the calculations were performed using the Bayesian model *eggCounts* in *R* and the web interface *shiny eggCounts* (eggCounts-2.3-2 on R version 4.4.0), respectively [28]. This program performs calculations based on the entire study population and not for individuals. When variables such as the individual efficacy for a given horse or the infection rate are unknown, typically the simplest model is advisable. To take this fact into account, the model setting 'two samples paired' was chosen for the calculations. The correction factor 20 was also set in the web

Table 2
Used anthelmintic compounds (pyrantel, fenbendazole, macrocyclic lactones and others) in absolute number and percentage for first treatment and first/second retreatment (rounded to one digit) (n_{total} = 1913).

	first treatment	first retreatment	second retreatment	total
pyrantel	1648 (89.4 %)	33 (53.2 %)	1 (14.3 %)	**1682 (87.9 %)**
fenbendazole	51 (2.8 %)	4 (6.5 %)	1 (14.3 %)	**56 (2.9 %)**
macrocyclic lactones	135 (7.3 %)	23 (37.1 %)	4 (57.1 %)	**162 (8.5 %)**
others	10 (0.5 %)	2 (3.2 %)	1 (14.3 %)	**13 (0.7 %)**
total	**1844 (100 %)**	**62 (100 %)**	**7 (100 %)**	**1913 (100 %)**

interface. All calculations were performed with a 90 % confidence interval threshold [30] and 95 % highest posterior density [41]. Additionally, the Mann-Whitney test was calculated to examine the differences of efficacy between the two study periods.

The recently updated WAAVP guidelines according to Kaplan et al. [30] were used for the interpretation of the efficacy, with the expected and lower efficacy for the clinical protocol being 98.0 % and 80.0 % for pyrantel, 99.0 % and 80.0 % for fenbendazole and 99.9 % and 92.0 % for macrocyclic lactones, respectively. In addition, the current Internal Parasite Control Guidelines of the AAEP by Nielsen et al. [42], which are based on the WAAVP guidelines, were taken into account. The AAEP guidelines provide suggestions for interpreting the percentage reduction for single horses, as confidence intervals cannot be calculated for single horses. They suggest that every compound should reach a faecal egg count reduction of more than 95 %.

3. Results

The detailed results are outlined in Table 3. In summary, according to the newest AAEP guidelines by Nielsen et al. [42], 68.7 % of pyrantel treatments (n = 1156) were effective, and resistance is assumed to be present (i.e., the treatment was not effective) in 31.3 % of the treatments (n = 526). According to the categories defined by Kaplan et al. [30], pyrantel is predicted to be 'low resistant'.

In 21 ineffective treatments with fenbendazole or unknown substances, pyrantel was used for retreatment. Of those, in 66.7 % (n = 14) the FECR was >95 %, and in seven (33.3 %) retreatments FECR was ≤95 %, indicating insufficient treatment efficacy to both fenbendazole and pyrantel.

After a failed initial treatment with pyrantel, it was used again for retreatment in 12 cases. Here, the FECR was >95 % in 41.7 % of the cases (n = 5). For these cases, it is plausible to assume a dosing or application error in the failed initial application. A FECR ≤95 % was found in 58.3 % (seven treatments). In these cases, the indication of insufficient treatment efficacy is substantiated after two unsuccessful applications of pyrantel. In one case with first, second and third treatment with pyrantel, we found a FECR of less than 95 % in all three applications, indicating resistance.

