Flea and tick control in the 21st century: challenges and opportunities

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Abstract
Historically, veterinarians have told their clients that one flea is all that is necessary to produce and maintain the clinical signs of flea allergy dermatitis (FAD). Newer adulticides, such as fipronil, imidacloprid, nitenpyram and selamectin, have had a positive clinical effect on dogs and cats with FAD. However, data on flea feeding and the effect of these products on flea feeding bring into question the once perceived dogma of the single flea bite concept. Current data would indicate that the primary role of these insecticides in managing FAD is in rapidly reducing flea numbers and reducing flea feeding rather than preventing flea bites. Controlling tick infestations is important not only because ticks are nuisance parasites of dogs and cats, but also because they are vectors of a variety of bacterial and protozoal diseases. Achieving satisfactory tick control is often difficult due to unrealistic expectations of pet owners, to residual acaricidal properties of products that are often less than 100% and because of constant re-infestation pressure. Some of the most important factors veterinarians must be aware of are regional changes in tick distributions, our inability to control wildlife tick hosts and expectation differences between flea and tick control. These factors probably cause most real and perceived product failures.

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Introduction

Advances in flea control using modern classes of insecticides and insect growth regulators/insect development inhibitors have markedly reduced the number of problem flea cases. However, several important issues such as speed of kill of residual insecticides, ability of insecticides to control flea feeding and reproduction remain unknown to most veterinary practitioners. Trying to manage client expectations concerning long-term flea control or management of flea allergy dermatitis (FAD) is more difficult without a proper understanding of the issues. In order to provide clients with an understanding of realistic flea control expectations, veterinarians need to acquire a better understanding of how flea biology can directly affect flea product performance and the management of FAD. Similarly, real and perceived failures in tick control programmes are often linked to an inadequate understanding of tick ecology. Three important elements that have a profound effect on tick control programmes, and which veterinarians need to understand, are: (i) changing geographic distribution of ticks; (ii) our inability to control ticks in the outdoor environment; and (iii) reproduction of ticks on their natural wildlife hosts.1 Tick control can be improved if veterinarians have a better understanding of these important ecological parameters and educate the pet owners so that control programmes can be modified or augmented.

Flea feeding and flea allergy dermatitis

Flea allergy dermatitis or flea bite hypersensitivity is the most common dermatologic disease of domestic dogs. Cats are also afflicted with FAD, which is one of the major causes of feline miliary dermatitis. Historically, it has been said that one flea is all that is necessary to maintain the clinical signs of FAD and therefore total flea eradication is necessary.2

Newer adulticides such as fipronil, imidacloprid, metaflumizone, nitenpyram, selamectin, and spinosad have had a positive clinical effect on dogs and cats with FAD.3–4 However, data on flea biology and the effect of these products on flea feeding bring into question the once perceived dogma of the ‘one flea bite’. Adult cat fleas begin feeding almost immediately once they find a host, with many fleas feeding within minutes.7 In one study, 25–60% of fleas were blood fed within 5 min9 and in another study the volume of blood consumed by fleas was quantifiable within 5 min.9 Feeding is so rapid that partially digested blood can be defaecated in as little as 2–6 min after fleas acquire a host. After rapid transit through the flea, the excreted blood dries within minutes into reddish black faecal pellets or long tubular coils (flea dirt). While initiation of feeding is rapid, daily blood consumption is voracious. Female cat fleas can consume up to ten times their body weight in blood the very first day7 they are on the host and peak consumption occurs within a few days at 15 times their body weight (13.6 μL) daily.7 With such rapid and voracious blood feeding, is it reasonable to assume that residual insecticides can truly prevent flea biting and feeding?
A study was conducted to evaluate the residual activity of fipronil and imidacloprid on egg production and blood feeding (M. W. Dryden, unpublished data). There were two objectives to this study: (i) to evaluate if these compounds would kill newly acquired fleas prior to feeding; and (ii) to determine how long these compounds would prevent viable egg production after application. In the first experiment, six cats were treated with either a fipronil spray (0.29% w/w) formulation, an imidacloprid spot-on (9.1% w/w) formulation at labelled rates or were left as untreated controls. Surprisingly, when 100 *Ctenocephalides felis* were placed on cats 6 days after treatment with imidacloprid or fipronil, the percentage of fleas that fed and consumed blood was 89% (imidacloprid) or 92% (fipronil). While the adulticidal efficacy of the products was 100%, neither product killed fleas before the vast majority could bite, feed and consume at least some quantity of blood.

