Comparative Nutritional Preferences of Tropical Pest Ants, *Monomorium pharaonis*, *Monomorium floricola* and *Monomorium destructor* (Hymenoptera: Formicidae)

by

Annie G.-H. Eow[1] & Chow-Yang Lee

ABSTRACT

In this study, we report the preference response of laboratory colonies of the three *Monomorium* species to 30 foods and the influence of colony development status (normal, queenless and broodless) on the selection of carbohydrate, protein and oil, respectively. Results demonstrated that different colony types of the three *Monomorium* species did not alter nutritional preference. Although there were slight deviations in preference sequence among species, 10% sucrose solution (w/w), mealworm and cricket, and peanut oil appeared to be most acceptable by all three species. In addition, studies on periodic changes in nutrient selection by different colony types were also executed. The development status of the colony did not play a significant role in altering nutritional preference, but instead affected the worker foraging rates. In addition, periodic alternation and interval fluctuations among nutrients were observed in long-term preference studies (24 weeks), irrespective of species. The results also demonstrated that *M. floricola* is an 'oil-loving ant', *M. destructor* - a 'sugar-loving ant', while *M. pharaonis* preferred both protein and oil.

Keywords: food preference, *Monomorium pharaonis*, *Monomorium floricola*, *Monomorium destructor*, colony development status, nutritional preference, periodic change

INTRODUCTION

The genus *Monomorium* consists of several important household ant species in Asia. Species in this genus such as *M. pharaonis*, *M. floricola* and *M.*

[1] Urban Entomology Laboratory, Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia.

[2]To whom reprint request should be addressed. Email: chowyang@usm.my

destructor are common pest ants in residential premises and food preparative outlets (Na & Lee 2001; Lee 2002; Lee et al. 2002a; 2002b). These *Monomorium* species also share basic characteristics of 'tramp ant species' of which they are polygynous and polydomous, having nest dissemination through sociotomy and readily migrate when under disturbance or instability within colonies (Passera 1994).

The food preference and feeding behavior of *M. pharaonis* have been reported earlier by Granovsky & Howell (1983) and Edwards & Abraham (1990). The former study found that apple mint jelly was more attractive while the latter one found that honey and peanut butter were more palatable to the Pharaoh's ant. Both studies also observed a phenomenon called 'bait switching' where ants alternated their feeding between carbohydrate and protein food types. These two studies, however, did not compare the food preference based on the major nutritional groups (food classes): carbohydrate, protein and lipid. To date, little is known about the food preference and feeding behavior of *M. floricola* and *M. destructor*, other than earlier reports that they are omnivorous and will feed on a wide variety of foodstuffs (Smith 1965; Hedges 1998).

In general, ant's feeding response and preference are influenced by formulation (physical structure) (Silverman & Roulston 2001; Beh 2002), particle size (Hooper & Rust 1997; Hooper-Bui et al. 2002), quality and nutrition of the food (Chong et al. 2002); nutritional requirements (Abbott 1978; Edwards & Abraham 1990), nutrition history (Edwards & Abraham 1990; Wheeler 1994), starvation level (Traniello 1977; Stradling 1987; Chong et al. 2002), development status of the colony (Traniello & Robson 1994; Edwards & Abraham 1990); periodical or seasonal effects (Sudd and Sudd 1985; Stein et al. 1990; Hooper & Rust 1997; Rust et al. 2000) and division of labors within the colony (Markin 1970; Abbott 1978; Sorensen et al. 1983a). However, how these factors affect the feeding response and diet selection of *Monomorium* species are poorly understood.

Hence, a comparative study was conducted to elucidate the preference response of the three pest species of *Monomorium* and the influence of colony development status on selection of carbohydrate, protein and oil. In addition, studies on periodic changes in nutrient selection in different colony types were also executed.

MATERIALS AND METHODS

Insects.

The *Monomorium* species used in this study have been cultured in the Urban Entomology Laboratory, Vector Control Research Unit, School of Biological Sciences, Univerisiti Sains Malaysia since 2000. They are reared in small wooden box with folded papers placed in rectangular polyethylene trays measuring 50 x 37 x 9 cm. The upper inner surfaces of the trays were smeared with a thin layer of fluon to prevent the ants from escaping. Food and water were provided *ad libitum*. Food consisted of 10% sucrose solution, boiled egg yolk, canned tuna fish, freshly-killed late nymphs of lobster cockroach (*Nauphoeta cinerea*) and peanut oil. The insects were maintained under environmental conditions of 26 $\pm$ 2°C, 60 $\pm$ 5% r.h. and 12-hour photoperiod.

Nutritional preferences of different colony types

A total of 30 colonies of *M. floricola, M. pharaonis* and *M. destructor* were set up from stock cultures and placed in aluminium pans (38 x 22 x 8 cm). Three types of colonies (normal, broodless, queenless) were compared for their nutritional preferences. A total of 2000 workers, 10 queens and 1.0 g brood were isolated as a normal colony while broodless and queenless colonies refer to colony with absence of brood or queen, respectively. Each colony type was replicated 10 times. Plastic Petri dishes (d = 9 cm) with lids painted in black and holes drilled along their sides were used as harborages and placed at the center of the testing arena. These colonies were acclimatized for a week with formulated agar (Bhatkar & Whitcomb 1970) to ensure uniformity among all experimental colonies. They were starved for 24 hours before the test. Ten types of foods were used to represent sources of protein, boiled chicken egg yolk, commercial canned tuna fish in water (Rex Trading Sdn. Bhd), milk powder (Anlene, New Zealand Milk (M) Sdn. Bhd), beef liver (wet market), beef (wet market), cricket (mix-stages) (aquarium shop), prawn meat (wet market), snail (aquarium shop), tubifex worms (*Tubifex tubifex*) (aquarium shop), and mealworms (mix-stages) (aquarium shop). All foods were oven-dried at 50°C for three days before being subjected to grinding and sieving (< 0.5 mm). Proximate analyses (according to Association of Official Analytical Chemists [AOAC 1997] method) were carried out to determine the major nutrient contents of these protein sources. Carbohydrate sources were 10% sucrose solution (w/w) (Malayan Sugar MFG.Co.Bhd.), orange jam (Citi, Kawison Trading, Malaysia), pineapple jam (Lady's Choice, CPC/AJI (Thailand) Ltd.), blackcurrant jam (Jammy, Network Foods (M) Sdn.Bhd), honey (Ben Trading (M) Sdn.Bhd), corn syrup (Hungry Jack, The Pillsbury Company), 10% glucose (w/w) (Glukolin, LFD Manufacturing Sdn.Bhd.), mixed-fruit jam (Delicia, Pacific Impact Industries Sdn.Bhd), skimmed milk (Dutch Lady, Dutch Lady Milk Industries Bhd.) and coconut jam (Auntie Rosie, Gardenia Sales and Distribution Sdn. Bhd). These foods were obtained in either liquid or semi-liquid form. Oils used in this study were commercially available in market, i.e. palm oil (Seri Murni, FFM Berhad), corn oil (Daisy, Lam Soon Edible Oils Sdn. Bhd), peanut oil (Knife, Lam Soon (M) Sdn. Bhd), olive oil (Fragata, Angel Camacho, S.A.), sunflower seed oil (Sunbeam, Sime Darby Edible Product Ltd.), sesame oil (Lee Kum Kee, Lee Kum Kee Co., Ltd.), rice-bran oil (Green Love, Greenlove Distribution Sdn. Bhd.), canola oil (Naturel, Lam Soon Edible Oil Sdn. Bhd.), soybean oil (Mazola, CPC/AJI (M) Sdn. Bhd.) and carotene (Carotino, Carotino Sdn. Bhd.). These oils were delivered in a piece of filter-paper (2 x 2 cm) and placed on lids of plastic Petri dishes (d = 3.5 cm). All foods were pre-weighed (ca. 0.5 g to the nearest 0.01 g) and placed close to the edges of the rectangular pan around the harborage. Food placements were rotated to avoid positional biases. The numbers of worker ants visiting (either foraging or feeding) within the lids of food types were visually estimated and recorded at 0.5, 1.0, 2.0, 3.0 and 6.0. These food types were placed up to 24 hours before being removed for weighing. Controls were placed in the same test arena, but were not accessible to the ants to determine weight loss or gain due to environmental conditions.

