Rodenticides are commonly used for control of roof rats, Norway rats and house mice (known as commensal rodents) in and around poultry facilities as one component of an integrated pest management program. Most commercial baits are registered for rats and mice, although level of susceptibility to the toxicants, as well as the attractiveness and palatability of the bait formulation varies between the species and even between individuals of the same species. No rodent bait ingredient is universally highly acceptable, and regional differences are the rule rather than the exception. To achieve good control of commensal rodents using rodenticides, selection of the appropriate toxicant and formulation (i.e., grain, pelleted, or wax block); as well as bait placement, are important considerations.

Bait Selection and Formulation

Contrary to popular belief, rats prefer fresh, high-quality foods and will reject spoiled or inferior food items when given a choice. Therefore, rodent baits should be made from high-quality food materials, and baits which have become rancid or insect-infested should be discarded. Usually corn, oats, wheat, or barley are the grains most preferred by commensal rodents. Preference varies between rodent populations and among individuals. Baits similar to foods that rodents are accustomed to eating are often a good choice, particularly if their normal foods are limited or can be made less available to them.

To determine bait preference, a bait-choice test can be conducted by placing about 4 ounces (115 g) of each of several nontoxic baits about one foot (30 cm) apart in several locations where rodents are present. Baits are then checked during the next few days to determine which foods are preferred. Rats are suspicious of new objects and novel foods; therefore, they may not accept a new bait until the third or fourth day.

Rodenticides are available in various formulations. Grain-based baits in a loose meal or pelleted form are available in bulk or packaged in small, 4- to 16-ounce (112-to 454-g) plastic, cellophane, or paper “place packs”. These packets keep bait fresh and make it easy to place baits into burrows, walls, or other locations. Rodents will gnaw into these bags to feed on acceptable baits. Pelleted baits can more easily be carried by rats to other locations. Such hoarding of food by rats is not uncommon and may result in bait being moved to places where it is undetected or difficult to recover. In some cases these baits may then become hazardous to nontarget
species. Anticoagulant baits have also been formulated into wax and extruded blocks. These are generally less readily accepted by rodents.

**Toxicants**

Rodenticides are classified into two groups, anticoagulants and all other compounds (“non-anticoagulants”).

**Anticoagulant Rodenticides**

Anticoagulant rodenticides were first discovered in the 1940’s and have since become the most widely used toxicants for commensal rodent control. Rodents poisoned with anticoagulants die from internal bleeding, the result of loss of the blood’s clotting ability and damage to the capillaries. Prior to death, the animal exhibits increasing weakness due to blood loss, though appetite and body weight are not specifically affected. Because anticoagulant baits are slow in action (several days following the ingestion of a lethal dose), the target animal is unable to associate its illness with the bait eaten. Therefore, bait shyness does not occur. This delayed action also has a safety advantage because it provides time to administer the antidote (vitamin K,) to save pets, livestock, and people who may have accidentally ingested the bait.

The first anticoagulants (*warfarin, pindone*, diphacinone and clorophacinone), are commonly known as the first-generation anticoagulants or multiple-feed rodenticides. These compounds are chronic in their action, requiring multiple feedings over several days to a week or more to produce death. In order to achieve this multiple feeding, the bait must be made available on a continuous basis until the desired control is reached.

Where anticoagulants have been used over long periods of time at a particular location, there is an increased potential for a population to become somewhat resistant to the lethal effects of the baits. Resistance of rats to warfarin was first noted in Scotland in 1958, some years following its repeated use. Shortly thereafter, anticoagulant resistance was identified in both rats and house mice in other European countries. Rats and mice that are resistant to *warfarin* also show some resistance to all first generation anticoagulants, rendering control with these compounds less effective. Although relatively uncommon, a few instances of resistance have been reported in the United States.

