Food Acceptability and Distribution in the Colony of the Bigheaded Ant, *Pheidole megacephala* (Fabr.) (Hymenoptera: Formicidae)[1]

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ABSTRACT. The distribution of oil, sugar, and protein was studied with dye and radioactive tracers among adult castes and larvae of laboratory colonies of the bigheaded ant, *Pheidole megacephala* (Fabricius). Larvae received 76.7% of the total recovered radioactive soybean oil in the colony at 6 h, and queens received 1% at 24 h. Coconut oil was less acceptable than other oils to worker ants. Sugars were highly acceptable to all members in the colony; no delay was observed by workers in feeding larvae and queens. Glucose was more acceptable than fructose. The protein composite (blended fried chopped meat and cooked chicken egg) was highly acceptable to workers and was fed to larvae and queens within 3 h. Workers distributed 87.5% of the total radioactive defatted egg yolk to larvae and only 2.2% to queens.

KEYWORDS: Insecta, Ants, *Pheidole*, Food distribution.

The bigheaded ant (BHA), *Pheidole megacephala* (Fabricius), was introduced to the Hawaiian Islands in the 1800s (Perkins 1913) and has become the dominant ant species in areas below the 1,000m elevation (Huddleston and Fluker 1968). It causes economic damage by attending the gray pineapple mealybug, *Dysmicoccus neobrevipes* Beardsley, and the pink pineapple mealybug, *D. brevipes* (Cockerell), the principal species involved in the pineapple mealybug wilt disease. The ants clean up the mealybug's honeydew and interfere with its natural enemies. Successful control of the disease and the mealybugs can be achieved by eliminating the ants (Beardsley et al. 1982). Ants also chew on walls and orifices of plastic irrigation tubes, causing uneven water distribution and affecting yield in sugarcane fields (Chang and Ota 1976). A toxic bait with an attractant could be used to control ants. The effectiveness of the bait is dependent on its acceptance by the foraging ants and on its distribution in the colony. Different foods are distributed differently among larvae and adults. Because of their high energy properties, sugars are consumed mostly by foraging workers (Sorensen et al. 1985), while proteins are consumed mostly by larvae and queens (Markin 1970) for growth and egg production. Only a small amount of proteins is retained by the workers. Oils, which are shared in quantities

[1]Published as Paper No. 782 in the Journal Series of the Experiment Station, Hawaiian Sugar Planters' Association.

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through trophallaxis by colony members, are called the "spreadable" food (Howard and Tschinkel 1981). Most toxic baits for the imported fire ant (IFA) *Solenopsis invicta* Buren, contain soybean oil (Lofgren et al. 1975) as an attractant.

This paper reports on the distribution rates of oil, sugar, and protein in laboratory colonies of the BHA, with an objective to develop an effective bait to control the BHA.

MATERIALS AND METHODS

Ants. Field-collected BHA colonies were separated from soil by a technique described by Chang (1985). Each colony contained 20 reproductive queens, 3,000 to 4,000 minor workers, 100 major workers, and 100 larvae of various instars. They were housed in a Wilson cell (Wilson 1962) that was placed in a plastic tray (54×41×13 cm) with walls coated with Fluon (Northeast Chemical Company, Woonsocket, R.I.) to prevent ants from escaping. Food was withheld from the colony for 4 days before testing.

Food. Each 3.5 ml of oils (safflower, soybean, peanut, and coconut) was labeled with 50 μCi of ^{14}C-linoleic acid (New England Nuclear, Boston, Mass.). Sugars (honey, glucose, and fructose) and protein composite were labeled with 40 μCi of ^{14}C-sodium acetate (NaOAc) per 5 g material. The defatted (with hexane), freeze-dried yolk of chicken egg (902 mg) was labeled with 4.05 μCi of ^{14}C-leucine. Rhodamine-B dye or calico red dye (0.1%) was added to all test foods.

Several types of liquid and solid proteins were tested for their acceptability to the BHA workers. The liquid proteins (in water) were 60% chicken egg yolk, 50% dissolved gelatin (Knox Gelatine, Inc., Johnstown, N.Y.), 50% yeast extract (Difco Lab., Detroit, Mich.), 50% casein hammersten (Nutritional Biochemical Corp., Cleveland, Ohio), and 50% vitamin-free casamino acid (Difco Lab.). The solid proteins were yeast extract, freeze-dried egg yolk and egg white, freeze-dried and defatted egg yolk, and protein composite (made by blending together 33 g of fried, chopped, lean beef and a cooked chicken egg).