The total numbers of visiting workers within six hours were analyzed in percentage separately according to different colony types and nutrients. All data in percentage were subjected to arc-sine transformation before analysis of variance (ANOVA), and means were further separated using Tukey's HSD at 95% confidence level. The percentage of workers feeding or foraging on the various food types and the amounts removed were used as indications of their relative attractiveness or palatability. Comparisons were made among colony types and ant species.

Periodical changes in nutritional preference

Normal (consisting of 2000 workers, 1.0 g of brood and 10 queens), broodless and queenless colonies of all three species of *Monomorium* were set up in rectangular aluminium pans (38 x 22 x 8 cm). Plastic Petri dishes (d = 9 cm) with lids painted black and holes drilled along their sides were used as harborages and placed at one end of the testing arena. They were acclimatized for a week with formulated agar (Bhatkar and Whitcomb 1970) prior to the experiment. Three standard food baits, 0.5 ml 10% (w/w) sucrose solution, 0.5 ml peanut oil and 0.5 g canned tuna fish were used as representative sources of carbohydrate, lipid and protein, respectively and placed on plastic Petri dish lids (d= 3.5 cm). The food baits were placed side-by-side on one side of the tray, opposite to the harborage. Their positions were rotated among different replicates. Three colonies from each colony type were used to study the periodic changes of nutritional preference for an 8-week period. Evaluation was made at week 0, 1, 2, 3, 4, 6, 8 and formulated agar was provided as normal food to the colonies. The numbers of workers foraging or feeding within the lids were visually estimated at 0.5, 1.0, 2.0, 3.0 and 6.0 hours during the experiment. Data were subjected to the analyses described earlier. Another separate experiment was conducted using 10 normal colonies to determine their changes in nutritional preference on a weekly basis up to 24 weeks post-treatment.

RESULTS AND DISCUSSION

Nutritional preferences of different colony types

Figures 1, 2 and 3 show the preference of the three *Monomorium* species to 10 carbohydrate sources. The worker ants of *M. floricola* showed equal preference for all 10 carbohydrate sources for normal colonies as well as broodless and queenless colonies (Fig. 1). However, 10% sucrose solution (w/w) was preferred by workers of *M. pharaonis* from normal and queenless colonies, followed by coconut jam (Fig. 2). In broodless colonies, 10% glucolin (w/w) and 10% sucrose solution (w/w) were significantly ($P < 0.05$) visited more frequently than the others. For *M. destructor* (Fig. 3), 10% sucrose solution (w/w) was generally preferred by all colony types, while skimmed milk and corn syrup were visited the least.

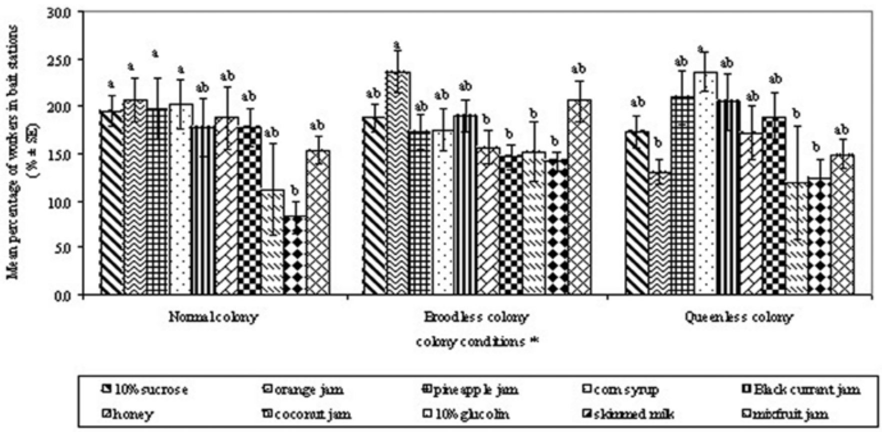

Fig. 1. Mean percentage of workers fed on 10 carbohydrate sources for 6 hours upon baiting in different colony conditions of *M. floricola*. (n=10) Means in the same colony condition followed by the same letters are not significantly different (Tukey HSD; P > 0.05).

