Effects of Nutritional Starvation and Satiation on Feeding Responses of Tropical Pest Ants, *Monomorium* spp. (Hymenoptera: Formicidae)

by

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ABSTRACT

The feeding responses of three urban pest ant species, *Monomorium pharaonis* (L.), *Monomorium floricola* (Jerdon) and *Monomorium destructor* (Jerdon) after being subjected to nutritional starvation and satiation (either for all nutrients, carbohydrate only, protein only or lipid only) were studied using laboratory-bred colonies. Sucrose solution (10%), canned tuna and peanut oil were used as representatives of carbohydrate, protein and lipid, respectively and the colonies were starved or satiated for 7 days before experiments on their feeding responses to different nutrients were executed. The numbers of foraging workers towards each nutrient were estimated. Results indicated that feeding preferences of *M. floricola* workers were correlated towards nutrients which they were deprived of. In the event when they were starved from all nutrients, lipid-based food remains the favored choice. Nutritional satiation would cause *M. floricola* to forage for either lipid or protein-based food. On the other hand, *M. pharaonis* consistently showed preference towards protein-based food, irrespective of what they were starved from, or satiated with. *M. destructor* workers foraged primarily towards both carbohydrate- and protein-based foods under both feeding conditions mentioned above. The implications from the results obtained and its possibility in enhancing the success of ant baiting program is discussed.

Keywords: feeding, starvation, satiation, nutritional preference, urban pest ants, *Monomorium pharaonis*, *Monomorium floricola*, *Monomorium destructor*.

INTRODUCTION

Surveys on urban pest ants in Malaysia (Yap & Lee 1994; Na & Lee 2001; Lee 2002; Lee *et al.* 2002) revealed that three *Monomorium*

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species, namely *M. pharaonis* (Linneaus), *M. floricola* (Jerdon) and *M. destructor* (Jerdon) are amongst the most important species in residential premises and food preparative outlets. All three species are known to be omnivorous and feed on a wide variety of foodstuffs (Smith 1965; Hedges 1998). It was also reported that food preferences among the ant colonies are usually highly variable, particularly under different nutritional conditions (Edwards & Abraham 1990). Various studies have shown that worker ants were able to manifest nutritional content and quality of foods on their first visit (Howard & Tschinkel 1981) and would respond differently to factors such as formulation (physical structure) (Silverman & Roulston 2001; Beh 2002), particle size (Hooper-Bui & Rust 1997; Hooper-Bui *et al.* 2002), quality (Chong *et al.* 2002), nutritional requirements (Abbott 1978; Edwards & Abraham 1990), nutritional history (Edwards & Abraham 1990; Wheeler 1994), starvation level (Traniello 1977; Stradling 1987; Chong *et al.* 2002) and development status of the colony (Traniello & Robson 1994; Edwards & Abraham 1990), periodical or seasonal effects (Sudd & Sudd 1985; Stein *et al.* 1990; Hooper & Rust 1997; Rust *et al.* 2000) and division of labor within the colony (Markin 1970; Abbott 1978; Sorensen *et al.* 1983a). To date, the mechanism of how these factors interactively influence feeding response and diet selection of *Monomorium* species remains poorly understood. However, it is speculated that there is alternation among nutrient types to ensure the colony receives a varied and balanced diet.

The three *Monomorium* species are considered tramp species with polygynous nests and are capable of disseminating their nests through sociotomy. Their nests are generally difficult to locate and they readily migrate in response to disturbances or instability within colonies (Passera 1994). Baiting has been proven as a better control measure to date against these species (Edwards & Clarke 1978; Newton 1980; Lee 2000; Lee & Lee 2002). Among the reported toxicants, pyriproxyfen (Vail & Williams 1995; Vail *et al.* 1996; Oi *et al.* 2000), methoprene (Edwards & Clarke 1978; Rupes *et al.* 1983; Edwards 1985; Varjas & Bajomi 2001), fenoxycarb (Williams 1990; Williams & Vail 1993; 1994), noviflumuron (Suiter 2002), hydramethylnon (Oi *et al.* 2000), and boric acid (Newton 1980; Klotz *et al.* 1997; Lee & Lee 2002) have demonstrated encouraging results against these species. Nevertheless, baiting is a passive control method that requires foraging ants to take in a sufficient amount of insecticidal bait and circulate it among nestmates before colony elimination can be achieved. Thus the bait matrix must be attractive to the targeted ants.