Table 3
Categorization of the mean percentage reduction of the faecal egg count (calculated using classic FECRT formula) according to the newest AAEP guidelines in absolute number and percentage for first treatment and first/second retreatment (rounded to one digit) for pyrantel, fenbendazole and macrocyclic lactones.

pyrantel	first treatment	first retreatment	second retreatment	total
>95 %	1137 (69.0 %)	19 (57.6 %)	-	**1156 (68.7 %)**
≤95 %	511 (31.0 %)	14 (42.4 %)	1 (100 %)	**526 (31.3 %)**
total	**1648 (100 %)**	**33 (100 %)**	**1 (100 %)**	**1682 (100 %)**

fenbendazole	first treatment	first retreatment	second retreatment	total
>95 %	12 (23.5 %)	-	-	**12 (21.4 %)**
≤95 %	39 (76.5 %)	4 (100 %)	1 (100 %)	**44 (78.6 %)**
total	**51 (100 %)**	**4 (100 %)**	**1 (100 %)**	**56 (100 %)**

macrocyclic lactones	first treatment	first retreatment	second retreatment	Total
>95 %	132 (97.8 %)	23 (100 %)	4 (100 %)	**159 (98.1 %)**
≤95 %	3 (2.2 %)	-	-	**3 (1.9 %)**
total	**135 (100 %)**	**23 (100 %)**	**4 (100 %)**	**162 (100 %)**

For macrocyclic lactones, FECR was >95 % in 98.1 % of the treatments (n = 159). A FECR ≤95 % was determined for 1.9 % of the treatments (n = 3). These three treatments were administered to three different horses. Two of the three horses were successfully treated with macrocyclic lactones six months earlier and after an insufficient macrocyclic lactone treatment, respectively. Therefore, dosage and application errors may be assumed here as well. The third horse was successfully treated with pyrantel nine months earlier, but had no follow-up treatment with macrocyclic lactones during the study period to confirm a resistance to macrocyclic lactones. Overall, according to the updated WAAVP guidelines macrocyclic lactones are classified as 'susceptible' if calculated with FECRT according to Coles et al. [40] and classified as 'low resistant', if calculated with *eggCounts*.

The results of reductions and confidence intervals of the classic FECRT and *eggCounts* are shown in Table 4. Pyrantel treatments achieve 90 % UCI/LCI of 91.1/89.5 with FECRT and 88.7/88.1 with *eggCounts*, fenbendazole treatments 65.0/49.1 with FECRT and 50.4/42.9 with *eggCounts*, macrocyclic lactones 100/99.0 with FECRT and 99.8/99.5 with *eggCounts*, and other active compounds 96.3/69.6 with FECRT and 84.2/75.1 with *eggCounts*, respectively. Fig. 1 shows all postcodes of the origins of the sampled horses with pyrantel treatment and sorts colours into FECR >95 % and ≤95 %, respectively, according to the categorisation by Nielsen et al. [42]. For the Mann–Whitney test the significance level is assumed to be = 0.05. As p > , there is no evidence that the null hypothesis of the median FECR of the two study periods being equal is rejected, indicating no significant difference in distribution between periods. Accordingly, none of the tested anthelmintics (pyrantel, fenbendazole and macrocyclic lactones) demonstrate a significant

Table 4
Comparison of classical FECRT and *eggCounts* for the total study period and the periods 2015-2019 and 2020-2023, respectively; FECRT calculated with 90 % confidence interval; *eggCounts* calculated with mode, 95 % HPD credible interval and calculated with 90 % upper/lower confidence interval (CI) according to WAAVP guidelines by Kaplan et al. [30].