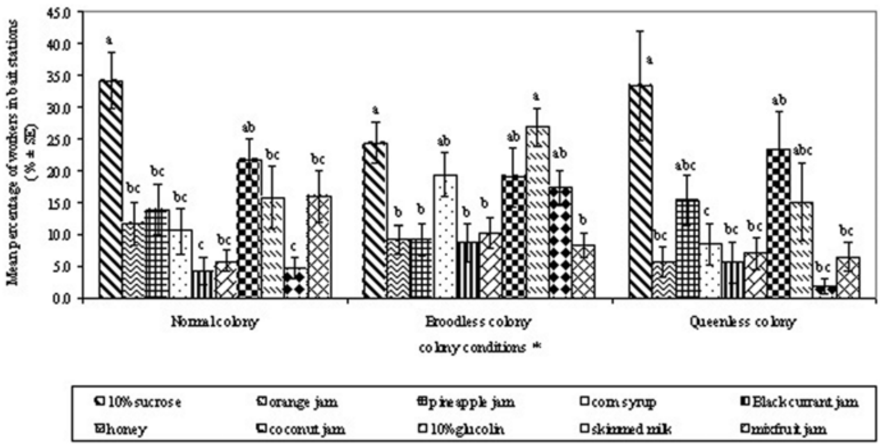

Fig. 2. Mean percentage of workers fed on 10 carbohydrate sources for 6 hours upon baiting in different colony conditions of *M. pharaonis.* (n=10). Means within the same colony condition followed by the same letters are not significantly different (Tukey HSD; P > 0.05)].

There appeared to be no difference among the three colony types (Figs 4, 5 and 6) in protein preference. Among the protein sources offered, cricket and mealworm were preferred by all colony types of *M. floricola* (Fig. 4) and *M. pharaonis* (Fig. 5). Snail and tubifex worm were the least preferred. For *M. destructor*, the most preferred protein source was mealworm only (Fig. 6). It

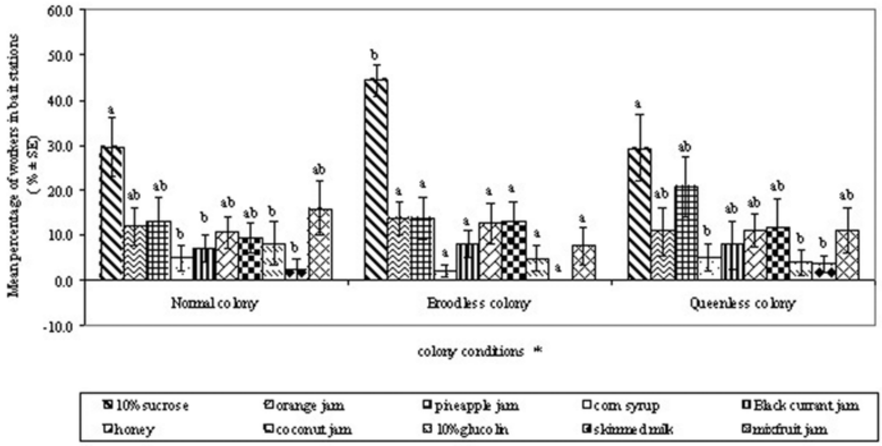

Fig. 3. Mean percentage of workers fed on 10 carbohydrate sources for 6 hours upon baiting in different colony conditions of *M. destructor.* (n=10) Means within the same type of colony condition followed by the same letters are not significantly different (Tukey HSD; P > 0.05)].

is not surprising that all three *Monomorium* species preferred insect protein because arthropods are a primary part of their natural diets. Sudd (1962) reported that the Pharaoh's ants feed on dead and dying bodies of insects that were attracted to lights in a house in Nigeria. In addition, the present of high portion of mealworm in a diet has been found to be highly attractive and needed for successful rearing of several ants in laboratories (Wright & Stout 1978; Keller et al. 1989).

As the protein sources in this study were not in pure form, proximate analyses were conducted to determine their major nutrition compositions (Table 1). Tuna fish contained the highest protein (85.07%), but the least lipid (1.00%). On the other hand, lipid content in egg yolk was the highest (62.56%), more than twice the amount of protein (28.20%). The protein-lipid ratios of the remaining foods ranged between 2.7:1 to 12.4:1, with exception to the most preferred sources, i.e. mealworm and cricket in which they both carried protein-lipid ratio of 5: 4. This may suggest that the three *Monomorium* species preferred solid food with protein-lipid ratio of 5: 4.

The preference of different oil types of *M. floricola* is shown in Fig. 7. Irregular orders of preference were found among different types of colonies. Peanut oil was generally preferred, followed by corn and olive oil in normal and queenless colonies. No significant (P > 0.05) preference was found among

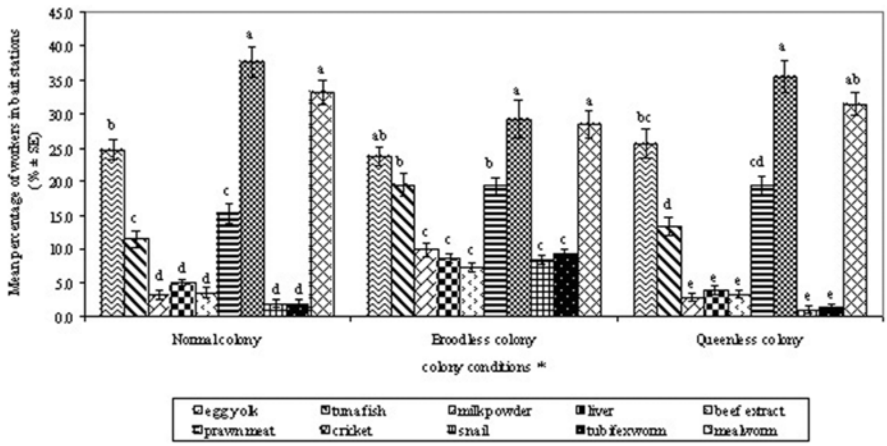

Fig. 4. Mean percentage of workers fed on 10 protein sources for 6 hours upon baiting in different colony conditions of *M. floricola.* (n=10). Means in the same colony condition followed by the same letters are not significantly different (Tukey HSD test; P > 0.05).

