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Food oils as kairomones for trapping *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) adults

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ABSTRACT

Insect infestation in the grain-based food in storage is often reported; *Tribolium castaneum* is a major pest. Determination of its population size using traps is entangled with the management attempts. Pheromone traps developed for *T. castaneum* often use kairomones with its aggregation pheromone 4,8-dimethyldecanal (4,8 DMD). However, low trapping efficacy is reported, and the information on promising kairomones is insufficient. The objective of this research was to evaluate the performance of some locally-available food oils as kairomones, alone and in combination with the pheromone for trapping *T. castaneum* adults. In the first experiment, the attraction of *T. castaneum* adults towards different food oils, the pheromone or the commercial kairomone was tested. In the second experiment, the attraction of *T. castaneum* to effective food oils + pheromone was determined under laboratory condition. In the third experiment, the attraction of *T. castaneum* by effective food oils + pheromone was evaluated under warehouse condition. Under laboratory condition, the highest attraction of *T. castaneum* adults was demonstrated by mee (*Madhuca longifolia*) and coconut (*Cocos nucifera*) oils. Either of these two oils when combined with the pheromone attracted more adults than the pheromone alone. Furthermore, attraction of *T. castaneum* adults by the two oils separately was similar to the commercially-available combination of pheromone and the kairomone. In contrast, under warehouse condition, the combination of mee oil and pheromone attracted *T. castaneum* adults similar to the commercially-available combination of pheromone and the kairomone. However, the attraction by the combination of coconut oil and pheromone was lower than that, and similar to the pheromone only. This study emphasizes the potential use of food oils as kairomones to trap *T. castaneum* adults, and augment the efficiency of pheromone traps available for this species.

1. Introduction

Tribolium castaneum (Herbst), the red flour beetle, is a cosmopolitan pest which feeds on a wide array of stored products including grains, oil seeds, pulses, spices, cacao (Mahroof and Hagstrum, 2012), dried fruits and nuts (Burks and Johnson, 2012). Its abundance in grain elevators, flour mills, feed mills, processing plants, granaries, retail stores and bakeries (Rees, 2004; Trematerra and Sciarretta, 2004; Mahroof and Hagstrum, 2012) which substantially cover the post-harvest distribution channel; ability of both the larvae and adults to damage food (Arbogast, 1991); and inferior quality acquired by the infested commodities (Mahroof and Hagstrum, 2012) rank *T. castaneum* as a serious pest of stored products.

Monitoring of population is a prerequisite in pest management; pheromone-based communication of insects essentially plays an important role. Additionally, the pheromones possess the uniqueness as a pest management tool due to their biorational nature and thus limit the risks accompanied by neurotoxic pesticides (Ghimire et al., 2016; Hill, 1990) and other alternatives such as modified atmosphere conditions (Wijayaratne et al., 2009) on the biotic and abiotic environment (Fields, 1992; Phillips and Throne, 2010; Wijayaratne et al., 2018). Male adults of *T. castaneum* biosynthesize and release the aggregation pheromone 4,8-dimethyldecanal (4,8 DMD) that is attractive to both sexes (Suzuki, 1980; Suzuki et al., 1984). The efficacy of 4,8 DMD as a monitoring tool for *T. castaneum* is well documented (Dissanayaka et al., 2018). Despite the availability of traps which use the pheromone 4,8 DMD, low trapping efficacy is a major constrain for adopting this biorational method by grain-handling personnel

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(Campbell, 2012; Duehl et al., 2011).

Food volatiles are good test materials for understanding stored-product ecosystem, leading to an improved scenario of semiochemical-based pest management (Burkholder, 1990). Food/plant oils are good important attractants to different stored-product insects (Nara et al., 1981; Mikolajczak et al., 1983, 1984; Landolt and Phillips, 1997). However, all food oils are not attractive to stored-product insects, and particular food oil may have different levels of attraction (and even repellence) for different insect species. Attraction of stored-products insects, in general, to food volatiles (kairomones) has been tested (Barak and Burkholder, 1985; Hodges et al., 1985; Mahroof and Phillips, 2007) but such information on *T. castaneum* is scarce.

Additionally, the combination of food odors and pheromone has tested the orientation of certain stored-product species (Phillips et al., 1993; Fields et al., 2010; Campbell, 2012; Dissanayaka et al., 2018). However, similar to the differential effects caused by food oil/kairomones when used alone, there is no uniformity in the attraction of insects when they are used in combinations with pheromone. For instance, attraction of *R. dominica* to its pheromone is neither increased nor decreased when used in combination with plant essential oil mixtures turpentine from *Pinus* spp. and cedar wood oil from *Juniperus* spp. (Edde et al., 2011). Besides, detailed studies on the response of *T. castaneum* to certain grain volatiles alone or in combination with pheromones are still lacking. Therefore, the objective of current study was to evaluate the attraction of *T. castaneum* adults to its aggregation pheromone 4,8 DMD and some food oils readily available at the local market (as kairomones) when used alone and in combination.