One major challenge in ant baiting is the bait switching behavior (Granovsky & Howell 1983) where ants alternated their feeding between food types. Edwards & Abraham (1990) have further reported that this phenomenon is due to food satiation. They found that when a colony is satiated with a particular type of food, their workers would not respond to the presence of new food, but also selected food with a different nutrition. A better understanding of this behavior will contribute greatly to improve the baiting strategy. Hence, this study was initiated to compare the feeding responses of the three *Monomorium* species under starvation and satiation of the three major nutrients (carbohydrate, protein and lipid).

MATERIALS AND METHODS

A total of 80 colonies, each consisting 2000 workers, 10 queens and 1.0 g brood were set up from stock colonies for each *Monomorium* species. These colonies were placed into rectangular aluminium trays (38 x 22 x 8 cm) and allowed to nest within a 9-cm diameter polyethylene petri dish placed in an inverted position inside the pans. They were acclimatized for a week with formulated agar (Bhatkar & Whitcomb 1970) *ad libitum*. Three types of food, 0.5 ml 10% (w/w) sucrose solution, 0.5 ml peanut oil and 0.5 g canned tuna fish were used as sources of carbohydrate, lipid and protein, respectively. The foods were placed on lids of 3.5-cm diameter plastic petri dishes and were positioned side-by-side horizontally at the opposite end of the trays to the harborage. The position of the foods was rotated among replicates to avoid location bias during testing.

The colonies were divided into 8 groups with 10 replicates each and each was subjected to one of the following: carbohydrate starvation, carbohydrate satiation, protein starvation, protein satiation, lipid starvation, lipid satiation, all nutrients starvation and all nutrients satiation. The colonies were starved or satiated with the nutrient for a week before they were evaluated.

During the test, the numbers of workers foraging or feeding within the lids which contained the food were visually estimated at 0.5, 1.0, 2.0, 3.0 and 6.0 hours upon baiting. After six hours, the foods were discarded. The effects of starvation and satiation were evaluated daily up to 3 days using the same procedure as described above. All data in percentage were subjected to arc-sine transformation before analysis of variance (ANOVA), and means were separated using Tukey's HSD at 95% confidence level using Statistix® Version 7.

RESULTS AND DISCUSSION

The effects of nutrient starvation on *M. floricola* food selection is shown in Fig. 1. The results obtained from colonies under all nutrients starvation showed that the worker ants have significantly higher preference for oil on the first day, but the preference changed to protein on the second day (Fig. 1). This confirms the existence of a preference

