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Open Access Study of attractiveness and palatability of the German cockroaches, *Blattella germanica* (L) to Peanut butter baits under laboratory conditions

Hatim, M.Mansour, Gubran, A.Mahi, El Rayah , El Amin ,Yahya, Hisham A, Bakheet, Ali Obaid

Abstract

This research has been conducted at the laboratory of Dubai Public Health Pest Control Section / Dubai Municipality. The project consists of two parts: The first part concerns the evaluation of attractivity and palatability of the German cockroach *Blattella germanica* to peanut butter baits under the laboratory conditions. The sources of this butter were Sudan, India, China, USA and Ethiopia. The apparatus used in these experiments was a five-chambered choice chamber denoted as the New Pentadevice Arena (60 cm in diameter). One fine strip of each food was placed in each chamber. Fifty insects of different stages of development were placed at the center of the arena. Number of insects in each chamber was counted after ten minutes. The Sudanese peanut butter food (PNB4) showed the highest record of numbers of insects. A third method was adopted to confirm these results– namely biting effects.

1. Introduction

Cockroaches considered as one of the important pests of public health due to their role in transmission of some pathogenic organisms to human and his environment. Cockroaches are pests in homes, restaurants, hospitals, warehouses, offices, and virtually any structure that has food preparation or storage areas. They contaminate food and kitchen utensils, destroy fabric and paper products, and impart stains and unpleasant odours to surfaces they contact.

The integrated pest management (IPM) is considered as one of the important methods and new trends to diminish the conventional ways in pest control industry. And this has come in response to eco-friend systems and global demand. IPM, which adopts the baiting technique, is one of the essential tools of the intervention element mechanisms. It is now progressing tremendously and globally. Efficient and Potent lures are needed to meet the challenges of trapping cockroaches in detection, monitoring, and pest reduction efforts. Baiting the pest by using the mechanism of elimination and suppression, could be considered as a greenish trend that marches in parallel way beside the other environmental services.

Most of the previous studies search in attractant foods and lures for German cockroaches is extensive and progressive trials to enhance the attractiveness and palatability of commercial baits and gels. In Such trials with fatty acids and esters

(Tsuji, 1966; Wileyto and Boush, 1983), cyclohexylalkanoates and n-alkylcyclohexaneacetates (Sugawara et al., 1975; Wiley to and Boush, 1983), and tetrahydropyran esters (Pandey et al. 1994, 1995) were evaluated. This is in addition to various household food materials (Tsuji, 1965, Reierson and Rust 1977, Rust and Reierson 1981, Ballard and Gold 1982) and insecticide baits (Rust and Reierson 1981, Scharf et al., 1994).

Several studies have examined the attractiveness of various food stuffs and chemicals to cockroaches (Tsuji, 1966; Sugawara et al., 1975a, 1975b; Reierson and Rust, 1977; Rust and Reierson 1981; Ballard and Gold 1982; Wiley to and Boush 1983; Brenner and Patterson 1989; Brenner and Pierce 1991; Pandey et al. 1994,

1995). Bread has emerged as one of the most attractive food substances; it is frequently used in trapping studies in apartments, often mixed with beer (Owens and Bennett 1982, 1983; Barcay et al. 1990).Bread was highly attractive in olfactory assays (Nalyanya, 2001). Bread was the second to Maxforce gel in attracting male *B. germanica.* Nalyanya (2001) believed that, some of the commercial baits are quite attractive, but they are not much more attractive than some domestic food substances.

With respect to adult male cockroaches, the food odorants in the tested food baits are relatively ineffective compared with even crude extracts of the sex pheromone of *B. germanica* (Liang and Schal, 1993). Because the available sex pheromones attract only males, pheromones can be integrated with food attractants to attract females and nymphs (Landolt et al., 1997; Liang et al., 1998).

Peanuts are rich in oil, naturally containing from 47to 50 %. The oil is pale yellow and has the characteristic odour and flavour of peanuts (O'Brien, 1998). Oil quality and its stability are very important for the consumers. Olfactometer experiments showed that headspace volatile extracts of peanut butter and solvent extract of beer attract male German cockroaches according to Karimifar et al (2011). They discovered that 1-hexanol, which is a semiochemical produced from Peanut butter, is a volatile compound resulting from decomposition of lipids .Synthetic equivalents of these semiochemical may be formulated as baits or be added to, and thus enhance the attractiveness of natural food sources and efficiency of insecticidal baits,(Karimifar et al.,2011). Peanut butter proved to be more attractive to rats compared to mice (Gould et al., 2007).Peanut butter and distiller's grain were equally attractive in trapping experiments in swine production barns and they captured significantly more cockroaches than the GP-2 tablet or the Victor pheromone lure (Nalyanya, 2001).In fact, Peanut butter elicited upwind responses from 84% of the cockroaches in Olfactometer assays (Nalyanya, 2001). Accordingly the overall goal of this research is to evaluate the attractiveness and phagostimulancy of the German cockroaches, *Blattella germanica* (L) towards different peanut butter baits using a new Pentadevice Arena apparatus in order to create an efficient control strategy.

2. Materials and Methods

Study site

All the experimental trials were conducted at Insect laboratory of Pest control section, Dubai municipality, Dubai, UAE.

Behavioral Assay Apparatus (Pentadevice Arena)

The new five-chambered circular arena apparatus, denoted by *Pentadevice Arena* is designed and made in Abulabyad Island, Abu Dhabi. It is made from woody material, laminated with layer of fiberglass material, and then coated with gel coat of white color. The diameter of the apparatus is 60 cm and height of 20 cm. The apparatus is attached to five chambers of 10 cm diameter and 3 cm height with five pipes of the same material and same length, the length of each connecting pipe is 6 cm and diameter 2.5 cm. (Plate 1).

