BRODIFACOUM (TALON™ RODENTICIDE), A NOVEL CONCEPT

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ABSTRACT: Brodifacoum, a new rodenticide, is described. This anticoagulant is shown to be of exceptional potency and capable of controlling resistant rodents as well as several non-commensal species. Results demonstrate that, in contrast to first generation anticoagulants, a bait concentration of only 50 ppm is adequate to give control and in only a single feeding for most species. In common with other anticoagulants, vitamin K_1 is an effective antidote. In contrast with other acute rodenticides, symptoms are delayed and no bait shyness is observed. The results of laboratory and field trials from many parts of the world are summarized and comparisons of efficacy and specificity with other rodenticides are made. In all cases, brodifacoum is shown to be an exceptional rodenticide, the single feeding action of which offers novel rodent control applications.

The discovery of warfarin (Link, 1945) and exploitation of anticoagulants as rodenticides (O'Connors, 1948) dramatically increased the efficacy and safety of rodent control programs. The chronic, antidotable action of warfarin eliminated the hazards of acute baits and the need for prebaiting, as bait shyness was not induced. Very rapidly other anticoagulants were developed as rodenticides. These included coumachlor, introduced in 1951; coumatetralyl, introduced in 1956-1957; diphacinone, first described in 1952; and pindone, in the 1940's (Martin and Worthing, 1971). For effective control, multiple bait applications were needed of all these rodenticides, and in general they were found about as equally effective as warfarin (Hayes and Gaines, 1959; Bentley and Larthe, 1959; Greaves and Ayres, 1969). By the late 1950's the anticoagulants became the primary means of rodent control worldwide.

Resistance was discovered in R. norvegicus in U.K. (Boyle, 1960), Denmark (Lund, 1967), Netherlands (Ophof and Langeveld, 1968), U.S. (Jackson and Kaukeinen, 1972), Germany (Telle, 1972), and France (Grand, 1976). Concern increased when resistance was also found to occur in the house mouse, Mus musculus (Rowe and Redfern, 1965; Anon., 1977), and the roof rat, R. rattus (Greaves, Rennison and Redfern, 1973; Anon., 1977). Cross resistance to other first generation anticoagulants has also been reported (Rowe and Redfern, 1968; Greaves and Ayres, 1969; Hadler and Shadbolt, 1975; Kosmin and Barlow, n.d.).

The difficulty of controlling resistant infestations of R. norvegicus in Europe was eased considerably by the development of difenacoum (Redfern, Gill and Hadler, 1976); results against R. rattus and M. musculus were less favorable (Handler, Redfern and Rowe, 1975) but difenacoum was still recommended by the Pest Infestation Control Laboratory (U.K.) as the best anticoagulant available for the control of resistant house mouse (PICL, 1976). Difenacoum has been commercially available in the UK and elsewhere for a few years, and partially as a result, the spread of warfarin resistance in the UK is no longer formally monitored. In the U.S., no anticoagulant is currently labeled for effective control of resistant rats or mice. Greater than 5% resistant Norway rats have been found in 37% of 73 sampled U.S. urban areas (Anon., 1977). In suspected areas of the U.S. 6/10 Rattus rattus infestations and 7/7 Mus musculus infestations were confirmed to be resistant (Anon., 1977). In certain areas, for example, Chicago and Sioux City, resistance has caused serious control problems (Jackson et al., 1975).

The anticoagulant described in this paper, brodifacoum, is a new development. Brodifacoum will be marketed worldwide and in the U.S. for commensal rodents as TALON rodenticide.

GENERAL PROPERTIES

Brodifacoum ($C_{31}H_{23}O_3BR$) is a draft ISO common name for the compound with structure so labeled in Figure 1. The proper chemical name is 3-(3-(4'-bromo(1-1'biphenyl)-4-yl-1,2,3,4-tetra-hydro-1-naphthalenyl)-4-hydroxy -2H-1-benzopyran-2-one. It is also denoted by the code number WBA 8119 and as PP581 or ICI 581, BFC.

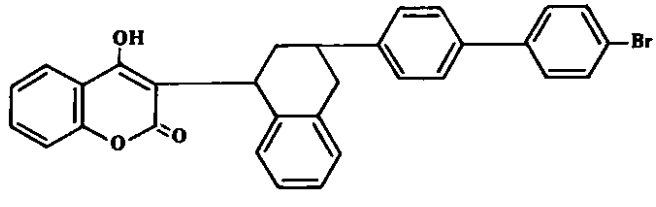

Figure 1. Structural Formula of brodifacoum.