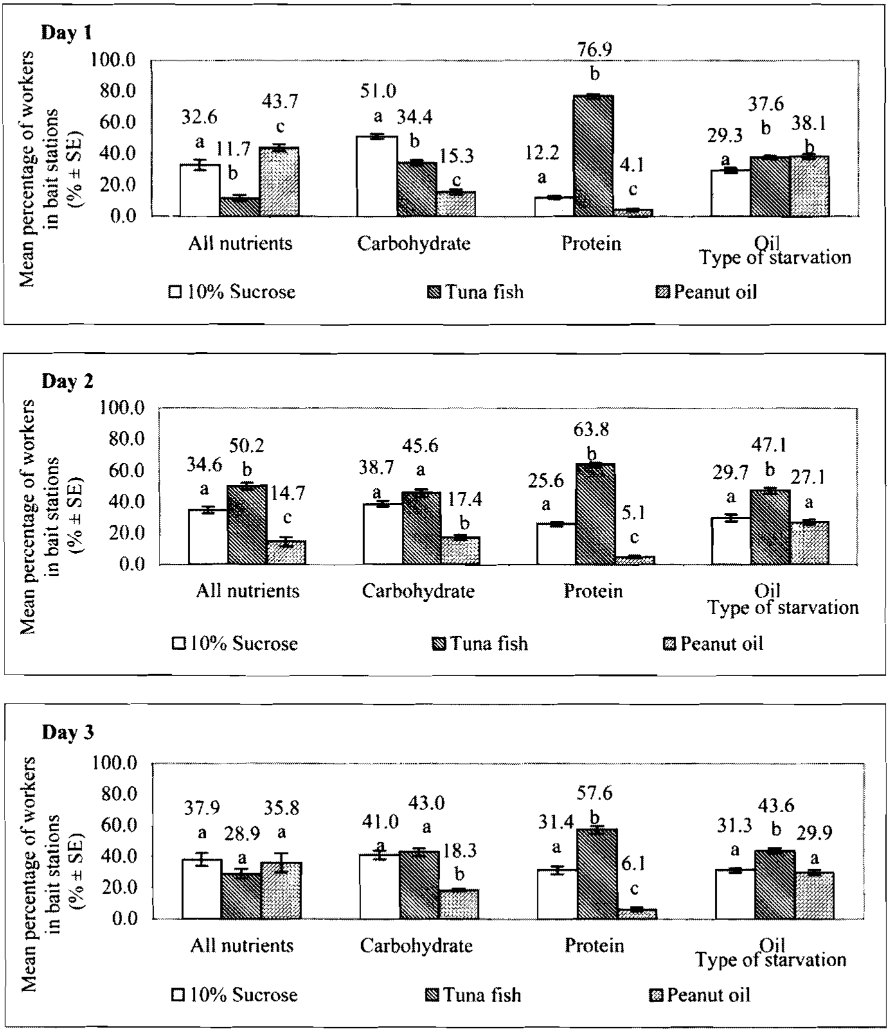

Fig. 1. Mean percentage foraging workers of *M. floricola* found on different nurtrients at day 1, 2 and 3 after subjected to nutritional staravtion for 1 week.

for a variety of diets in worker ants feeding behavior, which probably plays an important role in ensuring that the colony receives a balance nutritional profile, as proposed by Edwards & Abraham (1990). This also explains the increased in recruitment activities towards carbohydrate rich diet after a week long period of carbohydrate deprivation. However, this increment was only observed on the first day. A similar trend was also observed in colonies deprived of oil. In contrast, colonies that were deprived of protein showed significant increment in recruitment of workers to protein source for at least three days.

Fig. 2 shows the effects of nutrient satiation on selection of food type by *M. floricola*. When the colonies were continuously given carbohydrate food for a week, significantly ($P < 0.05$) higher recruitment activity to protein source was recorded on the first day. On the contrary, the foraging workers visited carbohydrate food least. However, the recruitment to carbohydrate food recovered after the first day. As anticipated from protein-satiated colonies, recruitments to the carbohydrate and oil increased, with significantly ($P < 0.05$) higher recruitment activity to oil. The high recruitment to oil lasted for at least three days. On the other hand, highest recruitment to protein was observed from oil-satiated colonies with enduring effects for at least three days.

For *M. pharaonis*, the results obtained from all nutrient-deprived colonies suggested that besides foraging for a balanced diet, the species also showed preference towards protein, when compared to carbohydrate and lipid. Results also indicated that irrespective of the type of nutrient the colonies were starved from, all colonies showed greater affinity towards proteinaceous food which lasted for 3 days (Fig. 3).

Similar findings were obtained where most worker ants of *M. pharaonis* were recruited to proteinaceous food, even under protein satiation or other nutrients (Fig. 4). With exception to recruitment to protein in protein-satiated colonies on the first day, all other colonies showed a preference for protein food source.

The results of the experiments on *M. destructor* are shown in Figs. 5 and 6. When the colonies were deprived from all nutrients for a week, the colonies appeared to prefer proteinaceous food. Most colonies showed greater recruitment activity towards proteinaceous food (Fig. 5), irrespective of the type of nutrients they were starved from for a week. On the other hand, under satiation of all nutrients, the ants showed a preference for carbohydrate and protein food sources (Fig. 6). Colonies satiated with carbohydrate and oil would forage more towards protein source, while higher recruitment to carbohydrate source was observed in protein-satiated colonies. The feeding responses of the

