Influence of Colony Caste Composition, Food Nutritional Content and Satiation on the Food Preference of a Tropical Pest Ant, *Monomorium orientale* (Hymenoptera: Formicidae)

by

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ABSTRACT

A laboratory study to determine the food preferences of *Monomorium orientale* was conducted. Our study focused on various factors such as colony caste compositions, nutritional contents of food and satiation effects that may influence its feeding decisions. Results revealed that *M. orientale* constantly prefers carbohydrate and different colony compositions do not affect its food preference. All colony types generally favored sucrose, saccharose, tuna and olive oil. Satiation effects were not observed in carbohydrate feeding, but were revealed after a week of continuous protein or lipid feeding.

Keywords: *Monomorium orientale*, food preference, colony caste composition, food type, nutrient, satiation.

INTRODUCTION

Food preference studies provide some of the fundamental information necessary for the development of control strategies, such as toxic baits. Ants modulate their feeding patterns to the diversity of resources available in their environment (Hölldobler & Wilson 1990). Besides food characteristics, there are several other factors such as physical environment, presence of competitors (Traniello 1987), predators (Nonacs & Dill 1991), level of colony starvation (Josens & Roces 2000) and the amount of brood (Portha *et al.* 2002) that influence food selection.

Several species of *Monomorium* are household pests, including *M. pharaonis*, *M. destructor*, and *M. orientale* (Yap & Foo 1984, Yap & Lee 1994, Na & Lee 2001, Lee *et al.* 2002). *M. pharaonis* feeds on live and dead insects, syrup, jelly, cakes, meat, grease as well as shoe polish, bath sponge and insect collections (Peacock & Baxter 1950, Sudd 1960, Edwards & Abraham 1990).

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M. destructor and *M. floricola* feed on similar foodstuffs when found indoors in addition to the natural honeydew sources from homopteran insects that are found outdoors. *M. orientale* is usually found in India and has been sighted in New Zealand and the Philippines, thus Malaysia is a reasonable extension of the identified range. A number of these tiny generalist *Monomorium* species are prospective pests, especially if they are translocated to a new country which supplies a suitable habitat. *M. orientale* is an outdoor species that nests in trees, under flower pots, cracks in the soil, but it is not rare to find them nesting indoors in wall crevices and cabinet voids (Hedges 1998).

The food preference of *M. orientale* has not been extensively explored. It is generally accepted that ants from this genus are omnivorous and would readily feed on a wide array of foods. In tropical countries like Malaysia, it is possible to find a few different ant species infesting the same area but it is very unlikely to control all the species with one bait material at the same time. One bait type may be effective for one species, but may not appeal to another. Lee (2002) found that baits which significantly reduced *Monomorium* spp. had increased the presence of other ant species.

Therefore, it is crucial to obtain as much information as possible regarding the feeding behavior of various pest ant species in order to formulate suitable baits for the target species. The objective of this study was to determine the factors that constitute the feeding behavior of *M. orientale*. Some of the factors integrated here are colony caste composition, primary nutrient content in food choices and satiation effects on its feeding behavior.

MATERIALS AND METHODS

Insects

Ants used in this study were from stock cultures at the Urban Entomology Laboratory, Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia. These subcultures were kept in petri dish-nests (9.0 cm diameter) with corrugated paper as harborage placed inside. The upper-inner sides of the trays were coated with a thin layer of Fluon® (polytetrafluoroethylene suspension) to prevent ants from escaping. Moisture and water were provided via an inverted plastic cup on a Petri dish lid sealed with damp cotton around its rims. Foods (standard laboratory diet) provided *ad libitum* comprised a mixture of carbohydrate, protein and lipid sources eg.

Lobster cockroach (*Nauphoeta cinerea*), boiled-egg yolk, honey solution 40% and peanut oil. Colonies were maintained in laboratory conditions (26.9 ± 0.3°C, 65.7 ± 1.5 % RH), 12:12 photoperiod. Each colony consisted of approximately 100-150 queens, 10,000 to 15,000 workers with at least 2.0 g brood of mixed stages.

