Development of a long-life bait for control of stoats

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ABSTRACT

Three types of long-life stoat bait (polymer, paste, and gel) were formulated from natural and synthetic bait ingredients after extensive testing of potential ingredients. Feeding trials demonstrated that baits containing natural extracts from rabbit and chicken were preferred to bait that contained only processed meals and synthetic flavours. The addition of preservatives and waterproofing agents to improve bait longevity, lowered palatability markedly in all bait types. The texture of bait also affected the amount of bait eaten, with most stoats rejecting baits that were hard or needed to be chewed before they could be swallowed. In this study, significantly more long-life polymer and paste bait was eaten than gel bait. The polymer bait remained palatable after one month in the field. Although all long-life bait formulations tested were less palatable than fresh meat, most stoats (i.e. ≥90%) consumed sufficient quantities of polymer and paste baits to receive a lethal dose (>5 g) if baits had contained a toxin. This was similar to the percentage of stoats eating pricked eggs, and better than consumption of non-pricked hen eggs. Methods for further increasing bait consumption and extending their effectiveness over time are being assessed, the ultimate goal being a long-life bait that is as palatable as fresh meat.

Keywords: stoat, *Mustela erminea*, bait, palatability, flavour additives

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1. Background

Stoats (*Mustela erminea*) predate New Zealand wildlife, exotic birds, and small mammals introduced by European settlers (King & Moody 1982). To protect indigenous wildlife threatened by predation, stoat control is currently reliant on trapping (King et al. 1994), the use of poisoned hen eggs (Spurr 1999) or secondary poisoning during pest control operations using 1080 or brodifacoum baits (Murphy et al. 1999; Alterio 1996). However, the effectiveness of these methods is constrained by high labour costs, the low palatability of hens' eggs, the lack of an effective long-life bait for kill traps, the limitations of secondary poisoning as a control strategy, and the large resource requirement for sustaining stoat control over extensive areas of the conservation estate with existing technologies. Clearly, more efficient and effective strategies for maintaining stoat populations below threshold densities are required if the threat to indigenous species (e.g. kaka) is to be reduced.

2. Introduction

Toxic baits currently used for stoat control have short field-lives, are not eaten by all stoats, and are not effective at killing most (i.e. >90%) stoats (Spurr 1999). Stoats have a high intrinsic rate of increase (McDonald & Lariviere 2001) and are likely to rapidly recolonise areas that were previously controlled (Murphy et al. 1999). Therefore, killing fewer than 90% of stoats during one-off control operations, in small-localized areas of the conservation estate, will at best provide only a temporary respite from ongoing predation of indigenous wildlife. A new approach to sustainable control of mustelids is required. This may be provided by the use of long-life baits in widely-spaced bait stations (Moller et al. 1996).

The development of long-life stoat baits was undertaken in two stages. The first stage was to develop a palatable non-toxic bait and then compare the consumption of this bait with existing stoat baits (e.g. fresh meat and eggs). The remainder of this research report details the results of the non-toxic bait development (Stage 1). Research investigating methods of improving the palatability of long-life baits and evaluation of toxicants is ongoing (Stage 2).

3. Objectives

To develop a long-life, non-toxic bait for control of stoats by:

- Capturing and acclimatising at least 12 stoats to captivity
- Formulating a palatable bait base for gel, paste and polymer baits
- Enhancing bait palatability with flavour additives and optimising polymer bait size
- Adding preservatives and waterproofing agents to extend the field-life of bait
- Assessing the relative palatability and efficacy of final bait formulations on caged stoats
- Comparing the best long-life bait with the 'best' existing bait, hens eggs.