In another study conducted in Europe, it was determined that the topical application of imidacloprid or fipronil to cats did not prevent fleas from biting and feeding. Unconfined fleas placed on cats treated with imidacloprid or fipronil had reductions in the percentage of fleas feeding of 49.6% and 39.5%, respectively, on day 7. Reductions in percentage of fleas feeding on day 28 were 0% and 3.4%, respectively. While topical applications of dichlorvos/fenitrothion or permethrin did reduce the per cent of fleas feeding by greater than 80%, these compounds also did not completely prevent flea bites or feeding. The data regarding percentage of fleas feeding on imidacloprid- and fipronil-treated cats in the European study differ from the data in the Kansas State University study. This probably occurred due to the known reduced susceptibility of the *KSU* flea strain to imidacloprid and fipronil.

Another study using dogs (M. W. Dryden, unpublished data) evaluated the ability of a 65% permethrin spot-on, a 13.8% fenothion spot-on and an 8% chlorpyrifos collar to reduce blood feeding by fleas. At 2 weeks post-treatment, evaluation of the feeding status of fleas revealed that an average of 66.7% of fleas from permethrin-treated dogs had fed. Fleas from chlorpyrifos-collared dogs and fenothion-treated dogs averaged 53.0% and 37% blood-fed status respectively. In this study, the percentage of fleas feeding on organophosphate- and pyrethroid-treated dogs was considerably higher than in the study conducted in Europe. It was later determined that the flea strain used in the *KSU* study was tolerant/resistant to certain organophosphates and pyrethroids.

Additional research has now been conducted to quantify the amount of blood consumed by fleas on insecticide-treated cats. In this study, fleas were confined for 24 h in confinement feeding chambers attached to treated cats once weekly for 4 weeks. Confinement feeding chambers were used so that fleas and their faeces could be collected for quantification and analysis. Cats were treated on day 0 with fipronil, imidacloprid or selamectin orally with nitrophen never consumed more than 1.63% as much blood as fleas placed on control cats (98.37% reduction in blood consumption). Topically applied, but transdermally absorbed selamectin also had a pronounced effect upon blood consumption of fleas. Even on day 28 post-treatment, there was an 88.9% reduction in blood consumption compared with fleas on untreated controls. As stated previously, compounds such as fipronil, imidacloprid, metaflumizone, selamectin and spinosad have had a major impact on reducing the occurrence of FAD. However, the data from the qualitative and quantitative studies demonstrate that these compounds neither stop flea bites nor completely stop flea feeding. Therefore, it appears that their role in managing FAD is probably related to a decrease in prolonged flea feeding and thereby the amount of salivary protein delivered to the pet and in the long-term reducing flea numbers. It is this author’s opinion that FAD is related to the degree of hypersensitivity of an individual animal, the numbers of fleas feeding and amount of antigen injected. This certainly brings into question the old dogma of a single flea elicit an FAD reaction, at least in the majority of clinically afflicted animals. If a single flea bite was responsible, it appears that no flea product would provide much relief, at least not until the flea population was eradicated. It is also worth noting that whether an insecticide works topically or systemically may be irrelevant in the management of fleas or FAD, as in one study the systemically active compounds had a pronounced effect on blood feeding.