2. Materials and methods

2.1. Test insects

The *T. castaneum* used in the study originated from a population collected from a rice milling center in Nochchiyagama, Anuradhapura, Sri Lanka. The adults were introduced into whole meal wheat flour medium in plastic bottles, at the density of 200 adults per 250 g, covered with a piece of cloth, and maintained inside the incubator (30 ± 0.5 °C, 65% relative humidity) for 15 days and removed. One-month-old progeny adults were used in the study.

2.2. Attraction of T. castaneum adults to pheromone, kairomone and food oils

This experiment was conducted using a transparent glass chamber ($25 \times 20 \times 12.5$ cm) with two holes in the bottom plate (3 cm diameter each, and separated by 20 cm). Top of the box had one hole (1 cm diameter) at the middle to insert the funnel (Fig. 1). Twelve materials were tested as attractants for *T. castaneum* (Table 1). From each food oil or the commercial kairomone solution, 3 mL was added into one of the two plastic vials (60 mL) placed underneath the holes of the bottom plate of the chamber using a disposable syringe (Changzhou Medical Appliances General Factory Co. Ltd., Jiangsu, China). In case of the commercial pheromone lure, two rubber septa (as accommodated in a single dome trap available commercially) were placed inside the vial. These rubber septa were maintained inside the refrigerator (5 °C) until used, and were kept under the room temperature for 1 h prior to usage. The remaining vial underneath the chamber was kept empty (control). Fifty unsexed *T. castaneum* adults were released gently into the center of the chamber through the funnel held in position through the hole in the top cover. To ensure the natural movement of beetles inside the chamber, the funnel was originally placed in the direction shown in Fig. 1 to touch the bottom of the chamber, and lifted only after the beetles turned to their natural position. This step was followed to ensure the uniformity in the original position of the beetles, and thus to prevent the different original positions affecting their subsequent movement. Following 2 h of introduction, the number of adults trapped in each vial was counted. Each experiment using the specific material (food oils, kairomone or the pheromone-containing rubber septa) was replicated four times. The experiment was repeated by turning the glass chamber by an angle of 180°.

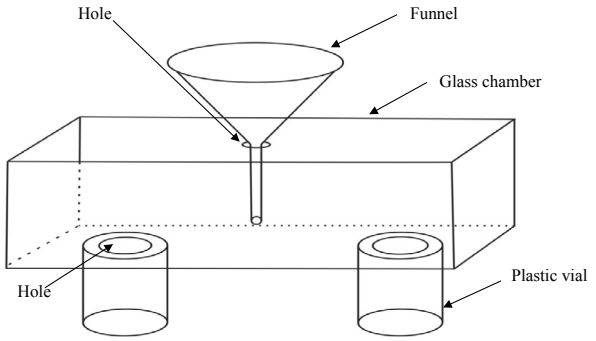

Fig. 1. Diagrammatic representation of the structure used to detect the attraction of *T. castaneum* adults to different food oils, pheromone and kairomones. The glass box (25 cm x 20 cm x 12.5 cm) has two holes 20 cm apart (each 3 cm in diameter) on the bottom plate, and one hole (1 cm diameter) on the top plate to introduce adults through the funnel.

2.3. Comparison of the trapping efficiency of mee and coconut oil with the commercially-available pheromone and kairomone under laboratory condition

This experiment was also conducted inside the glass chamber used in the previous study. Mee and coconut oil (which had the highest trapping percentages in the previous experiment) were combined with the aggregation pheromone (4,8 DMD) (similar to the method practiced commercially), and the percentage of *T. castaneum* adults trapped was determined to evaluate these two food oils as potential kairomones. In addition, aggregation pheromone + commercial kairomone solution (Trece Inc., Adair, OK, USA) and the pheromone (4,8 DMD) alone were also included in the experiment to compare the percentage of *T. castaneum* adults trapped. Similar to the previous experiment, 3 mL of mee oil, coconut oil or the commercial kairomone solution was added to one vial of the experimental set up (Fig. 1) using a disposable syringe (Changzhou Medical Appliances General Factory Co. Ltd., Jiangsu, China). In the third step which used both 4,8 DMD and the commercially-available kairomone solution, the two rubber septa were attached to the vial using a piece of metal wire in such a way that they did not touch the kairomone solution. In the fourth step, two rubber septa containing the commercial lure of the pheromone 4,8 DMD (Trece Inc.) were placed inside the vial. In all the steps, the second vial was kept empty as the control. Each of the four steps was replicated four times and repeated by turning the glass chamber by an angle of 180°.

2.4. Comparison of the trapping efficiency of mee and coconut oil with the commercially-available pheromone and kairomone under warehouse condition

This experiment was carried out inside a room (2.8 × 2.8 x 3 m). Four square-shaped experimental arenas, each of 1 m^2, were marked on the floor of the room. Polytetrafluoroethylene (Teflon)