Evaluation of Three Selenium Compounds on German Cockroach Mortality

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Introduction

The German cockroach, *Blattella germanica* (L.), is a cosmopolitan pest species that has significant economic impacts as well as implications to human health [1]. Baits are a common and widely used method for controlling cockroach populations in infested areas. Simply put, baits are composed of an insecticide and a phagostimulant that have the advantages of being relatively safe, useful in sensitive areas, and long-lasting [1]. Unfortunately, field populations of the German cockroach have developed resistance against many commercially available insecticides thus leading to failure in control efforts [2]. As a result, there is a vital need for novel active ingredients to combat resistant populations.

Selenium is a naturally occurring metalloid element that is essential in trace amounts to living organisms [3]. However, in large amounts, it exhibits toxic effects to the consumer [4]. Previous studies have shown that selenium can cause varying degrees of adverse effects ranging from increased developmental times to mortality [5,6]. Due to the insecticidal properties of selenium, it has been suggested that it can potentially be used as a pesticide against insects [7].

In order to evaluate the potential of selenium to be used as an active ingredient in cockroach bait, a series of no-choice liquid bait bioassays were conducted to analyze the toxicity of three different selenium compounds against adult male German cockroaches.

Methods

Arena Set Up: Test arenas used were made from 5 qt clear plastic storage boxes (29.2 x 15.2 x 10.8cm). A thin layer of petroleum jelly was applied on the sides of the arena to prevent escape. A sheet of filter paper was placed and taped down to the bottom surface with masking tape. A pleated rectangle (24 x 6 cm) of corrugated paper placed at one end of the arena served as harborage. 8 mL glass vials were filled with DI water and plugged with a piece of dental cotton roll. Two pieces of Purina dog chow were provided on either side of the water vial. A piece of tape was used to fix the vial to the center of the arena opposite to the harborage.

Test Insects: A susceptible strain (UCR) of *Blattella germanica* was used. It has been in culture at the University of California, Riverside for more than 40 years. The insects were reared in the laboratory under environmental conditions of 24 ± 2˚C, 30% R.H., and 12-hour photoperiod. Ten adult male German cockroaches were introduced into each arena 1 hour before scotophase to acclimate for 48 hours. Water vials were removed after 24 hours.

Liquid Bait Preparation: Sodium selenate 98% and seleno-DL-methionine 99% were obtained from Acros Organics (Fair Lawn, NJ). Sodium selenite 98% was obtained from Sigma Chemical Company (St. Louis, MO). All water-soluble selenium compounds were serially diluted to 0.025%, 0.05%, 0.1%, 0.25%, 0.5%, and 1% concentrations (m/v%) using 3% sucrose. All dilutions were adjusted to achieve 100% concentration. 8 mL glass vials were filled with the solutions and then plugged with a piece of dental cotton roll. 3% sucrose was used as the control liquid bait. All liquid bait vials were introduced after at the end of the 48-hour acclimation period.

Data Collection: Mortality was defined as the inability for a cockroach to right itself after 2 minutes. Data were recorded daily until 100% mortality.

Probit Analysis: Data were analyzed using PoloPlus Version 2.0 to obtain $LT_{50/95}$ and $LC_{50/95}$ values.

Results

Table 1. Evaluation of sodium selenate against adult male *Blattella germanica*

Time (hours)	n	LC_{50} (95% CI) (%)	LC_{95} (95% CI) (%)	Slope ± SE	χ^2 (df)	% Mortality
24	180	0.27 (0.21 - 0.35)	1.36 (0.91 - 2.63)	2.35 ± 0.32	1.137 (3)	38.3
48	180	0.13 (0.05 - 0.27)	2.09 (0.70 - 74.86)	1.36 ± 0.20	7.435 (4)	53.9
72	180	N/A	N/A	1.94 ± 0.37	5.421 (2)	68.9

Conc. (%)	n	LT_{50} (95% CI) (hrs)	LT_{95} (95% CI) (hrs)	Slope ± SE	χ^2 (df)
0.025	30	94.92 (89.11 - 102.12)	177.64 (153.34 - 223.75)	6.04 ± 0.73	7.152 (8)
0.05	30	64.53 (59.22 - 70.15)	173.675 (144.29 - 229.08)	3.83 ± 0.42	3.103 (11)
0.1	30	44.19 (40.31 - 48.12)	115.79 (99.39 - 142.84)	3.93 ± 0.36	3.266 (11)
0.25	30	26.78 (22.42 - 31.11)	140.687 (103.48 - 227.43)	2.28 ± 0.28	6.811 (9)
0.5	30	14.15 (8.31 - 19.42)	204.08 (124.00 - 521.00)	1.42 ± 0.24	5.889 (8)
1	30	10.39 (4.52 - 15.45)	29.46 (18.71 - 209.57)	3.63 ± 0.50	13.103 (4)

Table 2. Evaluation of sodium selenite against adult male *Blattella germanica*

Time (hours)	n	LC_{50} (95% CI) (%)	LC_{95} (95% CI) (%)	Slope ± SE	χ^2 (df)	% Mortality
24	179	N/A	N/A	1.28 ± 0.56	1.414 (1)	6.70
48	179	0.40 (0.29 - 0.56)	3.08 (1.69 - 9.20)	1.84 ± 0.30	2.350 (3)	31.11
72	179	0.12 (0.09 - 0.15)	0.96 (0.60 - 1.98)	1.79 ± 0.23	2.624 (4)	56.11

