Comparative Medicine
Copyright 2024
by the American Association for Laboratory Animal Science

Vol 74, No 3
June 2024
Pages 167–172

Evaluating a Reduction in Treatment Duration of Ivermectin Diet for Fur Mite (*Radfordia affinis*) Eradication in Mice

Wai H Hanson, DVM, PhD, DACLAM,[1,*] Cayden J Samuels, BA,[1] Cheryl L Woods, BS,[2] and Kenneth S Henderson, PhD, MSc[2]

Murine fur mites are commonly excluded in modern research animal programs, yet infestations continue to persist due to challenges in detection and control. Because all diagnostic methods and treatment options have limitations, programs must make many operational decisions when trying to eradicate these ectoparasites. The primary aim of this study was to assess various durations of treatment time with an ivermectin-compounded diet in eliminating *Radfordia affinis* in mice as determined by PCR testing and pelt examination. A shorter treatment duration would be highly advantageous as compared with the current regimen of 8 wk as it would minimize cost and time for animal management programs, impediments to research, and ivermectin drug effects on infested animals. Five experimental groups of *R. affinis*-positive mice received dietary ivermectin for 0, 2, 4, 6, or 8 wk. A fur mite-negative, naïve mouse was added to each group every 8 wk to perpetuate the infestation and amplify any remaining populations of fur mites. At 16 wk after the respective treatment end, PCR testing was performed for all treated groups in conjunction with the positive control group (no treatment). Visual examination of pelts for mites and eggs via direct microscopy was also performed at each time point. All treated mice were free of *R. affinis* at 16 wk after the end of treatment as confirmed by both PCR testing and pelt examination. These findings indicate that a dietary ivermectin treatment duration of as little as 2 wk is effective in eliminating *R. affinis*, making successful eradication initiatives more achievable.

DOI: 10.30802/AALAS-CM-24049

Introduction

Murine fur mites are commonly excluded in modern research animal programs, yet infestations from *Myocoptes musculinu*s, *Myobia musculi*, and *Radfordia affinis* continue to be challenging to detect and control despite advances in colony management.[17] These ectoparasites are species-specific, noninvasive, and primarily transmitted by direct mouse-to-mouse contact.[17] Depending on the species, fur mites complete a life cycle of fur-bound egg to motile nymph to reproductively mature adult in approximately 8 to 23 d.[1,22] Clinical signs in heavily infested mice include localized pruritus, alopecia, ulcerative dermatitis, lymphadenopathy, and weight loss.[18,22] However, more commonly, mice are minimally infested and exhibit subclinical alterations in the immune system.[18] Fur mite infestations are hurdles for both animal health and research objectives, experimental design, and collaboration. For example, the presence of fur mites in a research colony could prevent the importation and exportation of infested mice between institutions, impeding the sharing of animal models and the propagation of unique mouse lines.[3] This hindrance to collaboration and workflow also occurs within institutions if colonies of both clean and affected statuses are present.

Persistence in modern colonies is aided by pitfalls associated with traditionally employed diagnostic techniques. Direct microscopic examination, the traditional gold standard, can confirm a true positive diagnosis but commonly yield false negative results due to low sensitivity (that is, selection of a noninfested test animal, low mite yield, missed examination site, or examination error due to varied proficiency among observers).[22] Other microscopic methods, such as pelage tapes, fur plucks, and skin scrapes, also often result in false negative reports for the same reasons.[30] Colony health monitoring, such as by utilizing soiled bedding sentinels, is practiced at many institutions, leading to greater awareness of fur mite outbreaks.[16] More recently, PCR assays have been included as part of health monitoring methods due to their higher sensitivity,[30] providing greater confidence in negative diagnostic results.[2,8,9,12,13,24,30] However, because PCR testing cannot distinguish between live fur mites and residual fur mite nucleic acids, positive results can occur for up to 16 wk after treatment.[22,24] Nonetheless, PCR testing instills a higher confidence in negative results, making it the preferred method for many institutions.

Despite the availability of numerous therapeutic agents, outbreaks continue to occur, often due to recrudescence of a previous infestation or to a new outbreak associated with recent rodent importation and failure to detect affected animals during the quarantine period.[3] The latter has led to the common practice of initiating prophylactic treatment concurrent to standard quarantine. Treatment can be administered in a number of ways; elimination of fur mites has been successfully accomplished in mice by using topical parasiticides, oral treatments, injectable agents, environmental agents, cross-fostering paired with ivermectin treatment, and medication-compounded feed.[3,10,23] Regardless of method, administration of treatment for large-scale infestations can be costly in labor, time, and money.

