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Pen and field trials of a new anticoagulant rodenticide flocoumafen* against the house mouse (*Mus musculus* L.)

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SUMMARY

The efficacy of flocoumafen, a novel anticoagulant rodentide, was evaluated in feeding tests on confined and free-living populations of house mice (*Mus musculus* L.). In four pen trials, family groups of laboratory-reared wild mice were conditioned to feeding on plain foods and then offered flocoumafen at 0·005% in pinhead oatmeal bait. All 68 mice, comprising juvenile and adult animals, died within 10 days.

Ten field trials were carried out, using the same formulated poison bait, against mice infesting farm buildings. Mean treatment success, estimated from live-capture and mortality data, ranged between 87·1 and 100%.

The performance of flocoumafen is compared with that of difenacoum, bromadiolone and brodifacoum used at the same concentration in oatmeal bait. Flocoumafen gave an equally effective but quicker kill of mice. It is concluded that flocoumafen is a promising new rodenticide for the control of *M. musculus*.

INTRODUCTION

Recent work on rodenticides in this laboratory has been largely focused on compounds of potential value in overcoming the problem of resistance to warfarin and other anticoagulants of longstanding use. A major outcome has been the evaluation of difenacoum, bromadiolone and brodifacoum, three new anticoagulants now in use for the control of commensal and some other harmful rodents. The feeding tests on confined colonies of wild house mice (*Mus musculus* L.) showed that each compound was highly effective against warfarin-resistant animals (Rowe & Bradfield, 1976; Rowe, Plant & Bradfield, 1981) and these 'second generation' anticoagulants also gave good control of mice in field situations (Rowe, Swinney & Plant, 1978; Rowe, Plant & Bradfield, 1981).

The present paper reports on the results of comparable trials carried out using flocoumafen, 4-hydroxy-3-1,2,3,4-tetrahydro-3-4-4-trifluoro methylbenzyloxy) phenyl-1-naphthyl coumarin, another potent new anticoagulant (Bowler, Entwistle & Porter, 1984).

* Proposed common name.

METHODS

Pen trials

Family groups of wild mice were reared in a breeding cage, using parent stock known to be resistant to warfarin (Rowe & Bradfield, 1975). The cage was transferred to the nesting area of a metal pen measuring 9·5 × 2·5 m when two or more litters had been raised. Plain food, whole wheat grain mixed with powdered Diet FFG(M) (Dixon & Sons (Ware) Ltd) and water supplies were made available near the cage and the mice were allowed to range throughout the pen. Movement between the nesting site and the larger test arena was made possible through apertures cut in the intervening metal sheet. Illumination was controlled (alternate 12 h periods of white and dull red light) and a group was conditioned to the pen environment for 7 days before a poison trial was begun.

In four treatments, flocoumafen was included at 0·005 % in a cereal bait. The poison bait was prepared by thoroughly mixing an appropriate amount of the compound in corn oil (5 %) with wholemeal flour (5 %) and pinhead oatmeal (to 100 %). Amounts of bait (15–20 g) were placed in open trays at eight points, close to the walls forming the long sides of the arena. The sources of plain food were maintained during each treatment and the total amount of poison bait eaten was measured daily. The pen and the cage were searched daily to recover dead mice and autopsies were carried out to confirm symptoms of anticoagulant poisoning.

Field trials

Ten field trials were conducted, in granaries, animal feed stores and a utility barn, on farms in West Sussex. A building was selected for use after a survey had indicated that it was infested by mice and not also by rats (*Rattus norvegicus* Berkenhout).

Each mouse population was sampled before the poison treatment was begun. The Longworth live-traps (Chitty & Kempson, 1949) used for this purpose were distributed throughout the infested area and left set for 4 days. The traps were inspected daily; all new animals were sexed, weighed and marked and recaptured individuals were identified before release, also at the point of capture.

Treatment with 0·005 % flocoumafen in pinhead oatmeal bait began 3 days later. Small covered containers were sited 1–2 m apart, at ground and eaves height, and supplied with a generous amount (20–30 g) of poison bait. The take of bait in each week was measured daily over 4 days (Tuesday to Friday) and then over the next 3 days. Additional bait was added at needed points to ensure that a surplus amount was always available. The treatments were terminated, with one exception, when no feeding occurred over 3 days.

Longworth traps were set on the last day of each treatment to remove surviving mice and numerous patches of a fine dust, basic slag, were also laid in the buildings at this stage. The traps were picked-up when no signs of mice were found over 7 days.

Estimates of minimum treatment success were derived from counts of the number of mice known to have been present when poisoning was begun (the number of marked and of un-marked animals examined throughout the trial period) and the number of survivors.