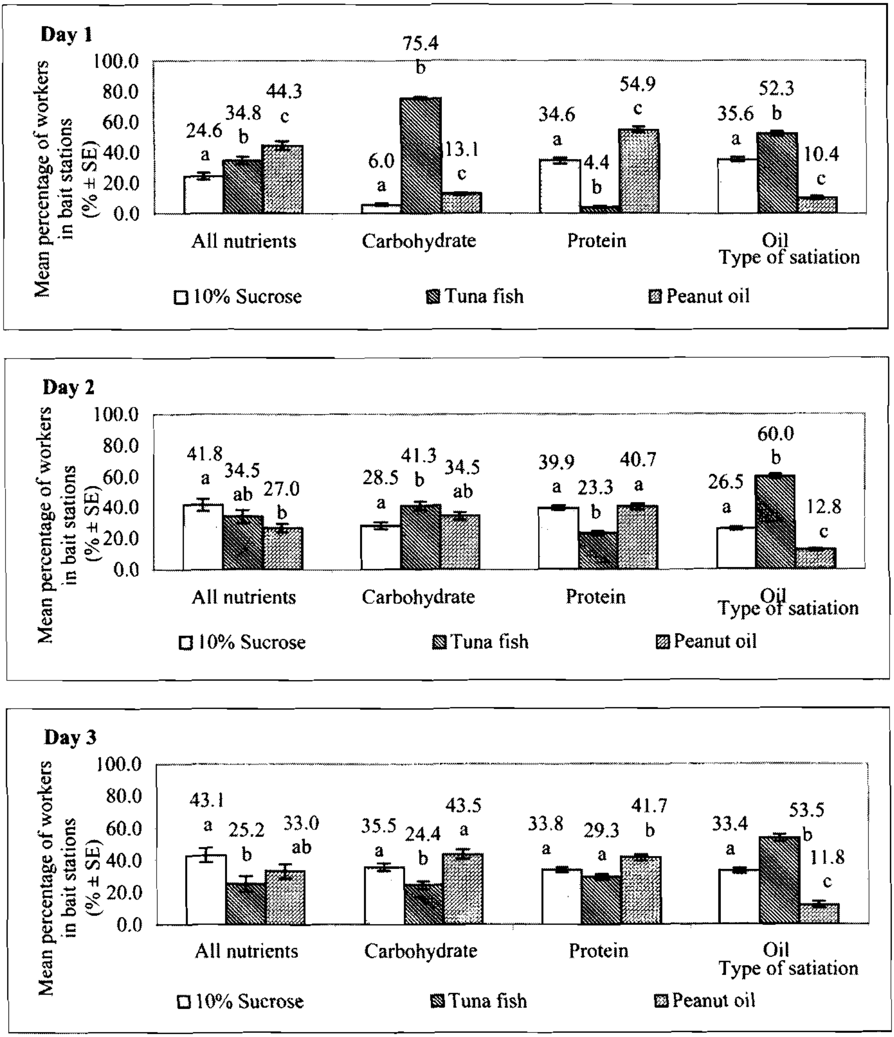

Fig. 2. Mean percentage foraging workers of *M. floricola* found on different nutrients at day 1, 2 and 3 after subjected to nurtitional satiation for 1 week.

three species of *Monomorium* after subjected to various nutritional starvation and satiation is summarized in Table 1.

The results demonstrated that even in colonies satiated with all nutrients, they will still have foraging workers to the food type of their preference. This result concurs with that reported by Howard & Tschinkel (1980, 1981) on fire ant, *Solenopsis invicta* that foraging and recruitment activity will increase when a colony is deprived of food or

