

UC Agriculture & Natural Resources

Proceedings of the Vertebrate Pest Conference

Title

The status of bromadiolone in the United States

Permalink

<https://escholarship.org/uc/item/7k77660v>

Journal

Proceedings of the Vertebrate Pest Conference, 12(12)

ISSN

0507-6773

Author

Poché, Richard M.

Publication Date

1986

THE STATUS OF BROMADIOLONE IN THE UNITED STATES

RICHARD M. POCHE, Chempar Products, Lipha Chemicals, Inc., New York, New York.

ABSTRACT: The anticoagulant rodenticide bromadiolone is used throughout the U.S. under a number of trade names. An expanded research program is underway within Chempar to examine the use of bromadiolone in commensal and field rodent control. Data are presented herein on the toxicology, metabolism, secondary hazards, efficacy, and formulation developments with bromadiolone. A new Maki 0.001% liquid bait is being tested and excellent control results obtained against Norway rats (*Rattus norvegicus*), roof rats (*R. rattus*), and house mice (*Mus musculus*). New Maki paraffin blocks containing 50 ppm bromadiolone have been developed and are soon to be on the market. Bromadiolone biogradability in the field and in animal tissues offers promise for expanded label claims for use in urban and field situations.

INTRODUCTION

The second-generation anticoagulant rodenticide bromadiolone was first introduced into the U.S. market in 1980 under the trade name MAKI. Details on its chemical structure and aspects of early development research are presented by Grand (1976) and Meehan (1978).

Summaries of early bromadiolone field testing in the U.S. were presented by Marsh (1977), Marsh et al. (1980), and Lechevin (1985). Since then, numerous research studies have been completed, most of which have not been published.

In the U.S. bromadiolone was first marketed under the trade name MAKI. Since then, through several licensing arrangements and subregistrations, many end-use baits containing the compound are now available in the PCO and consumer markets. Table 1 lists those trade names currently marketed and containing 0.005% of the compound.

Table 1. Products marketed in the U.S. containing bromadiolone.

Commercial Bromadiolone Products

- Maki Rat and Mouse Meal Bait
 - Maki Paraffinized Pellets
 - Maki Rat and Mouse Bait Packs (Pellets)
 - Maki Paraffin Blocks
 - Rat Arrest
 - Mouse Arrest
 - Contrac Rat and Mouse Bait
 - Blitz One Feeding
 - Rat Flip One Feed
 - Mousebuster
 - Ratfree
 - Chacon One Shot Rat and Mouse Killer
 - Just One Bite Rat and Mouse Bait
 - Pied Piper Rat & Mouse Bait Packs (Pellets)
 - Last-Stop Rat and Mouse Bait Packs (Pellets)
 - NCH Paraffinized Pellets
 - Rat-Tat-Tat II Rat and Mouse Bait Packs (Pellets)
 - Starbar Trax-One
-

As a second-generation anticoagulant, bromadiolone is more active than products such as warfarin and chlorophacinone. Bromadiolone, however, is less toxic than brodifacoum and difenacoum. A summary of toxicity information on rodents and key domestic and wildlife species is presented in Table 2. The compound is not very soluble in water (19 ppm) (Lipha, undated). Data on bromadiolone toxicity to fish are given in Table 3.

Table 2. Toxicity of bromadiolone to various rodents, domestic animals and wildlife (Anon.).

| Species | LD-50 | LC-50 |
|----------------|-------------|----------|
| House mouse | 1.750 mg/kg | -- |
| Norway rat | 1.125 | -- |
| Pine vole | 3.900 | -- |
| Dogs(1) | 15.000 | -- |
| Cats | 25.000 | -- |
| Rabbit (oral) | 1.000 | -- |
| Bobwhite quail | 138.000 | 62.0 ppm |
| Mallard | -- | 110.0 |

(1) Maximum tolerated dose of 10 mg/kg. LD-50 is an estimate.