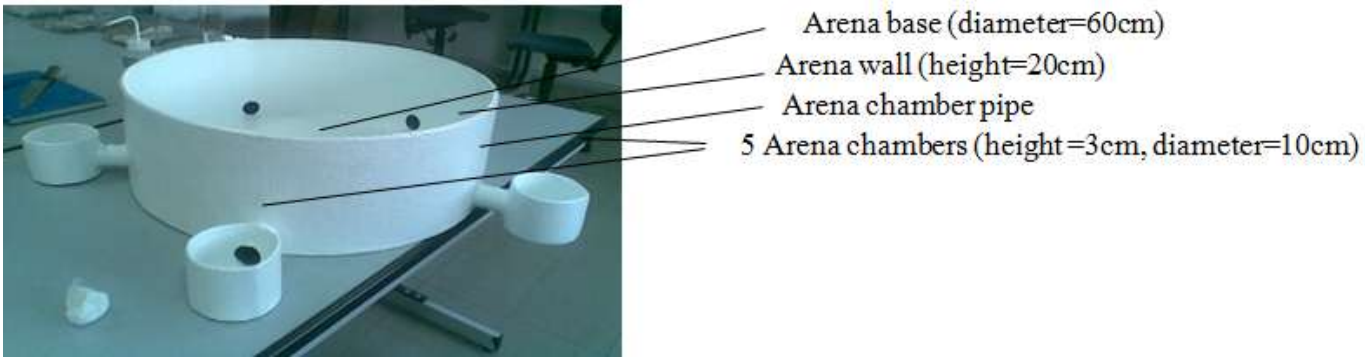


Plate (1) the new Behavioral Assay Apparatus (Pentadevice Arena)

The Insects

The German cockroaches, *Blattella germanica (L)* were obtained from Public Health Pest Control Section laboratories of Dubai municipality, Alqoz 3, Dubai, UAE. These cockroaches had been collected from the field and reared in the laboratory under controlled temperature (25 ºC) and RH (67 %) since 2005.The insects were provided rat chow and water ad libitum.3-14 day old adult cockroaches of both sexes (only non-gravid females) were used .The acclimatization of the tested insects was done, one day before starting the bioassay test.

The Tested Foods

Evaluated different ready made Peanut butter foods (Plate 2) which were selected and purchased from local market distributors. The peanut foods used are referred to as PNB1, 2, 3, 4 and 5 corresponding to the countries of origin.

Two hundred fifty gram from each peanut food sources were ground till paste form, kept in 500 ml covered plastic container and preserved in fridge to be ready for use.

The Bioassay Trials

Two hundred milligrams (mg) from each food source were taken and designed (shaped) into 50 mm length and 1 mm width band shape using 2 ml plastic syringe. Each band was placed on the top surface of an inverted petri-dish of 50 mm

diameter and height of 8mm.Then each dish was placed inside a chamber. All of the five chambers were covered with transparent plastic sheet which was being sealed tightly using flexible rubber band to prevent cockroaches from escape. Each chamber was provided with a corrugated cardboard harborage and a vial of water plugged with a moist cotton ball. The inner wall of the arena was treated 50mm high, at thin layer of talc powder to prevent cockroaches escape.

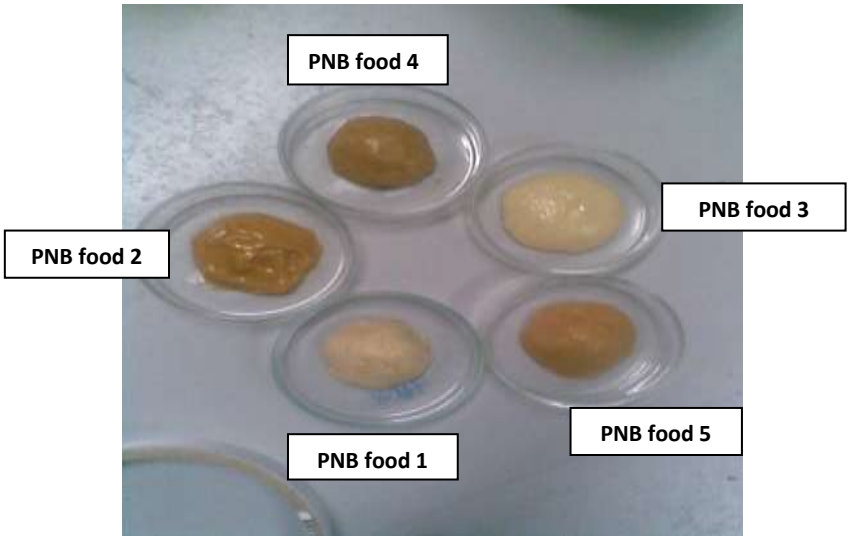


Plate (2) *The Five tested Peanut Butter Foods*

The release

Fifty German cockroaches of different stages were released at the center of the arena and allowed to choose, freely one of the five chambers.

Three parameters or indicators for measuring and evaluating the feeding behavior of the German cockroaches towards the tested five Peanut foods were adopted. These were: attractiveness, palatability and biting effects.