Test Methods. Each colony was given 300 mg of ^{14}C-labeled food with an estimated radioactivity of 1.33 μCi every 24 h, except egg yolk, of which 50 mg with an estimated radioactivity of 0.244 μCi was given. Samples were taken from test colonies at 0, 3, 6, 24, 48, 72, and 96 hours after food placement. Each sample consisted of 150 minor workers, 30 major workers or larvae, or 3 queens.

The number of ants ingesting dye-labeled food was visually determined by pulverizing each on ashless filter paper, which was then ashed in a biological material oxidizer (Model ox-100, R.J. Harvey Instrument Corp., Hillsdale, N.J.). The ^{14}C-burned products ($^{14}CO_2$) were absorbed in 15 ml of Oxifluor-CO_2 solution (New England Nuclear). The trapping solution of each sample was radioassayed using a Beckman 200L liquid scintillation counter. The measured radioactivity, expressed as counts per minute per unit weight (cpm/mg), gave a relative value of the amount of food con-

sumed by each adult caste and young in the colony. The average weight per individual ant used for calculating cpm/mg was as follows: minor worker, 0.541 mg; major worker, 1.516 mg; larva, 0.026 mg; and queen, 3.94 mg. The rate of food distribution among castes and larvae was expressed as a percentage of total recovered radioactivity at each sampling period.

RESULTS

Oils. Minor and major workers accepted safflower oil and peanut oil similarly, 98% and 99% of the minor workers and 93% and 83% of the major workers had fed on safflower oil and peanut oil, respectively, at 48 h. Coconut oil was less acceptable; only 65% of the minor workers and 53% of the major workers had fed within the same period.

Fewer major workers (7%) had fed on safflower oil at 3 h than the minor workers (34%). The difference still existed (37% vs. 81%, respectively) at 24 h, but not at 48 h (93% vs. 98%).

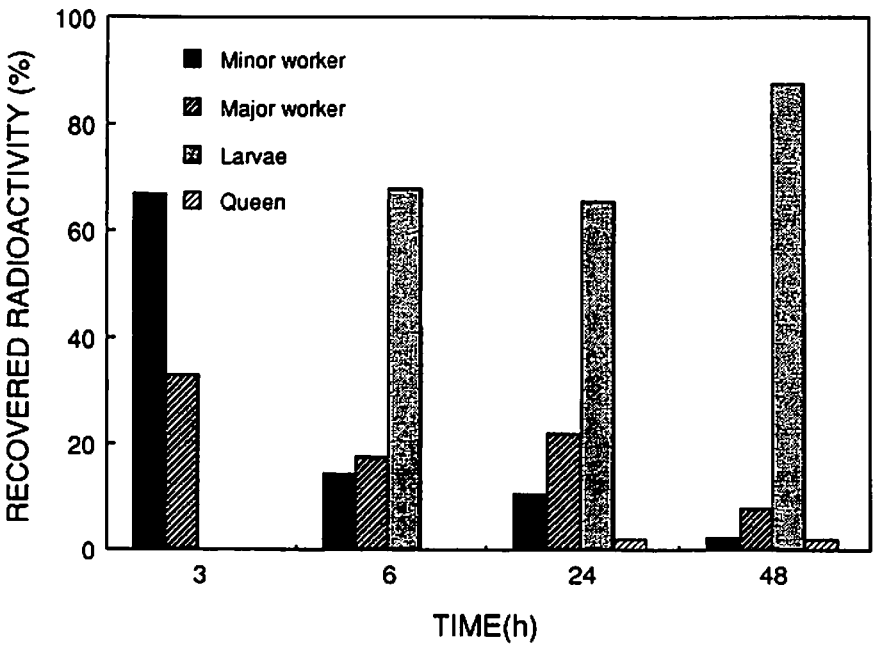

FIGURE 1. Distribution of soybean oil among colony members of the bigheaded ant.