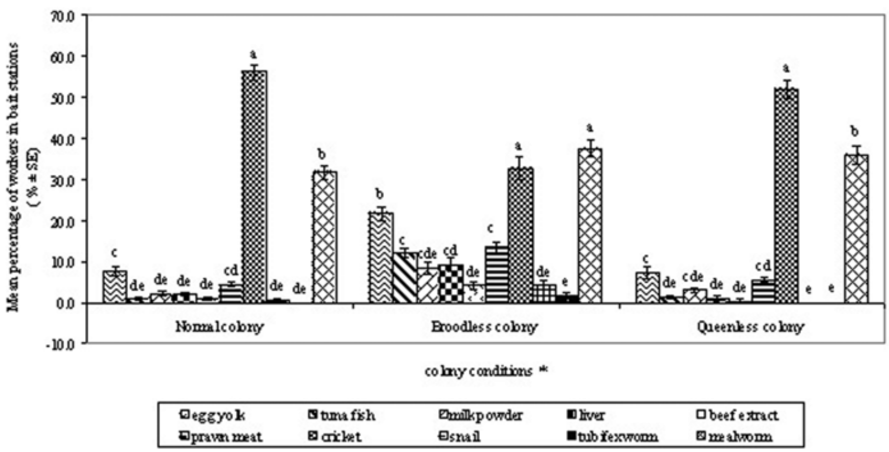

Fig. 5. Mean percentage of workers fed on 10 protein sources for 6 hours upon baiting in different colony conditions of *M. pharaonis* (n=10). Means within the same type of colony condition followed by the same letters are not significantly different (Tukey HSD; P > 0.05).

the oil types to broodless colony. As for *M. pharaonis*, there was no significant difference (P > 0.05) in oil preference among the three colony types (Fig. 8) as all colony types preferred olive oil the most. For *M. destructor*, with exception to the queenless colony which preferred peanut oil, there was no preference to the oil types (Fig. 9).

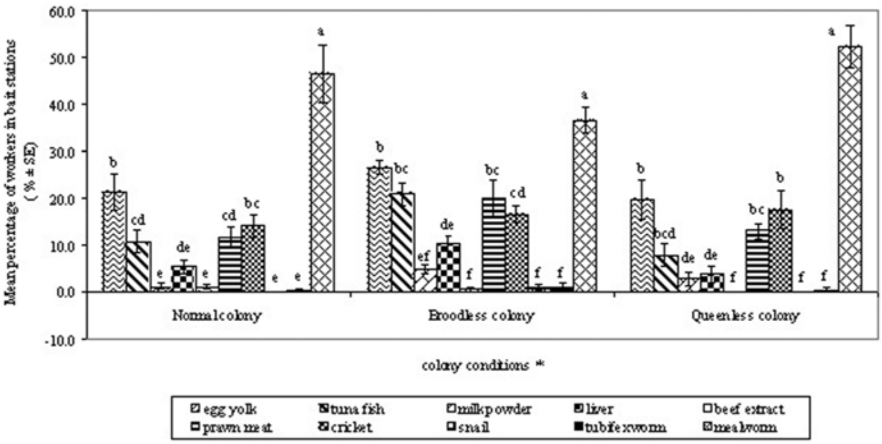

Fig. 6. Mean percentage of workers fed on 10 protein sources for 6 hours upon baiting in different colony conditions of *M. destructor* (n=10). Means within the same type of colony condition followed by the same letters are not significantly different (Tukey HSD; P > 0.05)].

Table 1. Proximate analysis (AOAC, 1997) of 10 protein sources used for food preference study. (The balances of the composition of each food are fiber and carbohydrate).

	FOOD	n	Moisture Mean % ± SE	Ash Mean % ± SE	Protein Mean % ± SE	Lipid Mean % ± SE
1	TUNA	3	2.45 ± 0.06	5.86 ± 0.07	85.07 ± 0.40	1.00 ± 0.02
2	EGG YOLK	3	1.80 ± 0.02	3.70 ± 0.02	28.20 ± 0.25	62.56 ± 0.10
3	MEALWORM	3	2.07 ± 0.07	3.89 ± 0.00	49.66 ± 0.15	37.40 ± 0.15
4	CRICKET	3	2.87 ± 0.06	4.32 ± 0.02	51.71 ± 0.07	36.91 ± 0.16
5	PRAWN MEAT	3	2.37 ± 0.14	8.28 ± 0.04	78.26 ± 0.09	6.31 ± 0.04
6	BEEF EXTRACT	3	3.37 ± 0.05	16.44 ± 0.02	69.62 ± 0.10	4.39 ± 0.06
7	LIVER	3	2.66 ± 0.02	5.15 ± 0.04	71.21 ± 0.11	12.98 ± 0.16
8	MILK POWDER	3	2.81 ± 0.03	11.96 ± 0.04	38.06 ± 0.12	0.57 ± 0.02
9	SNAIL	3	2.96 ± 0.10	10.64 ± 0.03	60.35 ± 0.05	4.81 ± 0.06
10	TUBIFEX	3	2.10 ± 0.02	6.58 ± 0.07	60.64 ± 0.03	22.14 ± 0.04

The results obtained from this experiment demonstrated that different colony types of the three *Monomorium* species do not alter nutritional preference. Although there was no obvious deviation in food preference among the three *Monomorium* species in this study, food preferences among ant colonies are usually highly variable (Glunn *et al.* 1981) especially among different nutritional types (Edwards & Abraham 1990). In addition, the distribution and flow of nutrients in an ant colony differ among castes (Howard & Tschinkel

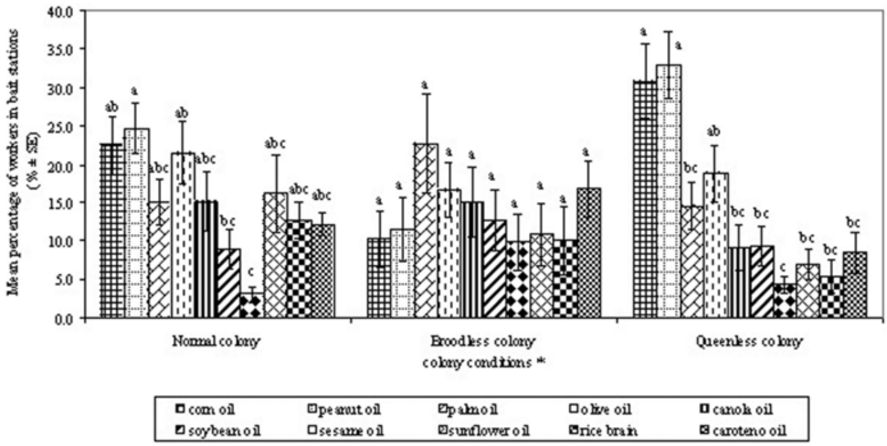

Fig. 7. Mean percentage of workers fed on 10 oils for 6 hours upon baiting in different colony conditions of *M. floricola* (n=10). Means within the same type of colony condition followed by the same letters are not significantly different (Tukey HSD test; P > 0.05).