Submitted: 22 Jan 2024. Revision requested: 8 Feb 2024. Accepted: 28 Mar 2024.
[1]Division of Animal Resources, Emory University, Atlanta, Georgia; and [2]Research Animal Diagnostic Services, Charles River Laboratories, Wilmington, Massachusetts
[*]Corresponding author. Email: wai.hung.hanson@emory.edu

At one institution, ivermectin-compounded feed was used to successfully treat a very large affected colony.[23] Likewise, our institution prefers the use of ivermectin-compounded diet for treatment as it requires no additional labor to routine husbandry processes (that is, scooping ivermectin diet in lieu of normal chow into cages).

In the aforementioned study, it was determined that a 1-wk course of 1.3 mg/kg ivermectin daily was effective in eliminating *M. musculinus* and *M. musculi* in C57BL/6 mice.[23] However, an 8-wk course was elected by the authors in light of anecdotal and previous reports of confirmed or suspected failures and because they were treating an extraordinarily large population involved in active research. Their success therein led our institution to follow suit with an 8-wk treatment duration as well. However, to prevent failed treatment, we also restrict the movement of cages while under treatment (that is, cages are not allowed to leave the housing room). This practice was especially implemented because our facilities are only partially infested with *R. affinis*, so some housing rooms were under ivermectin treatment while others were not. This made cross-contamination during treatment an even greater concern. Ultimately, we found it difficult to persuade investigators to undergo this long period of treatment with restricted research efforts, and this was the impetus for investigating the possibility of using a shorter treatment duration for large-scale eradication of *R. affinis*. In addition, researchers may be concerned about the effects of ivermectin on specific genes, phenotypic expressions, and microbiomes in studies that involve affected mice. Finally, a substantial quantity of ivermectin diet is necessary when attempting large-scale eradication, making these initiatives a large financial endeavor. Therefore, we conducted a prospective, controlled, small-scale study to determine the necessary treatment duration in a colony of mice infested with *R. affinis*. *R. affinis* was selected as it was the only mite species present in our own institution at the time of this study. The specific aim of this study was to determine whether an ivermectin diet treatment duration of less than 8 wk would be sufficient to effectively eradicate *R. affinis* as validated by PCR testing. Direct microscopic examination was also performed as an adjunctive and gold standard diagnostic method.

Materials and Methods

Animals. Four- to eight-week-old, female, CD-1 IGS mice (Charles River Laboratories, Raleigh, NC) were used for this study. Although *R. affinis* infestations do not discriminate between sex, females were selected to avoid aggression during the initial infestation process and during the addition of new, naïve mice to preestablished treatment groups. Initial *R. affinis* infestation was obtained by direct contact with institutional mice that were endemically infested with these ectoparasites. Once complete transmission of *R. affinis* infestation to CD-1 mice was confirmed by PCR testing (mode copy number of 50), institutional mice were removed from the study. Due to challenges with this infestation process, mice were 20 wk of age at the start of the study. Subsequent naïve mice were obtained from the same vendor and entered directly into the study. All mice were free of the standard panel of pathogens, including fur mites, according to vendor health monitoring, and were confirmed again upon arrival to be free of fur mites via PCR testing.

All mice were housed in static 18780 Rat Micro-Isolator cages (Lab Products, Seaford, DE). Using a rat cage allowed for a greater number of mice to be housed together, as additional naïve mice were continually added throughout the study, while staying within the requirements for minimum housing space.[11] All cage materials were autoclaved, and our standard husbandry methods were used. All mice were housed on 1/8-inch corncob bedding (Bed-o'Cobs; The Andersons Lab Bedding Products, Maumee, OH), fed irradiated chow (PicoLab Rodent Diet 20 [5053], LabDiet, St. Louis, MO) when not on treatment, and provided autoclaved reverse osmosis water in bottles. An abundance of physical enrichment was offered including cotton nestlets (Ancare, Bellmore, NY), Bed-r'Nests (The Andersons Lab Bedding Products), Mouse Igloos with Fast-Tracs, Crawl Balls, nylon bones, and trapezes (Bio-Serv, Flemington, NJ). All cages were accessed only under a HEPA-filtered, class II, type A2, biologic safety cabinet (NuAire, Plymouth, MN). When opening cages and handling animals, disposable personal protective equipment (that is, gown and gloves) was changed between each treatment group. Group 1 was always accessed last so as to not contaminate subsequent groups with fur mites. The animal housing room was maintained at 10 air changes per hour, a 12:12 light cycle, a temperature of 72 ± 2 °F (22 ± –17°C), and a relative humidity between 30% to 70%. All environmental conditions were maintained in accordance with the *Guide for the Care and Use of Laboratory Animals, 8th ed.*[11] Emory University is accredited by AAALAC International, and this study was approved by the Emory University IACUC.