Germany	FECRT 2015-2023 (2015-2019; 2020-2023)		*eggCounts* 2015-2023 (2015-2019; 2020-2023)		
	reduction (%)	**90 % UCI/LCI**	**reduction (%)**	**95 % upper HPD/ lower HPD**	**90 % UCI/LCI**
pyrantel	90.3 (90.7; 90.1)	91.1/ 89.5 (92.0/ 89.3; 91.2/ 89.0)	88.5 (89.3; 87.8)	88.7/ 88.1 (89.8/ 88.8; 88.3/ 87.4)	88.7/ 88.1 (89.7/ 88.9; 88.2/ 87.5)
fenbendazole	57.0 (53.5; 60.3)	65.0/ 49.1 (65.6/ 41.5; 70.7/ 49.9)	47.3 (37.0; 57.4)	50.8/ 41.7 (43.3/ 29.4; 62.3/ 50.9)	50.4/ 42.9 (42.5/ 30.5; 61.5/ 52.0)
macrocyclic lactones	99.5 (100; 99.4)	100/99.0 (-/-; 100.1/ 98.7)	99.7 (100; 99.7)	99.8/ 99.5 (100/ 99.6; 99.8/ 99.4)	99.8/ 99.5 (100/ 99.6; 99.7/ 99.4)
others	83.0 (78.9; 85.5)	96.3/ 69.6 (108.0/ 49.3; 97.1/ 73.9)	80.3 (67.2; 85.2)	85.5/ 74.7 (78.5/ 51.1; 89.5/ 78.9)	84.2/ 75.1 (76.4/ 52.0; 89.0/ 79.9)

90 % UCI/LCI: 90 % upper confidence interval/lower confidence interval
95 % upper HPD/lower HPD: 95 % upper highest posterior density/lower posterior density