Conc. (%)	n	LT_{50} (95% CI) (hrs)	LT_{95} (95% CI) (hrs)	Slope ± SE	χ^2 (df)
0.025	30	136.55 (125.42-142.48)	291.52 (256.34-349.24)	4.99 ± 0.50	1.174 (9)
0.05	30	110.78 (98.26 - 120.98)	212.88 (186.55 - 265.49)	5.80 ± 0.86	5.305 (8)
0.1	30	74.43 (69.13 - 79.49)	126.72 (114.60 - 146.53)	7.12 ± 0.79	4.259 (7)
0.25	30	57.93 (52.50 - 62.85)	111.72 (99.48 - 132.12)	5.77 ± 0.66	2.813 (8)
0.5	29	46.02 (40.92 - 50.72)	105.04 (90.76 - 130.18)	4.59 ± 0.53	1.484 (8)
1	30	32.92 (29.38 - 36.37)	81.51 (69.98 - 100.92)	4.18 ± 0.43	6.007 (8)

Table 3. Evaluation of seleno-DL-methionine against adult male *Blattella germanica*

Time (hours)	n	LC_{50} (95% CI) (%)	LC_{95} (95% CI) (%)	Slope ± SE	χ^2 (df)	% Mortality
24	180	0.38 (0.27 - 0.64)	2.64 (1.23 - 14.60)	1.95 ± 0.40	0.342 (2)	25.6
48	180	0.12 (0.09 - 0.16)	0.51 (0.32 - 1.17)	2.61 ± 0.43	1.172 (2)	45.0
72	180	0.08 (0.06 - 0.10)	0.35 (0.22 - 0.77)	2.49 ± 0.43	1.638 (2)	61.1

Conc. (%)	n	LT_{50} (95% CI) (hrs)	LT_{95} (95% CI) (hrs)	Slope ± SE	χ^2 (df)
0.025	30	123.50 (106.68 - 135.38)	214.01 (188.98 - 271.36)	6.89 ± 1.28	2.040 (7)
0.05	30	85.79 (75.96 - 93.63)	145.18 (130.65 - 171.38)	7.20 ± 1.06	0.870 (6)
0.1	30	53.51 (46.57 - 59.75)	120.49 (100.46 - 164.70)	4.67 ± 0.71	2.402 (7)
0.25	30	22.67 (15.92 - 28.96)	131.68 (92.21 - 244.07)	2.15 ± 0.34	5.179 (6)
0.5	30	21.41 (13.94 - 28.56)	275.44 (158.18 - 794.53)	1.48 ± 0.25	6.410 (8)
1	30	28.35 (8.43 - 42.74)	190.41 (102.82 - 2415.65)	1.99 ± 0.41	12.625 (7)

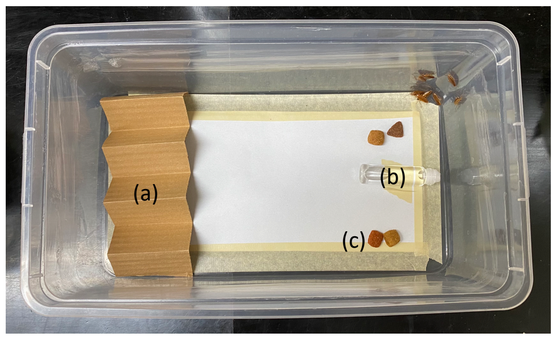

Fig. 1 Test arena with harborage (a), water source (b), and food source (c).

Discussion

Sodium selenate had the highest percent mortality at 24, 48, and 72 hours. On the other hand, sodium selenite had the lowest percent mortality at all three time points. Based on LC_{50} results at 48 hours, sodium selenate was significantly different from sodium selenite, but not compared to seleno-DL-methionine. LC_{50} values for sodium selenate at 0.5% and 1% were not significantly different, suggesting that a lower concentration can be used with similar efficacy. With regards to baits, lower concentrations are ideal because less material is required, resulting in reduced costs. Sodium selenate and sodium selenite had clear dose-dependent responses in contrast to that of seleno-DL-methionine.

Observations of toxicity symptoms included lethargy, disorientation, and energy depletion ultimately resulting in complete mortality. Although results suggest that seleno-DL-methionine was particularly effective, it is important to note that it exhibited high volatility and was observed to have a repellent effect. This may explain the unusual $LT_{50/95}$ results. The volatile compounds also seemed to be acting as a fumigant to accelerate mortality.

Conclusions & Future Directions

Overall, sodium selenate appears to be the most promising compound to be used as an active ingredient in cockroach bait. On the other hand, due to the repellent and volatile nature of seleno-DL-methionine, this compound will be excluded from future experiments as it has characteristics that are unsuitable for a bait active ingredient.

Toxicity of sodium selenate will be further studied and tested against laboratory resistant German cockroach strains. Future experiments will incorporate commercially available active ingredients for comparison studies. In addition, sublethal effects of selenium will be explored.

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