Ivermectin treatment. Study mice were randomly assigned into 1 of 5 treatment groups that received ivermectin diet in lieu of standard chow for 0, 2, 4, 6, or 8 wk (Figure 1). The ivermectin diet was compounded at 12 ppm in irradiated Laboratory Rodent Diet 5001 (TestDiet, St. Louis, MO) and delivered a daily dose of approximately 1.3 mg/kg. Each treatment group consisted of 5 cages, and each cage began the study with 5 *R. affinis*-positive mice.

Addition of naïve mice. A prior study suggested that fur mite burden wanes with animal age, particularly at 10 to 12 wk old.[24] To circumvent this decreasing burden, the authors introduced young naïve mice at regular intervals to an older established group to maintain the infestation within the cage. To accomplish this in our study, a single naïve mouse was introduced to each cage at Weeks 8 and 16 (Figure 1). The naïve mice were all female CD-1 IGS mice from Charles River Laboratories (Raleigh, NC). Four-week-old mice were originally used, but due to aggression from the preestablished groups, eight-week-old mice were later selected for their larger size. Nonetheless, due to unresolved fighting, 2 mice were eventually removed from the study (1 each from Groups 2 and 5). An additional 3 mice were removed from the study due to nonstudy-related clinical conditions (1 each from Groups 3, 4, and 5). Ultimately, Group 1 concluded the study with all 35 mice, Groups 2, 3, and 4 concluded the study with 34 mice each, and Group 5 concluded the study with 33 mice.

PCR testing of fur swabs. PCR testing for *R. affinis* was performed 16 wk after the respective treatment end for all treated groups in conjunction with Group 1 (no treatment, positive control). One fur swab was collected per mouse, and then all swabs were pooled together at the cage level. Fur was swabbed by using sterile adhesive swabs (VWR, Radnor, PA) and massaging and swabbing the dorsum of the mouse along the back, neck, and between the ears. For each mouse, fur was swabbed in the direction opposite to that of fur growth. Fur swabs were submitted to Charles River Laboratories (Wilmington, MA) for fur mite real-time PCR screening and were interpreted as previously reported.[12] Initial testing was performed using broadly reactive PCR assays that span the

