German cockroach bait aversion

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**Blattella germanica** – German cockroach

- Exclusively synanthropic
  - No evidence of populations apart from human-maintained structures
- Omnivores
- Coprophages
- Semisocial
  - aggregations
Blattella germanica - Importance

- Potent source of allergens causing asthma
- Mechanical vector of pathogens
- Nuisance, necessitating control with insecticides
  - Health and environmental impacts
Since mid-1980s

Transition to Baits

- Extremely high selection pressure for the evolution of insecticide resistance
- Some evidence of physiological/metabolic resistance to the AI
Product performance assessment
Bait Performance Decline Observed in Scattered Locations Across the Globe

- e.g. Florida, California, Puerto Rico, South Korea
Product performance decline

MAXFORCE and COMBAT Baits

% population reduction

Pre-1989  1989

National average
T-164
What went wrong?

• Determined that baits were effective against lab strain – i.e. no manufacturing errors

• T-164 Blattella were not resistant to hydramethylnon
What went wrong?

• Determined that baits were not consumed by T-164 and some other strains

• Subsequently deleted bait components one by one and evaluated against T-164
Bait component deletion study findings

• No rejection of hydramethylnon
• No rejection of bait binders
• No rejection of preservatives
• No rejection of oatmeal

• What’s left?
Effect of corn syrup on strain consumption

- Stimulates feeding
- Inhibits feeding

Bar chart showing:
- Orlando normal strain has a significantly higher consumption percentage.
- T-164 strain has a lower consumption percentage.
Effect of sugar on consumption by cockroach strain

- 1 M Glucose
- CS55
- 1 M Fructose

Stimulates feeding
Inhibits feeding
Glucose aversion and food preference

Wild-type

Glucose/agar

Fructose/agar

Glucose-averse
Genetics of glucose aversion

- Incompletely-dominant
- Autosomal
- Likely single major gene
- Chromosome 9
Glucose aversion: A case of behavioral resistance

Glucose Aversion in the German Cockroach, *Blattella germanica*

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- Behavioral aversion to a bait ingredient, but not to the AI
- Glucose is not toxic
- Genetically-based
- Highly adaptive under toxic bait pressure
- Multiple populations

How do cockroaches mis-process glucose as a deterrent?
Glucose-aversion: Peripheral vs. Central?

Peripheral ?  CNS ?

Tastants ➔ GRs ➔ GRNs ➔ Brain processing ➔ Behavior expressed

Acceptance  ➔  Rejection
Which sensory appendages are involved?

Ablation assays

Wild-type

Glucose-averse
Paraglossae most important in glucose aversion

- Paraglossae
- Labial palps
- Maxillary palps

Ablation assays

Paraglossae represent a minimal sensory system for discriminating gustatory stimuli

Wada-Katsumata et al. 2011. Chemical Senses
Dose-response of the paraglossae to tastants

Phagostimulants
- Fructose
- Maltose
- Maltotriose
- Glucose

Wild-type
- Glucose (82)
- Fructose (192)
- Maltose (46)
- Maltotriose (36)

Glucose-averse
- Glucose (81)
- Fructose (236)
- Maltose (37)
- Maltotriose (47)
Glucose-averse % cockroaches responding

Wild-type

Concentration (mmol$^{-1}$)

Glucose Fructose Maltose Maltotriose

Phagostimulants

Deterrents

Caffeine Quinine NaCl

% cockroaches responding
Do wild-type and glucose-averse strains differ in peripheral gustatory coding?
Different types of neurons excited by different types of chemical cues

Sensory differences: Tip recording

Glass capillary
Recording electrode
Test solution
Fructose
Glucose
Caffeine

Gustatory neurons
Indifferent electrode
D-fructose stimulates 3 types of GRNs:

- **GRN1**
- **GRN3**
- **GRN4**
Fructose (8 mmol\(^{-1}\))

- Stimulation of a sugar receptor neuron with fructose.
- Comparison of responses in wild-type and glucose-averse conditions.
- Graphs showing amplitude and duration of responses for different GRN1, GRN3, and GRN4 markers.

Wild-type vs. Glucose-averse conditions.
Fructose stimulated a **sugar** receptor neuron = GRN1
Caffeine stimulated a **bitter** receptor neuron = GRN2
In glucose-averse cockroaches:

- Glucose stimulates both **sugar** and **bitter** receptor neurons

**Changes in gustatory sensillum function underlie glucose aversion (CNS may also be involved)**

Wada-Katsumata et al. 2013. *Science*
Generalization: Other strains

% of cockroaches responding

Lab strains

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<th>WT</th>
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Field collected strains (2009-2012)

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Response to hydramethylnon – glucose bait
bait consumption by strain

bait consumption

strain

normal  pr308  pr712  t164
Resistance to Hydramethylnon

Resistance ratios – LD-50

- T-164 – 1.0
- PR 712 - 30.4
- PR 308 - 33.0
What’s next?

• Assay other field-collected strains for resistance/aversion

• Resistance to other bait AIs?

• Aversions to other sugars (fructose)?

• Determine linkage between resistance and aversion (in population and/or individual)
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Southern IPM Center