Table 3. Toxicity of bromadiolone to aquatic organisms.

| Species | LC-50 (mg/L) | | |
|------------------|--------------|---------|---------|
| | 24 hrs. | 48 hrs. | 96 hrs. |
| Daphnia | 8.8 | 0.24 | -- |
| Rainbow trout | 3.9 | 2.4 | 1.4 |
| Bluegill sunfish | 4.4 | 4.1 | 3.0 |

FIELD TRIALS

Numerous field trials have been conducted through the U.S. to control commensal rodents with MAKI. Table 4 (Marsh et al. 1980) outlines major studies completed in the U.S. to support bromadiolone registration by the Environmental Protection Agency. As the efficacy data illustrate, the compound is very effective in reducing rodent numbers in various regions of the country.

Table 4. The results of field trials conducted for several rodent species with Bromadiolone (MAKI) in the U.S. (Marsh et al. 1980).

| Species | Site | State | Efficacy (% mortality) |
|--------------------------|----------------------|---------------|---------------------------|
| Norway rat | Horsebarn | New York | > 75% |
| | Grain elevator | Texas | 70-80% |
| | Chicago Inner City | Illinois | 86% |
| | Commercial buildings | California | 99% |
| | Hog farm | Ohio | 85% |
| | Farm home | Wisconsin | Near 100% |
| | Store | New Jersey | 100% |
| | Feed lot | Nebraska | 95% |
| | River bank | Minnesota | Near 100% |
| | Poultry farm | N. Carolina | 89% |
| | Vacant lot | Massachusetts | > 90% |
| | Apartment bldg. | Massachusetts | > 90% |
| Norway rats & House Mice | Farm home | Wisconsin | 68-85% |
| | Grain mill | Wisconsin | Near 100% |
| Roof rat | Residential block | Florida | 100% |
| | Hospital | Texas | 100% |
| | Residential block | California | 100% |
| | Feed lot | California | 85% |
| House mouse | Store room | New Jersey | 100% |
| | Apartments | Massachusetts | Near 100% |
| | Home | Wisconsin | 100% |
| | Grain mill | California | Near 100% |
| | Barn | Florida | > 75% |
| | Old field | Florida | > 90% |
| | Univ. campus bldg. | Kansas | Near 100% |
| | Office bldg. | Texas | Near 100% |
| Warehouse bldg. | Texas | Near 100% | |

A more recent study by Salmon et al. (1984) resulted in a 96% rodent population reduction on a dairy farm. Table 5 outlines research completed on field rodent species throughout the U.S. The compound is very good at controlling virtually any pest species. Meehan (1985) reported on the good palatability of bromadiolone making it readily accepted by rodents.

Table 5. The results of field trials using Bromadiolone to control key field rodent species.

| Species | Concentration | Site | State | Researcher | Efficacy(%) | Notes |
|----------------------------|---------------|----------|------------|----------------------------|-------------|--------------|
| Columbian Ground Squirrel | 500 | pasture | Montana | D. Sullivan | 90.3 | Handbait |
| | 50 | pasture | Montana | D. Sullivan | 95 | Bait Station |
| | 50 | pasture | Washington | L. Askham (1985) | 70-80 | Mid-Season |
| | | | | | 100 | Late-Season |
| California Ground Squirrel | 200 | pasture | California | R. Baker | 78-91 | Handbait |
| | 50 | pasture | California | R. Baker | 79-80 | Handbait |
| Pocket Gophers | 300 | pasture | California | R. Baker | 62 | Handbait |
| | 400 | pasture | California | R. Baker | 62 | Handbait |
| | 500 | pasture | California | R. Baker | 85 | Handbait |
| | 175 | clearcut | California | Tunberg et al(1984) | 100 | Handbait |
| Wood Rat | 50 | indoor | California | R. Baker | 100 | Buildings |
| | 50 | outdoor | California | R. Baker | 100 | |
| Meadow Voles | 50 | orchard | Washington | R. Hunter | 100 | |
| | 50 | orchard | Virginia | R. Byers | 71 | |
| | 50 | orchard | New York | Richmond and Miller (1980) | 100 | |

Ground squirrel control ranged from 70 to 100% and varied according to time of application and species controlled (Table 5). Pocket gopher control results were more variable. Results using bromadiolone in a study by Tunberg et al. (1984) demonstrated that the rapid reinvasion of pocket gophers may hamper control efforts if made on a localized basis.