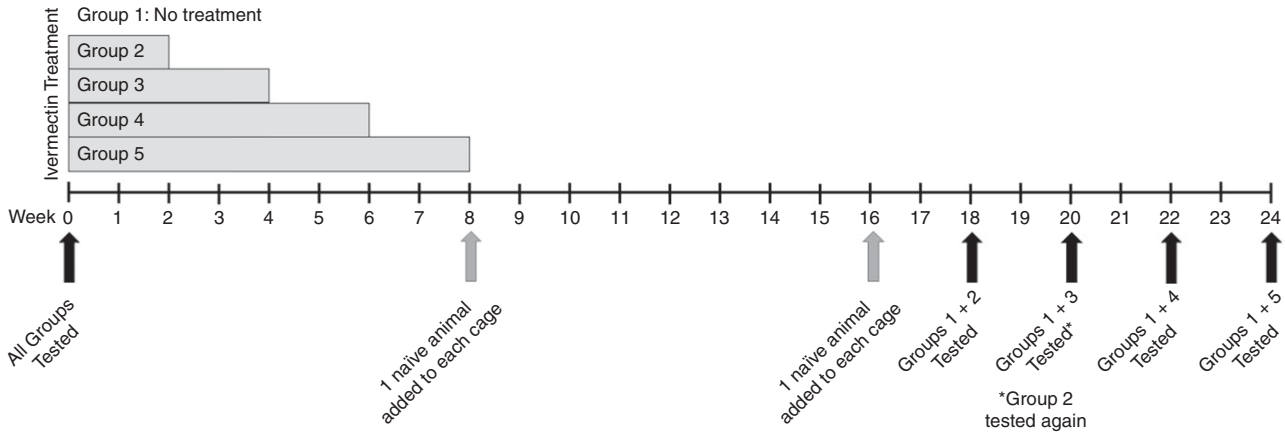

Figure 1. Study design illustrating 5 groups treated with ivermectin diet for 0, 2, 4, 6, or 8 wk. All groups were tested for *R. affinis* by PCR assay at the start of the experiment to confirm fur mite infestation (Week 0). To perpetuate any remaining live fur mites, 1 naïve animal was added to each cage at Weeks 8 and 16. All groups were tested again by PCR assay and pelt examination for *R. affinis* 16 wk after their respective treatment ends (Weeks 18 to 24). Group 1 (positive control) was tested concurrently with each treated group. Group 2 was tested at both Weeks 18 and 20 due to negative results from the positive control group at Week 18.

rodent fur mite genera ("Mite Screen"), and secondary testing was then performed to differentiate at the species level ("Species Specific"). The template copies per reaction in a sample were estimated by comparing the average sample and 100-copy positive template control cycle-threshold values; a difference of 3.3 cycle threshold values approximately corresponds to a 10-fold difference in copy number.[29] As reported in a previous publication, treatment success was evaluated by PCR testing of the animals at 16 wk posttreatment.[24] Before the 16-wk time point, positive results have been shown to persist due to the presence of residual fur mite nucleic acid.[22,24,30] Group 2 was tested at both 16 and 18 wk posttreatment (Figure 1) due to negative results from the positive control group (Group 1) at the 16-wk time point. Therefore, Groups 1 and 2 were both tested again at 18-wk posttreatment of Group 2.

Pelt examinations. Visual examination for fur mites was performed using direct microscopy at each respective timepoint, concurrent with fur swab sampling. Fur swab sampling for PCR assays occurred before pelt examinations on the same day (that is, the former occurred in the morning and the latter occurred in the afternoon). Direct microscopy was performed with an Accu-Scope 3075 Binocular Zoom Stereo Microscope on Coaxial Coarse Fine Focus LED Stand (3075-LED-CF, Commack, NY). Examiners scanned the pelt at 4× magnification and increased it as needed. One representative mouse was chosen at random from each cage for examination. Mice selected from Groups 2 to 5 were euthanized for the microscopic pelt exams. To avoid reducing group size and causing waning of the fur mite population, mice selected from Group 1 were anesthetized for the microscopic pelt exam, ear-punched to avoid evaluating the same mouse again at another time point, and then returned to the cage. Pelts were examined by veterinary technicians who were experienced with the technique, blind to the treatment group, and otherwise not involved in the study. Each mouse was examined by 2 individuals, and examinations were limited to 5 min per mouse per person to prevent bias. If mites or eggs were detected on the representative mouse, the entire cage was scored as positive.

Results

Treatment of *R. affinis*-infested mice with ivermectin diet for 2, 4, 6, and 8 wk was found to be effective in producing negative PCR test results and negative microscopic pelt examinations (Tables 1–3). Even though 8 wk of treatment was the previously employed regimen, as little as 2 wk of treatment was comparably effective.

At Week 18 (that is, 16 wk posttreatment of Group 2), *R. affinis* was not detected by PCR testing in Group 1 (no treatment, positive control), and fur mites were only seen in 2 of 5 cages on microscopic pelt examination (Table 4). Therefore, Groups 1 and 2 were retested again 2 wk later (Week 20), at which time all control results were positive (Table 1). From then on, Group 1 maintained a steady and consistent population of fur mites as detected by PCR testing and pelt examination (Tables 2 and 3).