Technical brodifacoum exists as an off-white/buff powder of molecular weight 523. It is a stable solid under normal storage conditions with a melting point of 228-232°C. It is insoluble in water and petroleum ether but soluble in a variety of alternative organic solvents. High pressure liquid chromatography is necessary for analysis. Technical brodifacoum exists as two isomers (Hadler and Shadbolt, 1975); there is no significant difference in anticoagulant potency, palatability, resistance, acute oral LD_{50} or rate of kill of the two isomers when tested against albino mice, albino rats and homozygous resistant rats. The major impurities of technical brodifacoum have been identified as 4-hydroxy-coumarin and a bromo diphenyl dihydronaphthalene fraction. Both have LD_{50}'s in excess of 100 times that of the parent compound, brodifacoum. The impurities are also fully as palatable as brodifacoum. Lack of toxicity of these impurities has been confirmed by long period feeding of 50 ppm impurities in baits to mice. Radiolabeling studies are currently underway to determine metabolic and breakdown products of brodifacoum and allow assessment of their toxicity. Potential mutagenic activity of brodifacoum has been assessed using the Ames test (Ames et al., 1973) utilizing different strains of histidine-requiring bacteria. No mutagenic activity was found in any of the tests.

BRODIFACOUM AS A "SINGLE DOSE" ANTICOAGULANT

The acute LD_{50}'s of brodifacoum to several commensal rodents have been determined (Table 1). These values are lower than corresponding ones for other anticoagulants (Table 2). It can be seen that the

Table 1. Acute oral LD_{50} (mg/kg) for brodifacoum.

Species	Sex	Strain	Acute LD_{50} (95% C.L.) mg/kg	Reference
R. norvegicus	Male	Wistar	0.26 (0.20 - 0.37)	Redfern, et al., 1976
R. norvegicus	Female	Wild	0.22	Savarie, pers. comm.
M. musculus	Male	Albino	0.40 (0.30 - 0.63)	Redfern, et al., 1976
R. rattus	Male	Wild	0.73 (0.55 - 0.91)	Marsh, unpublished
R. rattus	Female	Wild	0.65 (0.40 - 0.90)	Marsh, unpublished

Table 2. Acute oral LD_{50} of a.i. and bait for several anticoagulants.

Anticoagulant	LD_{50} (mg/kg) to Albino Norway Rats		Normal Bait Concentration (ppm)	LD_{50} (g of bait/ 250 g Rat)
brodifacoum	0.26	(Redfern et al., 1976)	50	1.3
bromadiolone	1.125	(Grand, 1976)	50	5.6
difenacoum	1.8	(Bull, 1976)	50	9.0
coumatetralyl	16.5	(Thomson, 1976)	375	11.0
diphacinone	3.0	(Thomson, 1976)	50	15.0
chlorophacinone	20.5	(Thomson, 1976)	50	102.5
warfarin	186.0	(Thomson, 1976)	250	186.0
pindone	50.0	(Martin & Worthing, 1977)	250	250.0
coumachlor	900.0	(Thomson, 1976)	250	4500.0
	LD_{50} (mg/kg) to Albino House Mice			
brodifacoum	0.40	(Redfern et al., 1976)	50	0.2
difenacoum	0.80	(Bull, 1976)	50	0.4
bromadiolone	1.75	(Grand, 1976)	50	0.9
warfarin	374.0	(Hagan & Radomski, 1953)	250	37.0
diphacinone	141.0	(Kosmin & Barlow, n.d.)	50	71.0

mean lethal dose of brodifacoum bait is only a very small percentage of the total daily food requirements. Continuous feeding normally characteristic of anticoagulants is not necessary. This is especially useful in control of house mice which, with their small appetites and sporadic feeding behavior, are probably the most difficult commensal rodent species to control with anticoagulants. In laboratory choice and no-choice feeding tests for restricted periods, extremely good control of all species tested was achieved after very short exposure time (Table 3). Time to death was similar to that expected from first generation anticoagulants. These results compare favorably with other anticoagulants (Table 4).

Demonstration of "single feeding" acitivity in the field with brodifacoum is difficult. However, Rowe and Bradfield (1976), noted complete control of penned family groups of warfarin-resistant Mus musculus at the lowest concentration tested, 20 ppm. Feeding on the 20 ppm brodifacoum bait was minimal after 5-day no-choice, and noticeably greater over the first 3 days. In similar "choice" pen trials, excellent control was achieved; only one individual of 72 offered 20 ppm bait survived the trial and it died 12 days later. Rennison and Dubock (1978) using 20 ppm brodifacoum bait with no prebaiting, obtained minimum estimates of 41, 51 and 68% control, respectively, of populations of warfarin resistant Norway rats in the UK treated for 1, 4 or 7 days on farms as a mimic for single applications of different amounts of bait. An average of 68-71% control has been obtained in similarly situated infestations of Norway rats by the same operating staff in the UK (Rennison, Hammond and Jones, 1968; Dubock and Rennison, 1977) using 2.5% zinc phosphide but with prebaiting.