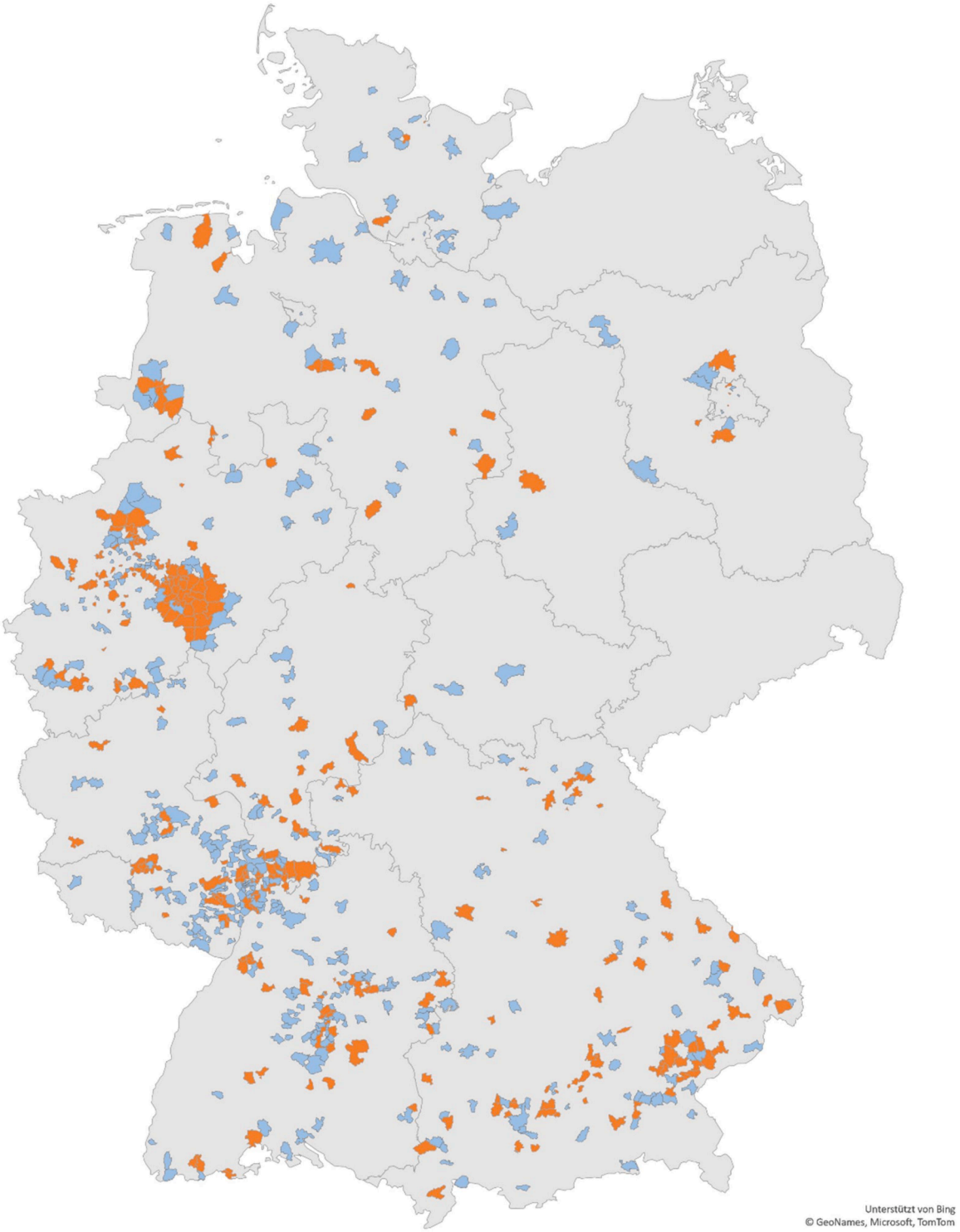

Fig. 1. Classification of the treatment efficacy of pyrantel treatments: distribution of the participating horses on the basis of the postcodes; categorization according to AAEP guidelines by Nielsen et al., 2024; colour blue: „faecal egg count reduction (FECR) >95 %“, orange: „FECR ≤95 %“; if one postcode has both is marked in orange.

difference in reduction between these calculation methods (see Fig. 2). This does not indicate a clear progression of the resistance situation or decreasing efficacy over the past eight years. For macrocyclic lactones, the three horses mentioned above with reduced reductions categorized ≤95 % were examined in the 2020–2023 period.

4. Discussion

In this study, we confirmed the presence of reduced susceptibility of strongyles to pyrantel and fenbendazole in Germany. This finding is in accordance with the observation of pyrantel and fenbendazole resistance in many other European countries, as reviewed by Nielsen [10]. However, we postulate that pyrantel demonstrates better efficacy than