Discussion

The primary aim of this study was to determine whether an ivermectin diet treatment period of less than 8 wk is sufficient to effectively eradicate *R. affinis* as validated by PCR testing and

Table 1. Diagnostic test results at Week 20 for *R. affinis* as detected by microscopic pelt examination and PCR assay for Group 1 (positive control), Group 2 (ivermectin treatment for 2 wk), and Group 3 (ivermectin treatment for 4 wk)

		Pelt Examination		PCR Assay	
Group	Cage	Observer 1	Observer 2	Mite Screen	Species Specific: *R. affinis*
1	A	+	+	+ (807)	+ (402)
	B	+	+	+ (402)	+ (402)
	C	+	+	+ (200)	+ (100)
	D	+	+	+ (402)	+ (402)
	E	+	+	+ (1,622)	+ (807)
2	A	—	—	—	—
	B	—	—	—	—
	C	—	—	—	—
	D	—	—	—	—
	E	—	—	—	—
3	A	—	—	—	—
	B	—	—	—	—
	C	—	—	—	—
	D	—	—	—	—
	E	—	—	—	—

PCR assay copy numbers are indicated in parentheses.

Table 2. Diagnostic test results at Week 22 for *R. affinis* as detected by microscopic pelt examination and PCR assay for Group 1 (positive control) and Group 4 (ivermectin treatment for 6 wk)

		Pelt Examination		PCR Assay	
Group	Cage	Observer 1	Observer 2	Mite Screen	Species Specific: *R. affinis*
1	A	+	+	+ (811)	+ (100)
	B	+	+	+ (1630)	+ (402)
	C	+	+	+ (811)	+ (100)
	D	+	+	+ (201)	+ (25)
	E	+	+	+ (811)	+ (200)
4	A	—	—	—	—
	B	—	—	—	—
	C	—	—	—	—
	D	—	—	—	—
	E	—	—	—	—

PCR assay copy numbers are indicated in parentheses.

direct microscopy. Results of this study showed that effective treatment to eliminate *R. affinis* from mice can be achieved in as little as 2 wk. This reduced treatment time is highly advantageous as compared with the previously employed 8-wk protocol as it minimizes cost and time for animal management programs, impediments to research, and ivermectin drug effects on infested mice. A large-scale *R. affinis* eradication initiative that requires 8 wk of treatment time is a daunting undertaking. Conducting this type of effort requires intricate planning and coordination, financial resources, and time. While planning and coordination would be necessary for any such initiative, reducing the duration of the treatment regimen will markedly reduce the overall quantity and cost of the medicated diet, making mass eradication more fiscally feasible for programs. In addition to cost savings, shortening the overall treatment time may be easier for researchers to accommodate. Shortening the treatment regimen may also relieve researcher concerns that ivermectin might affect gene expression, phenotypes, or any other factors for which treatment could confound results (for example, immunology or microbiome studies).[5–7,14,19,28]

At the start of this study, we experienced several challenges in developing an *R. affinis*-positive mouse colony for experimental treatment. Overall, it took 16 wk for all treatment groups to achieve infestation as determined by PCR testing. During this time, mice were regularly transferred between cages in an attempt to transmit *R. affinis* via direct contact. The time course of Group 1 (no treatment, positive control) suggests that there is a delay in detection of *R. affinis* by PCR testing. Naïve mice were added to Group 1 at Week 16 to perpetuate the *R. affinis* infestation. Two weeks later (Week 18), none of the cages were positive for *R. affinis* as determined by PCR testing even though mites were visualized in 2 of the cages by microscopic pelt examination. However, another 2 wk later (Week 20), all 5 Group 1 cages were positive for *R. affinis* via PCR assay. This time course suggests that up to 4 wk may be necessary to allow PCR testing to consistently detect *R. affinis* in newly infested or newly amplified colonies. Based on this timeline, we suggest that PCR detection of fur mites may be largely dependent on the presence of fur mite-associated particles, which might include defecate, chitin shells due to molting, and possibly egg casings, on mouse fur, and to a lesser degree, whole adult mites or eggs. Detection of *R. affinis* transference may be delayed because adult mites move onto a new host and must then reproduce and create sufficient biologic waste for detection via PCR testing.

This hypothesis is further supported by the observation that mouse grooming behavior can allow fur mite eggs and chitin shells to be microscopically visualized in mouse feces; however, there has only been one report of successful fur mite diagnosis using a fecal sample type for PCR testing.[15] We can suggest a few explanations for this. First, the parasites observed under microscopy may not have been fur mites but rather another ectoparasite that was morphologically similar, such that fur mites and chitin shells might be difficult to differentiate after gastrointestinal transit. Second, if only the chitin shell survives gastrointestinal travel for visual detection, then the internal soft tissue containing nucleic acids was likely exposed and eliminated by digestive enzymes, bacteria, and biochemical conditions, thereby making fur mite markers undetectable by PCR in mouse feces. Third, when fecal samples are processed in the diagnostic laboratory, a slow centrifugation is used to remove large conglomerations of fecal debris while retaining bacteria and viruses. This process reduces feces-associated inhibitors and large particles that may interfere with nucleic acid isolation or the PCR assay. This centrifugation process might remove fur mite adults and eggs from the sample. Regardless of the cause, murine fecal pellets are not an ideal sample type for the detection of fur mites by PCR assay based on current protocols.