### Flea egg production

An indirect indicator of an insecticide’s ability to reduce blood consumption is the ability of the compound to reduce egg production. Reduction in egg production is not only an indicator of blood consumption; it is important for modern day flea control. Topical and systemic flea products are capable of controlling flea populations in the premises through their action on flea reproduction. In this situation, as pets move through the flea-infested premises, fleas jump on treated pets and these products either kill fleas before substantial egg production is initiated or kill flea eggs (insect growth regulators or ovicides). In this manner, fleas are driven to extinction in the localized premises because they cannot produce subsequent generations.

The first pilot tests conducted by this author on reproductive control through adulticide application evaluated dogs treated with either a 65% permethrin spot-on, a

13.8% fenthion spot-on or an 8% Chlorpyrifos collar (M. W. Dryden, unpublished data). Evaluation of these compounds on flea egg production revealed that permethrin provided 83.8% and 49.1% control of eggs following flea infestations 2 and 3 weeks post-treatment respectively. Fenthion provided 86.9% and 57.7% control of eggs following the 2- and 3-week post-treatment infestations respectively. The chlorpyrifos collars provided only 36.6% and 8.5% reduction in egg numbers 2 and 3 weeks post-application respectively.

Similar evaluations were also conducted on imidacloprid- and fipronil-treated cats (M. W. Dryden, unpublished data). When cats were infested on days 6 and 13 post-treatment, the efficacy of both products was 100% and no eggs were recovered from treated cats following these reinfestations. These data indicated that these newer formulations were more effective in reducing egg production than the older pyrethroid and organophosphate formulations. This improvement in reduction in egg production probably results from more rapid speed of kill. Following the 20-day reinfestation, a few viable eggs were collected from the treated cats and an increasing number of eggs were recovered from the cats following the day 27 reinfestation. Per cent control of egg production from days 27–31 ranged 73.7–96.7 and 46.1–95.4 for imidacloprid and fipronil treatments respectively.

It is interesting that in the dog study, fenthion (which was once marketed as a systemically active compound) had the lowest percentage of blood fed, dead fleas and the greatest effect on egg production. Similarly, the blood quantification study in cats also demonstrated that topically applied and systemically active selamectin reduced blood feeding more than topically active fipronil or imidacloprid.9

Another study that further confirms the effect that a systemically active compound can have on egg production was conducted comparing selamectin (6% w/v) spot-on and a fipronil (9.8% w/w)–(s)-methoprene (11.8% w/w) spot-on formulation on flea-infested cats.18 In this study, cats were treated with one of the two formulations or served as untreated controls. Adulcidual activity and the effect of these compounds on egg production and egg viability was also evaluated weekly. Weekly residual adulcidual efficacy up to day 45 was 100.0%, 100.0%, 99.7%, 97.3%, 90.2% and 78.0% for selamectin-treated cats. Weekly residual adulcidual efficacy for fipronil/(s)-methoprene-treated cats was 99.5%, 99.6%, 97.9%, 79.3%, 84.9% and 51.3%.18 Residual activity against egg production was demonstrated on all selamectin-treated cats with geometric egg counts of 0.1 on day 9 and 45.7 on day 45. No eggs were collected from selamectin-treated cats on days 10, 16 and 23. Egg production was also reduced on all fipronil/(s)-methoprene-treated cats with geometric egg counts of 1.5 on day 9 and 179.8 on day 45. Selamectin, which had previously been demonstrated to reduce flea blood consumption more than fipronil on treated cats, was shown in this investigation to reduce egg production more than fipronil.9,18

It was noted that, due to the ovicidal effects of these formulations, larvae emergence from eggs did not occur or was negligible from day 2 to day 37 post-treatment, regardless of treatment group. The hatch rate of eggs deposited from selamectin and fipronil (s)–methoprene-treated cats during days 2–37 varied from 0% to 13.2% and 0% to 0.03% respectively.18 On day 45 post-treatment, per cent larval emergence was greater in eggs from selamectin (23.3%)-treated than from fipronil/(s)-methoprene (0.1%)-treated cats.