Food choice test (applicable to all sections)

The arrangement of the food choices at the opposing end of the tray from the harborage was rotated among replicates to avoid positional bias. This was conducted on a 7-day basis where each replicate was given the food choices for 5 h. The number of ants feeding on each food type was recorded at 30, 60, 120, 180, 240 and 300 min. After the choice test, the colonies were returned on their standard laboratory diet.

I. Colony caste composition

Three food types from the three main food classes were used; 40% (w: w) sucrose solution (carbohydrate), tuna fish (protein), and olive oil (lipid). Experimental colonies with different compositions of queens, workers and brood of mixed stages were separated from the main colony into new aluminium trays (40.0 cm x 24.5 cm x 8.0 cm): A (10 queens: 2000 workers: 50 mg brood), B (20 queens: 2000 workers), and C (2000 workers: 100 mg brood). Each composition was replicated six times. Foods were placed on transparent plastic cards (3.0 cm x 3.0 cm); 0.5 g tuna, 2.0 ml sucrose while the olive oil was absorbed into a 2.0 cm x 2.0 cm filter paper in order to prevent ants from being pulled and drowned in the oil.

Concurrently, the development of the experimental colonies with the various compositions was monitored and recorded. Still digital images were captured (Nikon Coolpix 880) at intervals 0 (pre-trial), 1, 2, 4, 8 and 12 wk and the ants were counted on the computer screen. The weight of brood was estimated using manual mapping of the brood distribution in the nest (assuming it to be arranged in a single layer) on graph paper. Preliminary work found that 1 $mm^2 \cong 1$ mg of mixed stages of brood. The primary interest here was not the development of the colonies per se but was more on how changes within the colony affect its food preference.

II. Nutrient content of foods

Choice tests were conducted for carbohydrate, protein and lipid. The food choices used to represent carbohydrate (40.0 % (w:w) concentration) were sucrose (sugar), brown sugar, honey, glucose, pineapple jam and corn syrup. Proteins were all in dried ground powder form: anchovy, beef, liver (beef), prawn, tubifex and tuna fish. Lipids were commercial oils: corn, olive, palm, peanut, soybean, and sunflower. Crude carbohydrates (laboratory grade), also in 40% (w:w) solutions were tested; D(+) saccharose, D(+)- glucose (monohydrate), maltose hydrate, D(-)- fructose, D(+) galactose anhydrose and lactose (monohydrate). Crude proteins were casein from bovine milk (protein content > 80%) and laboratory bacto-liver extract. Lipid was not included as the various oils tested were understood to mainly, if not solely contain lipid. The six laboratory grade carbohydrate sources were tested together with six other regular human-consumable carbohydrate sources. Tuna fish, having the highest protein content (> 80%) was tested with the two laboratory protein representatives. Experimental colonies with three different colony compositions (A, B and C) similar to section I of the study were formed, each of which was replicated six times.

III. Satiation

Each experimental colony consisted of 10 queens: 2000 workers: 50 mg brood kept in aluminum trays. Three food types from the three main food classes were used; 40% sucrose solution (w:w) (carbohydrate), tuna fish (protein) and olive oil (lipid). The colonies were fed strictly on one of the respective foods for up to a period of eight weeks (n=12). A choice test comprising the three food types was conducted at intervals Wk 0 (pre-trial), 1, 2, 4 and 8 post-satiation. At those intervals (except for Wk 0 where all 12 replicates were tested together before being placed on the strict diet), only three replicates were randomly selected to be subjected to the choice test. To determine whether colony size has any influence on the satiation effect, another experimental colony consisting of 10 queens, 4000 workers and 100 mg brood (large colony) was tested. Foods were placed on transparent plastic cards (3.0 cm x 3.0 cm).