The mouse immune system response to fur mites could have also contributed to our difficulty in attaining *R. affinis*-positive experimental groups. One of the many effects of mite infestations is an increase in total serum IgE. IgE is produced by the immune system in mammals in the presence of an allergen, and total serum IgE elicits an allergic-type response to fur mites[21,25] Therefore, high IgE levels early on in the study, in response to the growing exposure to *R. affinis*, could have contributed to our difficulty in deriving an *R. affinis*-positive mouse colony.

It was unexpected to have positive pelt examinations and negative PCR assay results in Group 1 at Week 18 (Table 4). Detection of fur mites can be sporadic when sampling mice directly for either parasitology or PCR methods, especially in a low infestation scenario. PCR is typically more sensitive as it does not require intact mites or eggs and can detect residual genetic material from either mites or eggs. However, if swabbing is performed less thoroughly or only on selected areas of the pelt, it could miss the mites. Also, pooling can introduce a dilution factor that could impact sensitivity. Nonetheless, the Charles River Laboratories fur mite PCR assays have been

Table 3. Diagnostic test results at Week 24 for *R. affinis* as detected by microscopic pelt examination and PCR assay for Group 1 (positive control) and Group 5 (ivermectin treatment for 8 wk)

		Pelt Examination		PCR Assay	
Group	Cage	Observer 1	Observer 2	Mite Screen	Species Specific: *R. affinis*
1	A	+	+	+ (807)	+ (50)
	B	+	+	+ (807)	+ (50)
	C	+	+	+ (402)	+ (50)
	D	+	+	+ (807)	+ (50)
	E	+	+	+ (1,622)	+ (100)
5	A	—	—	—	—
	B	—	—	—	—
	C	—	—	—	—
	D	—	—	—	—
	E	—	—	—	—

PCR assay copy numbers are indicated in parentheses.

Table 4. Diagnostic test results at Week 18 for *R. affinis* as detected by microscopic pelt examination and PCR assay for Group 1 (positive control) and Group 2 (ivermectin treatment for 2 wk)

		Pelt Examination		PCR Assay	
Group	Cage	Observer 1	Observer 2	Mite Screen	Species Specific: *R. affinis*
1	A	—	—	—	—
	B	+	+	—	—
	C	—	—	—	—
	D	—	—	—	—
	E	+	+	—	—
2	A	—	—	—	—
	B	—	—	—	—
	C	—	—	—	—
	D	—	—	—	—
	E	—	—	—	—

qualified to detect down to the 1 to 10 copy range. Regarding pelt examinations, proficiency varies widely among individuals. For this experiment, we recruited our 2 most experienced and skilled pelt examiners, which may have led to the 2 positive fur mite observations.

Although females were chosen for this study due to their less aggressive nature, we nonetheless observed notable fighting after the introduction of new mice, and we took steps to ameliorate fighting multiple times throughout the study. Gradual introduction methods were used to mitigate initial aggression when adding naïve mice to the preestablished groups, including titration of scent via transfer of nesting material, slow introductions through protected contact barriers, and introductions in a neutral environment for all mice. An abundance of enrichment devices was also offered in an attempt to divert focus and aggression. While most introductions were successful, 2 mice were eventually separated and removed from the study due to continued fighting. The removal of these 2 mice likely did not affect the *R. affinis* infestation as one was naïve but had been cohoused with the group for at least 2 wk before its removal and the other was an older dominant mouse from the original group. A previous study suggested that mice housed on standard corncob bedding, as in our study, showed greater incidences of aggression than do mice on wood-based bedding.[27]