**Tick control issues**

While recent pharmaceutical advances have been made in flea control, in the area of tick control such advances are lacking. One major area of difference between flea and tick control is in the control of reproduction. With the exception of the brown dog tick *Rhipicephalus sanguineus*, our ability to manage tick reproduction is limited, if not almost nonexistent. As discussed previously, in most flea infestations we have the opportunity to control flea reproduction by either killing fleas before they can reproduce or killing flea eggs. However, it is not just because we have effective residual insecticides, insect growth regulators or insect development inhibitors that we are successful, it is also due in large part to the fact we can often target the primary reproductive host, the flea-infested dog or cat. Failures in flea control may occur when flea-infested feral pets or flea-infested urban wildlife invade the owner’s yard.19

However, when dealing with most three-host ticks, the problem is that the majority of the reproducing ticks are not on the dogs or cats, but on their wildlife hosts. As we are limited in our ability to manage ticks on wildlife, reinfestations are a common occurrence and protracted use of acaricides as preventives is routine in many areas.

As mentioned earlier, one tick species that is an exception is *R. sanguineus*. While this tick is a three-host tick, practically it can be said to function as a one-host tick, as it prefers to feed upon dogs at all stages of its life cycle. Therefore, we have the opportunity through rigorous application of acaricides to kill female ticks before they reach repletion.

As tick control can be extremely difficult, and because ticks are vectors of a variety of bacterial and protozoal diseases, veterinarians should have an understanding of the ecology of the ticks encountered in the practice area. Veterinarians must be educated on the various aspects of tick ecology, disease transmission and control methodologies so that they can then educate their staff and pet owners.

Further compounding the problem is that these factors vary not only from country to country, but very commonly they vary regionally. Veterinarians must search out the best sources of information in their respective areas to find out about local tick species, local tick ecology and potential list of diseases transmitted by ticks in their area. Additionally, in some regions of the world, tick species and their respective diseases have been increasing due to a variety of factors including changes in climate, vegetation, agricultural practices, wildlife host abundance, acaricide usage and probably several other factors.20–24

Therefore, information garnered over several years previously may not be valid today and may yet again change in future. Changes in tick distributions and densities may

have a direct impact upon success or failure of a tick control programme.

Acaricide efficacy

Numerous studies have been conducted to evaluate the efficacy of various acaricides such as amitraz, fipronil and permethrin against ticks infesting dogs.\textsuperscript{25–34} While such studies demonstrate a high level of efficacy of the various products, the residual activity is rarely 100%. In addition, variation in the efficacy of products occurs between and within species, even in the same laboratory.\textsuperscript{28,31} Evaluations of acaricides under natural or field conditions further illustrates that while efficacy is good it is not 100%.\textsuperscript{33,34}

In a field efficacy trial conducted in Kansas, USA, an imidacloprid (8.8% w/w)–permethrin (44.0% w/w) formulation was evaluated on dogs against naturally occurring populations of Amblyomma americanum. When dogs were walked in a naturally tick-infested environment, the 48-h post-exposure efficacy of imidacloprid–permethrin formulation was 93.5%, 98.9%, 94.6%, 94.1% and 96.6% on days 3, 7, 14, 21 and 28 post-treatment respectively.\textsuperscript{33}

In another field trial, the efficacy of imidacloprid (8.8% w/w)–permethrin (44.0% w/w) and fipronil (9.8% w/w)–(s)-methoprene (8.8% w/w) formulations was determined in dogs naturally infested with R. sanguineus.\textsuperscript{34} The efficacy of the imidacloprid–permethrin and fipronil–(s)-methoprene formulations on days 7, 14, 21 and 28 post-treatment against immature and adult ticks was 87.5%, 95.9%, 95.01%, 98.43% and 88.54%, 88.52%, 91.15%, 77.56% respectively.\textsuperscript{34}