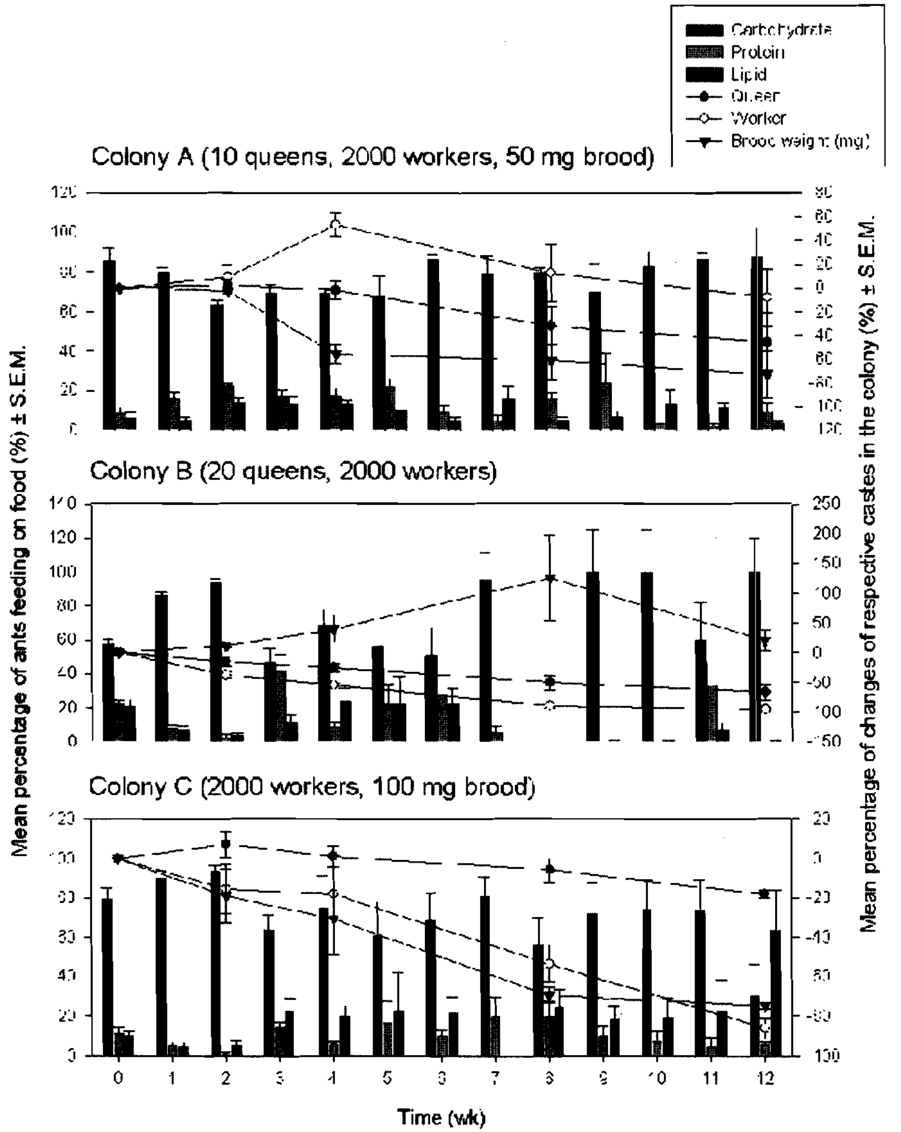

Fig. 1. Effects of colony caste composition on the food preference *Monomorium orientale*. Error bars represent SEM.

Analysis

Weekly results in percentage were arc-sine transformed prior to One-Way ANOVA. Means were separated with Tukey's HSD (p = 0.05) using SPSS 11.0 for Windows.

RESULTS

I. Colony caste composition

Throughout the entire course of the study (12 weeks), all colonies showed a significant preference for carbohydrate ($p < 0.05$) despite the various compositions (Fig. 1). Changes of caste composition within the colony did not decide its food preference. The increase or decrease of certain castes in the colony did not change the colonies' incessant preference for carbohydrate.