1. *Measuring the Attractiveness*

Measuring the Attractiveness was conducted by counting the number of insects that were found inside each chamber of the apparatus, after 10 minutes of the cockroaches' release. Counting was conducted once at the first day of the test, every week, using the normal visual counting of all the insects which were stabilized at the chambers and been calmed enough to be counted easily .However, the weekly tests were prepared after cleaning the Pentadevice Arena and new insects and baits were used and same conditions .The test of attractiveness was replicated five times for obtaining the average of the records.

2. *Measuring the Palatability*

The palatability was measured (Gordon, 1967, Cochran, 1983) and the same Peanut butter foods used for measuring the attractiveness were used also to determine the daily food consumption or intake per milligram of weight by the cockroaches. The weight of the tested foods were

measured and recorded to the nearest 0.001 mg .Weighing measures were continued every day, at the same time, for the period of five days.

3. *Measuring the Biting effects*

The third measuring method of feeding behavior is the *biting effects*. The purpose of this test is to confirm the attractiveness and verify how the German cockroach could react physically at the food. They can be expressed with bite marks or scars caused by mandibular scratching of the insect's mouthpart (Sakuma et al, 1996; Tsuji, 1966, 1965*).* The Five strips of the tested foods were placed under microscope then marks of biting resulting from feeding behavior were measured .The size and counts of the bite marks were calibrated by adopting measuring criteria such as follows: very small mark (<3 mm) ,small (3-4 mm) medium (4 - 5 mm) and large mark (>5 mm).The Four determined by a microscope using appropriate magnifications. The four of marks sizes were converted into numerical data, using the degree of 3 for large (l), 2 for medium (m) 1 for small (s) and 0.5 for very small mark (vs.).The selected locations on the surface of the tested food strip .The regions of the strips examined were: upper side right, upper side left, lower side right, lower side left and topside. The measuring of biting effects was conducted at the end of the test period, after five days also the test was repeated for each of the five then the average, from data obtained, was calculated.

Experiment conditions

All trials were carried out, at temperature of 27$\pm$ 2(^{O}C), Relative humidity, RH of50% $\pm$5) and the light/dark durations (L/D) were 14/10.

Statistical analysis

Data collected from the records of the five replicates (5 weeks) were subjected to statistical analysis to determine whether there are significant differences of the feeding behavior of the tested German cockroaches towards the foods. The test used was the Analysis of Variance, ANOVA. SPSS, software of was used to conduct the analysis (Landau and Everitt, 2004).

3. Results

1. *Measuring the attractiveness*

After 10 minutes of the release of the 50 cockroaches at the center of the arena the visual counting was conducted for the number of cockroaches found inside each chamber of the five Pentadevice Arena Chambers **.**The results of the counts of insects per chamber of each food were shown in Table (1).

The present data represented averages of the five replicates (Table 2). Both PNB food 3 & 4, received the high mean of cockroaches, inside chambers 8.6 and 10.3 respectively in comparison to the other three PNB foods.

Table (1) *Counts of German cockroach found inside chamber of Pentadevice Arena after 10 minutes of release*

Peanut butter foods	Means of 5 replicate daily count of insect per chamber					Total
	DAY 1	DAY2	DAY 3	DAY 4	DAY 5	
PNB Food 1	5.8	5.4	6.4	6	7.5	31.1
PNB Food 2	7.8	6.6	7	4.8	8.2	34.4
PNB Food 3	11.5	6.4	8.4	9.2	7.6	43.1
PNB Food 4	12	10.8	8.7	10.4	9.6	51.5
PNB Food 5	6.6	7	8.2	5.8	4	31.6

Table (2) *Descriptive statistic of counts of German cockroach per chamber*

Peanut butter foods					95% Confidence Interval for Mean	
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound
PNB Food 1	6	6.4833	.96419	.39363	5.4715	7.4952
PNB Food 2	4	6.6500	1.40831	.70415	4.4091	8.8909
PNB Food 3	5	8.6200	1.91364	.85580	6.2439	10.9961
PNB Food 4	5	10.3000	1.24499	.55678	8.7541	11.8459
PNB Food 5	5	6.3200	1.55949	.69742	4.3836	8.2564
Total	25	7.6680	2.06150	.41230	6.8171	8.5189

The data were subjected to statistical analysis; using one-way ANOVA. Levene gave results of significance of0.792 indicating of no homogeneity. The attractiveness behaviour of the tested cockroaches towards the five foods is significant results i.e. (means of the cockroaches count per chamber is different). Using Anova between groups gave (mean Ms: F = 7.86, significant result of 0.01 at P value (0.05)) .Multiple comparison, LSD comparison shows that at P-value of (0.05) the PNB food 3 and 4 with significant results and the clear variation of the two Peanut foods (3 and 4), 14 significant records from total of 20 (4*5).

2. *Measuring the Palatability*

The weighing of the foods was conducted every day and continued for five days for every replicate so as to calculate the consumption from each food .Then obtained data were collected and averages of weighs were calculated for each PNB food. The data of results were subjected to statistical analysis for determining the variations and clarified the most food with higher consumption. The means values of the five replicates of effects of palatability are illustrated in Table (3).