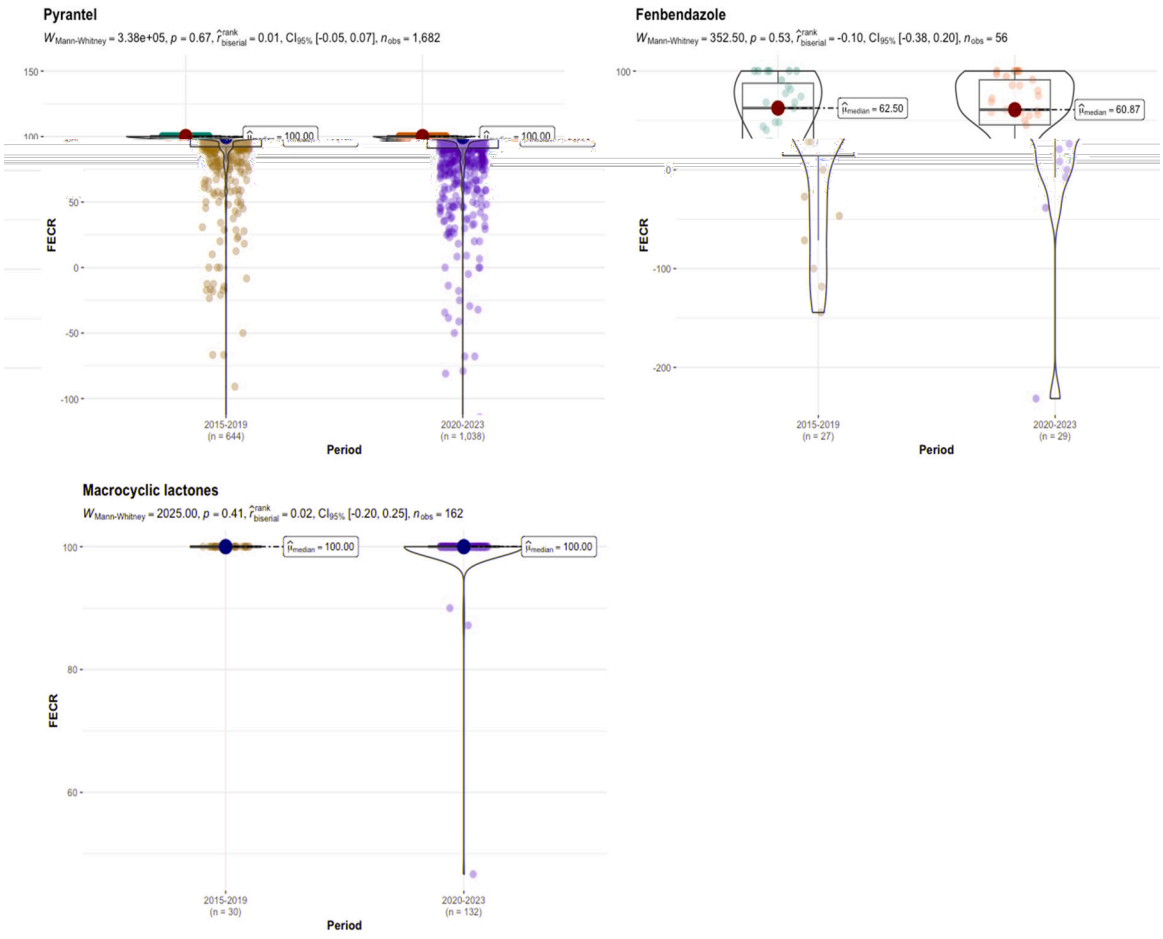

Fig. 2. Distribution of FECR in periods 2015-2019 and 2020-2023 for each compound including Mann-Whitney-test with null hypothesis "median FECR of two periods is equal" and = 0.05; no significant reduction in efficacy is evident for any of the compounds.

expected. We clearly find that the efficacy is higher than the possible occurrence of resistance. The occurrence of pyrantel resistance is limited to some of the treatments, as recently demonstrated in a Swedish study [43] and documented across several European countries, including some neighbouring Germany [13,15,25,26,44–53].

For fenbendazole treatments, the alarming results with widespread reduced treatment efficacy (47.3 % calculated using *eggCounts*) corroborate with the findings of previous studies addressing the global situation [10]. However, the level of resistance varies considerably: efficacies of 1.99 % and 23 % in Brazil and of 48.8 % in France have been demonstrated [22,54,55]. The use of fenbendazole for treating strongyle infections can therefore be recommended only in conjunction with subsequent efficacy monitoring.

Multiple studies across European countries have previously documented resistance to macrocyclic lactones [10,25,26,46]. In the present study, macrocyclic lactone treatments were rated 'susceptible' in the FECRT and 'low resistant' in *eggCounts*. This does not imply full treatment efficacy, but the examined group size is small, and dosing and application errors were identified in one of the three horses with reduced treatment efficacy.

This field study did not fully comply with the current WAAVP guidelines for verifying anthelmintic resistance; however, reliable results regarding treatment efficacy were achieved. If inadequate application of anthelmintics in the field is assumed a higher level of reduced efficacy might be expected. Based on the results of our study, the notion that veterinarians consider macrocyclic lactones to be more suitable and preferable is not sustainable. Therefore, due to the high success rate of pyrantel treatments and the few active compounds available for use in horses, there is no reason not to use pyrantel or to categorically exclude it from the beginning. Relying solely on macrocyclic lactones should be avoided. Otherwise, there may be a risk of accelerating the development of resistance to these compounds [56]. Rotation between anthelmintic classes does not constitute a comprehensive solution for resistance mitigation and may create a false impression among livestock owners that they have viable anti-resistance programs. However, such rotation may still be recommended for the prevention of accelerated resistance development [56] and remains a practical solution, especially for high shedders that have to be treated regularly [57]. In addition, pyrantel can be administered a second time after a failed first treatment, especially when dosing and application errors are suspected, as sufficient reductions are often observed. It is crucial to detect potential insufficient treatment efficacy at an early stage, allowing for appropriate intervention strategies. Therefore, treatment efficacy controls and egg count reduction tests should be carried out after treatments, regardless of the anthelmintic. Only in this way can insufficient treatment efficacy be detected in a timely manner.