II. Nutrient content of foods

For colony A, when six laboratory grade carbohydrate sources were tested together with six other regular human-consumable sources, *M. orientale* showed a preference in the following order ($p < 0.05$): Sucrose (27.07 ± 9.54%) > laboratory glucose (5.13 ± 1.41%) = common glucose (4.90 ± 1.86%) = fructose (3.42 ± 1.36%) = galactose (2.44 ± 0.51%) = maltose (2.84 ± 1.59%) = lactose (4.92 ± 1.23%). Sucrose was not significantly preferred over saccharose, brown sugar, honey, pineapple jam and syrup ($p > 0.05$). When only regular carbohydrates were tested, the ants significantly preferred sucrose (34.33 ± 7.99%) and brown sugar (35.22 ± 6.87%) to the other choices ($p < 0.05$). Colony B's preference was shown in the following order ($p < 0.05$): Saccharose (22.00 ± 7.48%) > fructose (2.58 ± 1.18%) = galactose (2.28 ± 0.77%) = maltose (2.29 ± 0.67%) = lactose (4.89 ± 3.04%) = common glucose (2.92 ± 0.86%). Nonetheless, saccharose was not significantly preferred when compared with laboratory glucose, sucrose, brown sugar, honey, pineapple jam and syrup ($p > 0.05$). Among the six regular choices, there was a significantly higher preference for sucrose (35.66 ± 9.16%) to honey (2.97 ± 1.67%) and syrup (5.98 ± 2.47%) but this fondness for sucrose was found not significantly different from that for brown sugar, glucose and pineapple jam ($p > 0.05$). For colony C, we found preference in the following order ($p < 0.05$): Saccharose (19.73 ± 8.20%) > fructose (2.22 ± 1.88%) = maltose (3.90 ± 1.27%). Almost similar to colonies A and B, sucrose (56.70 ± 11.89%) was preferred when given a choice of the six regular sources ($p < 0.05$).

In the case of protein, it was clearly shown that all colonies with the different compositions significantly preferred tuna to the crude protein sources; casein and bacto-liver ($p < 0.05$). However, when tuna was tested with five other regular protein choices, no significant preference was recorded for B