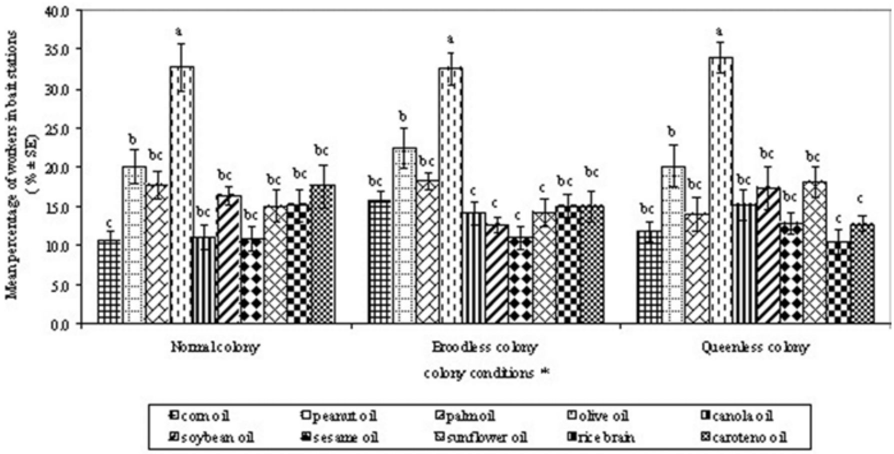

Fig. 8. Mean percentage of workers fed on 10 oils for 6 hours upon baiting in different colony conditions of *M. pharaonis.* (n=10.) Means within the same type of colony condition followed by the same letters are not significantly different (Tukey HSD test; P > 0.05).

1981; Sorensen & Vinson 1981; Chong et al. 2002). The flow of nutrients in *M. floricola* and *M. destructor* is still poorly understood although Chong et al. (2002), and Haack & Vinson (1990) have reported that carbohydrate is primarily retained and utilized by workers while solid protein is mainly directed towards larval stages of Pharaoh's ant.

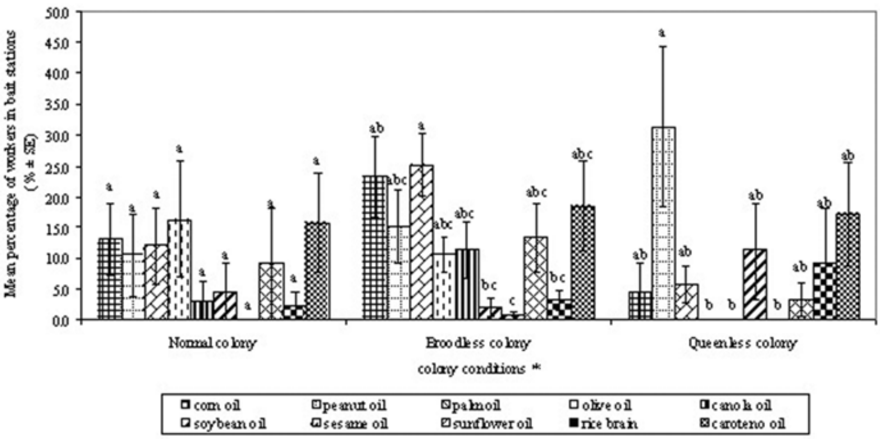

Fig. 9. Mean percentage of workers fed on 10 oils for 6 hours upon baiting in different colony conditions of *M. destructor.* (n=10). Means within the same type of colony condition followed by the same letters are not significantly different (Tukey HSD test; P > 0.05).

Periodic changes in nutrient selection

Canned tuna fish was used in this study because it has the highest protein content when compared to other protein sources (Table 1) and relatively more preferred by the three *Monomorium* species. As for the carbohydrate and lipid sources, sucrose solution 10% (w/w) and peanut oil were selected due to preferences in the earlier experiment. Figures 10, 11 and 12 show the periodic changes in nutritional preference of three colony types (normal, broodless and queenless) of three *Monomorium* species over an 8-week period. Worker ants of *Monomorium* species were firstly recruited to the 10% sucrose solution (w/w) upon introduction of the foods, but usually stopped feeding after two to three hours. The recruitment towards peanut oil started one to two hours after foods were introduced, and the workers took more time feeding on oil. These behavioral observations were also found earlier by Haack & Vinson (1990) on the Pharaoh's ant, and Vinson (1968) on southern fire ant, *Solenopsis xyloni*. In addition, Ali & Reagan (1986) reported the delay in recruitment activity in *Solenopsis invicta* to oil, when compared to molasses. The differential time-response to food types should thus be taken into consideration when running nutritional preference experiments. As for protein, the workers usually forage towards tuna fish after feeding on sucrose solution, but often before going for peanut oil.

Differences in recruitment activities may be due to the heterogeneity in food form (solid vs liquid), food viscosity (water-based vs oil-based liquid), as well as the feeding method. Deviations in recruitment order suggested that the worker ants are able to differentiate type of food on their first visit and would feed accordingly when given choices. Their earliest recruitment to sucrose solution is probably due to sucrose solution being a more ready-to-used energy source that will fulfill the requirement of the active workers. In all replicates, feeding and food gathering activities of workers were usually ceased within 6 hours, either due to dehydration of the foods or when food was completely consumed.

Carbohydrates and oils are shared among workers which require high energy to perform a variety of tasks, while proteins will be given to developing larvae and egg-producing queens (Markin 1970; Edwards & Abraham 1990; Howard & Tschinkel 1981; Sorensen & Vinson 1981). In an ant colony, only the brood is capable of digesting solid food. Workers feed solid protein directly to larvae, which in turn workers would receive the protein from larvae through brood cannibalism and by feeding on larval secretions (Sorensen et al. 1983b). Therefore, ant larvae enable workers to utilize solid proteins that they cannot digest and serve as sources of stored protein. As a result, it is anticipated that there would be changes in nutritional preferences depending on the colony composition.

Among normal, broodless and queenless colonies of *M. floricola* (Fig. 10), our results showed that the development status of the colony did not play a significant role in altering nutritional preference, but instead affected the worker foraging rates. The normal and queenless colonies involved two times more worker foragers than those in broodless colony of *M. floricola* and *M. pharaonis*. On the other hand, the mean total foragers of normal and broodless colonies of *M. destructor* were two to three times more than that in a queenless colony. This deviation is probably due to the digestion and storage responsibility of the brood, particularly the larvae. According to Cornelius & Grace (1997), the foraging rates of workers on different food types were not only influenced by the differences in colony composition, but also further complicated by brood cannibalism and the ability of ant colonies to store proteins for later use. Thus, further investigation regarding brood cannibal-