Table 3. Results of no-choice feeding tests of brodifacoum baits.

Species	Concentration ppm, ai	Period Bait Offered (hours)	Mortality	%	Reference
No Choice					
R. norvegicus, resistant	10	24	10/10	100	Redfern et al., 1976
M. musculus, resistant	50	24	20/20	100	Redfern et al., 1976
M. musculus	10	24	30/30	100	Hadler, unpublished
R. rattus, wild	50	24	18/20	90	Marsh, unpublished
R. rattus, wild	50	48	10/10	100	Redfern et al., 1976
R. rattus, resistant	20	48	4/5	80	Redfern et al., 1976
R. rattus, resistant	50	48	5/5	100	Redfern et al., 1976
R. norvegicus, albino	50	6	24/24	100	
R. norvegicus, wild	50	6	23/24	96*	
Choice					
R. norvegicus	50	24	18/20	90	
R. norvegicus, UK resistant	20	48	5/5	100	Redfern et al., 1976d
R. norvegicus, US resistant	50	72	12/12	100	Jackson, unpublished
R. rattus	50	48	20/20	100	Marsh, unpublished
M. musculus	20	48	10/10	100	Redfern et al., 1976

*Survivor ingested 0.3 mg/kg.

Table 4. Comparative table of no-choice feeding efficacy of anticoagulants.

Species	Anticoagulant ppm	Feeding Period (hours)	% Mort.	Reference
R. norvegicus	diphacinone, 50	24	83	Bentley & Larthe, (1959)
R. norvegicus	coumatetralyl, 50	24	30	Greaves & Ayres, (1969)
R. norvegicus	coumatetralyl, 500	24	70	Greaves & Ayres, (1969)
R. norvegicus, resistant	coumatetralyl, 500	24	27	Greaves & Ayres, (1969)
R. norvegicus	bromadiolone, 50 (in EPA meal)	24	100	Marsh (1977)
R. norvegicus	bromadiolone, 50	24	82	Fradois (1977)
R. rattus	bromadiolone, 50	24	12	Grand (1976)
R. rattus	bromadiolone, 50	72	84	Fradois (1977)

BRODIFACOUM AS A "MULTIPLE DOSE" POISON

In addition to the advantages of brodifacoum as a "single-dose" material, it is also a potent multiple dose rodenticide when used in a manner similar to normal anticoagulant baiting practices, even at extremely low concentrations. The subacute oral LD_{50} for the Norway rat and albino mice are shown in Table 5. Comparison of these values with the acute oral LD_{50} suggest that the subacute oral toxicity is strictly cumulative. With multiple feedings brodifacoum is active at much lower concentrations than other available anticoagulants (Table 6).

Similar efficacy of multiple dose activity of brodifacoum at low concentrations (e.g. 10 ppm) has been demonstrated for wild Norway rats in the U.S. (Savarie, unpublished), for rats and mice in UK by Redfern et al. (1976); and similarly for mice by Rowe and Bradfield (1976). Comparative trials against resistant house mice in UK show brodifacoum has superior properties (Table 7).

In pen trials with family groups of resistant Mus musculus, 20, 50 or 100 ppm brodifacoum baits and plain food were offered for up to 21 days (Rowe and Bradfield, 1976; Klimstra, pers. comm.). The results are given in Table 8.

Table 5. Subacute oral LD_{50} (mg/kg of brodifacoum).

Species	Sex	Strain	Subacute Oral LD_{50} (95% C.L. mg/kg x days	Reference
R. norvegicus	M	Wistar	$\frac{0.06}{(0.04\text{-}0.08)} \times 5$	Redfern et al., 1976
R. norvegicus	M	UK resistant wild	0.05×5	Hadler, unpublished
R. norvegicus	F	Wistar	0.14×5	Hadler, unpublished
M. musculus	M	Albino	$\frac{0.035}{(0.021\text{-}0.050)} \times 5$	Hadler, unpublished

Table 6. 10-day no-choice feeding tests.