To date, the FECRT remains the preferred method for assessing anthelmintic efficacy [30]. In this study, the classic FECRT formula and *eggCounts* were used comparatively. The classical FECRT formula is a widely known, simple and inexpensive method for calculating egg count reduction and estimating the resistance status [29,58]. However, for the classical FECRT, only pre- and post-epg are used as a basis for calculation, whereas *eggCounts* include various other factors [29,59–61]. Important issues, such as overdispersion among animals, Poisson errors, and individual efficacy, must be considered [30,31]. In addition, the classical FECRT does not account, even for large sample sizes, for

individual efficacy and factors specific to individual horses such as feeding, race or life condition. Moreover, factors including infection rate and individual efficacy are unknown. By contrast, *eggCounts* assumes a binomial gamma-Poisson distribution, where the binomial distribution captures sampling variability both at the single-animal level and in relation to count processes [60–63]. The Poisson distribution includes the resulting Poisson error due to the random distribution of eggs in a faecal sample. The gamma distribution accounts for the aggregation of eggs between individuals in a herd [60,61,64]. In addition, by down-weighting outliers, a more accurate calculation can be assumed when using *eggCounts*. Therefore, the most recent WAAVP guidelines propose *eggCounts* as a tool for calculating egg count reductions, confidence intervals and density distribution [31,32]. In the present dataset, the distributions of efficacy and infection rate, among other factors, are unknown. We therefore used the simplest model setting of *eggCounts*, which excludes individual efficacy and zero inflation. As a result, due to its model-based assumptions and in light of the simulation studies by Li [41], *eggCounts* can be considered more accurate than the classical formula of the FECRT. However, until now *eggCounts* and other statistical packages are rarely used in veterinary practice.

In this FECRT study, the individual reduction is calculated first and then the mean value is calculated as the overall reduction. This approach does not follow the recommendation of Levecke et al. [65], who propose the calculation of a mean epg before and after treatment for determining the FECR. They justify this approach with the uneven distribution of certain parasite eggs in the faeces. However, a homogeneous distribution of equine strongyles in the faeces can be assumed [66,67].

As discussed before, our study was planned and designed to monitor the performance of treatment efficacy of anthelmintics in the field and largely conducted prior to the publication of the updated WAAVP guidelines by Kaplan et al. [30]. The authors are aware that the new WAAVP guidelines do not give any suggestions for the assessment of treatment efficacy of single horses, which is essential for veterinarian practitioners, but only for groups or stables. The newest AAEP guidelines however, provide guidance on the interpretation of single-horse results. We therefore interpreted the results of single horses with the corresponding suggestions of the AAEP guidelines [42]. We would have preferred to additionally include stables to follow intra-herd events of reduced efficacy. However, this could not be achieved either because of the low level of egg excretion before deworming (<20–180 eggs) in most regularly monitored stables or due to inadequate compliance from horse owners or stable managers.