Minor workers started to distribute soybean oil to larvae 3 h after exposure. Radioactivity in minor workers decreased from 71% at 3 h to 9.4% at 6 h (Fig. 1). At 6 h, larvae were the principal recipients of soybean oil, accounting for 76.7% of the total radioactivity in the colony. Radioactivity

in larvae remained at the 80% level up to 168 h. Major workers had 30% of the radioactivity at 3 h but only 14% at 6 h. Queens did not receive a detectable amount of oil until 24 h after exposure. Radioactivity in queens reached a maximum of 2.7% at 48 h and remained at that level up to 96 h.

Safflower or peanut oil was fed by workers to 6% of the larvae at 24 h and 66.6% at 48 h. In contrast, only 30% of the larvae showed dye-labeled coconut oil at 48 h. However, larvae consumed and retained more coconut oil (13,850 cpm/mg) than safflower oil (2,592 cpm/mg) or peanut oil (1,195 cpm/mg) at 48 h. A possible explanation is that larvae did not digest and excrete coconut oil as fast as safflower oil or peanut oil.

Coconut oil was fed to all queens, but safflower and peanut oils were fed to only 66% of the queens at 24 h.

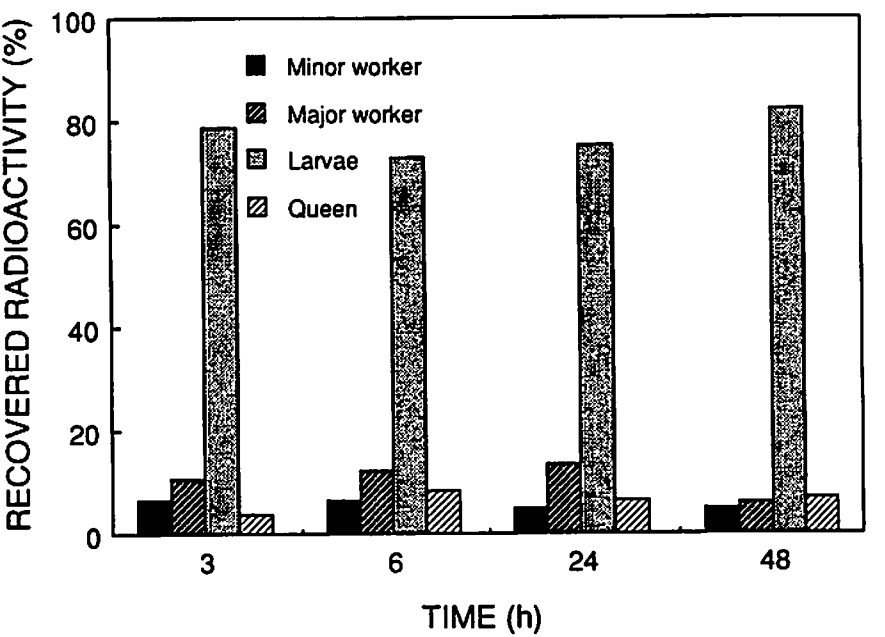

FIGURE 2. Distribution of honey among colony members of the bigheaded ant.

Sugars. Intense feeding of glucose was observed in workers. Large numbers of minor and major workers began feeding 5 to 10 min. after the introduction of glucose into the colony. The workers completely removed glucose within 1.5 h. At 6 h, all minor and major workers had fed on glucose or received it through trophallaxis. Major workers consumed almost three times more (234 cpm/mg) than minor workers (94 cpm/mg) in the first 3 h. The amount of radiolabeled glucose in minor and major workers reached a peak at 6 h and declined thereafter, as was shown in subsequent sampling periods.

Only 20% of the larvae received glucose at 3 h, but all larvae had been fed after 48 h. The larvae were the principal recipients of glucose in the colony, receiving almost 10 times (1,598.5 cpm/mg) the amount of glucose than did the minor workers (173 cpm/mg at 6 h). The amount of detected radioactivity in larvae remained constant for 72 h. Glucose was distributed faster than oil. It was detected in 66% of the queens at 3 h and in 100% at 24 h.