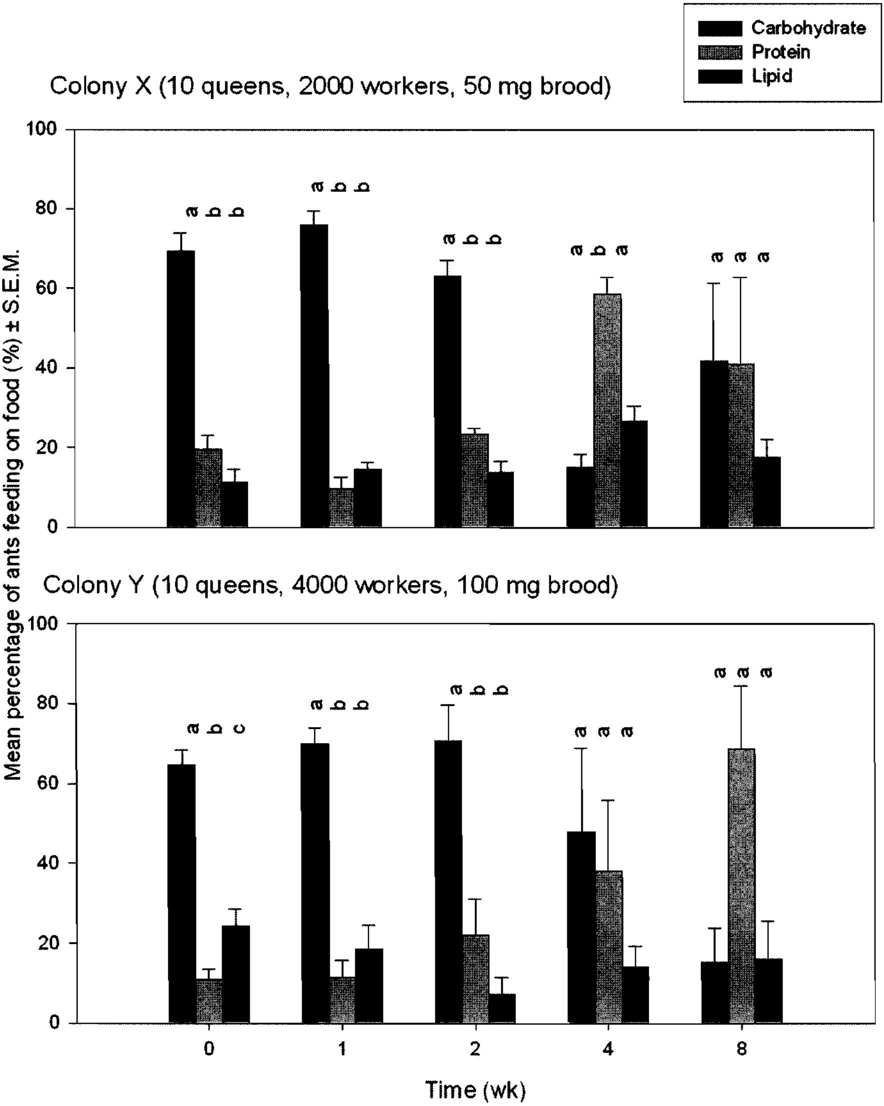

Fig. 2. Effects of carbohydrate satiation on the feeding preference of *Monomorium orientale*. Error bars represent SEM. Means with different letters within the same food type are significantly different (Tukey's HSD, $p < 0.05$). For Wk 0, n=12 while the rest, n=3 (randomly picked from the initial 12 reps).

and C colonies ($p > 0.05$). In colony A, tubifex (31.98 ± 7.42%) was preferred over anchovy (5.22 ± 1.28%) and liver (11.02 ± 4.08%) but there was not one particular most preferred choice ($p > 0.05$).