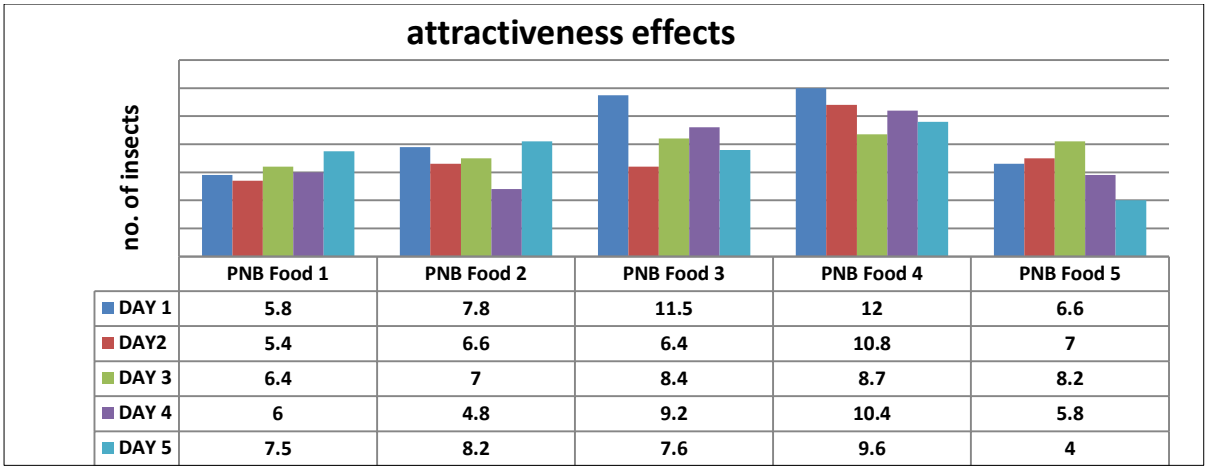


***Fig (1)**: diagram showed the attractiveness effects of German cockroaches towards the five PNBs; the average numbers of insects on the columns (represent the days).*

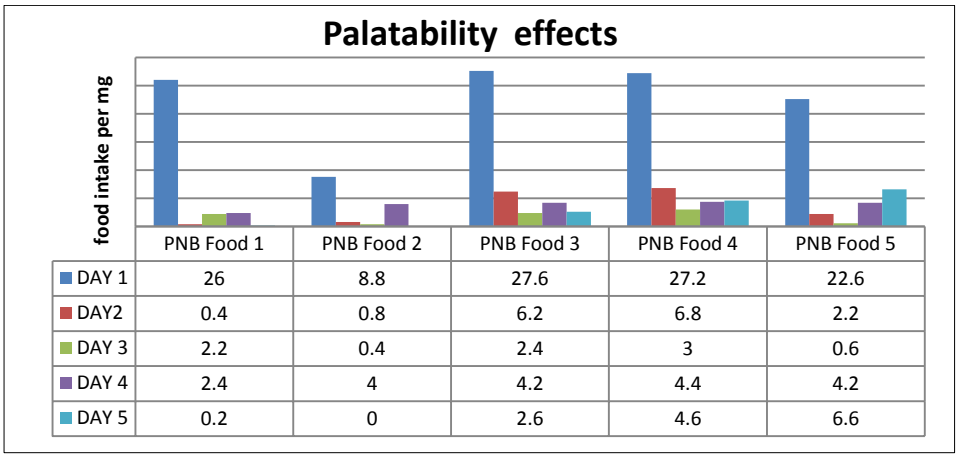
Table (3) *showing data of intake per mg German cockroach*

Peanut butter foods	Available per mg	Means of 5 replicate daily intake per mg per chamber					
		DAY 1	DAY2	DAY 3	DAY 4	DAY 5	TOTAL
PNB Food 1	200	26	0.4	2.2	2.4	0.2	31.2
PNB Food 2	200	8.8	0.8	0.4	4	0	14
PNB Food 3	200	27.6	6.2	2.4	4.2	2.6	43
PNB Food 4	200	27.2	6.8	3	4.4	4.6	46
PNB Food 5	200	22.6	2.2	0.6	4.2	6.6	36.2

The highest mean of intake was registered by PNB food 4 which showed consumption of 9.2 mg, the second in consumption was the PNB food 3 which showed 8.6 mg, as shown in Table (4) and Fig (2).

Table (4) *statistical Descriptive showed the Palatability effects to the five foods*

Peanut butter foods					95% Confidence Interval for Mean	
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound
PNB Food 1	5	6.2400	11.09180	4.96040	-7.5323	20.0123
PNB Food 2	5	2.8000	3.70945	1.65892	-1.8059	7.4059
PNB Food 3	5	8.6000	10.73033	4.79875	-4.7235	21.9235
PNB Food 4	5	9.2000	10.15382	4.54093	-3.4076	21.8076
PNB Food 5	5	7.2400	8.87513	3.96908	-3.7799	18.2599
Total	25	6.8160	8.80983	1.76197	3.1795	10.4525



	PNB Food 1	PNB Food 2	PNB Food 3	PNB Food 4	PNB Food 5
DAY 1	26	8.8	27.6	27.2	22.6
DAY2	0.4	0.8	6.2	6.8	2.2
DAY 3	2.2	0.4	2.4	3	0.6
DAY 4	2.4	4	4.2	4.4	4.2
DAY 5	0.2	0	2.6	4.6	6.6

***Fig (2)**: Diagram showed the palatability effects of the German cockroach's .Notice the highest intake per mg at first day and declining of the intake in next days of PNB food 1 and 2 but both PNB food 3 and 4 showed the highest result relatively.*

The statistical analysis of the homogeneity, Levene statistics showed no significant result, or difference 0.633. However, the ANOVA also showed no significant result of 0.829 at F=0.367. All these results were built on P-value of 0.05. When conducting the multiple comparisons of post hoc tests, the results of LSD test showed the variations of the effects of palatability of the German cockroaches towards the five types of foods. The table illustrated multiple tests that showed many values of no significance between the values of the five PNF foods.