Vole control using MAKI ranged from 71 to 100% (Table 5). Research by Byers (1978, 1979, 1981), Byers et al. (1982), and Steblein et al. (1983) demonstrated the compound to be relatively consistent in reducing orchard mice problems. A major factor affecting efficacy is that of bait acceptance which varies in various parts of the U.S. No one formulation can meet all the needs within pest control.

FORMULATIONS

Currently MAKI is marketed as pellets, meal bait, and paraffin blocks. Several grain formulations are currently being tested. Submission of the registration support data is scheduled for late 1986. Two products which show promise are MAKI SOL and the new MAKI PARAFFIN BLOCK.

Liquid Bait

A 10 ppm end-use MAKI liquid bait is near test completion. When registered, the product will be sold under the name MAKI SOL and will be available in a liquid concentrate of 0.011% bromadiolone. Table 6 presents the result of laboratory testing of MAKI SOL against Norway rats and house mice. In rats, 100% mortality was achieved with a 5-ppm liquid bait; however, 10 ppm was required to attain the same level of control in mice. Dye-free baits increased acceptance significantly.

Table 6. Liquid MAKI bait laboratory evaluations using various concentrations (tap water as controls) and following EPA test protocol.

| | Test no. | Days exposed | Color | Concentration (ppm) | Mortality (deaths/total) |
|-------------|----------|--------------|-------|---------------------|--------------------------|
| Norway rats | | | | | |
| | 84006 | 14 | Red | 50 | 25/25 |
| | 85004 | 12 | Red | 50 | 10/10 |
| | 85006 | 13 | Red | 10 | 8/10 |
| | 85006-B | 9 | Clear | 10 | 20/20 |
| | 85009 | 8 | Clear | 5 | 10/10 |
| House mice | | | | | |
| | 85008-B | 6 | Clear | 10 | 10/10 |
| | 85008-A | 7 | Clear | 5 | 7/10 |
| | 85010-A | 8 | Clear | 10 | 20/20 |
| | 85010-B | 7 | Clear | 10 | 20/20 |

Field testing of MAKI SOL was completed in California (R. Baker, unpubl.). Table 7 summarizes the results with over 95% efficacy after 6 days and up to 99% after 12 days when used against roof rats (*Rattus rattus*). Additional test results are given in Table 8, again demonstrating the excellent control against three commensal species.

Table 7. Results of a field trial using MAKI SOL (50 ppm bromadiolone) liquid bait to control roof rats in a hay shed near Fullerton, California (R. Baker, unpubl.).

| Census type | Efficacy (percent reduction) | | |
|------------------------|------------------------------|------|------|
| | Days after bait provided | 6 | 12 |
| Untreated water | | 95.7 | 99.7 |
| Dry census bait (mash) | | 95.9 | 90.9 |
| Electric counter | | 96.0 | 98.0 |

Table 8. Test data using 10 ppm MAKI SOL (liquid bait) to control three rodent species in a barn-type enclosure (R. Baker, unpubl.). Water consumption, census ration and electric counters were used to estimate efficacy.

| Species | Number of test animals | Efficacy (% mortality) |
|-------------|------------------------|------------------------|
| House mice | 40 | 100% |
| Norway rats | 20 | 80%(1) |
| Roof rats | 20 | 100% |

(1) Test still in progress.

