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Effectiveness and persistence of cinnamic aldehyde as an antifeedant on rats under storage conditions

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ABSTRACT

The house rat, *Rattus rattus* (Linnaeus), is responsible for causing severe damage in outdoor commercial grain stores where rodent proofing is not possible. Rodenticides are the preferred option for preventing rodent attacks. However, secondary poisoning and development of bait shyness and resistance among rodents after exposure to toxic chemicals has increased the search for new, safe, ecofriendly and effective control methods, which can prevent damage for a long duration. In the present study, the effectiveness and persistence of cinnamic aldehyde as an antifeedant against *R. rattus* were evaluated. Cinnamic aldehyde treated bait at 5% concentration was effective as an antifeedant and secondary repellent against *R. rattus* in bi-choice feeding tests. The antifeedant effect was retained for at least 14 days after treatment. There was no significant difference between consumption of treated and untreated bait during the first four hours of exposure of rats under bi-choice feeding tests, indicating absence of a primary repellent effect of cinnamic aldehyde. Feeding bait mixed with 5% cinnamic aldehyde continuously for 27 days in bi-choice feeding tests revealed the persistence of the antifeedant effect. This study demonstrated that 5% cinnamic aldehyde can be used under field conditions to prevent the damage caused by house rats for long durations. A formulation of 5% cinnamic aldehyde containing sodium bicarbonate as an emulsifier prevented rodent damage in terms of consumption of wheat grains, number of cuts on bags, quantity of grains spilled from bags cut by rats and percent damage due to rat urine under simulated storage conditions in laboratory pens for durations up to the experimental period of 15 days. Study of feeding behaviour in feed scale consumption monitoring also confirmed the secondary repellent effect of cinnamic aldehyde against the house rat. Our results indicate that the sodium bicarbonate emulsified formulation of 5% cinnamic aldehyde has the potential to protect stored products from rodent damage in a manner that is effective, persistent and environmentally acceptable.

1. Introduction

Rodents are significant economic pests that devastate crops, gardens, orchards, landscape plantings, and damage commercial forest plantations or impede reforestation efforts (Tobin and Fall, 2004; Singla and Babbar, 2010, 2012; Singla and Parshad, 2010; Singla, 2011). A national study made by the Indian Grain Storage Management and Research Institute (IGMRI) revealed a total post-harvest loss of 4.75% to wheat grains with rodents accounting for 0.59% (Rao, 2003). Overall losses of grains due to rodents in India were approximately 25% at pre-harvest and 25–30% at post-harvest situations, bringing the loss to at least US$5 billion annually in stored food and seed grain in India (Hart, 2001). The house rat, *Rattus rattus* (also called the black rat, ship rat, or roof rat), is a native of the Indian sub-continent and is now found worldwide and nominated as among 100 of the world's worst invaders (Gillespie and Myers, 2004). It causes severe damage in outdoor commercial grain stores by consuming the stored food items and also contaminates the food material by urination and defecation, thus making it unfit for human consumption (Prakash and Ghosh, 1992; Drummond, 2001; Brown et al., 2007).

Chemical control is the preferred option worldwide to prevent rodent attacks. However, environmental pollution, secondary poisoning and health problems caused by the use of rodenticides and development of bait shyness and resistance among rodents after exposure to toxic chemicals have increased the search for new, safe, ecofriendly and sustainable control methods (Rao, 2005). Natural compounds provide protection against pests with different modes of action i.e. by either killing the pest or by acting as primary or secondary repellents for pests (Sbeghen-Loss et al., 2011). Over

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the last 50 years, thousands of plants have been screened as potential sources of repellents (Sukumar et al., 1991). Repellents used for the management of birds and mammals often rely on the development of a conditioned taste aversion (CTA) in response to post-ingestional malaise (Johnson et al., 1982) or alternatively, repellency is mediated through sensory irritation by contact or olfactory avoidance (Mason et al., 1991). CTA is acquired through an association between the taste of the food and feeling of illness experienced after ingestion and thus avoidance of that food in future (Garcia et al., 2001; Provenza, 1995). Repellents which induce CTA are more effective because they promote long term avoidance responses that are proportional to the severity of the malaise caused by the compound. Antifeedants or secondary repellents causing CTA have been proposed as alternatives to synthetic pesticides (Ballesta-Acosta et al., 2008). Pyrethrum, rotenone, neem and plant essential oils have been used for centuries to protect stored commodities or to repel pests from human habitations (Isman and Machial, 2006).