Warfarin resistance led to the development of the second-generation anticoagulants, bromadiolone and brodifacoum. These compounds are much more potent than the first-generation anticoagulants, making them effective for the control of *warfarin*-resistant rats and mice. As one feeding can produce death if a sufficient amount of bait is consumed, they are often referred to as ‘single-feed’ anticoagulants. In commensal situations where rodents are often marginal or reluctant feeders, these compounds can be extremely effective. The effects of these compounds are also cumulative and will result in death after several feedings of even small amounts. As in the case of all anticoagulants, death is delayed for several days following the ingestion of a lethal dose.

Where anticoagulant resistance is known or suspected, the use of first-generation anticoagulants should be avoided in favor of the second-generation anticoagulants or one of the non-anticoagulant rodenticides like bromethalin or cholecalciferol.
Because of their similarity in mode of action, all anticoagulant baits are used in a similar fashion. Label directions commonly instruct the user to “maintain a continuous supply of bait for 15 days or until feeding ceases”, thus ensuring that the entire rodent population has ample opportunity to ingest a lethal dose of the bait. Anticoagulants have the same effect on nearly all warm-blooded animals, but the sensitivity to these toxicants varies among species. If misused, anticoagulant rodenticides can be lethal to nontarget animals such as dogs and cats. Additionally, residues of anticoagulants which are present in the bodies of dead or dying rodents can cause toxic effects to scavengers and predators. In general, however, the secondary poisoning hazard from anticoagulants is relatively low.

**First-generation anticoagulants:**

**Warfarin** (Final®, and others)
3-(alpha-acetonylbenzyl)-4-hydroxycoumarin

Warfarin was the first marketed anticoagulant and therefore became the best known and most widely used. It has relatively limited sales today, due to the availability of more potent anticoagulants.

**Pindone** (Pival®, Pivalyn®)
2-pivalyl-1,3-indandione

Pindone is also one of the early anticoagulants which is still available for use in commensal rodent control. Although regarded as slightly less effective than warfarin, it has some properties that resist insects and growth of mold. For optimal control using warfarin or pindone, bait must be available to rodents over a period of several days, so that there is no longer than 48 hours between feedings. Ideally, daily feedings should occur.

**Second-generation anticoagulants:**

**Chlorophacinone** (RoZol®)
2-[(p-chlorophenyl)phenylacetyl]-1,3-indandione

**Diphacinone** (Ramik®, Ditrac®)
2-diphenylacetyl-1,3-indandione

Chlorophacinone and diphacinone are similar in potency and are significantly more toxic than the anticoagulant compounds developed earlier. Consequently, they are formulated at lower concentrations. Chlorophacinone and diphacinone may kill some rodents in a single feeding, but multiple feedings are needed to give adequate control of an entire population.

With these compounds, feeding does not always have to be on consecutive days. When anticoagulants are eaten daily, however, death may occur as early as the third or fourth day. For optimal lethal effects, several feedings should occur within a 10-day period with no longer than 48 hours between feedings.

**Brodifacoum** (Talon®, Havoc®)
3-[3-(4' bromo[1,1'- biphenyl]-4-yl)-1,2,3,4-tetrahydro-1-naphalenyl]-4-hydroxy-2H-1-benzopyran-2-one

Brodifacoum is the most potent rodenticide currently available for commensal rodents. It is available in 0.005% pellet formulations and in wax blocks. Because of its acute toxicity, a lethal dose can be obtained in a single feeding, although death is delayed for 4 or 5 days.

**Bromadiolone** (Maki®, Contra&)
3-[3-(4' bromo[1,1'-biphenyl]-4-yl)-3-hydroxy-1-phenylpropyl]-4-hydroxy-2H-1-benzopyran-2-one

Bromadiolone is not quite as toxic to rodents as brodifacoum but can result in the same level of control. It is available in 0.005% pellet formulations and in wax blocks.
**Anticoagulant bait formulations**

Most of the anticoagulant baits used today are commercial ready-to-use baits in grain, pelleted or wax form. Grain and pelleted anticoagulant baits are used extensively in tamper-resistant bait boxes or stations for a permanent baiting program for Norway rats and house mice. They may not be effective on roof rats, however, because of their placement. Bait stations are difficult to place for roof rat control because of the rodents’ overhead traveling habits.