Paraffin Blocks

During 1985 a new paraffin block containing 50-ppm bromadiolone was developed. Test results are presented in Table 9. In Norway rats and house mice, acceptance was near 50% for both species, while acceptance of the incubated bait averaged in the range of 39%. Mortality in the test animals was 100%. Regional field testing is currently being organized for the three commensal species. It is anticipated that this new formulation will be available by early summer.

Table 9. Laboratory test results with a new 0.005% bromadiolone paraffin bait formulation used against Norway rats and house mice in standard EPA choice tests.

| | House mice | | Norway rats | |
|---|------------|-------|-------------|-------|
| | 1 | 2 | 1 | 2 |
| Unincubated bait | | | | |
| Test no. | | | | |
| Acceptance(1) | 52.6% | 48.3% | 48.6% | 49.4% |
| Mortality(2) | 20/20 | 20/20 | 20/20 | 20/20 |
| Incubated bait (100°F, 100% humidity x 15 days) | | | | |
| Acceptance | 35.7% | 38.2% | 42.7% | 37.7% |
| Mortality | 20/20 | 20/20 | 20/20 | 20/20 |

- (1) Test bait consumption / Test and placebo consumption
(2) No. rodents died / No. rodents in test

Pelleted and Meal Baits

In laboratory tests recently completed, MAKI was compared to other rodenticide products on the market. In these tests, a new MAKI pellet formulation attained an acceptance of 71.3% in males and 68.1% in female Norway rats and 100% mortality. Tests using the MAKI MEAL BAIT had an average acceptance of 50.8% (44.8-58.6) with 100% mortality when used against house mice. A study by Frantz (1982) showed MAKI baits to be highly palatable to Norway rats with acceptance results of 56.6% and 67% in two pelleted formulations. A summary of these results is presented in Table 10.

Table 10. Test results from 1985/86 using MAKI formulations against Norway rats and house mice.

| | % Acceptance (1) | | | Mortality (2) (deaths/total) |
|--------------|------------------|------|------|---------------------------------|
| | M | F | C | |
| Norway rats | | | | |
| MAKI Pellets | 71.3 | 64.0 | 68.4 | 20/20 |
| MAKI Meal | 61.2 | 48.4 | 54.6 | 20/20 |
| House mice | | | | |
| MAKI Pellets | 26.7 | 57.2 | 43.6 | 20/20 |
| MAKI Meal | | | 50.8 | 40/40 |

- (1) M=male, F=female, C=combined sexes
(2) No. rodents died / No. rodents in test

RESISTANCE TESTING

Historically, secondary-generation anticoagulants have been marketed as a tool to control warfarin- or cross-resistant rats and mice. As with resistance in most pest species, a compound that is too toxic may result in other environmental problems, while a product with less potency may control rats adequately but might be less susceptible to mice (Marsh 1977).

Early resistance testing results in the U.S. are presented in Table 11 and show Norway rats to be very susceptible to bromadiolone. Additional research on resistance was completed by Frantz (1982). Summary data (Table 12) from a study completed in Chicago demonstrated that a resistant Norway rat population could be reduced by 85.5% by using MAKI (Ashton and Jackson 1979).

Table 11. Laboratory tests using 0.005% bromadiolone bait fed to anticoagulant resistant Norway rats.

| Test type | Resistance Type ¹ | Sex | Number test animals | Consumption (g) Challenge | Test | Mortality (deaths/total) | Source |
|-------------------|------------------------------|-----|---------------------|---------------------------|------|--------------------------|-----------------------------|
| No-choice (6-day) | W | M | 7 | -- | 91.6 | 7/7 | BGSU ² , unpubl. |
| | W | F | 10 | -- | 80.4 | 10/10 | |
| Choice (15-day) | C | M | 10 | 146.9 | 15.9 | 7/10 | BGSU, unpubl. |
| | C | F | 10 | 123.9 | 21.9 | 10/10 | |
| No-choice (6-day) | C | M | 5 | 31.0 | 73.0 | 5/5 | BGSU, unpubl. |
| | C | F | 5 | 70.5 | 30.2 | 5/5 | |
| | C | F | 5 | 29.1 | 61.6 | 5/5 | |