3. *Measuring the biting effects*

The results of effects of bite marks caused by German cockroaches on the tested PNB food showed in Table (5) and Figure (3).Analysis of variance (ANOVA) conducted, illustrated significant difference between the groups (0.046) at p-value of 0.05 and *F*= 2.941. When conducting the multiple comparisons of post hoc tests, the results of LSD tests showed the variations between the five food samples .The comparison showed that PNB food 3 with food 2 (sig.0.021), food 3 with food 5 (sig.0.019), food 4 with food 2 (sig.0.033) and food 4 with food 2 (sig.0.030). Ranking of the five PNB foods according to the variability or homogeneity caused by the biting effects was conducted using Duncan test. The PNB Food 3 (8.6) then food 4 (8.1) were the most affected by biting as shown in Figure (3).

Discussion

The new Pentadevice Arena made from fiberglass and laminated with odourless white paint is characterized by some advantages that contributed well in the experiment such as: (1) the even distribution of the five chambers of Pentadevice Arena, (37.7 cm distance

Plate (3) *showed the food bands after the end of the replicate, the effects of intake and biting is noticed*

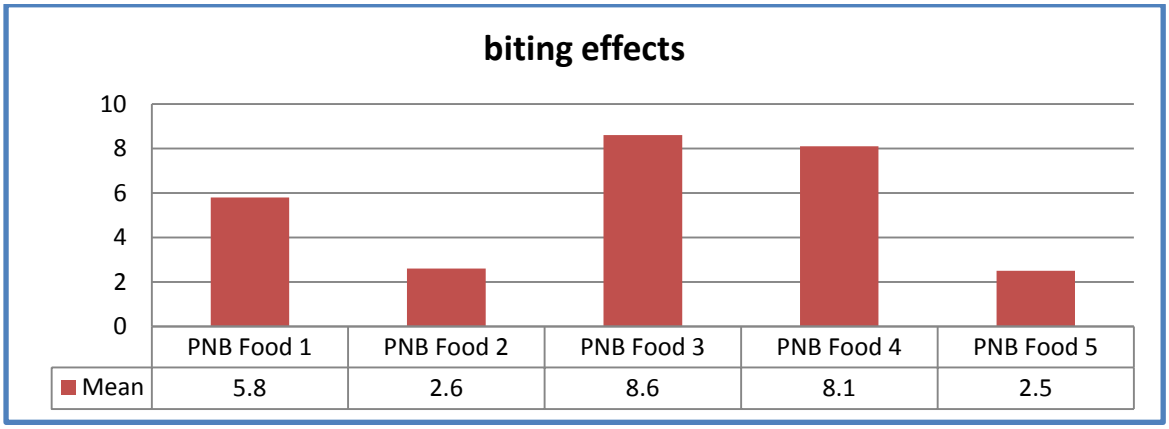


Figure (3)*: showed the average of biting effects notice here the effects on the PNB 3&4*

Table (5): *Analysis the bites effects after conversion to numerical data*

Peanut butter foods					95% Confidence Interval for Mean	
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound
PNB Food 1	5	5.8000	5.05717	2.26164	-.4793	12.0793
PNB Food 2	5	2.6000	.41833	.18708	2.0806	3.1194
PNB Food 3	5	8.6000	5.37820	2.40520	1.9221	15.2779
PNB Food 4	5	8.1000	3.91152	1.74929	3.2432	12.9568
PNB Food 5	5	2.5000	1.41421	.63246	.7440	4.2560
Total	25	5.5200	4.36482	.87296	3.7183	7.3217

between each chamber) prevented the bias among the insects for choosing the nearest chamber, as the release was at the center of the arena. (2) the sealed closed

chambers and presence of tunnel (20 mm cylinder) between the arena and chambers enhance the insect to enter because the cockroaches prefer the microhabitats areas (Schal and Hamilton, 1990). (3)The circular shape of the arena device has properties that it prevents the cockroaches to resort for rest, close to walls, so it encourages the insects to walk towards the chambers. Cockroaches are intended to go to corners in condition of Oblong-like arena. In fact, cockroaches are able to locate the position of their shelter or of a spatially stable food source with visual landmarks (Dabouineau and Rivault 1995; Rivault and Dabouineau 1996; Durier and Rivault 2000). However, this new Pentadevice arena might work as an olfactometer device because one resemblance which is flow of wind that may occur when the sealing of chambers conducted to allow the cockroaches to respond to the attractant by olfaction.

The susceptible laboratory strain of *Blattella germanica* obtained from Pest control section laboratories of Dubai Municipality, which has been reared since 2005, was the only strain used for the present laboratory trials. The tested Peanut Butter foods for attractiveness were denoted by PNB .Five PNB types of foods have been screened so as to match with the new Pentadevice Arena and also to avoid some repellency that may elicit in the attractiveness of cockroaches. However, the non-attractiveness of Peanut Butter results shown by Rust and Reierson (1981) was due to differences in cockroach's strains, lure formulations and in methodology for evaluating the attractants (Nalyanya and Schal, 2001). So the selection of one strain type of cockroaches and adoption of three different methods in addition to selection of five types of foods belonging to one source (Peanut butter) was a trial to obtain better evaluation.

Allowance of ten minutes for insects to move and enter the five chambers was adequate time to give all stages of the 50 German cockroaches the opportunity to a short acclimatization for the new environment of the Pentadevice arena. Also the period allowed induction and activation of the phagostimulant behavior for the cockroaches to be oriented towards the source of foods. The tendency of German cockroach to shelter preference also justified the moving of the insects towards the chambers.