The sampling process was based on sample submissions from veterinarians and animal owners to diagnostic laboratories. Therefore, some compromises in methodology were made against the suggestions of WAAVP to accommodate compliance from horse owners and ensure cost-effectiveness, which were crucial for gaining access to a high number of samples. The interval between the two egg-count results was set to 35 days (with an estimated 14-21 days between deworming and final FEC). Since a high level of egg shedding consistency over time and a consistent distribution of strongyle eggs in faecal samples have been confirmed in various studies, we assume that there are no significant changes during the relatively short period of the estimated 14 days between the initial value and deworming [6,18,66,68,69]. However, the potentially short ERP of 4-6 weeks for pyrantel might influence the final FEC because of the chosen period 35 days between the two laboratory results [46,70,71]. Due to the characteristics of an, in parts, retrospective field study, laboratory/result dates and not sampling dates were used for the analysis. Therefore, we had to extend the time period between the initial and the control value. The estimated period of 14 days between initial FEC and deworming and 14 plus 7 days between deworming and final FEC takes into account time factors that influence the process of efficacy control under field conditions, such as the time needed for the consultation of the veterinarian and the provision and application of the anthelmintic, for sample collection and preparation, as well as for postal shipment and laboratory work. However, a majority of the samples after deworming (n = 1526) had been processed within 28 days.

The delaying factors mentioned above are not considered by the scientific approach of the WAAVP, but they do have a substantial influence on field studies, which reflect the daily work of veterinarians. As previously described by Hedberg Alm et al. [72], for further protocol simplification anthelmintic administration was carried out by the horse owner or local veterinarian, which potentially contributed to underdosing. Nonetheless, most owners are aware of their horse's weight due to the widespread availability of mobile horse scales nowadays. However, while simplified protocols may lead to potential limitations and uncertainties, they are necessary to obtain a realistic assessment of anthelmintic treatment efficacy under field conditions. Additionally, there is a potential bias in the selection of study participants. Approximately 95.9 % of the samples derived predominantly from southern and western Germany. This geographical bias may reflect the locations of the participating laboratories, the adoption patterns of the Targeted Selective Treatment (TST) protocols or more specifically routine faecal sampling, and the regions where most German horses are kept (as documented in reports of the national association *FN Deutsche Reiterliche Vereinigung* [73]). Most samples sent to laboratories are obtained in the course of TST schemes. Horse owners performing TST are generally well-informed about issues such as anthelmintic resistance and deworming strategies. However, in horse populations without regular monitoring of parasite status, the problem of anthelmintic resistance may be more substantial.

Therefore, it is essential for veterinarians to perform regular faecal analysis, to check if the applied parasite control program is working at the respective stable. Unfortunately, neither FECs, nor FECRTs, nor simple controls of treatment efficacy, are often performed. However, this is unacceptable due to the worldwide resistance situation.

So far, despite some limitations, the FECRT is the gold standard in veterinary practice. However, the WAAVP guidelines suggest the use of *eggCounts*, and further advise that the *R*-package *eggCounts* [28] be executed by a qualified statistician [30]. This is likely to be too complicated in daily veterinary practice. The *shiny eggCounts web interface* should facilitate easier data entry for non-experts and provide compressed results (http://shiny.math.uzh.ch/user/furrer/shinyas/shiny-eggCounts/). The establishment of the *shiny eggCounts* web interface in veterinary practice is the focus of ongoing research projects.

5. Conclusion

Pyrantel and macrocyclic lactones have shown good treatment efficacy in the field. Although some uncertainties exist due to the nature of field data, these positive results accurately reflect the treatment efficacy within the study population. Notably, pyrantel's efficacy is superior to that reported in other countries. As an anthelmintic's effectiveness can vary by individual, it is recommended to monitor treatment efficacy after each deworming.

Ethics in Publishing Statement

I testify on behalf of all co-authors that our article submitted followed ethical principles in publishing.

All authors agree that:

This research presents an accurate account of the work performed, all data presented are accurate and methodologies detailed enough to permit others to replicate the work.

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All authors have been personally and actively involved in substantive work leading to the manuscript and will hold themselves jointly and individually responsible for its content.

CRediT authorship contribution statement

J. Döberl: Writing – original draft, Investigation, Formal analysis, Data curation. **Z. Li:** Writing – review & editing, Methodology, Formal analysis. **R. Furrer:** Writing – review & editing, Validation, Supervision, Software, Methodology. **M.C. Jäger:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization.

Declaration of competing interest

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jevs.2025.105715.

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