¹W=Warfarin resistant; C=Cross-resistant²Bowling Green State University, W. B. Jackson

Table 12. Results of a field trial using 0.005% MAKI in an area of Chicago to control anticoagulant resistant rats. Approximately 71% of the rodent test population was considered resistant (Ashton and Jackson 1979).

| | Number premises surveyed | Percent premises infested | Number of applications | Efficacy (% mortality) |
|-----------------------|--------------------------|---------------------------|------------------------|------------------------|
| Test 1 (Talon) | 137 | 65 | 3 | 77.7% |
| Test 2 (Maki Pellets) | 108 | 59 | 1 | 41.7% |
| Test 3 (Maki Meal) | 128 | 59 | 3 | 85.5% |
| Control | 168 | 64 | - | -2.5%* |

* % change

House mice are more difficult to control with anticoagulants. In France, laboratory tests using resistant mice revealed bromadiolone to be effective, as outlined in Table 13 (Lorgue, unpubl.). Tests recently completed in the U.S. (Table 14) resulted in 85% mortality in the resistant mice.

Table 13. Laboratory tests using 0.005% bromadiolone bait against house mice (*Mus musculus*) from France (Lorgue unpubl.).

| Test type | No. test mice died / Total test mice | |
|--------------------|--------------------------------------|---------|
| | Males | Females |
| Nonresistant | Tank | 27/27 |
| | | 22/22 |
| | Individual Cages | 11/11 |
| | | 6/6 |
| Totals | 66/66 | |
| Warfarin-resistant | Tank | 20/20 |
| | | 17/17 |
| | Cages | 3/3 |
| | | 7/8 |
| Totals | 47/48 | |

Table 14. Laboratory tests from February 1986 using MAKI (50 ppm) bait to control warfarin-resistant house mice (Ashton, unpubl.).

| | Acceptance (percent) | Mortality (deaths/total) |
|----------|-------------------------|-----------------------------|
| Males | 31.7 | 10/10 |
| Females | 37.0 | 7/10 |
| Combined | 34.35 | 17/20 |

Reports by Lund (1984) and Siddiqi and Blaine (1982) indicate the potential for house mice to develop resistance to bromadiolone after extended use.

NONTARGET HAZARD POTENTIAL

Of concern in the use of rodenticides is not only the activity, or toxicity, of a compound to various target species, but also its potential effect on domestic animals and wildlife (Poché and Sharp 1986). Toxicosis to rodenticides may occur by animals feeding directly on the bait or by consuming toxic-laden target species. Since anticoagulants have a delayed mode of action when compared with acute products, the tendency is increased for a rodent to accumulate a toxic load greater than the required lethal dose. Therefore, factors such as dose level (ppm) in the baits, methods of application, timing and rate of application of the bait, carriers and bait type, metabolism of the compound in biological systems, and fate of the product in the environment contribute to the potential impact of its use. A combination of factors interact in determining the fate of a compound in a target species. Data on residue levels, degradation, half-life, and metabolism of rodenticides are but a few important considerations in determining the relative safety of a product.

With bromadiolone, within 4 days after ingestion by rats, over 89% of the compound is eliminated through the feces via the bile duct (Table 15). Of the amount excreted, about 90% of the bromadiolone degrades into metabolites.

Table 15. Elimination of 14-C bromadiolone from rats in percentages of the dose administered. Test rats were gavaged with 5 mg/kg body weight bromadiolone (Lipha, unpubl.).

| | Day | | | | Total |
|-------|-------|-------|------|------|----------|
| | 1 | 2 | 3 | 4 | |
| Feces | 58.90 | 20.25 | 8.65 | 1.30 | 89.10 |
| Urine | 0.42 | 0.19 | 0.06 | 0.07 | 0.74 |
| Total | 59.32 | 20.44 | 8.71 | 1.37 | 89.84(1) |

(1) Only 10% was bromadiolone. Remainder was degraded metabolites.