A. Homozygous (Welsh) Resistant Norway Rats.

	Mortality at Concentration (ppm)						
Anticoagulant	250	200	100	50	20	10	5
Warfarin	0/5	0/5	-	-	-	-	-
diphacinone	0/5	-	-	-	-	-	-
chlorophacinone	1/5	-	-	-	-	-	-
difenacoum	5/5	-	5/5	10/10	10/10	7/10	-
brodifacoum	-	-	-	-	5/5	5/5	5/5

B. Susceptible Albino Rats (Wistar) and Mice (LAC).

Species	Conc.	Mortality	Days Till Death	Total Consumption (g)	Mean Consumption brodifacoum mg
Norway rat	10	5/5	4-8	150	1.50
	2	5/5	7-12	300	0.60
Mouse	2	10/10	6-14	320	0.64
	1	10/10	6-10	345	0.35
	0.5	9/10	7-13	485	0.24
	0.2	1/10	12	475	0.10
	0.1	0/10	-	520	0.05

A. and B. from Hadler (unpublished).

Table 7. No-choice feeding of anticoagulants to groups of resistant Mus musculus for up to 21 days. (Adapted from UK Data: Rowe and Bradfield, 1976; Hadler et al., 1975).

Anticoagulant	Concentration (ppm)	Mortality	% Mortality
brodifacoum	20	12/12	100
difenacoum	50	14/15	93
coumatetralyl	50	3/13	23
chlorophacinone	250	6/13	46
diphacinone	125	0/9	0

Table 8. Results of choice feeding trials with brodifacoum against wild house mice.

Concentration of brodifacoum (ppm)	Mortality	% Mortality	Days to Death Range	Days to Death Mean
A. SUSCEPTIBLE US MICE				
20	20/20	100.0	1-10	5.5
50	20/20	100.0	2-18	6.0
100	20/20	100.0	4-22	6.7
B. RESISTANT UK MICE				
20	71/72	98.2	3-18	6.35
50	62/63	98.4	3-26	6.90
100	57/57	100.0	3-15	5.83

Data A from Klimstra, pers. comm.; data B adapted from Rowe and Bradfield, 1976.

In the U.S. a trial of 50 ppm TALON against a typical agricultural infestation of house mice showed a reduction in census bait consumption of 92%, and of tracks on tracking boards of 91% after treatment (Figure 2). Preliminary examination of the data from other trials in the U.S. against Mus musculus suggest similar results. Similar methods have been used to assess efficacy of TALON bait against Norway rats at several farm sites in the U.S. At a typical infestation (Figure 3) reduction in total consumption of post treatment census bait was 96%, and similarly there was an 89% reduction in tracks.

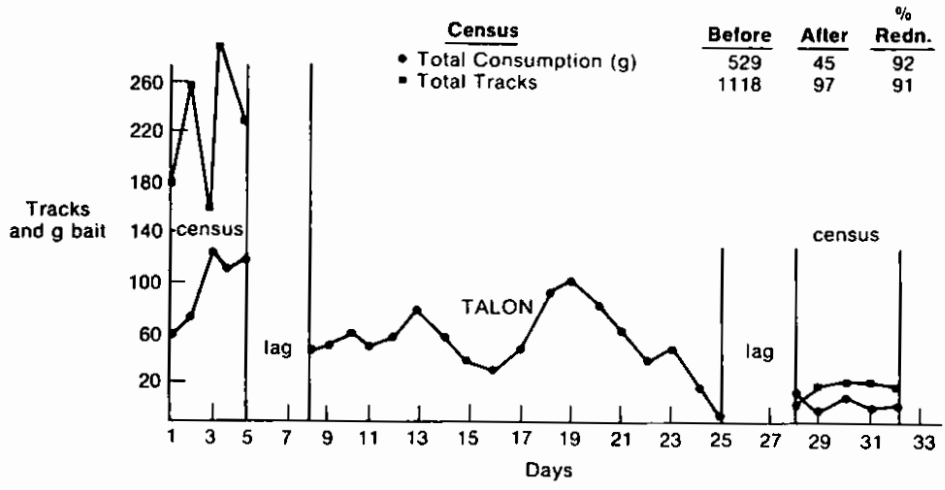

Figure 2. Trial of TALON bait against a house mouse infestation. Census bait was milo meal.