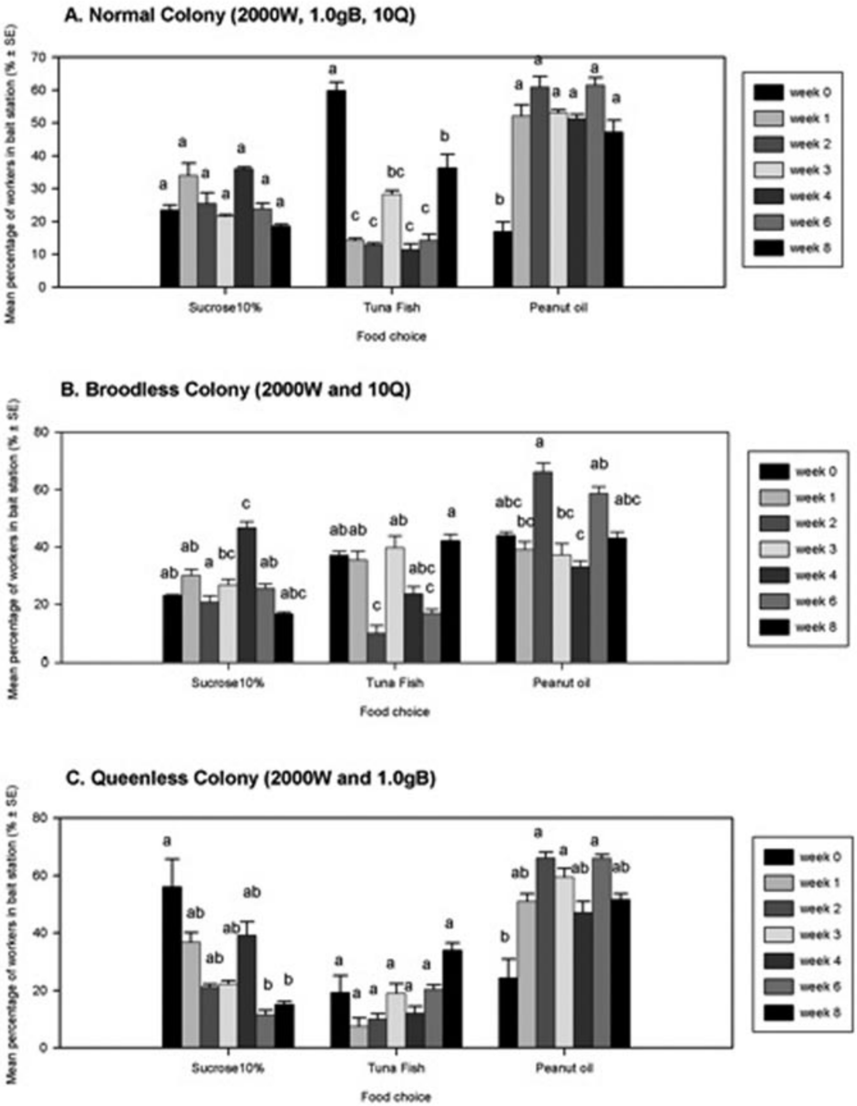

Fig. 10. Periodic changes in nutrient represented food selection of *M. floricola* in different colony conditions within 8 weeks.[Means (after arcsine transformed) within the same type of food followed by the same alphabets are not significantly different (ANOVA, Tukey HSD test; p > 0.05)].

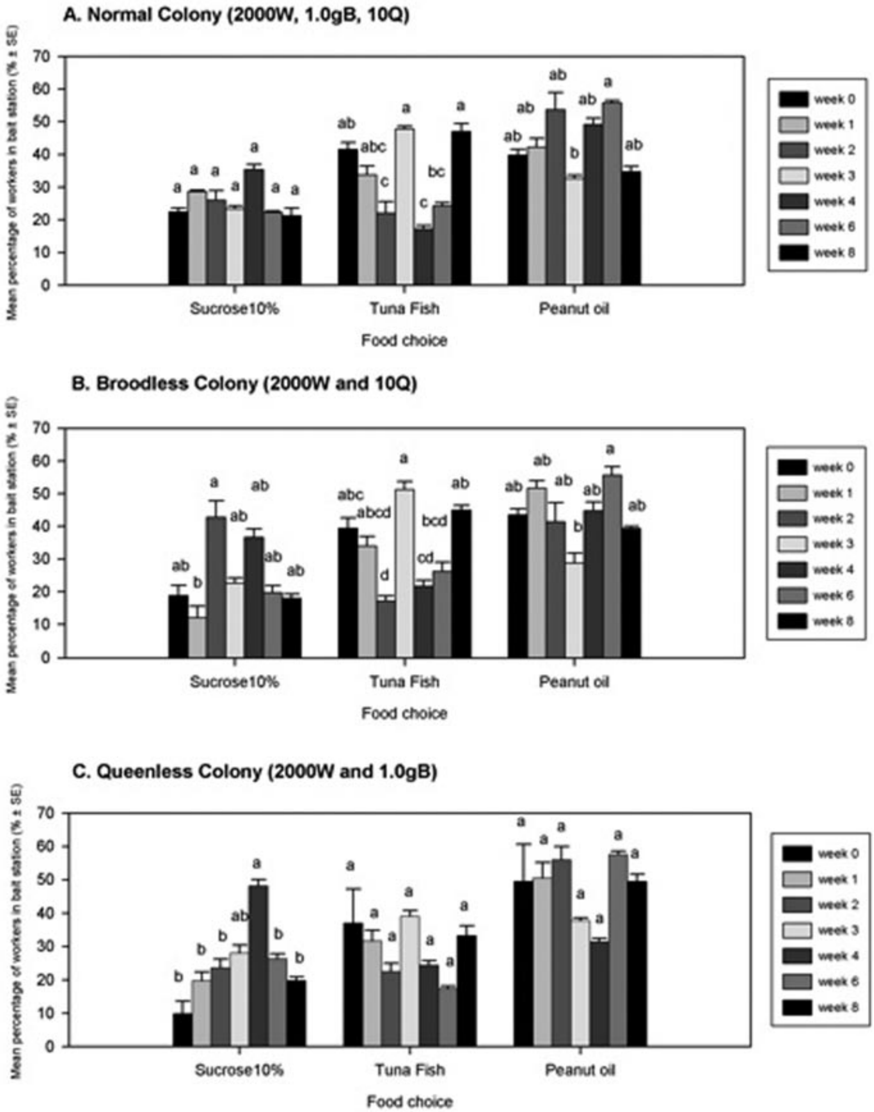

Fig. 11. Periodic changes in nutrient represented food selection of *M. pharaonis* in different colony conditions within 8 weeks. [Means (after arcsine transformed) within the same type of food followed by the same alphabets are not significantly different (ANOVA, Tukey HSD test; $p > 0.05$)].