As mentioned previously, variation in product efficacy can also occur within a species. In two studies conducted in the same laboratory, different results were found when evaluating the efficacy of acaricides against Dermacentor variabilis infestations in dogs from two different regions of the USA.\textsuperscript{28,31} In the first study, the efficacy of imidacloprid–permethrin and fipronil–(s)-methoprene formulations were evaluated against a D. variabilis isolate from California.\textsuperscript{28} The 48-h post-infestation efficacy on day 30 post-treatment was 92.0% and 83.2%, respectively, for the imidacloprid–permethrin and fipronil–(s)-methoprene formulations. In the second study, the 48-h post-infestation efficacy on day 30 for the imidacloprid–permethrin and fipronil–(s)-methoprene formulations against a D. variabilis isolate from Oklahoma was 17.5% and 75.7% respectively.\textsuperscript{31}

Practical considerations in tick control

While product efficacy is often excellent in most studies, significant variation in efficacy can occur and 100% control is rarely achieved. Therefore, it can be expected that under natural conditions in areas where dogs are being frequently exposed to ticks, pet owners will see ticks on treated dogs. We might also expect that efficacy in real-world situations might be lower due to such factors as bathing and swimming, differences between dog breeds and haircoat types and frequency and correctness of product application.

As 100% tick kill is rarely achievable, perceived efficacy of acaricides may be directly related to the numbers of ticks to which dogs are exposed. If a dog is treated with one of these highly efficacious acaricides and encounters just a few ticks it is likely that all those ticks will be killed. However, if tick exposure is considerably larger, we can expect a few ticks to be observed on these dogs and pet owners may perceive a lack of efficacy. Therefore, in areas where tick populations are increasing the perception may be that the products are not as effective as they once were.

Pet owners often view tick infestations of their pets differently from flea infestations.\textsuperscript{1} Whether this is due to concerns about tick transmitted diseases or simply a phobia, the presence of a couple of ticks on the pet often elicits a more pronounced negative reaction than presence of a couple of fleas. A 95% effective flea product may provide great client satisfaction while a similarly effective tick product may be perceived as a failure. Therefore, it is not uncommon that label recommended application of a product does not appear to control the problem.\textsuperscript{1} This may be real or perceived, based upon pet owner’s expectations of product performance. Given pet owner’s concerns, there is a need to reduce tick-borne diseases and lack of 100% efficacy; occasionally additional control measures are needed.\textsuperscript{30,36} If additional control measures are deemed necessary, pet owners need to be educated as to why additional control measures are necessary and notations made in the pet’s record before extra-label uses are conducted.\textsuperscript{1}

One of the most common practically attempted solutions to this problem in dogs is to increase the frequency of application.\textsuperscript{1} Here, increased residual efficacy is the expected outcome, as you are increasing the residual acaricide levels with the shorter application intervals. Additionally, with many three-host ticks, destruction of tick habitat can reduce exposure pressure. Areas that serve as refuge for ticks and wild mammals such as grass, weeds and brush piles, between runs and along buildings, can be eliminated or treated with an approved acaricide.

In some situations, especially in tropical and subtropical regions and in climate-controlled kennels, brown dog ticks may infest buildings, with ticks crawling up walls, curtains and throughout the home or kennel.\textsuperscript{1,35} In these situations acaricides may need to be sprayed indoors into cracks and crevices, behind and under furniture or cages and along walls and the ceiling.\textsuperscript{1,36} Following application, make sure the acaricide is dry before animals or humans are allowed back into the premises to minimize toxicity problems. Finally, restricting pet access from tick-infested environments may be necessary.