4. Methods

4.1 HUSBANDRY OF STOATS

Stoats were caught from the wild using Edgar (King et al. 1994) and Holden live-capture traps (Livecapture Traps, Waipara). Traps were usually pre-fed for 3–5 days with rabbit meat and/or hens eggs before they were set. Once set the traps were inspected daily and captured stoats shifted to the Pest-Tech animal facility where they were housed individually in cages. Each cage contained a nest box that was lined with shredded paper. Stoats were provided fresh water *ad libitum*, and were fed daily on a mix of minced beef and offal (i.e. livers, kidneys, heart, and lungs) supplied by a local pet food manufacturer. Once stoats had adjusted to captivity they were used in feeding trials to assess food preferences and to formulate palatable baits.

4.2 FORMULATION OF A PALATABLE BAIT BASE

Three bait bases were formulated (polymer, gel, and paste). The bait bases were manufactured as follows:

Polymer baits were formulated from a mix of 14 protein ingredients. Bait ingredients were blended into a homogenous loose mix with a dough mixer, and then manufactured into protein baits with an orbital pelleter. Once the optimal mix of ingredients was determined, a final formulation containing water-resistant polymers was manufactured with an extruder.

Gel baits were manufactured from solutions of sugar, water, hydrocolloids and oils.

Paste baits were prepared by blending processed meals and synthetic flavours into a bait base containing petrolatum and vegetable oils.

Each bait type was formulated from ingredients that were unlikely to degrade following the addition of preservatives and waterproofing agents. Potential ingredients were included in prototype baits at a minimum of 3 different concentrations. The effect of an ingredient on bait palatability was then tested in 2-choice feeding trials (Grote & Brown 1971), which compared consumption of test and control baits over 12 hours. Control baits were formulated from the same ingredients but did not contain the test ingredient. Paired trays containing test and control baits were presented to stoats on the day they were manufactured.

Bait palatability was calculated as the percentage of test bait eaten relative to total bait consumption (i.e. test + control). The palatability of bait eaten during 2-choice feeding trials was compared between the concentrations of each additive using ANOVA. The percentage of stoats eating ≥5 g of bait (i.e. the amount of bait containing a fast-acting poison that is lethal to most small mammalian pests) was also calculated for each bait type.

4.3 EVALUATION OF FLAVOUR ADDITIVES AND POLYMER BAIT SIZE

Flavour additives were used at low concentrations in final bait formulations (i.e. <7.5% of total bait weight). The flavour additives used individually were as follows:

Proprietary compounds used during the manufacture of pet foods. These proprietary compounds were supplied by Bush, Boake & Allen (Auckland), Bronson & Jacobs (Auckland), Sensient (Auckland), and Quest International (Auckland).

Natural extracts from chicken, rabbit, hare, and rat. Natural extracts were prepared as 'emulsions' or as 'digests' and contained individual components of the carcasses (i.e. pelage, kidney, liver, heart, lungs, head, and meat). Emulsions did not require the use of heat during their preparation, whereas digests were prepared using temperatures of 70–130°C.

Waste cooking oils that had been used to deep-fry foodstuffs;

Synthetic compounds that are routinely used during food processing.

The palatability of new flavour additives consumed during 12 hour, 2-choice trials was compared between the concentrations of the additive and between additives using ANOVA.

Bait size is likely to limit food consumption by some carnivores (Beauchamp et al. 1977). To assess whether the size of bait influenced the amounts eaten by stoats, polymer baits were extruded through 4 mm, 10 mm, and 18 mm diameter dies. The amount of bait eaten by stoats in 2-choice feeding trials was tested by ANOVA, using bait size as a treatment factor.

4.4 PALATABILITY OF BAIT FORMULATIONS CONTAINING PRESERVATIVES AND WATERPROOFING AGENTS

Two types of proprietary fungicide, bactericide, and antioxidant were sourced from commercial suppliers to food manufacturers and the cosmetics industry. The preservatives were included in baits at recommended concentrations. The palatability of each preservative/waterproofing agent was assessed using the same bait without the agent as a control bait in 12 hour, 2-choice feeding trials.