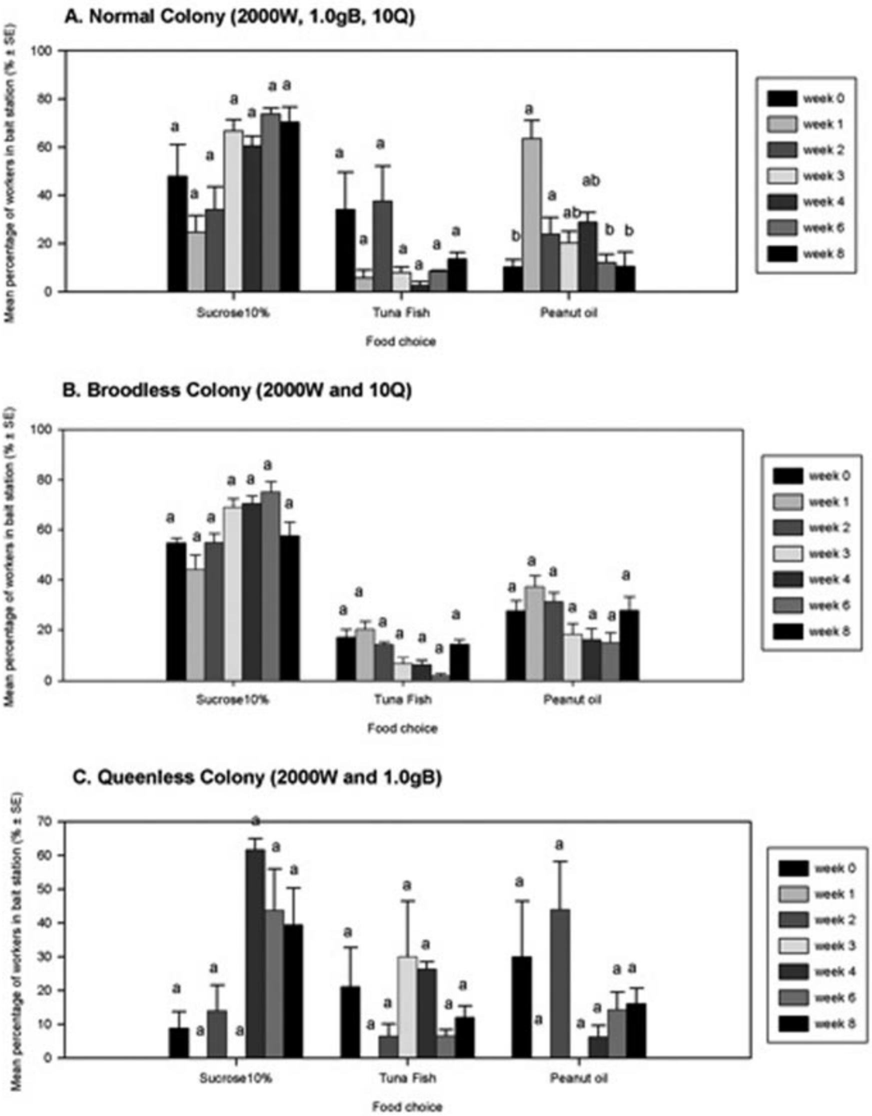

Fig. 12. Periodic changes in nutrient represented food selection of *M. destructor* in different colony conditions within 8 weeks. [Means (after arcsine transformed) within the same type of food followed by the same alphabets are not significantly different (ANOVA, Tukey HSD test; p > 0.05)].

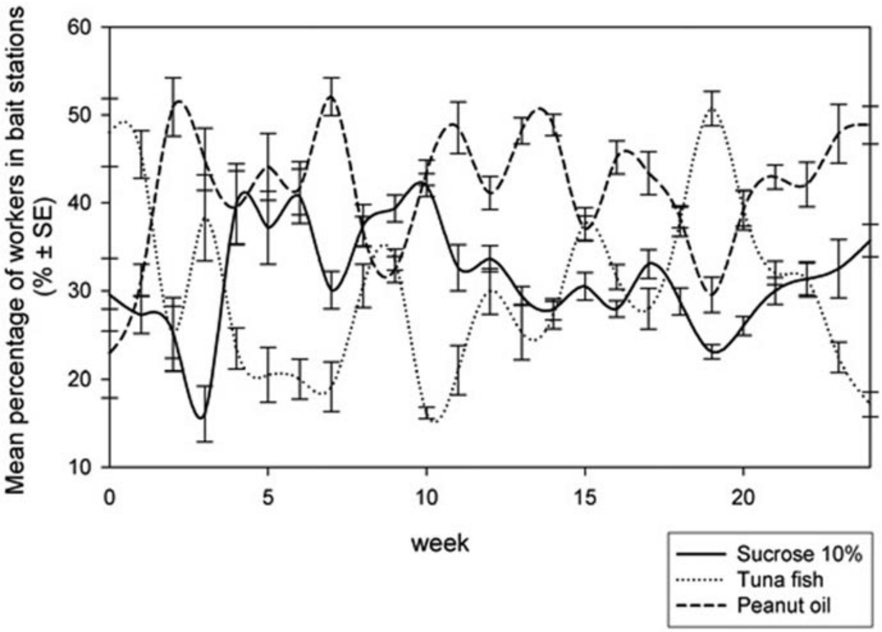

Fig. 13. Changes in nutrient represented food selection of normal colony of *M. floricola* throughout 24 weeks. (n=10)

ism and protein storage in *Monomorium* species should be done before any conclusion can be made.

In all colony types, only slight fluctuations were observed among nutritional preference over the 8-week period. The workers of *M. floricola* showed significantly ($P < 0.05$) highest preference (up to 83%) towards peanut oil. On the other hand, the mean percentages of workers which visited both tuna fish and 10% sucrose solution (w/w) ranged between 10 and 40%. We also found an alternated in preference for tuna fish and 10% sucrose on a two-week basis.

Similar observations were also registered in the colonies of *M. pharaonis* (Fig. 11). However, nutritional preference in colonies of *M. pharaonis* was clearly different from that of *M. floricola*. Higher percentages of Pharaoh ants were recruited towards peanut oil and the tuna fish. In contrast, all colonies of *M. destructor* were found to be consistently retained their most frequent visits to the 10% sucrose solution (w/w) when compared to the peanut oil and the tuna fish (Fig. 12).