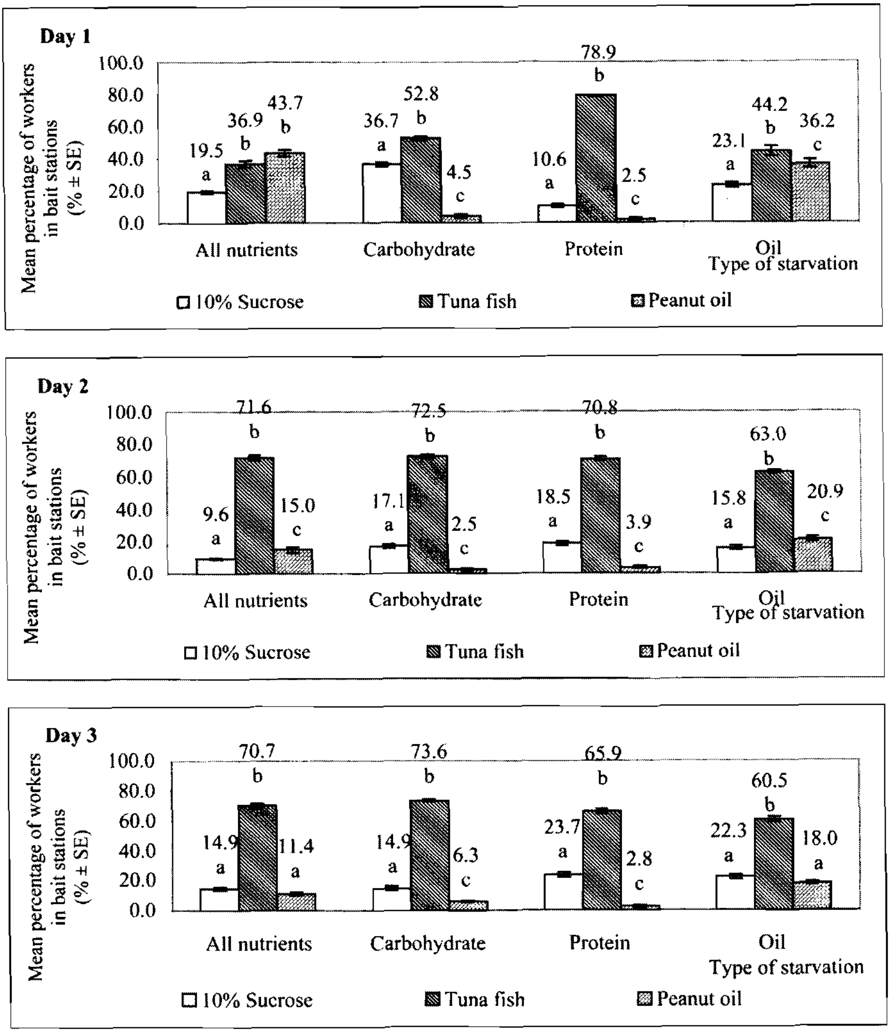

Fig. 3. Mean percentage foraging workers of *M. pharaonis* found on different nutrients at day 1, 2 and 3 after subjected to nurtitional starvation for 1 week.

certain nutrient. However, results in Fig. 7 showed that satiation would not merely reduce foraging activity, but actually enhance recruitment activity if the colony was induced under satiation of certain nutrient. Nevertheless, 'starvation of a nutrient' mentioned in this study was in fact satiation of the other two nutrients, and vice versa. Thus, it is tempting to suggest that the satiation behavior could be exploited in