Fructose was less acceptable than glucose. At 6 h, 99.3% of the minor workers and 66% of the major workers had fed on fructose, but each ant consumed only a slight amount (63 cpm/mg or less). Few larvae (6%) were fed fructose within 3 h of exposure, but even after 72 h only 66.6% of the larvae were fed. Larvae were again the major recipients, having five times more radioactivity (313.9 cpm/mg) than workers at 6 h. Most queens (75%) received a low detectable amount (23.1 cpm/mg) of fructose at 6 h.

Honey was consumed by workers in the first 3 h of exposure. Major and minor workers had average recoveries of 6.4% and 10.6%, respectively, of the colony radioactivity at 3 h (Fig. 2). The workers fed larvae and queens within 3 h. Larvae had an average of 79.0% of the colony radioactivity whereas queens had only 4.0%. The amount of honey consumed by minor workers and larvae was constant but not the amount by major workers and queens for which a gradual reduction in the amount of radioactivity occurred after 48 h, indicating honey was not continuously consumed by major workers or fed to the queens.

Proteins. Major and minor workers did not feed on any liquid proteins. However, when the liquids solidified the workers removed the food and stored it in the nest. Workers did not feed on the dry yeast extract, freeze-dried egg yolk or egg white, or freeze-dried and defatted egg yolk. They were either discarded in the rubbish pile or covered with debris after 24 h.

The protein composite was highly acceptable to colony members. The workers were observed at the feeding site 10-15 min. after its introduction. Within 3 h 20% of the minor workers and 10% of the major workers consumed the protein and the percentage peaked to 45% and 25%, respectively, at 48 h. Major workers consumed four times the amount of protein (3,255 cpm/mg) than did the minor workers (797 cpm/mg) within 24 h. Larvae were fed within 3 h; however, fewer larvae received the protein after 24 h. The decreased radioactivity in larvae was a result of workers removing the protein pieces after 24 h. It appeared that the protein became unacceptable to worker ants after 24 h. Larvae consumed the most of the proteins, and the radioactivity peaked at 38,445 cpm/mg at 48 h. The feeding of protein to queens by workers was not observed. However, at 6 h all queens were found to have dye in the midgut, along with a small amount of radioactivity (297 cpm/mg), suggesting they fed on the protein.

All colony members accepted the moist defatted egg yolk but ate little of it in comparison to the protein composite. The radioactivity in major workers was only 349 cpm/mg at 24 h vs. 3,255 cpm/mg from the protein composite. At 3 h, 67% of the total radioactivity was recovered in minor workers and 33% in major workers (Fig. 3). The percentage of radioactivity

recovered from major and minor workers gradually decreased, whereas the percentage in larvae and queens increased after 3 h. The larvae received 68% of the colony radioactivity at 6 h, peaking at 87.5% at 48 h with a value of 6,720 cpm/mg. Queens contained 1.9% of the colony radioactivity at 24 h and remained at that level for 96 h. The radiolabeled yolk was fed to queens only after the larvae were fed.

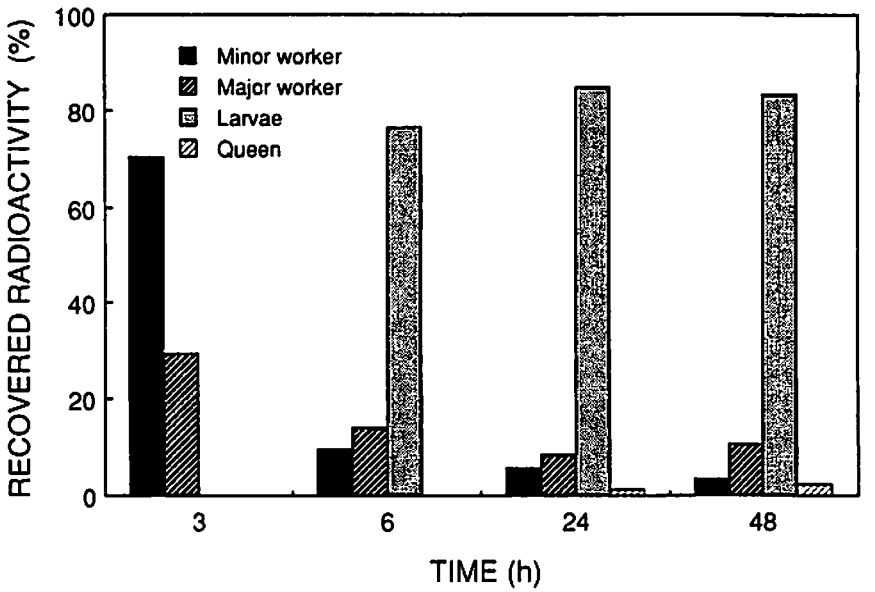

FIGURE 3. Distribution of defatted egg yolk among colony members of the bigheaded ant.