Both PNB foods 3 and food 4, were the most significant attractive to the cockroaches due to the presence of high numbers (8.6 and 10.3 respectively), of insects inside their chambers in respect to the other three chambers. Walking of the insects towards a chamber was probably enforced by the tracking of the magnitude of odour coming from the chamber (Willis and Avondet, 2004). The contents of both PNB 3and 4 foods elicit and might consist some attractive ingredients enhance the cockroach pulling mechanism. Odour effects of the foods increased the mechanism of cockroaches to be pulled towards foods in the shelters. Shelter selection was greatly influenced by the presence of repellents and attractants (Nalyanya et al, 2000). But behaviorally, cockroaches, in many times, choose feces-contaminated or neutral untreated shelters and avoid some substances like neodecanamide (Nalyanya et al, 2000). Sometimes attractants and arrestants, presumably components of the aggregation pheromone (Sakuma et al, 1997) lured cockroaches towards specific areas.

In the current trial the observed attractiveness of the Peanut butter might

be due to ingredients such as *β-sitosterol* (Awad et al, 2000) .The *β-sitosterol* is a steroid glycoside and is considered as the mother compound that can convert, synthetically, to 7 successive compounds to produce *blattellastanoside* which is considered as the arrestant component of the aggregation pheromone(Kenji 1993). However, the discovery of the arrestant component which contributes to the effects of the aggregation pheromone to attract cockroaches was the efforts of Sakuma and Fukami (1990) .However; Karimifar (2009) elaborated olfactometer experiment and proved that 1-hexanol is an attractive extract to German cockroaches. Kells and Bennett (1998) confirmed the distance-related behavioral pattern, during food foraging and diet selection. Other factors affecting the consumption of the bait, is the gender or the reproductive status of adults. The ootheca-bearing females are slow in feeding because of physiological effects but the adult males are known to be active foragers. Rhythms of food intake are related to sexual cycles in females, gravid females do not eat (Cochran, 1983).

There is a need to distinguish attractiveness from feeding stimulation, according to Dethier *et al.*(1960) Attractiveness was measured by first choice whereas feeding stimulation was measured by duration of feeding on each type of food (Rivault, 1999). The first food eaten was considered to be the most attractive, whereas the longest feeding durations were observed on the most stimulating food sources (Tsuji, 1965, 1966).

When measuring the palatability the present study, it is noticed that the highest intake per mg was registered by PNB food 4 (9.2), then PNB food 3 (8.6). This result, confirmed the findings of Tsuji (1965, 1966) and Rivault (1999) about both attractiveness and feeding stimulation (palatability).But according to Tsuji (1965, 1966), only a few of the compounds are found to be attractive and also feeding stimulants. Other are feeding stimulants for German cockroaches but are not attractive .The attractive effects of rice bran extract was due to its neutral fraction whereas the feeding stimulant effect was attributed to both the neutral and acidic fractions (Rivault, 1999).

The data of the present results of the five replicates indicated that the feeding intake for each food was high at the first day but declined for the other days .The reasons of this might be attributed to: (1) the insects fed to satiation. (2) the elicit of repellency occurred due to minimizing of the moisture from the available foods(Silverman and Bieman 1993). However, maximizing attraction and first-time consumption of a bait prevent a sub-lethal dose and delay (or avoid) bait aversion of products thus PNB food be used for bait purposes (S.Kells, 2005). In fact, the depriving of food affects feeding behavior according to Gelperin (1971) and Barton Brown (1975). Thus enhancement in activity might indicate that starvation modulated the gustatory sense which affects the feeding stimulancy accordingly. Gustatory sensation that is elevated by starvation causes the increase in food consumption of the German cockroach (Van Herrewege, 1974).Nutritional demand will depend internally on cockroach age, sex, and stage of development and externally on what nutrients are available (Kells, 2005).

However, all the five tested PNB food have a relatively high fat content (> 40%), German cockroaches in the field consume less protein and carbohydrates, and more

fat compared to those provided a standard laboratory diet such as rodent chow (Kells et al, 1998).

The declining of the consumption for some PNB foods might be attributed to many factors such as presence of sugar, that may cause aversion for the cockroach and minimize the feeding stimulancy (Silverman and Bieman 1993) .This is in addition to the reason of the roasting effects, due to presence of some ingredients that cause repellency and un palatability for the insect to feed.

The biting effects were adopted as confirmation method for the attractiveness and the palatability. High bite marks (mouth mandibular effects) caused by German cockroaches on the PNB food 3 and food 4 strips, were observed. However, Duncan test, confirmed that PNB food 3 then PNB food 4 were the most significantly affected by biting. Such method was adopted by Tsuji (1966) and Nojima et al(1996). Starving the insects (one insect), using small plastic cup of the bottom arena of 5.5 cm and then putting a frass-contaminated filter paper, containing an aggregation pheromone was adopted by Tsuji (1966) to clear the biting effects was the first to use this feeding assay .But Nojima et al (1996) developed Tsuji trial and used PEG film media instead of filter paper. The scars of biting were clear enough to register results even in satiated insects; the biting response was detectable .In these trials one depended on shaping strips of Peanut food itself and allowing many insects to respond. However, the biting effects were clearly detected. The biting marks are clear to be detectable when using the microscope for measuring the effects. In Nojima et al (1996) trial they examined some other materials such as sugars, polyols, oleyl alcohol and capric acid and checked their response towards the German cockroaches'.