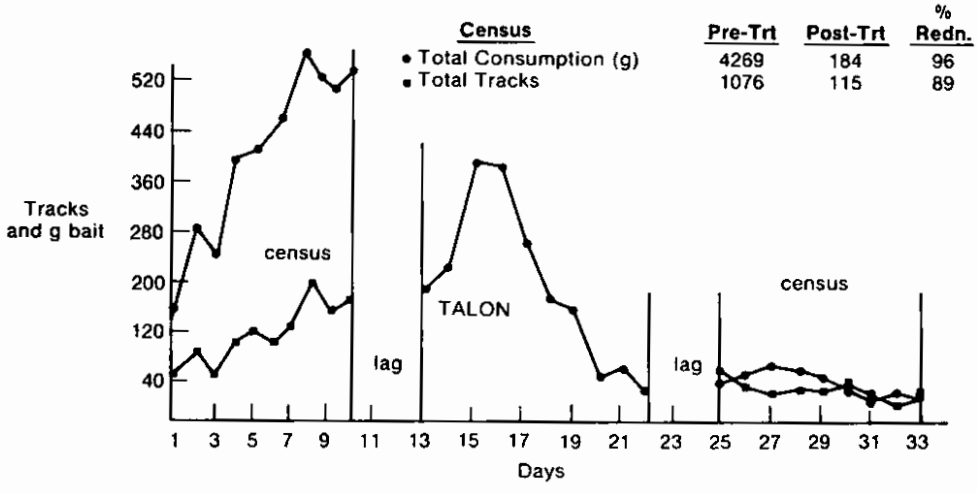

Figure 3. Trial of TALON bait against a Norway rat infestation. Census bait was corn meal.

Other trials of TALON pellets against Norway rat, house mouse and roof rats have been completed. Preliminary examination of the data suggest good control.

Baiting with brodifacoum at 5, 10 or 20 ppm completely controlled infestations of resistant rats on 36 UK farms when the poisoned baits were maintained until rats ceased to feed on them. The length of the individual treatments was from 11 to 25 days and was not affected by the concentration of the poison (Rennison and Dubock, 1978).

A simplified version of the monitoring graph (Drummond and Rennison, 1973) with results from the second day of poison baiting with brodifacoum at 0.002% is given in Figure 4. When the line monitoring the level of bait taken (mean of 9 farm trials) crosses the y axis complete control has been achieved of the resistant Norway rat population.

EFFICACY OF BRODIFACOUM AGAINST RESISTANCE STRAINS

Hadler and Shadbolt (1975) introduced the concept of rodenticide resistance factors as the ratio of prothrombin ED_{50}'s for UK resistant and normal rats. It is a measure of a compound's potential activity against resistant rodents. The resistance factors of several anticoagulants are given in Table 9. The closer the value is to unit the more potentially effective is the compound against resistant rats.

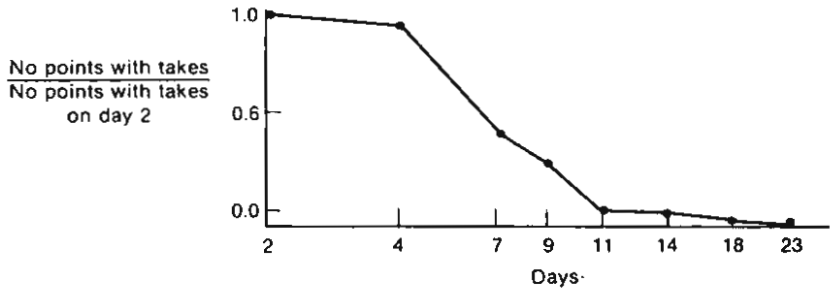

Figure 4. 20 ppm brodifacoum trial, (see text).

Table 9. Rattus norvegicus resistance factors of anticoagulants (Hadler and Shadbolt, 1975).

Anticoagulant	Prothrombin ED_{50} Wistar mg/kg	Prothrombin ED_{50} Homozygous Resistant mg/kg	Resistant Factor
brodifacoum	0.08	0.10	1.3
difenacoum	0.17	0.32	1.9
coumatetralyl	0.31	4.4	14.2
chlorophacinone	0.22	>20.0	>90.9
diphacinone	0.22	>50.0	>227.3
warfarin (S-)	0.30	>50.0	>166.7

These resistance factors are reflected in laboratory and field trials as follows: Chlorophacinone, diphacinone, and warfarin are acknowledged as being of limited effect against many resistant rodent populations (Fradois, 1977; Grand, 1976; Kosmin and Barlow, n.d.; Boyle, 1960). Coumatetralyl, with a resistance factor of 14, is effective only against a proportion of resistant rodents (Greaves and Ayres, 1969). While a resistance factor for bromadiolone is not shown, Grand (1976) reported that 3-day no-choice feeding of 50 ppm bromadiolone bait to 4 resistant R. norvegicus killed 2. In comparison, brodifacoum at 10 ppm for 1 day caused total mortality in a similar no-choice test against 10 resistant Norway rats (Redfern et al., 1976).