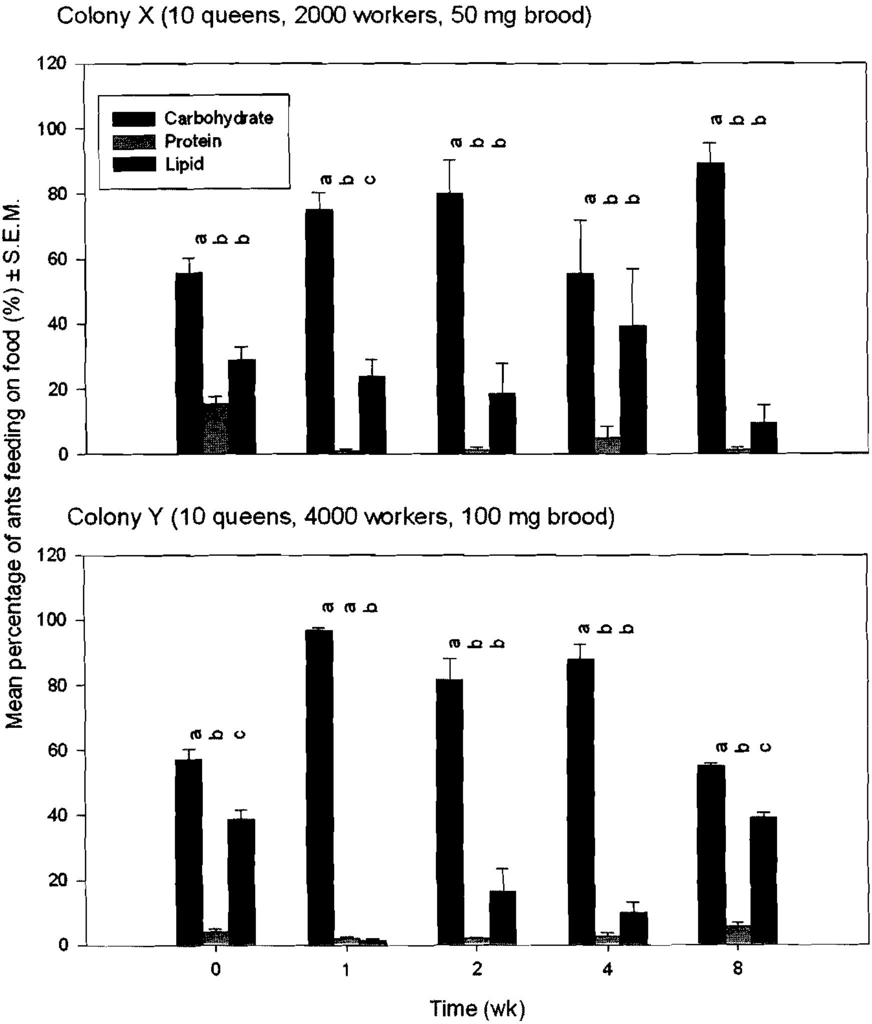

Fig. 3. Effects of protein satiation on the feeding preference of *Monomorium orientale*. Error bars represent SEM. Means with different letters within the same food type are significantly different (Tukey's HSD, p < 0.05). For Wk 0, n=12 while the rest, n=3 (randomly picked from the initial 12 reps).

The lipid preference study showed that colonies A and C preferred olive oil, respectively 34.16 ± 5.41% and 45.21 ± 6.90% ($p < 0.05$), concurring with Eow (2005) which reported that *M. pharaonis* selects olive oil under all colony conditions. However, colony B showed no particular preference ($p > 0.05$).