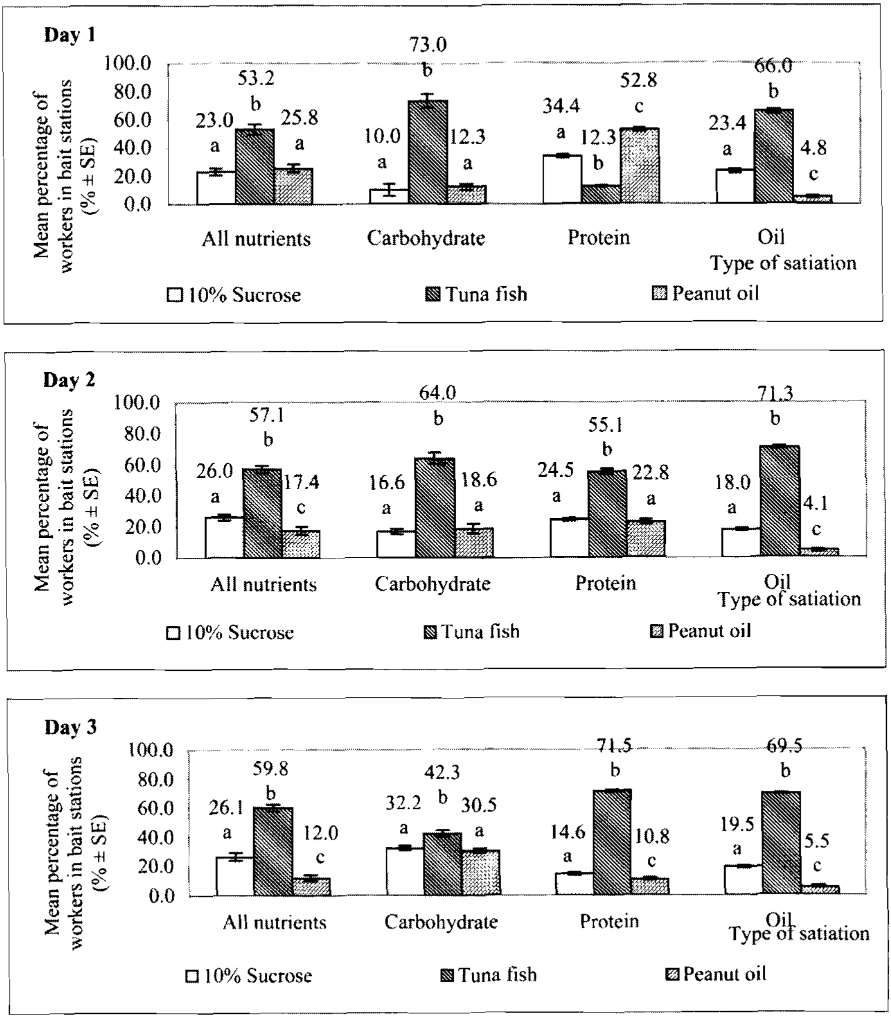

Fig. 4. Mean percentage foraging workers of *M. pharaonis* found on different nutrients at day 1, 2 and 3 after subjected to nutritional satiation for 1 week.

baiting strategies against these *Monomorium* species as it could alter the feeding response of the ants towards different nutritional types.

In a situation when removal of competing food sources in an infested area is not feasible, the results obtained could be used as a guideline in bait selection according to the feeding response of the particular species. In circumstances where the food-based attractant of a toxic bait has poor palatability to a particular ant species, the colony could