No figures are given for control of resistant R. rattus with bromadiolone, but at least 5-day no-choice consumption of 50 ppm bait is necessary for 95% mortality of susceptible R. rattus (Grand, 1976). The effect of 50 ppm bromadiolone in EPA bait on house mice (susceptible) was 95% in a 15 day test (Marsh, 1977). No data is known concerning the effect on resistant mice. Conversely, difenacoum, and especially brodifacoum, are well documented in the UK as being equally as effective against resistant as against susceptible individuals of R. norvegicus in the field and the laboratory, R. rattus in the laboratory, and M. musculus in the laboratory and in pen trials (Hadler, et al., 1975; Rennison and Hadler, 1975; Redfern et al., 1976; Rowe and Bradfield, 1976; Rennison and Dubock, 1978). Further data are given above.

In the U.S. the efficacy of TALON bait (containing 50 ppm brodifacoum) to cross resistant Norway rats has also been shown. After 6-day no-choice feeding of the same group of 7 rats with one month cleansing periods between treatments, only TALON gave any mortality. With TALON mortality was 100% (Table 10).

Table 10. Efficacy of TALON to cross-resistant wild Norway rats (U.S. data Jackson unpublished).

Treatment	Concn. ppm.	Body Weight mean (g)	Dose ingested mean mg/kg.	Mean daily consumption (g)	Mortality
warfarin	50	228	25.6	18.2	0/7
PIVAL	50	289	25.9	24.6	0/7
TALON	50	285	16.4	15.6	7/7

EFFICACY OF BRODIFACOUM AGAINST NON-COMMENSAL SPECIES

The following species have been briefly investigated.

Cricetus cricetus (East Europe)

At only 10 ppm, brodifacoum bait offered no choice for 24 hours resulted in 100% mortality in 7-13 days. Normally Cricetus is very tolerant of anticoagulants, including difenacoum (acute oral LD_{50} 100 mg/kg) compare brodifacoum (acute oral LD_{50} 0.56 mg/kg).

Arvicola terrestris (Western Europe)

At all levels down to 25 ppm, 100% control (5/5) was achieved with 1 or 3 days feeding in no-choice tests (poisoned bait was presented for 16 hours each 24 hours of test).

Microtus arvalis (Europe)

The results of laboratory trials are summarized in Table 11.

Table 11. Efficacy of brodifacoum and chlorophacinone in control of Microtus arvalis.

Poison	Concentration ppm	No. of Days Offered	wt. of bait given daily (g)	Mort.	%
brodifacoum	50	1	5	52/52	100
chlorophacinone	75	1	10	19/34	56
chlorophacinone	75	3	10	19/20	95

Rattus exulans (Asia and Pacific)

At 50 ppm for 1-day no-choice, or 3-day free choice, 100% control (5/5 and 10/10 respectively) were obtained.

Meriones unguiculatus (Asia and Africa)

One day no-choice feeding on 50 ppm brodifacoum bait killed 20/20 jirds by day 8 after treatment (Marsh, unpublished).

Mystromys albicaudatus (South Africa)

One day no-choice feeding of 50 ppm brodifacoum bait killed 20/20 white-tailed rats (Marsh, unpublished).

Large scale trials of brodifacoum against rodent pests of rice and oil palm are underway or being analyzed in various parts of South East Asia. Preliminary results indicate good control is being achieved. Species involved are R. rattus mindenensis, R. argentiventer, and R. tiomanicus. The acute oral LD_{50} of brodifacoum for R. r. mindenensis from the Philippines has been established as 0.28 mg/kg (male) and 0.3 mg/kg (female). In a 3-day choice test with 50 ppm brodifacoum bait, 8 of 10 test animals of this species were killed. One of the survivors ate no bait, the other discriminated against it (Savarie, pers. comm.). In a 1-day no-choice test with 50 ppm brodifacoum 9/10 R. argentiventer were killed. Brodifacoum is being used in trials against Bandicota indica, B. savilei and Rattus losea in Thailand; against Microtus montebelli in Japan; against the possum Trichosurus velpecula and the European rabbit, Oryctolagus cuniculus in New Zealand. In all cases preliminary results are promising.

Preliminary results of trials against some Mid and South American rodents are given in Table 12.

Table 12. brodifacoum (50 ppm) results with mid and South American rodents.