Once a rodent ingests a rodenticide, the chemical is assimilated into the system and residue levels may appear in various tissues. Carbon-14 labeled bromadiolone studies in rats, demonstrated that within 48 hours after intubation, residue levels degraded within various body tissues an average of 61% (Table 16). The breakdown was most rapid in the carcass (81%) and slowest in fat tissues (27%) 46 hours later (HRC 1977).

Table 16. Concentrations of 14-C labeled bromadiolone (BDN) in rat tissues at 2 and 48 hours after intubation with 5 mg/kg of the compound (HRC 1977).

| Organ | Concentrations of BDN in micrograms per gram of organ (ppm) | |
|---------|---|---------------|
| | 2 Hrs. (n=2) | 48 Hrs. (n=4) |
| Liver | 43.50 | 20.54 |
| Kidneys | 3.53 | 1.36 |
| Lungs | 1.60 | 0.49 |
| Heart | 1.25 | 0.25 |
| Muscle | 0.37 | 0.15 |
| Fat | 3.04 | 2.22 |
| Carcass | 5.95 | 1.11 |

Studies on bromadiolone tissue concentrations in Japanese quail (*Coturnix japonica*) over time were completed in the United Kingdom (Table 17). Adult birds, averaging about 235 g in weight, were gavaged with 1000 mg per kg body weight. At time intervals of 1, 2, 4, 7, 14 and 56 days after intubation four birds were sacrificed. The legs were removed at the hock joint and discarded, the birds plucked, and the whole carcass examined by HPLC for levels of bromadiolone. The average residue level was 286.5 ppm after 1 day. By day 4, the figure dropped to 0.19 ppm and after 7 days the birds contained an average of 0.065 ppm bromadiolone in the tissues. Extrapolation of these revealed the half-life of bromadiolone in quail tissues is about 4.5 days.

Table 17. Determination of tissue concentration of bromadiolone (BDN) in Japanese quail after a single oral dose of 1000 mg/kg (HRC 1980).

| Sampling time (days) | Amount of BDN in tissue (ppm) |
|----------------------|-------------------------------|
| 1 | 286.500 |
| 2 | 2.250 |
| 4 | .190 |
| 7 | .065 |
| 14 | .092 |
| 56 | .050(1) |

(1) Limit of detection

A study with owls by Mendenhall and Pank (1980) demonstrated the hazard potential of using anticoagulants in field situations. Although laboratory studies do not always indicate a true picture of what one might expect in the field, such data are necessary to determine the "potential" hazard to nontarget animals.

As part of their study, Mendenhall and Pank (1980) fed bromadiolone-killed rats to barn owls (*Tyto alba*) (Table 18). The birds were fed only treated rats for periods of 1 to 10 days. Mortality was observed in one of the six owls which consumed bromadiolone-killed rats for 10 consecutive days during which it consumed 463 grams of rat tissues. Although one might interpret these data as being evident that bromadiolone is a potential hazard to raptors, one has to examine carefully the probability of a wide-ranging avian species to consume only bromadiolone-killed rodents for 10 consecutive days.

Table 18. Secondary toxicity of bromadiolone to barn owls (Mendenhall and Pank 1980).

| Days Dosed | OWLS | | RATS OFFERED | | RATS EATEN | | | INTOX. |
|------------|-------|-----|--------------|-----------|-------------|--------|------------|--------|
| | Wt(g) | Sex | Total wt | Dose (mg) | Total wt(g) | Livers | Intestines | |
| 1 | 460 | M | 118 | 2.65 | 52 | 1 | 0.8 | - |
| 3 | 450 | M | 358 | 6.60 | 281 | 3 | 3 | - |
| 3 | 425 | M | 228 | 3.96 | 146 | 3 | 2.8 | - |
| 6 | 490 | M | 625 | 11.11 | 295 | 5 | 4 | - |
| 10 | 540 | F | 1106 | 14.59 | 576 | 7.8 | 4.5 | - |
| 10 | 635 | F | 710 | 9.63 | 463 | 8.5 | 5.2 | D(11) |