The palatability of the best long-life bait formulations for each bait type was evaluated shortly after manufacture, and then after bait had been stored in bait stations for one month. Bait was presented to caged stoats in 2-choice feeding trials over 12 hours using recently made bait as a control. The amount of test bait eaten during feeding trials was compared by ANOVA, using duration of storage and bait type as treatment factors.

4.5 ASSESSMENT OF FINAL BAIT FORMULATIONS

Final formulations of polymer, gel, and paste bait each using one of two flavour enhancers were presented to stoats over 12 hours in a randomised Latin-square design. Each stoat was given 60 g of long-life bait in a no-choice feeding trial. Stoats were also given 60 g of supplementary fresh meat, so any initially refusing bait would not be forced to eat it, and ensuring that the amount of test bait consumed would provide a conservative and rigorous assessment of palatability. The amounts of bait eaten were tested by ANOVA, using bait type and flavour type as treatment factors.

4.6 CONSUMPTION OF LONG-LIFE BAIT COMPARED WITH EGG

The most palatable long-life bait and hen eggs were presented to stoats in 2-choice feeding trials on 4 successive nights. The long-life bait was stored for one month prior to the trial. Stoats were also given 60 g of supplementary fresh meat. Each day the amount of bait eaten was measured and interference with eggs recorded. A week later the trial was repeated using the same long-life bait and 'pricked' eggs (i.e. eggs containing a small hole in either end).

This research was undertaken with the approval of the Lincoln University Animal Ethics Committee (No. 859), and conformed to the New Zealand standards for care and use of animals for scientific purposes (Animal Welfare Advisory Committee 1995).

5. Results

5.1 HUSBANDRY OF STOATS

Fifteen stoats were caught from the wild and acclimatised over a two-week period to captivity at the Pest-Tech animal facility. During the 15-month period of the study, 3 stoats died from age-related maladies. The remaining stoats were healthy and readily ate the maintenance diet that was provided.

5.2 FORMULATION OF A PALATABLE BAIT BASE

To formulate the 3 bait bases, a total of 27 potential bait ingredients were evaluated in 95 palatability trials. Only 4 potential bait ingredients were palatable to stoats in the three bait types.

5.3 EVALUATION OF FLAVOUR ADDITIVES

Twenty-five flavour additives were evaluated in the 3 different bait types during 83 palatability trials. The only synthetic flavours that increased the amounts of bait eaten by stoats were salt, propylene glycol, sodium lactate, and carbon disulfide.

Animal extracts significantly enhanced the amounts of bait eaten by stoats. Emulsions made from rabbit and chicken increased bait consumption more than emulsions made from rats and hares. Although digests were not as palatable as emulsions, they increased the amounts of paste and gel bait eaten.

The different parts of rabbit and chicken used to make emulsions significantly affected the palatability of bait ($F_{4,121} = 4.57$, $P = 0.002$). Not surprisingly, the pelage of chicken and rabbits was highly attractive to stoats. Emulsions made from vital organs (i.e. liver, kidneys, heart, and lungs) also made highly palatable baits. However, baits containing emulsions from the meat and heads of animals were less preferred.

TABLE 1. THE MEAN CONSUMPTION OF BAITS CONTAINING OPTIMAL CONCENTRATIONS OF SYNTHETIC FLAVOURS AND ANIMAL EXTRACT*.

BAIT TYPE	MEAN WEIGHT OF BAIT EATEN (g)†	PERCENTAGE EATING ≥5 g OF TEST BAIT†
Polymer‡	37.2	100
Gel	16.5	83
Paste	15.5	75

* By individually caged stoats, over 12 hours. Each animal was presented with 60 g of supplementary fresh meat and the test bait.

† With optimal mix of additives.

‡ As detailed in section 4.2, the polymer bait at this stage was in pellet form.

Baits containing an optimal mix of ingredients were eaten in moderate–high amounts by caged stoats (Table 1).

There was no significant difference in the consumption of 3 sizes of polymer bait ($F_{2,25} = 0.85$, $P = 0.16$). Therefore, the size of baits is likely to be less important than bait palatability and bait texture in determining the percentage of wild stoats that eat lethal amounts of bait.