Pa&in-type bait blocks provide an alternative to bait stations containing pelleted or loose cereal bait. If permitted by the label, bait blocks can be placed or fastened in locations where bait boxes with loose grain or pelleted bait would be difficult to place, and where they are readily accessible to roof rats.

Generally, roof rats are less susceptible to first-generation anticoagulant rodenticides than Norway rats and a few more feedings are necessary to produce death. This is less significant with the second-generation anticoagulants. For best results, several baits should be tried to find out which one rats consume most. House mice are susceptible to all of the various anticoagulant rodenticides, but they are generally less sensitive (often less sensitive) to the active ingredients than are Norway or roof rats. It usually requires a few more feedings to produce death with the first-generation anticoagulants than with the second-generation anticoagulants.

**Anticoagulant Bait Failure**

Resistance is only one (and probably the least likely) reason for failure in the control of rodents with anticoagulant baits. Control with baits that are highly accepted may fail for one or more of the following reasons:

- Too short a period of bait exposure.
- Insufficient bait and insufficient replenishment of bait (none remains from one baiting to the next).
- Too few bait stations and/or too far apart. In some situations, stations may have to be within 20 to 30 feet (7 to 10 m) of one another.
- Too small a control area, permitting rodents to move in from untreated adjacent areas.
- Genetic resistance to the anticoagulant. Although this is unlikely, it should be suspected if about the same amount of bait is taken for a number of weeks.

Control with anticoagulant baits that are poorly accepted may fail for one or more of the following reasons:

- Poor bait choice, or bait is formulated improperly. Other more attractive foods are available to rodents.
- Improperly placed bait stations. Other foods are more convenient to rodents.
- Abundance of other food choices.
- Tainted bait: the bait has become moldy, rancid, insect-infested, or contaminated with other material that reduces acceptance. Discard old bait periodically, and replace it with fresh bait.

Occasionally, rodents accept bait well and an initial population reduction is successful. Then bait acceptance appears to stop although some rodents remain. In such instances it is likely that the remaining rodents never accepted the bait either because of its formulation or placement. The best strategy is then to switch
to a different bait formulation, place baits at
different locations, and/ or use other control
methods such as traps.

Non-anticoagulant Rodenticides

The older rodenticides, formally referred to as
the acute toxicants (e.g., arsenic, red squill and
phosphorus) are either no longer registered or
of little importance in commensal rodent
control. Newer rodenticides are much more
effective and have resulted in the phasing out
of these older materials over the last 20 years.

At present there are three non-anticoagulant
rodenticides - zinc phosphide, cholecalciferol
(Vitamin D3) and bromethalin - registered and
available for commensal rodent control. Since
none of these are anticoagulants, all can be
used to control anticoagulant resistant rodent
populations.

Of these active ingredients, bromethalin and
cholecalciferol are formulated to serve as
chronic rodenticides, applied so that rodents
will have the opportunity to feed on the baits
one or more times over the period of one to
several days. Because they are slow-acting in
comparison to zinc phosphide, bait shyness is
not usually a problem, nor is prebaiting
necessary to get good control in most
situations. Zinc phosphide differs in that
prebaiting (offering rodents similar but non-
toxic bait prior to applying the toxicant-treated
bait) is recommended to increase bait
acceptance. Zinc phosphide is not designed to
be left available to rodents for more than a few
days, as continued exposure is likely to result
in bait shyness within the population.

Non-anticoagulant rodenticides, particularly
zinc phosphide, remain useful tools to achieve
rapid reductions in rodent populations. When
population levels are high, the cost of baiting
with these materials may be lower than for the
anticoagulants.

Bromethalin  (Assault®, Vengeance®,
Trounce®)
N-methyl-2,4-dinitro-N-(2,4,6-tribromophenyl)-6-
(trifluoromethyl) benzenamine

Bromethalin is a single-dose rodenticide that
causes central nervous system depression and
paralysis, leading to death in 2 to 4 days. Bait
should be renewed at intervals of several days.
Continuous bait availability (as with
anticoagulants) is not required, but bait needs
to be present long enough to allow all animals
in the area to feed. The amount of bait needed
is usually about one-third that used with
anticoagulants, since an animal ingesting a
lethal dose does not feed again. This effect is
unlike that of anticoagulants, in which rodents
continue to consume bait after they have
ingested a lethal dose. Bait shyness has not
been reported.