The potential hazard bromadiolone poses to avian species is low (Grolleau and Lorgue 1984). As listed in Table 2, for example, the acute LD-50 of bromadiolone in bobwhite quail is 138 mg per kg. For a 50-ppm bait this translates to about 2.76 kg of MAKI. The propensity for bromadiolone to accumulate in avian tissues is not evident, as demonstrated in the rapid metabolism of the compound in Japanese quail.

A laboratory secondary hazard evaluation of bromadiolone was conducted in adult coyotes (Canis latrans) (Marsh, unpubl.). Fifty-ppm bromadiolone oat bait was fed to California ground squirrels (Spermophilus beecheyi) for 3 days in a choice test. As the test squirrels died, each was frozen and later fed to coyotes conditioned to feed on the sciurids. Each of four adult coyotes was fed one bromadiolone-killed squirrel daily for 5 consecutive days (Table 19). The protocol followed EPA recommendations for a worse-case situation in which in the canids consumed only rodenticide-killed squirrels. The coyotes were observed for 30 days posttreatment during which time none of the test animals died. Two, however, exhibited a reduction in food consumption, which returned to normal after 8 and 16 days into the observation period.

Table 19. Results of feeding bromadiolone-killed ground squirrels to adult coyotes (Canis latrans) for 5 consecutive days with no other food provided (UCD(1), unpubl.).

| Animal Number | Sex | Weight (kg) | Wt. (g) of squirrels consumed | Toxicant (mg) consumed by squirrels | Toxicant (mg) consumed by coyotes | Results |
|---------------|-----|-------------|-------------------------------|-------------------------------------|-----------------------------------|-----------------------------------|
| B-1 | M | 13.6 | 3,199 | 22.5 | 18.0 | Survived; no symptoms |
| B-2 | F | 7.9 | 2,165 | 22.5 | 15.75 | Survived; feeding reduced 16 days |
| B-3 | F | 10.4 | 3,445 | 22.5 | 22.5 | Survived; feeding reduced 8 days |
| B-4 | M | 7.5 | 3,133 | 22.5 | 22.5 | Survived; no symptoms |

(1) University of California, Davis; Rex Marsh, principal investigator

As with avian species, the potential secondary hazard of bromadiolone to coyotes is extremely low. In this study, which simulated exclusive feeding on bromadiolone-killed squirrels, no mortality was observed in adult coyotes.

ACKNOWLEDGMENTS

I would like to thank Karen Wilkins for her assistance in completing portions of the in-house laboratory testing.

LITERATURE CITED

ANONYMOUS. (Undated). MAKI, Bromadiolone rodenticide technical bulletin. Chempar, Division of Lipha Chemicals, Inc. 9 pp.

ASHTON, A. D., and W. B. JACKSON. 1979. Field testing of rodenticides in a resistant-rat area of Chicago. *Pest Control*:8:14-16.

ASKHAM, L. R. 1985. Effectiveness of two anticoagulant rodenticides (Chlorophacinone and Bromadiolone) for Columbian ground squirrel (Spermophilus columbianus) control in eastern Washington. *Crop Protection* 4:365-371.

BYERS, R. E. 1978. Performance of rodenticides for the control of pine voles in orchards. *J. Amer. Soc. Hort. Sci.* 103:65-69.

BYERS, R. E. 1979. Results of pine vole control studies in 1978. *Proc. 3rd Pine and Meadow Vole Symposium*:64-76.

BYERS, R. E. 1981. Pine vole control with anticoagulant baits in apple orchards. *J. Amer. Soc. Hort. Sci.* 106:101-105.

BYERS, R. E., M. H. MERSON, and S. D. PALMATEER. 1982. Control of orchard voles with broadcast baits. *J. Amer. Soc. Hort. Sci.* 107:613-619.