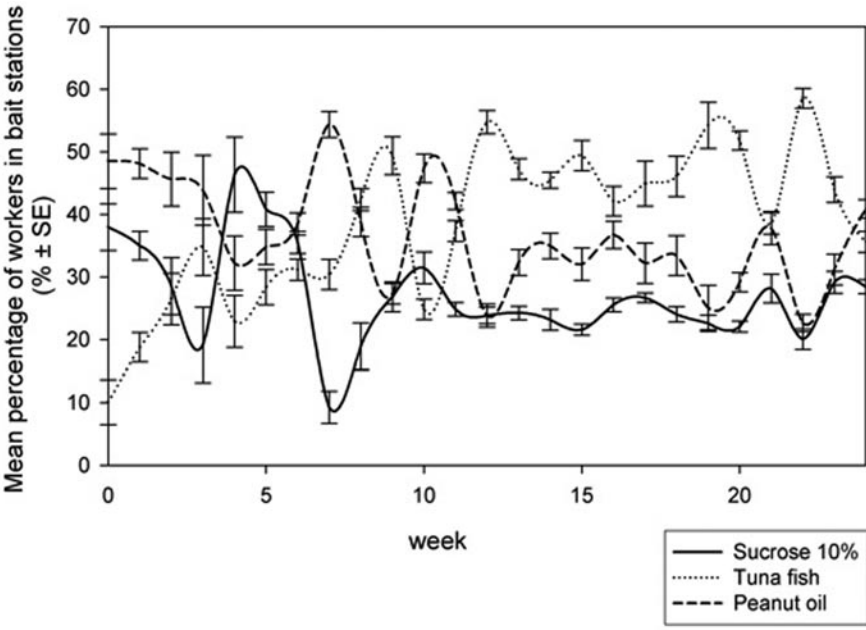

Fig. 14. Changes in nutrient represented food selection of normal colony of *M. pharaonis* throughout 24 weeks. (n=10)

Figures 13, 14 and 15 show long-term periodic changes in nutritional preference of the normal colonies of the three *Monomorium* species. In general, the trend of nutritional preference did not differ much from earlier experiments. In normal colony of *M. floricola* (Fig. 13), the mean percentages of workers that visited the three nutrients consistently fluctuated every two weeks. However, it was clearly shown that the highest preference was for peanut oil, followed by 10% sucrose (from 4^{th} – 14^{th} week) and tuna (from 15^{th} – 24^{th} week).

The nutritional preference of *M. pharaonis* (Fig. 14) was found to change between peanut oil (week 0 to week 11) and tuna fish (week 12 to week 21) while maintaining its 10 % sucrose solution intake throughout the experimental period. As for *M. destructor*, the nutritional alternation was also observed where more ants visited the 10% sucrose. This was followed by a second preference towards peanut oil from week 4 to week 13, which was eventually replaced by tuna fish on subsequent weeks (Fig. 15).

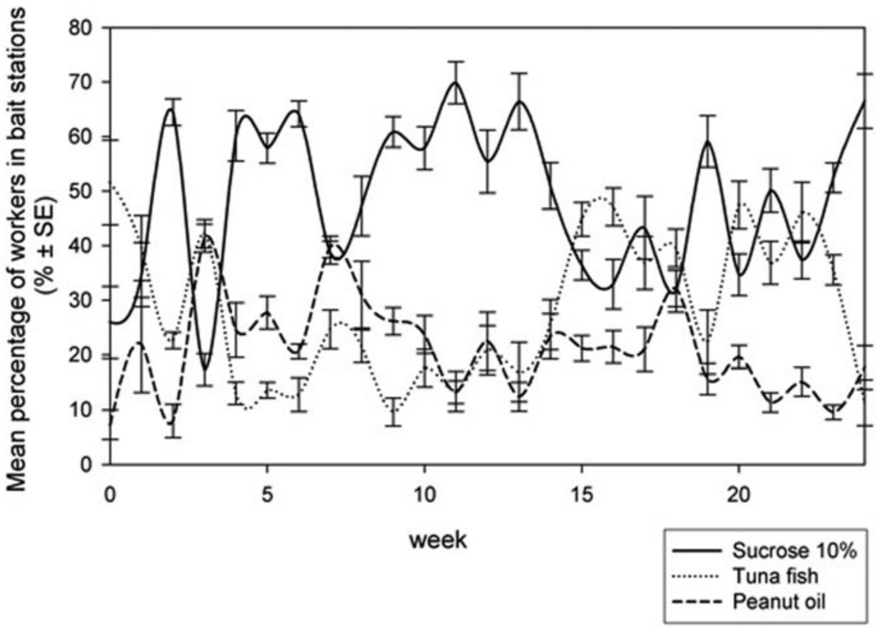

Fig. 15. Changes in nutrient represented food selection of normal colony of *M. destructor* throughout 24 weeks. (n=10)

This study shows no apparent effect of colony composition on the nutritional selection of the three *Monomorium* species. Seasonal changes in bait preference have been observed in imported fire ants, *Solenopsis invicta* (Stein et al. 1990), Argentine ants (Rust et al. 2000) and wood-ants, *Formica lugubris* (Sudd & Sudd 1985) which could either be affected by changes in temperature or abundance and quality of natural resources in the field environment. This experiment was carried out under controlled laboratory conditions where temperature and humidity were almost constant throughout the experiment. Therefore, periodic alternations and interval fluctuations detected could be due to the peculiarity suggested by Edward & Abraham (1990) in which the selections of foods by an omnivorous insect is to ensure that the colony receives a varied and balanced diet. The results obtained also suggested that substantial changes can occur in as little as two weeks.

On the other hand, the ants also demonstrated a clear nutritional preference of carbohydrate, protein and lipid which was relatively distinct among the three *Monomorium* spp. When comparing nutritional preference, it can be concluded that *M. floricola* is an 'oil-loving ant' while *M. destructor* is a 'sugar-loving ant'. However, *M. pharaonis* has showed an equal preference for both protein and oil sources. It is important to take note that the formulated agar (Bhatkar & Whitcomb 1970) given during the intervals of experiment is limited in oil composition, thus the high oil selection of *M. floricola* and *M. pharaonis* could be due to the oil-deprived history in the colonies. Haack & Vinson (1990) have reported that laboratory colonies of the Pharaoh's ant have to undergo a period of starvation before they could be stimulated to accept oil-based baits.

In summary, this study provides an insight into the nutritional preferences of three *Monomorium* pest species. *M. pharaonis* was found to prefer both protein and lipid sources, while *M. floricola* and *M. destructor* prefer lipid and carbohydrate sources, respectively. Colony development status did not appear to influence nutritional preferences in the three species evaluated, but it affected the worker ant's foraging rates to different food.

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