Table 1. *The toxicity of flocoumafen* (0·005%) *to family groups of warfarin-resistant* Mus musculus

Trial no.	Poison bait eaten (g) Days 1–2	3–4	5–6	7–8	9–10	Days to death: Mortality	Range	Mean
1	70·5	34·0	1·9	0·8	0·4	17/17	3–10	5·1
2	47·8	7·2	0·4	—	—	15/15	3–6	4·3
3	48·9	15·5	0·0	0·0	—	17/17	3–8	5·2
4	47·0	30·2	7·7	0·0	—	19/19	3–8	5·7

Table 2. *The results of flocoumafen poison treatments against infestations of* Mus musculus

Trial no.	Pre-treatment number of mice	Poison bait eaten (g) Week 1	2	3	4	5	6	Post-treatment number of mice	Estimated success (%)
1	32	363	45	46	—	—	—	0	100
2	23	501	101	9	—	—	—	0	100
3	28	75	44	0	—	—	—	3	89·3
4	22	194	30	0	—	—	—	1	95·5
5	19	165	48	0	—	—	—	0	100
6	29	324	102	53	—	—	—	0	100
7	31	195	189	104	8	25	7	4	87·1
8	121	835	62	3	—	—	—	0	100
9	33	118	158	64	3	—	—	0	100
10	37	800	152	63	30	2	—	0	100

Laboratory feeding tests

Surviving mice were transported to the laboratory, individually caged and maintained on Diet FFG(M) and water *ad lib*. After a rest period lasting 3 weeks or more, the laboratory diet was withdrawn and each animal was offered 0·005% flocoumafen in pinhead oatmeat bait. The amount of poison bait eaten was measured daily until death.

RESULTS

Pen trials

The results of the pen trials are given in Table 1. In each treatment, the consumption of flocoumafen bait declined markedly after 2–3 days. All four family groups were killed, males and females numbering 30 and 38 respectively. The first dead mice were found on day 3 and only five animals (7·4%) survived more than 7 days.

Field trials

The amounts of poison bait eaten by mice in the field trials are shown in Table 2. Except in trial 9, consumption was highest during the first week and, thereafter, there was a progressive decline in take. As in the pens, dead mice were first picked-up

Table 3. *The results of laboratory feeding tests on the survivors of the flocoumafen field treatments*

Trial no.	Sex	Body weight (g)	Poison bait eaten (g)	Dosage that killed (mg/kg)	Day to death
3	M	20·0	12·8	32·0	4
3	F	14·9	25·3	84·9	10
3	F	15·7	24·2	77·1	11
4	M	12·1	5·0	20·7	3
7	M	16·5	12·1	36·7	9
7	M	11·6	17·4	75·0	12
7	F	14·4	9·1	31·6	9
7	F	11·7	17·7	75·6	13

Table 4. *The comparative efficacy of four anticoagulant rodenticides in pen trials against* Mus musculus

	Poison bait eaten (g) Week					
Poison (0·005%)	1	2	3	Mortality	%	Mean day to death
Difenacoum	376·6	125·5	83·7	72/81	88·9	8·6
Bromadiolone	376·8	64·9	27·0	55/58	94·6	8·1
Brodifacoum	315·3	28·0	21·4	62/63	98·4	7·3
Flocoumafen	304·7	0·7	—	68/68	100	5·1

on day 3. Feeding was more protracted than that in the pens however, two of the treatments (trials 7 and 10) lasting 6 and 5 weeks respectively.

Seven treatments were completely successful and the control achieved in the other three ranged between 87·1 and 95·5%.

Laboratory feeding tests

Two of the ten survivors (trials 3, 4 and 7) showed symptoms of anticoagulant poisoning and died in the laboratory soon afterwards. The remaining animals were fed poison bait; they died between days 3 and 13 (Table 3).

DISCUSSION

Flocoumafen proved to be highly effective in both the pen and field trials, supporting earlier findings on the potency of this new anticoagulant against *M. musculus* (Bowler, Entwistle & Porter, 1984).

Its performance is best compared with that of difenacoum, bromadiolone and brodifacoum, anticoagulants recently examined in comparable work. The results of equivalent pen trials on the four compounds are summarized in Table 4. Poison bait was offered for a maximum 21-day period; there were few survivors but only flocoumafen gave complete control of all four family groups. Feeding on flocoumafen bait, moreover, was shortest and death was also quickest using this poison, the last animal dying on day 10.

The farm infestations of mice chosen to test flocoumafen under field conditions

were typical of those selected for use in six equivalent trials undertaken with difenacoum and bromadiolone (Rowe, Plant & Bradfield, 1981) and with brodifacoum (Rowe, Swinney & Plant, 1978). Not surprisingly, considering the food supplies and cover present in the buildings, flocoumafen bait was consumed over a longer period than in the pens.

Treatment success was high, nevertheless, the overall mortality (97·9 %) comparing favourably with that achieved using difenacoum (96·0 %), bromadiolone (92·4 %) and brodifacoum (98·8 %). Further comparison of the field data showed that 7 of the 10 flocoumafen treatments were completed in 3 weeks against only 4 of the 18 undertaken with the other anticoagulants. Thus, as in the pens, flocoumafen gave comparably quicker control of mice in the field.

The laboratory feeding tests conducted on mice caught at post-treatment showed that the survivors were susceptible to flocoumafen. The amount of bait consumed (5·0–25·3 g) and the range in days to death (4–13) indicated differential susceptibility to the poison, however. Feeding on flocoumafen bait was most protracted in trial 7; this treatment was continued for 6 weeks but it was largely ineffective in its latest stage, bait consumption persisting at a low level. Dead mice were found in the store as early as day 3 but the four survivors died between days 9 and 13 in the subsequent 'no-choice' test in the laboratory. This suggests the possibility that selection, favouring the least susceptible animals, occurred during the course of the treatment. There was no strong evidence of resistance to flocoumafen however, as found in the trials of difenacoum and bromadiolone (Rowe, Plant & Bradfield, 1981).

It is concluded that flocoumafen is highly toxic to *M. musculus* and that bait containing 0·005 % of the compound is most suitable for field use.

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