5.4 PALATABILITY OF BAIT FORMULATIONS CONTAINING PRESERVATIVES AND WATERPROOFING AGENTS

Preservatives and waterproofing agents reduced the palatability of all types of bait. For example, the mean consumption of the dry–meal protein bait declined from 37.2 g (Table 1) to 12.5 g after the addition of polymers and preservatives (Table 2). The palatability of the long-life gel bait reduced to sub-standard levels and we excluded this bait from the remainder of the trial. The reduced consumption of baits was mainly attributed to increases in the 'hardness' or viscosity of baits as they were made more durable.

TABLE 2. MEAN CONSUMPTION OF LONG-LIFE POLYMER, PASTE AND GEL BAITS (±SE)*.

BAIT TYPE	ANIMAL EXTRACT	MEAN AMOUNT EATEN (g) ± SE
Polymer	Chicken	12.5 ± 2.9
Polymer	Rabbit	12.0 ± 2.8
Gel	Chicken	4.9 ± 1.4
Gel	Rabbit	4.5 ± 1.4
Paste	Chicken	12.3 ± 3.4
Paste	Rabbit	14.3 ± 4.3

* By individually caged stoats, over 12 hours that were also fed 60 g of fresh meat.

The amount of paste eaten by stoats significantly declined after it had been stored for one month ($F_{1,38} = 13.92$, $P < 0.001$). This suggests that either:

- The antioxidant, bactericide, or fungicide used in the final bait formulation did not prevent biodegradation or
- That one or more bait ingredients had reacted to produce an unpalatable residue.

The polymer bait did not lose palatability during one month's storage in humid conditions ($F_{1,38} = 0.04$, $P = 0.84$) and this indicated that the inclusion of waterproofing agents and preservatives was effective at maintaining the palatability of this bait type (Table 3).

TABLE 3. MEAN CONSUMPTION (±SE) OF PASTE AND POLYMER BAIT SHORTLY AFTER BAIT MANUFACTURE, AND AFTER STORAGE FOR ONE MONTH IN BAIT STATIONS*.

BAIT TYPE	MEAN 'FRESH' BAIT CONSUMPTION	MEAN BAIT CONSUMPTION AFTER 1 MONTH STORAGE
Paste	13.3 ± 2.8	5.4 ± 0.7
Polymer	12.3 ± 2.0	11.6 ± 2.9

* By individually caged stoats, over 12 hours that were also fed 60 g of fresh meat.

5.5 ASSESSMENT OF FINAL BAIT FORMULATIONS

The amount of long-life bait eaten was dependent on bait type ($F_{2,60} = 4.74$, $P = 0.012$) (Table 2). Polymer and paste baits were more preferred than gel. Bait containing animal extracts from either rabbit or chicken was eaten in similar amounts ($F_{1,60} = 0.02$, $P = 0.88$).

The most palatable fresh long-life bait was the paste formulation. Accordingly, we used paste bait in the comparison with hens' eggs (see below). However, the storage trial indicated that the palatability of the paste bait significantly declined after it was stored in a bait station for one month (see Table 3). A further trial comparing the stored polymer bait with hens' eggs is clearly required.

5.6 CONSUMPTION OF LONG-LIFE BAIT COMPARED WITH EGG

Stoats initially consumed less than 5 g of paste, when presented with 60 g of fresh meat and hens' eggs (Table 4). However, most hen eggs were also not eaten on the first day stoats were exposed to them. The mean consumption of paste increased over time and the majority of stoats were eating >5 g of paste on the second day.

Although the proportion of hens' eggs eaten by stoats increased after day one, one stoat refused both whole and 'pricked' eggs during the 8 days of the trial. This stoat was the only one not to eat more than 5 g of bait over the 4 days of either trial. The proportion of hen eggs eaten by caged stoat was increased by 'pricking' the shell to release odours from inside the egg ($\chi^2 = 20.8$, d.f. = 1, $P < 0.001$).