Spp.	Preservation	Days Presentation	Mortality	% Mortality
Sigimodon hispidus	No Choice	1	5/5	100
S. hispidis	Free Choice	3	20/20	100
Holochilus braziliensis	No Choice	1	20/21	95
Akodon spp.	No Choice	1	27/30	80

Trials on U.S. non-commensal species are also encouraging. The deer mouse, Peromyscus maniculatus completely succumbed (20/20 mortality) in a 1-day no-choice feeding test with 50 ppm brodifacoum (Marsh, unpublished). 100% mortality has been obtained against the ground squirrel Spermophilus beecheyi when offered 50 ppm brodifacoum bait no choice for 1, 2 or 3 days (Marsh, unpublished).

The acute oral LD_{50} of various anticoagulants to pine and meadow voles Microtus pineforum and M. pennsylvanicus has been determined (Table 13), and it can be seen that the specificity of brodifacoum to these U.S. Microtus species in relation to other anticoagulants should offer excellent prospects for control in the field, given good bait acceptance. Laboratory 3-day choice studies have indicated over 50% acceptance opposite a ground lab diet/oatmeal standard. Table 13 shows the results of one field trial (Byers, op, cit.) in which 50 ppm brodifacoum pellets achieved control superior to other anticoagulants at only half the application rate. Additional trials recently completed, also indicate good control with broadcast applications of brodifacoum against both pine and meadow voles (Fig. 5, Byers, unpublished).

Table 13. Acute oral LD_{50} of various rodenticides to pine and meadow voles (from Byers, 1978).

Rodenticide	Vole Species	LD_{50} mg/kg	95% Confidence Limits mg/kg
brodifacoum	Pine	0.36	0.22 - 0.59
	Meadow	0.72	0.53 - 0.98
bromadiolone	Pine	3.9	2.3 - 6.8
chlorophacinone	Pine	14.2	11.4 - 17.6
diphacinone	Pine	57.0	34.4 - 94.3
	Meadow	14.0	8.8 - 22.1

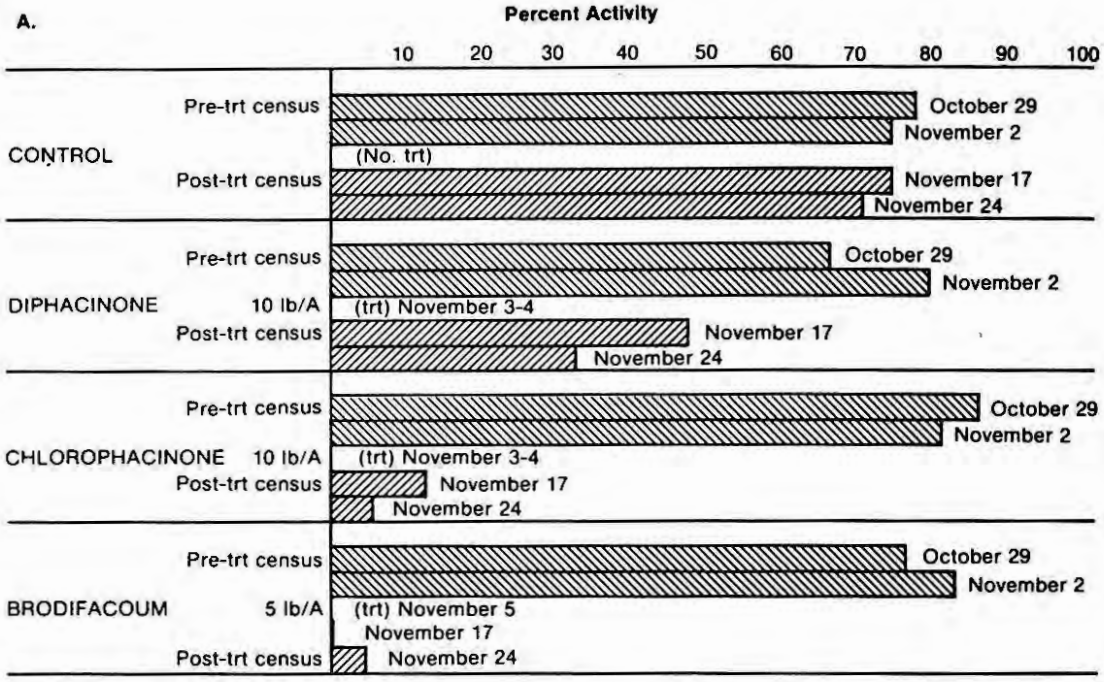

Figure 5. Results of Hand Application of Various Rodenticides for Control of Pine Vole in a Virginia Orchard, 1976 (Byers, 1978).