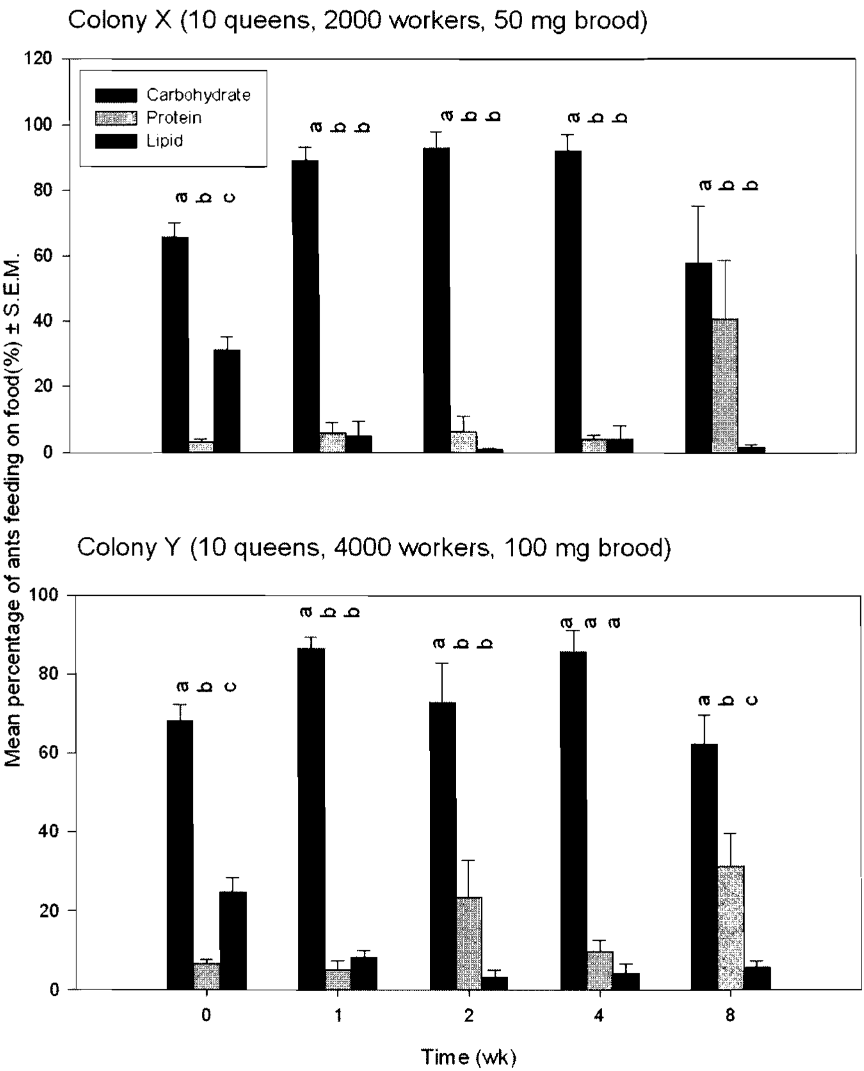

Fig. 4. Effects of lipid satiation on the feeding preference of *Monomorium orientale*. Error bars represent SEM. Means with different letters within the same food type are significantly different (Tukey's HSD, $p < 0.05$). For Wk 0, n=12 while the rest, n=3 (randomly picked from the initial 12 reps).

III. Satiation

For carbohydrates, satiation effects were only observed in colony X after four weeks when the choice test revealed that protein (58.56 ± 4.23%) was significantly preferred over carbohydrate (14.96 ± 3.36%) in comparison to the previous weeks when carbohydrate had always been the sole preference (p

< 0.05) (Fig. 2). However, after eight weeks, the effect disappeared. In colony Y, a longer time was needed to reveal the satiation effect. Only after eight weeks that a switch of preference to protein (68.79 ± 15.69%) was recorded.

For proteins, colony X had a quicker response in revealing the satiation effect. It only took one week before the colonies showed a lower preference for protein (Fig. 3). Although it is not significantly less selected over the course of the following three weeks, protein nevertheless recorded the lowest number of visits by the ants. Similar results were shown in colony Y.

Colony X also was relatively more easily satiated with lipid. After a period of one week's satiation, a lower number of ants fed on lipid for the remaining course of the study (Fig. 4). In colony Y, the preference for lipid decreased after two weeks but more prominent was that the longer the colonies were satiated with lipid, the more they seemed to switch their preference from carbohydrate to protein. This was increasingly observed from one week's satiation to eight weeks'.

DISCUSSION

I. Colony caste composition

Our results contradict with the previous report by Josens *et al.* (1998) who manipulated the colony's nutritional conditions instead of changing the stimuli. They found that not only the duration and frequency of feeding interruptions were varied with the nutritional state of the colony but the behaviors of ants as well. However, our results showed that changes in the colony compositions did not have different effects. Greenslade (1971) reported that the availability of food may cause slight seasonality in the feeding preference of certain ant species. Sudd & Sudd (1985) reported that ants that are exposed to variation in the availability of food resources must be maintained on a mixed diet. This is autonomously managed by changing the feeding preferences of individual ants or by regulating the proportion of ants in the population which accepts a certain food. Since force-feeding choice tests were employed in our laboratory study, the availability of food was never varied. This could probably be one of the main reasons for the constant preference for sucrose. Our findings did not correspond with the population regulation factor because different colony compositions did not influence the change of food preference. This also contradicts with Sudd & Sudd (1985) which reported that the change of preference might be related to developmental changes in the worker ant population or addition of workers into the foraging force. At week 12, the immature colonies switched their constant preference for carbohydrate (30.56 ± 15.28%) towards lipid (63.89 ± 20.23%). This indicated that the drastic decrease of workers, which are the principal carbohydrate consumers in the colonies (86.00 ± 5.36 %) could have caused the preference switch at that point of time. Our results agree with Eow (2005) which reported no effects of colony changes on the food preference of three other *Monomorium* species. Judging from the lack of colony effects on the feeding preference of *M. orientale* on top of its almost constant selection for carbohydrate, it can be concluded that this ant is similar to *M. destructor* which was labeled a sugar-loving ant.