Our study revealed that as little as 2 wk of ivermectin diet was effective in eliminating *R. affinis* as detected by PCR assay. Using this shorter duration substantially reduces the time, cost, effort, and effects on animals, researchers, and management programs. Since this study was performed using CD-1 mice with *R. affinis* infestation, definitive conclusions can only be made regarding this stock of mice and species of fur mite. However, one could extrapolate these findings, at their own comfort level, to other mouse stocks and strains and fur mite species as ivermectin efficacy has been shown to be reliable in other scenarios as well.[4,10,23] Because we only performed a small-scale study, further evaluations performed on a larger scale would be beneficial. Even though our results showed that a 2-wk treatment time was adequate for elimination of *R. affinis* in our experimental groups, the length of the fur mite life cycle is an important consideration. While ivermectin has been previously reported as an adulticide only,[20,26] the results of this study support that of other studies suggesting that ivermectin is also ovicidal.[4,23] Regardless, a 4-wk treatment duration may be a more conservative approach to ensure that all fur mite life stages present will be successfully affected by the medication. A treatment duration of 4 wk may also complement the duration of most standard quarantine programs. Whether using 2 or 4 wk, the shorter treatment duration would reduce costs and conserve resources when large-scale outbreaks occur and make eradication initiatives more feasible to achieve.

Acknowledgments

We thank Dr. Lindsey Ferguson, Maya Encantada Meeks, Kristy Calderon, Lorna Waldrop, and Leela Geeter for their technical support of this study.

Conflict of Interest

PCR testing was performed by Charles River Laboratories and provided at no cost to the institution. Kenneth Henderson and Cheryl Woods are employees of Charles River Laboratories, a company that produces and distributes research models and provides diagnostic services.

Funding

This work was supported by the AALAS Grants for Laboratory Animal Science (GLAS) Program.

References

1. **Baker DG.** 2008. Flynn's parasites of laboratory animals. Hoboken (NJ): Wiley.
2. **Bauer BA, Besch-Williford C, Livingston RS, Crim MJ, Riley LK, Myles MH.** 2016. Influence of rack design and disease prevalence on detection of rodent pathogens in exhaust debris samples from individually ventilated caging systems. J Am Assoc Lab Anim Sci **55**:782–788.
3. **Bornstein DA, Scola J, Rath A, Warren HB.** 2006. Multimodal approach to treatment for control of fur mites. J Am Assoc Lab Anim Sci **45**:29–32.
4. **Burdett EC, Heckmann RA, Ochoa R.** 1997. Evaluation of five treatment regimens and five diagnostic methods for murine mites (*Myocoptes musculinus* and *Myobia musculi*). Contemp Top Lab Anim Sci **36**:73–76.
5. **Conole J, Wilkinson MJ, McKellar QA.** 2003. Some observations on the pharmacological properties of ivermectin during treatment of a mite infestation in mice. Contemp Top Lab Anim Sci **42**:42–45.
6. **Davis JA, Paylor R, McDonald MP, Libbey M, Ligler A, Bryant K, Crawley JN.** 1999. Behavioral effects of ivermectin in mice. Lab Anim Sci **49**:288–296.
7. **Edwards G.** 2003. Ivermectin: Does P-glycoprotein play a role in neurotoxicity? Filaria J **2**:S8.
8. **Gerwin PM, Ricart Arbona RJ, Riedel ER, Henderson KS, Lipman NS.** 2017. PCR testing of IVC filter tops as a method for detecting murine pinworms and fur mites. J Am Assoc Lab Anim Sci **56**:752–761.
9. **Hanson WH, Taylor K, Taylor DK.** 2021. PCR testing of media placed in soiled bedding as a method for mouse colony health surveillance. J Am Assoc Lab Anim Sci **60**:306–310.
10. **Huerkamp MJ, Zitzow LA, Webb S, Pullium JK.** 2005. Cross-fostering in combination with ivermectin therapy: A method to eradicate murine fur mites. Contemp Top Lab Anim Sci **44**:12–16.
11. **Institute for Laboratory Research.** 2010. Guide for the care and use of laboratory animals, 8th ed. Washington (DC): National Academies Press.
12. **Jensen ES, Allen KP, Henderson KS, Szabo A, Thulin JD.** 2013. PCR testing of a ventilated caging system to detect murine fur mites. J Am Assoc Lab Anim Sci **52**:28–33.
13. **Karlsson EM, Pearson LM, Kuzma KM, Burkholder TH.** 2014. Combined evaluation of commonly used techniques, including PCR, for diagnosis of mouse fur mites. J Am Assoc Lab Anim Sci **53**:69–73.
14. **Kropp PA, Rushing GV, Brockman AA, Yu ENZ, Ihrie RA, Gannon M.** 2020. Unexpected effects of ivermectin and selamectin on inducible Cre(ER) activity in mice. Lab Anim Res **36**:36.