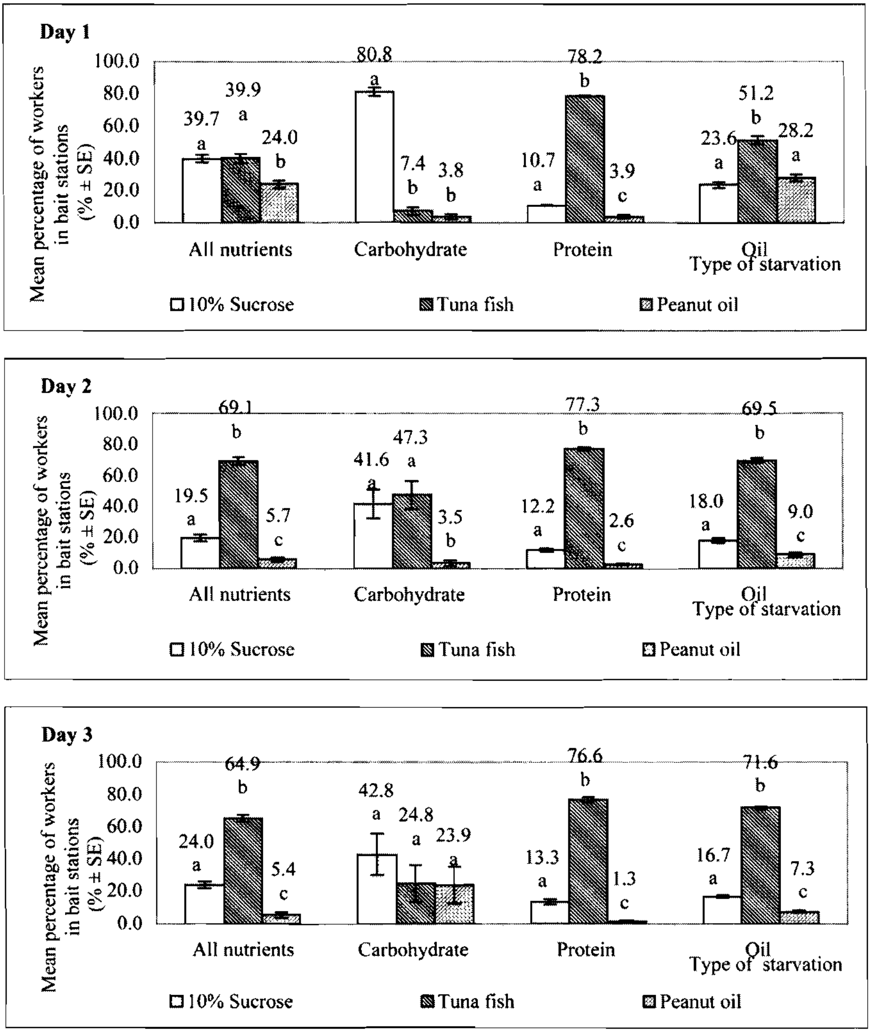

Fig. 5. Mean percentage foraging workers of *M. destructor* found on different nutrients at day 1, 2 and 3 after subjected to nutritional starvation for 1 week.

first be satiated with a different nutritional source so that a sufficient intake of the toxic bait is ensured. Thus, this would possibly facilitate the use of a food-based toxic bait against a wider variety of ant species.

In conclusion, we believe satiation behavior can be exploited in baiting strategies to enhance the effectiveness of the baits for a more successful control program. However, more studies in this respect should be conducted to further substantiate this hypothesis.