Peanut butter food 4 (studied previously in chapter 2) demonstrated relatively high attractiveness performance for German cockroaches, when used amongst different peanut butter types. However; significant results of Karimifar et al (2009) showed same attractiveness

Conclusion

This research determined the feeding behaviour of German cockroaches towards five types of peanut butters using the Pentadevice Arena .The relative different responses of insects towards the PNB foods were clear and a highest attractiveness towards the Peanut butter 4 (Sudanese PNB was recorded NP attractiveness was confirmed by measuring the food intake the biting effects .The efficacy of the attractiveness using the new Pentadevice arena may encourage other researchers to conduct same trial for other insects and other types of foods .

Recommendations

1. The results of the attractiveness and palatability of the German cockroaches to the five peanut butters should encourage future researches to conduct more trials using these substances.
2. The attractant ingredients, inside the Peanut butter, should be separated and extracted to be implicated into the formulation of the new baits.
3. Developing the biting effects method, using modern method, should be continued to access highly advanced type of evaluation and measuring of the insect behaviours.

References

Awad A.B., Chan K.C., Downie A.C.and Fink CS (2000). Peanuts as a source of beta-sitosterol, a sterol with anticancer properties. Department of Physical Therapy, exercise, and nutrition sciences, State University of New York, Buffalo 14214, USA. awad@acsu.buffalo.edu.

Ballard, J. B., and R. E. Gold. (1982). The effect of selected baits on the efficacy of a sticky trap in the evaluation of German cockroach populations. J. Kans. Entomol. Soc. 55: 86-90.

Barcay, *S.J., B.M. Schneider and G.W. Bennett (1990).* *Influence of insecticide treatment on German cockroach (Dictyoptera: Blattellidae) movement and dispersal within apartments. J. Econ Entomol. 83 (1): 142-147.*

Brenner, R.J. and Patterson, R.S. (1989). Laboratory feeding activity and bait preferences of four species of cockroaches (Orthoptera: Blattaria). J. Econ. Entomol. 82: 1, 159-162.

Barton Browne, L. (1975). Regulatory mechanism in insect feeding .Adv. Insect Physiol.11:1-116.

Cochran, D. G. (1983). Food and water consumption during the reproductive cycle of female German cockroaches. Entomol. Exp. Appl. 34: 51-57.

Dabouineau, L. and C. Rivault (1995). Ontogenetic development of spatial orientation in first- and second-instar cockroach larvae (*Blattella germanica* (L.), Dictyoptera). Ethology 101: 148-159.

Dethier, V. G., L .B. Browse and C. N. Smith (1960). The designation of chemicals in terms of the responses they elicit from insects. J. Econ. Entomol. 53: 134-136.

Durier, V. and Rivault C. (2000). Learning and foraging efficiency German cockroaches, *Blattella germanica* (L.) (Insecta: Dictyoptera). Anim. Cogn. 3: 139-145.

Gelbrin, A.(1971). Regulation of feeding. Ann.Rev.Entomol. 16: 365-378.

Gordon, H.T. (1967). Intake rates of various solid carbohydrates by male German cockroaches Journal of Insect Physiology,Vol. 14, Issue 1, : pages 41-52.

Gould,Elaine M. Selena J. Holmes; Grant W. Tempero(2007). The potential of an insect pheromone lure, Z-7-dodecen-1-yl acetate, compared with peanut butter to attract laboratory and wild rats and mice .New Zealand Journal of Zoology (January 2007), 34 (4), pg. 363-369 .

Karimifar, Nooshin (2009). Semiochemical based food in German cockroaches foraging, *Blattella germanica*, M.P.M Thesis, Dep. of biological sciences, Simon Fraser University.

Karimifar, N, Regine Gries, GrigoriKhaskin, and Gerhard Gries. (2011). General Food Semiochemical Attract Omnivorous German Cockroaches, *Blattella germanica*. Publication Date (Web): January 18, 2011Copyright © 2011 American Chemical Society.

Kells, S.A. , James T. Vogt b, Arthur G. Appel b. and Gary W. Bennet (1998). Estimating nutritional status of German cockroaches, *Blattella germanica* (L.) (Dictyoptera: Blattellidae), in the field.

Kenji, Mori and Kunio Fukamatsu(1993). Synthesisof Blattellastanoside A, the aggregation pheromone of a steroid Qiucoside isolated as the German cockroach Department of Agricultural Chemistry, The University of

Tokyo,1-1-1 Yayoi, Bunkyo-ku, Tokyo 113.

Landau, Sabine and B.S. Everitt (2004).A Handbook of Statistical Analysis Sing SPSS, Chapman &Hall/CRC Press Company.

Landolt, P. J., R. R. Heath, J. G. Millar, K. M. Davis-Hernandez, B. D. Dueben, and K. E. Ward. (1997). Effects of host plant, *Gossypiumhirsutum*L., on sexual attraction of cabbage looper moths, *Trichoplusiani*(Hu¨ bner) (Lepidoptera:Noctuidae). J. Chem. Ecol. 20: 2959-2974.

Lawson, F. A. (1951). Structural features of the oothecae of certain cockroaches (Orthoptera). *Ann. Ent.*

Liang, D. & Schal, C. (1993). Volatile sex pheromone in the female German cockroach. *Experientia*, 49**,** 324-328.

Liang, D., A. Zhang, R. J. Kopanic, Jr., W. L. Roelofs, and C. Schal. (1998). Field and laboratory evaluation of female sex pheromone for detection, monitoring, and management of brown banded cockroaches (Dictyoptera: Blatellidae).J. Econ. Entomol. 91: 480-485.

Nalyanya G. and C. Schal, (2001). Evaluation of attractants for monitoring populations of the German cockroach (Dictyoptera: Blatellidae) J. Econ. Entomol. 94(1): 208-214.