Many plant derived extracts have been found to have repellent properties against rodents. Methanol extracts of *Piper nigrum* L. (Piperaceae), *Aucklandia lappa* Dene. (Compositae), *Cinnamomum cassia* Pres l. (Laurac eae), *Illicium verum* Hook. (Magnoliaeceae), *Rheum coreanum* Nakai. (Polygonaceae), and *Pinus densiflora* Sieb. et Zucc. (Pinaceae) showed the potent antignawing activity against mice (Yun et al., 1998). Many cinnamomum species are rich in essential oils and tannins. The main components of the essential oil obtained from the bark of *Cinnamomum zeylanicum* are cinnamic aldehyde, eugenol and linalool. While *C. cassia* bark contains cinnamic aldehyde, cinnamic acid, cinnamyl alcohol and coumarin (He et al., 2005). Cinnamic aldehyde is reported to repel dogs and other canids (Mason, 1998). It also acted as an irritant for brown tree snake (Clark and Shivik, 2002). Antignawing activity of cinnamic aldehyde is also reported against mice (Lee et al., 1999). Systematic work on cinnamic aldehyde as an antifeedant against rodents, particularly against *R. rattus*, is lacking. Moreover no report is available on the persistence of antifeedant effect of cinnamic aldehyde and development of any formulation using antifeedant for field application against rodents. The objectives of the present study were (i) To determine the effective concentration of cinnamic aldehyde as an antifeedant against the house rat. (ii) To determine the persistence of an effective concentration of cinnamic aldehyde in laboratory cages and (iii) To determine the persistence of different formulations containing an effective concentration of cinnamic aldehyde under simulated storage conditions in laboratory pens.

2. Materials and methods

The present study was carried out at the Animal House and Rodent Research Laboratory, Department of Zoology, Punjab Agricultural University (PAU), Ludhiana, Punjab, India (30°55′ N; 75°54′ E). Animals were used and maintained as per the guidelines of Animal Ethics Committee. Approval of Institutional Animal Ethics Committee, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India was obtained for the usage of animals. Adult rats were collected from poultry farms at Ludhiana using multi catch rat traps and acclimatized for 10–15 days on food and water provided *ad libitum*.

2.1. Determination of effective concentration of cinnamic aldehyde

Cinnamic aldehyde was evaluated as an antifeedant against *R. rattus* in the present studies. It was purchased from S.D Fine-chem limited, Mumbai, India. Three different concentrations of cinnamic aldehyde (1, 2.5, 5%) were tested against adult house rats. Treated baits containing different concentrations of chemical were prepared by dissolving the required chemical in a known volume of methanol and then mixing in a known quantity of plain WSO (Wheat:Sugar:Oil – 96:2:2) bait. Rats of treated (3 groups) groups ($n = 10$, 5 males and 5 females in each group) were fed on different concentrations of cinnamic aldehyde (1, 2.5, 5%) in bi-choice feeding tests for three consecutive days during treatment period 1 (D0) after recording pre-census bait consumption. Treatments were repeated again after 7 days (treatment period 2 – D7) of treatment period 1 and after 14 days (treatment period 3 – D14) of treatment period 2 to test whether rats could retain the memory of the compounds after 7 and 14 days of treatment. Simultaneously, rats of untreated group ($n = 10$, 5 males and 5 females) were fed on plain WSO bait mixed with known volume of methanol. Bait consumption (g) of both untreated and treated bait was recorded daily to calculate mean daily bait consumption in g/100 g body weight (bw) as per the formula given below:

$$\text{Daily/hourly bait consumption (g/100 g bw)} = \frac{\text{Daily/hourly bait consumption by rat (g)}}{\text{Weight of rat (g)}} \times 100$$

2.2. Determination of primary repellent effect of cinnamic aldehyde

Experiments were also conducted in laboratory cages to record the hourly consumption of groups of adult rats ($n = 10$, 5 males and 5 females) treated with effective dose of cinnamic aldehyde (determined from Section 2.1) up to 4 h under bi-choice conditions in order to determine the existence of primary repellent effect. For this treated group was fed on known weight of WSO bait mixed with 5% cinnamic aldehyde dissolved in methanol in bi-choice feeding test for 4 h consecutively to observe the hourly consumption of treated bait.

2.3. Determination of development of habituation in rats to effective dose of cinnamic aldehyde

In order to confirm whether the rats treated with effective dose of cinnamic aldehyde became habituated to treated bait, consumption of bait treated with the effective dose of compound and untreated bait was recorded daily for up to 27 days under bi-choice conditions using adult rats of both sexes ($n = 10$, 5 males and 5 females).

2.4. Calculation of antifeedant index (AFI)

Percent antifeedant index (AFI) was calculated as per the method described in Singla and Parshad (2007) which is given below:

$$\text{AFI (\%)} = \frac{\text{Consumption of untreated bait} - \text{Consumption of treated bait}}{\text{Consumption of untreated bait} + \text{Consumption of treated bait}} \times 100$$