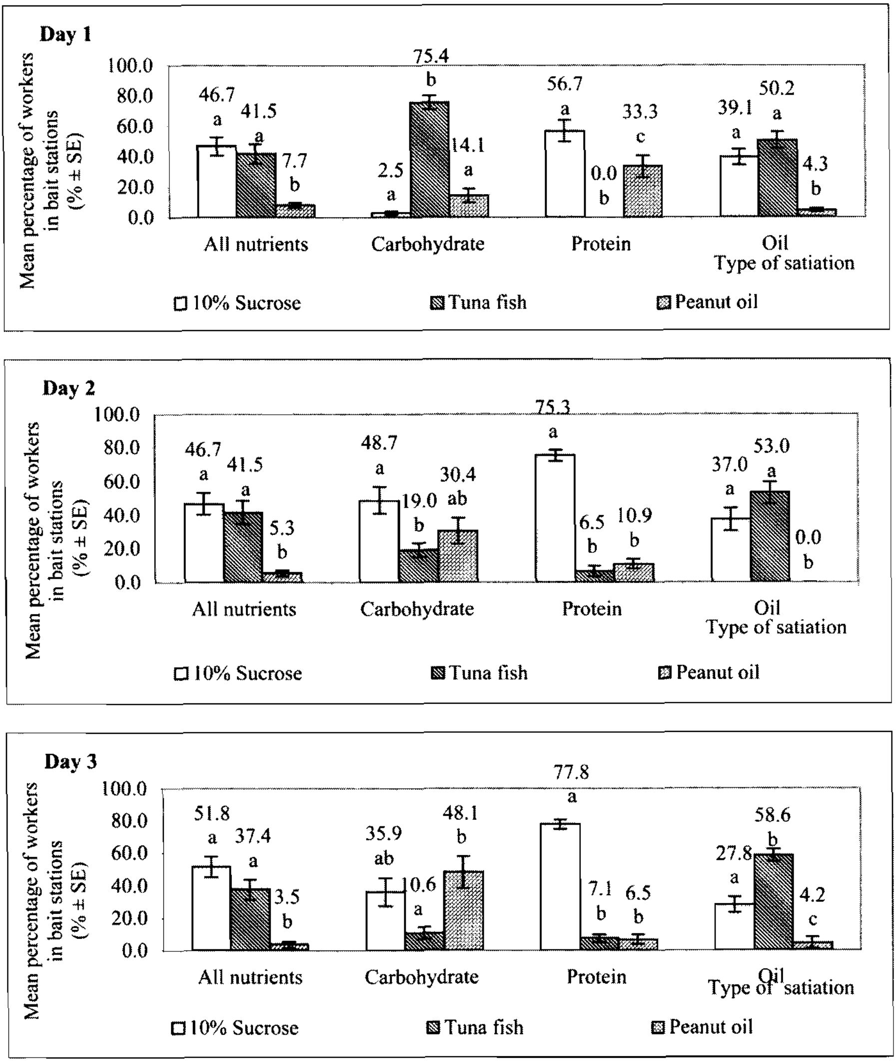

Fig. 6. Mean percentage of foraging workers of *M. destructor* found on different nutrients at day 1, 2 and 3 after subjected to nutritional satiation for 1 week.

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Table 1. Preference (rank 1 – 3 from most preferred to least preferred) of three nutrients by urban pest ants, *Monomorium* spp. at the first day after subjected to nutritional starvation and satiation for 1 week.

	Starved				Satiated			
	Carbohydrate	Protein	Lipid	All	Carbohydrate	Protein	Lipid	All
M. floricola								
carbohydrate	1	2	2	2	3	2	2	3
protein	2	1	1	3	1	3	1	2
lipid	3	3	1	1	2	1	3	1
M. pharaonis								
carbohydrate	2	2	3	2	2	2	2	2
protein	1	1	1	1	1	3	1	1
lipid	3	3	2	1	2	1	3	2
M. destructor								
carbohydrate	1	2	2	1	2	1	1	1
protein	2	1	1	1	1	3	1	1
lipid	2	3	2	2	2	2	2	2

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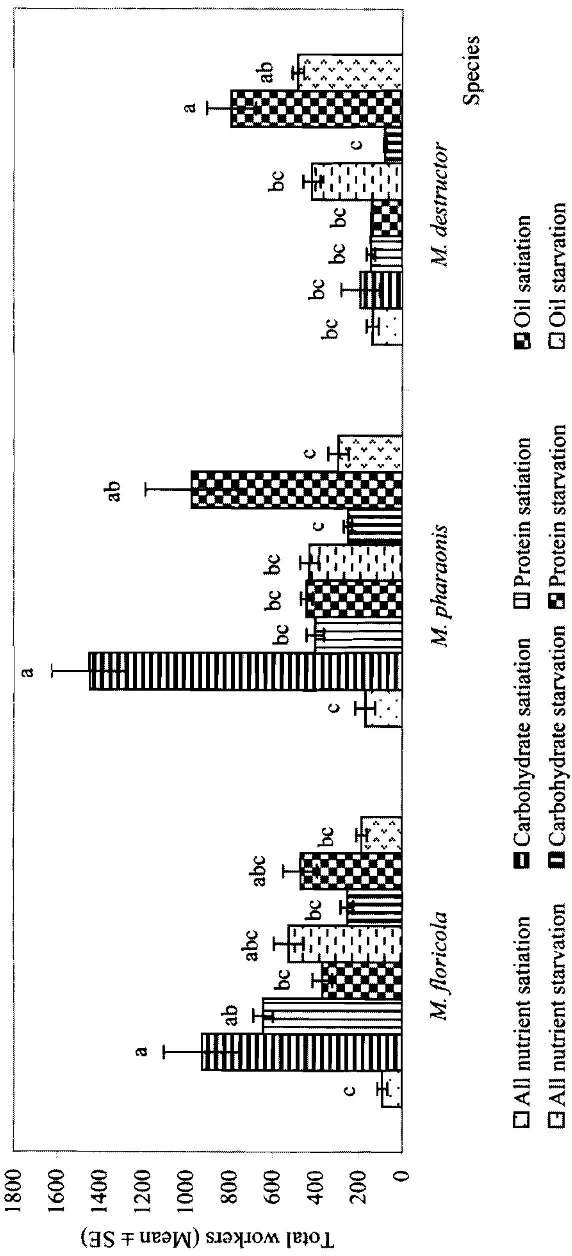

Fig. 7. Total worker faragers of *M. floricola*, *M. pharaonis* and *M. destructor* after subjected to nutritional starvation and satiation for 1 week.

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