During the egg feeding trial, all stoats ate most of the 60 g of fresh meat that was provided each day.

TABLE 4. CONSUMPTION OF PASTE (±SE) AND HEN EGGS*.

DAY	MEAN AMOUNT OF PASTE EATEN (g)	PERCENTAGE OF INTACT EGGS EATEN	PERCENTAGE OF PRICKED EGGS EATEN
1	4.5 ±1.2	0	10
2	8.9 ±1.5	20	90
3	9.3 ±0.8	10	80
4	5.5 ±1.7	30	80

* By individually caged stoats during 2 trials (a week apart). The animals were also fed 60 g of supplementary meat each day.

6. Discussion

The amounts of bait eaten by stoats during this study was increased by:

- Suffusing baits with 'natural prey odours'
- Ensuring baits did not have a hard texture
- Enhancing a palatable bait base with flavour additives
- Preventing biodegradation of bait ingredients during storage.

Previous research has demonstrated that the ingestion of processed food is significantly increased in satiated carnivores by suffusing the food with odours from meats (Mugford 1977). During this study, the use of meat extracts also increased bait consumption. Baits containing odours from chicken and rabbit were significantly more palatable to stoats than baits constituted solely of processed meals and synthetic flavours. Animal extracts prepared as a digest were less preferred than emulsions, presumably because the application of heat to digests had denatured some aromatic compounds in chicken and rabbit that are attractive to stoats. The effectiveness of prey odours for enhancing bait consumption was ranked: chicken = rabbit > hare = rat > freeze-dried rat. Although freshly caught rats are an effective odour attractant for stoats (Spurr 1999), they are not readily eaten in baits. Freeze-dried rat is now widely used as a lure for stoat traps, but is not an effective component of baits. This suggests that some wild stoats are responding more to the visual cues provided by a freeze-dried rats, rather than the slight odour that rats retain after they have been dried.

Only four artificial flavours improved bait palatability. Salt has previously been shown to be attractive to carnivores when combined with sugar (Bartoshuk et al. 1971). The explanation for the enhanced effect seen with propylene glycol is not at all clear. Sodium lactate is likely to mimic the lactic acid component of meat. Carbon disulfide may have simulated the sulphurous odours associated with meat and eggs. Because carbon disulfide is extremely volatile, it could only be included in baits formulated without heat (i.e. paste or a cold gel).

The texture of food is a factor that affects consumption of possum baits (Henderson & Frampton 1999) and cat food (Beauchamp et al. 1977).

Throughout this study bait texture was also important in determining the amounts of bait eaten by stoats. A 'soft' pelleted bait containing chicken emulsion was readily eaten by all stoats (mean consumption = 37 g). However, including a polymer in this bait formulation (to waterproof baits) made baits harder and significantly reduced bait consumption (mean consumption = 16 g). Similarly, gels and pastes were progressively eaten in smaller amounts as the viscosity of each bait matrix was increased. Further development of long-life baits for control of mustelids should ensure that final bait formulations do not have a texture that is either very viscous or hard.

Stoats did not readily eat hen eggs during this study. Few (5%) stoats ate eggs on the first day they were offered, and one of 10 stoats did not eat any whole or pricked eggs during 8 days of trials. Although piercing the shell of eggs resulted in a higher percentage of eggs being eaten (65%) than eggs with an intact shell (15%), most stoats preferred to eat meat and the relatively unpalatable stored paste bait performed as well as the pricked eggs.

At this early stage of bait development it is likely that the short-life protein bait already produced will prove much more palatable as a vehicle for a toxicant or as a bait for traps than the hens eggs used currently. Additionally, the long-life polymer bait although not as palatable with the addition of preservatives, is also likely to be far more effective than hens' eggs and has the distinct advantage that it can be left in the field for at least a month without requiring regular visits to maintain fresh bait. Research to further improve the effectiveness of the polymer bait should be completed by June 2003.

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