15. **Lee MA, Shen Z, Holcombe HR, Ge Z, Franklin EG, Ricart Arbona RJ, Lipman NS, Fox JG, Sheh A.** 2019. Detection of *Myocoptes musculinus* in fur swab and fecal samples by using PCR analysis. J Am Assoc Lab Anim Sci **58**:796–801.
16. **Lindstrom KE, Carbone LG, Kellar DE, Mayorga MS, Wilkerson JD.** 2011. Soiled bedding sentinels for the detection of fur mites in mice. J Am Assoc Lab Anim Sci **50**:54–60.
17. **Metcalf Pate KA, Rice KA, Wrighten R, Watson J.** 2011. Effect of sampling strategy on the detection of fur mites within a naturally infested colony of mice (*Mus musculus*). J Am Assoc Lab Anim Sci **50**:337–343.
18. **Moats CR, Baxter VK, Pate NM, Watson J.** 2016. Ectoparasite burden, clinical disease, and immune responses throughout fur mite (*Myocoptes musculinus*) infestation in C57BL/6 and Rag1(-/-) mice. Comp Med **66**:197–207.
19. **Nyangahu DD, Darby M, Havyarimana E, Brown BP, Horsnell W, Jaspan HB.** 2020. Preconception helminth infection alters offspring microbiota and immune subsets in a mouse model. Parasite Immunol **42**:e12721.
20. **Plumb DC.** 2018. Plumb's veterinary drug handbook: desk. Hoboken (NJ): Wiley.
21. **Pochanke V, Hatak S, Hengartner H, Zinkernagel RM, McCoy KD.** 2006. Induction of IgE and allergic-type responses in fur mite-infested mice. Eur J Immunol **36**:2434–2445.
22. **Ricart Arbona RJ, Lipman NS, Wolf FR.** 2010. Treatment and eradication of murine fur mites: II. Diagnostic considerations. J Am Assoc Lab Anim Sci **49**:583–587.
23. **Ricart Arbona RJ, Lipman NS, Wolf FR.** 2010. Treatment and eradication of murine fur mites: III. Treatment of a large mouse colony with ivermectin-compounded feed. J Am Assoc Lab Anim Sci **49**:633–637.
24. **Rice KA, Albacarys LK, Metcalf Pate KA, Perkins C, Henderson KS, Watson J.** 2013. Evaluation of diagnostic methods for *Myocoptes musculinus* according to age and treatment status of mice (*Mus musculus*). J Am Assoc Lab Anim Sci **52**:773–781.
25. **Roble GS, Boteler W, Riedel E, Lipman NS.** 2012. Total IgE as a serodiagnostic marker to aid murine fur mite detection. J Am Assoc Lab Anim Sci **51**:199–208.
26. **Sharaf MS, Othman AA, Abd El Ghaffar AE, Ali DM, Eid MM.** 2023. Evaluation of the scabicidal effect of a single dose of fluralaner in a rabbit model of crusted scabies. Parasitol Res **122**:2477–2490.
27. **Theil JH, Ahloy-Dallaire J, Weber EM, Gaskill BN, Pritchett-Corning KR, Felt SA, Garner JP.** 2020. The epidemiology of fighting in group-housed laboratory mice. Sci Rep **10**:16649.
28. **Toth LA, Oberbeck C, Straign CM, Frazier S, Rehg JE.** 2000. Toxicity evaluation of prophylactic treatments for mites and pinworms in mice. Contemp Top Lab Anim Sci **39**:18–21.
29. **Villegas EN, Augustine SA, Villegas LF, Ware MW, See MJ, Lindquist HD, Schaefer FW 3rd, Dubey JP.** 2010. Using quantitative reverse transcriptase PCR and cell culture plaque assays to determine resistance of Toxoplasma gondii oocysts to chemical sanitizers. J Microbiol Methods **81**:219–225.
30. **Weiss EE, Evans KD, Griffey SM.** 2012. Comparison of a fur mite PCR assay and the tape test for initial and posttreatment diagnosis during a natural infection. J Am Assoc Lab Anim Sci **51**:574–578.