Conclusions

Having a correct understanding of how the control of fleas and FAD is achieved will certainly enhance a veterinarian’s selection of an appropriate flea product. A product or product combination that produces rapid residual speed of kill and pronounced ovicidal activity is expected to produce excellent results. As new compounds are developed and brought to the market, investigations on the impact of these formulations on flea feeding kinetics and egg production will need to be conducted in order to provide a clearer indication of their ability to control flea populations and manage FAD. However, it is apparent that just because a compound works systemically does
not disqualify it if an effective flea treatment for the dog or cat with FAD.

It is apparent that the range and local density of certain tick species have increased in many areas. Irrespective of the factors, it must be recognized that tick infestation pressure may be much higher and associated tick-transmitted diseases may be more prevalent in some locations today than in the past. The increase in tick populations means that pets are encountering ticks more frequently, are exposed to more ticks per encounter and clients may be seeing more ticks on their pets than in the past. As tick products do not kill or repel all ticks instantly, clients may get the false impression that the products are not performing as well as in the past. These situations necessitate that veterinarians set client expectations, before clients set their own unrealistic expectations of control.

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**Résumé** Les vétérinaires disent habituellement à leurs clients qu’une seule puce peut induire puis entretenir les signes de dermatite allergique aux piqûres de puces (FAD). Des adulticides récents comme le fipronil, l’imidaclopride, le nitenpyram et la selamectine ont eu un effet positif sur les chiens et les chats atteints de FAD. Cependant, les données sur la prise alimentaire de la puce et l’influence de ces molécules sur cette prise alimentaire remettent en cause le concept de la puce unique. Les données actuelles indiquent que le rôle primaire de ces insecticides dans la gestion de la FAD est de réduire le nombre de puces et leur prise de nourriture plutôt que de prévenir leurs morsures. Le contrôle des infestations par les tiques est important non seulement parce que les tiques sont des parasites nuisibles des chiens et des chats mais aussi parce qu’elles sont vectrices de différentes protozooses et maladies bactériennes. Le contrôle satisfaisant des tiques est souvent difficile en raison des attentes irréalistes des propriétaires, des propriétés acaricides résiduelles des molécules souvent inférieures à 100% et de la pression de réinfestations permanente. Certains des facteurs les plus importants auxquels les vétérinaires doivent prêter attention sont les variations régionales de distribution des tiques, notre incapacité à contrôler leurs hôtes sauvages et les différences de contrôle entre les puces et les tiques. Ces facteurs sont davantage à l’origine des échecs des traitements que les molécules elles-mêmes.

**Resumen** Históricamente, los veterinarios han dicho a sus clientes que una pulga es todo lo que se necesita para producir y mantener los signos clínicos de la dermatitis alérgica a las pulgas (FAD). Adulticidas de nueva generación como el fipronil, imidacloprid, nitenpyram y selamectina han tenido un efecto clínico positivo en perros y gatos con FAD. Sin embargo, los datos acerca de la alimentación de las pulgas y del efecto de estos productos en su alimentación ponen en duda el dogma antes generalizado del concepto de una sola pulga. Datos actuales indican que la función primaria de los insecticidas en el manejo de la FAD es la reducción rápida del número de pulgas y reducir la alimentación de las pulgas, en lugar de la prevención de la picadura de las pulgas. El control de las infestaciones por garrapatas es importante no sólo porque las garrapatas son una molestia para perros y gatos, sino también porque son vectores de una variedad de enfermedades bacterianas y protozoarias. Obtener un control adecuado de las garrapatas es a menudo difícil debido a expectaciones poco realistas de los propietarios, a la actividad residual de acaricidas que con frecuencia son menores de un 100%, y debido a la presión constante de las reinfecciones. Algunos de los factores más importantes que los veterinarios deben tener en cuenta son los cambios regionales en la distribución de las garrapatas, nuestra incapacidad para controlar los hospedadores salvajes de garrapatas, y las diferencias en la expectativa de control de pulgas y garrapatas. Estos factores probablemente causan mayores fallos reales y percibidos de los productos.