FRANTZ, S. 1982. Paired preference efficacy evaluation of Maki pelletized baits. NY State Dept. of Health Report. 27 pp.

GRAND, M. 1976. Experimental results on a new anticoagulant rodenticide-bromadiolone. *Phytiatric-Phytopharmacie* 25:69-88.

GROLLEAU, G., and G. LORGUE. 1984. Secondary toxicity of an anticoagulant rodenticide-bromadiolone - for the common buzzard (Buteo buteo) - Experimental study. In: *The International Symposium of Ectotoxicology. Les Arcs, Savoy. 12-14 Dec. 1984.*

HUNTER, K. 1983a. Determination of coumarin anticoagulant rodenticide residues in animal tissue by High-Performance Liquid Chromatography. I. Fluorescence detection using post-column techniques. *J. of Chromatography* 270:267-276.

HUNTER, K. 1983b. Determination of coumarin anticoagulant rodenticide residues in animal tissue by High-Performance Liquid Chromatography. II. Fluorescence detection using ion-pair chromatography. *J. of Chromatography* 270:277-283.

- HUNTINGTON RESEARCH CENTRE. 1980. Determination of tissue concentrations of bromadiolone in Japanese quail after a single oral dose (1000 mg/kg). HRC, unpublished report. 36 pp.
- HUNTINGTON RESEARCH CENTRE. 1981. The metabolism of ¹⁴C-LM-637 (Bromadiolone) in the rat (Interim Summary Report). Unpublished Huntington Research Centre Report. 8 pp.
- LECHEVIN, J. C. 1985. Bromadiolone. Lipha, unpublished report. 42 pp.
- LIPHA. (Undated). Bromadiolone. Technical bulletin. 18 pp.
- LIPHA. 1977. Fate of bromadiolone (LM-637) in the rat urinary and fecal elimination. Lipha, unpublished report. 11 pp.
- LOGGUE, G. 1981. Bromadiolone rodenticide on semolina. National Veterinarian School of Lyon, unpublished report. 15 pp.
- MARSH, R. E. 1977. Bromadiolone, a new anticoagulant rodenticide. EPP0 Bull. 7:495-502.
- MARSH, R. E., W. E. HOWARD, and W. B. JACKSON. 1980. Bromadiolone: a new toxicant for rodent control. Pest Control 8:22-26.
- MEEHAN, A. P. 1978. Rodenticidal activity of Bromadiolone - a new anticoagulant. Proc. 8th Vertebrate Pest Conference. pp. 122-126.
- MENDENHALL, V. M., and L. F. PANK. 1980. Secondary poisoning of owls by anticoagulant rodenticides. The Wildlife Society Bulletin 8:311-315.
- POCHÉ, R. M., and R. SHARP. 1986. Vole control in the eastern United States. Proc. 2nd Eastern Wildlife Damage Conference, September 22-25, 1985. Raleigh, N.C. pp. 52-59.
- RICHMOND, M. E., and P. N. MILLER. 1980. Field evaluation of candidate rodenticides. Proc. 4th Eastern Pine and Meadow Vole Symposium: 78-87.
- SALMON, T., W. P. GORENZEL, R. E. MARSH, and G. HUTTON. 1984. Rodent control down on the farm. Pest Control Technology 12(1):52,54.
- SIDDIQI, Z., and W. D. BLAINE. 1982. Anticoagulant resistance in house mice in Toronto, Canada. Pest Management:10-14.
- STEBLEIN, P. F., P. N. MILLER, and M. E. RICHMOND. 1983. Efficacy of spring broadcast rodenticides in the Hudson Valley, N.Y. Proc. 7th Pine and Meadow Vole Symposium:19-24.
- TUNBERG, A. D., W. E. HOWARD, and R. E. MARSH. 1984. A new concept in pocket gopher control. Proc. 11th Vertebrate Pest Conference. pp. 7-16.