DISCUSSION

The acceptance of oils is likely to be related to their unsaturated fatty acid components. Vinson et al. (1967) identified polyunsaturated fatty acids, such as oleic and linoleic acids, as phagostimulants to IFA workers. Soybean oil, safflower oil, and peanut oil are composed of 75% or more of these two fatty acids. However, coconut oil is composed primarily of saturated fatty acids (lauric, myristic, and palmitic acids) and has less than 8.1% of oleic and linoleic acids. This may explain why BHA workers preferred soybean oil over coconut oil.

Larvae did not receive oil until 24 h after exposure. Sorensen and Vinson (1981) also observed a delay in the feeding of oil to the IFA larvae. Petralia et al. (1980) suggested that oil is predigested in the crop of IFA workers for 12-24 h before oil is regurgitated to larvae. Our results support this hypothesis. Apparently, the larvae of many ant species have weak, or lack, lipase activity in the labial gland and midgut, which results in the

inability of larvae to digest oil (Ayre 1967). However, Howard and Tschinkel (1981) did not find this delay in the feeding of soybean oil to IFA larvae. They reported that most of the larvae received radioactive food within 1 h, with the number of labeled larvae increasing only slightly thereafter.

Sugars are highly acceptable to workers because they are used as a source of energy (Abbott 1978). The appeal of glucose and fructose was intense within the first 15 min. after its introduction. However, cessation of feeding occurred rapidly within 30 min. Sugars may be released from the crop into the midgut, quickly satisfying the nutritional needs of workers. This would reduce the amount of sugar available for distribution among other members in a colony. Sudd (1967) reported that workers regurgitate a small amount of sugar to larvae and queens. Markin (1970) remarked that larvae and queens of the Argentine ant, *Iridomyrmex humilis* Mayr, have no dietary need for sugar. Our tests showed that larvae and queens of BHA received a significant amount of glucose. Workers shared sugars with larvae and queens, possibly as a result of a dietary habit of BHA. In field studies, BHA feeds primarily on other arthropods and on homopteran honeydew excretions (Williams 1931). The honeydew of pineapple mealybug consists of several amino acids and four sugars: glucose, fructose, sucrose, and glucose-phosphate (Gray 1952). The high acceptance rate of glucose among colony members suggests that glucose is a feeding stimulant to BHA workers.

The IFA workers cannot ingest particles larger than 1 micron, owing to an oesophageal screen that filters out large particles (Glancey et al. 1981). Also, the absence of proteinase in the foregut of the workers suggests that proteinaceous food is distributed to the larvae primarily in an undigested state (Ricks and Vinson 1972). The workers carved the solid protein food into small pieces at the site and carried these into the nest. The workers placed small pieces of proteins in a depression near the head of each larva. In IFA larvae, protein is digested externally through enzymatic action of labial gland secretions, and internally in the midgut (Petralia et al. 1980). However, our results indicated that BHA workers had radio-labeled protein, but fewer than 45% of the individuals contained the Rhdomine-B dye. The dye was bound to the solid portion of the protein and left the liquid portion uncolored. In contrast, the radiation labeled both the solid and the liquid portions. Apparently the BHA workers ingested only the radio-labeled liquid portion (water and amino acids) of the protein.

Toxic baits containing oils as food attractants would require a slow-killing toxicant to ensure that they are distributed to larvae and queens. Baits containing sugars, especially glucose, as food attractants could be readily accepted and quickly distributed in the colony. However, such baits could present a problem because they are often fed upon by many other arthropods. A bait could be formulated by using proteins such as protein composite as a food attractant for BHA control. The solid protein is not consumed by workers, but is fed directly to larvae and queens without delay. However, such a bait may attract other nontargeted animal species in the field, and is not practical for use in large areas.

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