II. Nutrient content of foods

Our data agree with Eow (2005) who reported that normal and queen-less *M. pharaonis* colonies as well as all colony types of *M. floricola* and *M. destructor* preferred sucrose solution. Sugar is a highly acceptable food to workers as it serves as a source of energy (Abbott 1978) but is known to be less required by the queens and brood. Sanders *et al.* (1992), however, reported an unusually significant amount of glucose in the queens and larvae of the big-headed ant. The high acceptance rate proposed that glucose could be a phagostimulant. Our results showed that sucrose and saccharose were the top two choices of all three colony types so they could most likely be more effective phagostimulants to *M. orientale*. Such findings in the protein section show that *M. orientale* does not share similar protein preference with *M. floricola* and *M. destructor* which did not favor tubifex (Eow 2005). In the natural environment, proteins are usually found in solid forms but it is noteworthy that some pure protein, those in egg whites for instance, may not be preferred (Petralia & Vinson 1978) even when it is essential for larval growth. This possibly explains why the pure proteins tested in our study may not be preferred by *M. orientale*.

III. Satiation

Eow *et al.* (2005) reported three *Monomorium* species which showed visible carbohydrate satiation effects after only one week but this was not observed in our study. We, on the other hand, agree that *Monomorium* spp.

would not absolutely cease feeding on their preferred food choice even when satiation effects of that particular food takes place. It is unusual to find larvae feeding extensively on carbohydrate but when this is discovered, it is possibly caused by the need for additional storage space besides the designated workers' crops (Chong *et al.* 2002). Worker ants store a smaller proportion of ingested sugar water than amino acids due to the different volume ingested and the higher pressure on the crop may cause the surplus of sugar to be shunt quickly into the midgut (Howard & Tschinkel 1981a). This may be a possible reason for the lack of satiation effects found in carbohydrate feeding. For proteins, the colonies had a quicker response in revealing the satiation effect, concurring with Eow *et al.*'s (2005) report on protein satiation in *M. pharaonis*, *M. floricola* and *M. destructor*. In terms of qualitative difference in foods (Vinson 1968), workers share sugar among them but regurgitate protein and amino acids to larvae. This hinders them from sacrificing their own nutritional needs. Howard & Tschinkel (1981b) also suggested that sugar may be shoved down quickly into the midgut to satisfy the forager's own nutritional needs thus decreasing the ability for spread throughout the colony. On the other hand, proteins may be retained largely in the forager's crop, therefore permitting regurgitation. As a result, the foragers showed a decreased preference for protein once their crops are sated. This means that the larvae have already been well-fed; hence the solicitation of protein from foragers ceased and eventually caused the foragers to lower their foraging activity for protein. Reyes-Lopez & Fernandez-Haeger (2002) and Whitford & Ettershank (1975) reported that the colony's food reserves levels influence its food selection criteria. This is modified by relative abundance of the various foods available but this becomes indistinct when food reserves are plentiful.

The implication of this study is on the use of food-based baits. There may be several types of food that are attractive but there is not one food that can remain highly attractive over a long period of time. Therefore, the efficacy of the bait may decrease in time and could result in bait shyness as reported in *M. pharaonis* (Edwards & Abraham 1990). The development of a more durable bait for this species is rather difficult. There are numerous factors that can be taken into account should baits be formulated against this species. Although contrasting with reports on other *Monomorium* spp. preferring protein foods, our findings suggest that carbohydrates would be ideal as an attractant in baits for *M. orientale* since satiation effects would not affect its appeal. To further substantiate this proposal, studies that involve manipulating and assessing compatibility of carbohydrate sources with various toxicants in addition to the durability of baits in various physical formulations need to be conducted both in the laboratory as well as in the field.

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