Cholecalciferol  (Vitamin D3, Quintox®,
Rampage®)
9,10-Secholesta-5,7,10(19)-trein-3beta01

Cholecalciferol is a single-dose or multiple-
dose rodenticide that causes mobilization of
calcium from the bone matrix to plasma and
death from hypercalcemia. Time to death is 3
to 4 days after ingestion of a lethal dose. As
the toxicant is slow-acting, bait shyness
apparently does not occur. As with
Bromethalin, once a rodent consumes a lethal
dose, all food intake ceases.

Zinc phosphide

Zinc phosphide is a dark gray powder,
insoluble in water, that has been used
extensively in the control of rodents. When
zinc phosphide comes into contact with dilute
acids in the stomach, phosphine (PH3) is
released. It is this substance that probably
Rodenticides used for commensal rodent control in California.

<table>
<thead>
<tr>
<th>Common name and typical trade names</th>
<th>Percent active ingredient</th>
<th>Acute oral LD₅₀ (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>House mouse</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6 for 3-9 days</td>
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<tr>
<td><strong>Anticoagulants</strong></td>
<td></td>
<td></td>
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<tr>
<td>Warfarin (Final® and others)</td>
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<td></td>
</tr>
<tr>
<td><strong>Pindone (Pival®, Pivalyn®)</strong></td>
<td>0.025</td>
<td>280</td>
</tr>
<tr>
<td>Diphacinone (Ramik®, Ditrac®)</td>
<td>0.005</td>
<td>141 - 340</td>
</tr>
<tr>
<td>Chlorophacinone (RoZol®)</td>
<td>0.005</td>
<td>1.06</td>
</tr>
<tr>
<td>Brodifacoum (Talon®)</td>
<td>0.005</td>
<td>0.4 - 0.86</td>
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<tr>
<td>Bromadiolone (Maki®, Contra&amp;)</td>
<td>0.005</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Non-anticoagulant rodenticides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromethalin (Assault®, Vengeance®)</td>
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<td>5.25 - 8.13</td>
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<tr>
<td>Cholecalciferol (Quintox®, vitamin D₃)</td>
<td>0.075</td>
<td>42.5</td>
</tr>
<tr>
<td>Zinc phosphide</td>
<td>1.0 - 2.040</td>
<td>27 - 40</td>
</tr>
</tbody>
</table>

To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products that are not mentioned.
causes death. Rats and mice that ingest lethal amounts of bait usually succumb overnight with terminal symptoms of convulsions, paralysis, coma, and death from asphyxia. They typically die in a prone position with their legs and tails outstretched. Because zinc phosphide is not stored in muscle or other tissues of poisoned animals, there is no secondary poisoning with this rodenticide. The bait, however, remains toxic up to several days in the gut of a dead rodent. Other animals can be poisoned if they eat enough of the gut content of rodents recently killed with zinc phosphide.

Zinc phosphide is available in ready-to-use dry baits and also in concentrates for use by persons trained in rodent control who may wish to prepare their own baits. Its strong garlic-like odor appears to be attractive to rodents that are not bait-shy and apparently makes the bait unattractive to some other animals. Bait shyness can be a problem; so prebaiting is recommended or necessary for achieving good bait acceptance.

**USE PRECAUTIONS**

Rodenticides, like all other pesticides, must be handled responsibly, and used in accordance with the label instructions. The rodenticides listed in this article are currently registered for use in California as of July 1996. One or more of these pesticides may not be legal to use within California at later dates.

Because some pesticides are restricted within certain locations in California, check with your local Agricultural Commissioner for information about those that are allowed to be used in your county.

**For additional information:**


-Desley Whisson

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