FORMULATIONS

On the basis of these and other data the 50 ppm concentration has been shown to possess the optimum potential for single-feeding action with all pest rodents thus far investigated, while minimizing environmental stress.

TALON pellets, containing 50 ppm brodifacoum, are a cereal based pellet with high acceptability to rodents. In challenge tests against EPA meal TALON pellets are frequently preferred, achieving 40-60% acceptability (Table 14).

Table 14. Results of 3-day choice test with albino and wild Norway rats in individual cages fed TALON pellets and EPA meal.

Strain	Sex/Number	Mortality	Mean Acceptance of TALON (S.D.)	Mean ai. injested mg/kg	KT (Range)
Albino	40M/40F	40/40	56.5 (19.2)	9.0	7.1 (4-13)
Wild	40M/40F	40/40	58.8 (29.8)	6.8	6.4 (4-12)

Previous data demonstrate that only a very small amount of TALON is necessary to kill most rodents. The single feeding capability of the TALON pellet leaves more room for operator error, manifest as underbaiting, which is so often the reason for failed treatments.

Work is underway in Asia to develop a brodifacoum wax block for use in oil palm plantations and rice paddies. This type of formulation is particularly suitable for hot, humid conditions, as also found in the sewers of temperate zone cities as in the U.S. The use of brodifacoum in such sewers should be advantageous in comparison with existing alternatives such as warfarin, which requires laborious rebaiting, or 1080, which is very toxic.

A brodifacoum tracking powder is also being developed. Davis and Moran (unpublished) using techniques described elsewhere (Davis, 1976) have provided the following data (Table 15).

Table 15. Results of one (albino mice) or two (albino rats) 60-second exposures to various brodifacoum tracking powder concentrations (mouse observed for 11 days after test and rats for 7 days after test).

brodifacoum % Concentration	Sex	Mouse Mortality	Rat Mortality
0.1	Male	0/5	0/5
	Female	0/5	0/5
0.2	Male	5/5	5/5
	Female	0/5	5/5
0.25	Male	5/5	5/5
	Female	0/5	5/5
0.4	Male	3/5	5/5
	Female	4/5	5/5

Mouse KT_{50} = 6.6 days (range 2-11 days)
Rat KT_{50} = 3.5 days (range 1- 7 days) (From Davis and Moran, unpublished).

HAZARD

As an anticoagulant rodenticide, brodifacoum is antidoted with Vitamin K_1. There is good species specificity for rodents to the low concentration bait (Table 16). Nevertheless, as with all pesticides, brodifacoum should be used with intelligence and respect to minimize hazard. During the past three to four years extensive field trials have taken place in many different parts of the world and in the hands of many researchers and field staff. During this time there have been no reports of non-target hazard greater than would be expected with the use of other anticoagulants.

Table 16. Bait (g) required to deliver 1 acute oral LD_{50} of various rodenticides of different species based on acute oral LD_{50} of technical material.

Species	Body wt. kg.	Brodifacoum 0.005%	Warfarin 0.025%	Pyriminyl (RH 787) 2.0%	Zinc Phosphide 2.5%	1080 0.25%
Rat, Albino	0.25	1.35	186	0.15	0.45	0.25
Mouse, Albino	0.025	0.2	37	0.105	--	0.17
Rabbit	1	5.8	3200	> 15.0	--	--
Pig	50	500-2000	200-1000	1250	40-80	60-80
Dog	5	25-250	400-5000	> 125	4-8	0.12-0.4
Cat	2	1000	48-320	6.5	1.6-3.2	0.24-0.4
Chicken	1	200-2000	4000	36	0.8-1.2	4-12
References			1,2,3	4	5,6	6,7

1-Thompson, 1976; 2-Hagan and Radomski, 1953; 3-Fitzpatrick, McGirr, and Papworth, 1955; 4-Whitmoyer, n.d.; 5-Martin, 1972; 6-Garner, 1967; 7-Spector, 1959.

CONCLUSIONS

Brodifacoum has been described as having "greater activity than other known anticoagulants against the three commensal species" (Redfern, et al., 1976); in particular it is "the most active anticoagulant so far tested for the control of warfarin resistant house mice" (Rowe and Bradfield, 1976).

The novel single feeding properties of brodifacoum (TALON rodenticide) have been described. The compound has high potency against a wide range of rodent species so that even at very low doses, it will act as an antidotable, classical indirect anticoagulant, even in controlling resistant rodents.

Brodifacoum appears to combine the efficacy and safety of the anticoagulants with the ability to kill resistant rodents and the low bait requirements of the acute poisons. This combination must have a great impact on the future of rodent control.

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