Nalyanya, G., C. B. Moore, and C. Schal. (2000). Integration of repellents, attractants and insecticides in a "push-pull "strategy to control the German cockroach (Dictyoptera: Blatellidae). J. Med. Entomol. 37: 427-434.

Nojima, S., Masayuki Sakuma and YasumasKuwahara (1996). Polyethylene glycol film method: a test for feeding stimulants of German cockroach, *Blattella germanica* (l.)(Dictyoptera: Blatellidae) Pesticide Research Institute, Faculty of Agriculture, Kyoto University, Kitashirakawa, Sakyo-Ku 606-01, Japan. App.Entoml.Zool.31 (4)537-546.

O'Brien, R. D. (1998). Fats and oils formulating and processing for applications. Technomic Publishing Co., Inc. Lancaster-USA.

Owens, J. M. & G. W. Bennett (1982). "German cockroach movement within and between urban apartments." J. Econ. Entomol. 75: 570-573.

Owens, J. M., and G. W. Bennett. (1983). Comparative study of German cockroach population sampling techniques. Environ. Entomol. 12: 1040-1046.

Pandey,K.S. , Shriprakash, K. M. Rao and R. Vaidyanathaswamy, (1994). Tetrahydropyran esters as new attractants for cockroaches. Biosci. Biotech. Biochem. 58: 647-651.

Pandey, K.S., Shriprakash, K. M. Rao and R. Vaidyanathaswamy, (1995). Synthesis and bioevaluation of alicyclic and heterocyclic alkanoates as cockroach attractants. Biosci. Biotech. Biochem. 59: 725-727.

Reierson, D., and M. Rust. (1977). Trapping, flushing, counting German roaches. Pest Control 10: 41-45

Rivault, C., and L. Dabouineau (1996). Weighting of different orientation sources in conflict experiments in *Blattella germanica* (L.), Dictyoptera: Blatellidae. Anim. Learn. Behav. 24: 318-326.

Rivault C. and Durier, V. (1999). Food bait preference in German cockroach,*Blattella Germanica* (L.) (Dictyoptera: Blatellidae).Ethologie-Evolution-Ecologie, Université de Rennes 1-CNRS, Campus de Beaulieu, Avenue

du Général Leclerc 35042 Rennes Cédex, France.

Rivault, C. and A. Cloarec. (2001). Food Bait Preference In German Cockroach, *Blattella germanica* entomology.

Rust, M. K., and Reierson D. A. (1977a). Increasing blatticidal efficacy with aggregation pheromone. J. Econ. Entomol 70: 693-696.

Rust, M. K., and Reierson D. A. (1977b). Using pheromone extract to reduce repellency of blatticides. J. Econ. Entomol. 70: 34-38.

Rust, M. K., and Reierson D. A. (1981). Attraction and performance of insecticidal baits for German cockroach control. Int. Pest Control 23: 106-109.

Sakuma, M., and H. Fukami. (1990). The aggregation pheromone of the German cockroach, *Blattella germanica* (L.) (Dictyoptera: Blatellidae): isolation and identification of the attractant components of the pheromone. Appl. Entomol. Zool. 25: 355-368.

Sakuma, M., H. Fukami, and Y. Kuwahara (1996a). Aggregation pheromone of the German cockroach, *Blattella germanica* (L.) (Dictyoptera: Blattellidae): Controlled release of attractant amines by salt formation. Appl. Entomol. Zool. 32: 143-152.

Sakuma, M., H. Fukami, and Y. Kuwahara. (1996b). Attractiveness of alkyl amines and amino alcohols related to the aggregation attractant pheromone of the German cockroach, *Blattella germanica* (L.) (Dictyoptera: Blattellidae). Appl. Entomol. Zool. 32: 197-205.

Schal, C., and R. Hamilton (1990). Integrated suppression of synanthropic cockroaches. Annu. Rev. Entomol. 35: 521-551.

Scharf, M. E., B. L. Reid, and G. W. Bennett, (1994). Efficacy of sticky trap attractants. Arthropod Manage. Tests 19:362.

Silverman, J. and D.N. Bieman (1993). Glucose aversion in the German cockroach, *Blattella germanica*. J. Insect. Physiol. 39: 925 933.

Sugawara, R., S. Kurihara, and T. Muto (1975). Attraction of the German cockroach to cyclohexylalkanoates and *n*alkylcyclohexaneacetates. J. Insect Physiol. 21: 957- 964.

Tsuji, H. (1965). Studies on the behavior pattern of feeding of three species of cockroaches, *Blattella germanica* (L.), *Periplaneta americana*L. and *Periplaneta fuliginosa* S. with special reference to their responses to some constituents of rice bran and some carbohydrates. Japanese J. Sanit. Zool. 16: 255-262.

Tsuji, H. (1966). Attractive and feeding stimulative effect of some fatty acids and related compounds on three species of cockroaches. Japanese J. Sanit. Zool. 17: 89-97.

Van Herrewege, C. (1974). Regulation of food consumption under various alimentary conditions, after a period of starvation by the German by the German cockroaches. Entomologia Experimentalis et Applicata 17, 234–244.

Wileyto, E. P., and Boush G. M. (1983). Attraction of German cockroach *Blattellagermanica*(Orthoptera: Blatellidae), to some volatile food components. J. Econ. Entomol. 76: 752-756

Willis, M. A. and Avondet J. L. (2004). Odor-modulated orientation in walking male cockroaches *Periplaneta americana*, and the effects of odor plumes of different structure. J ExpBiol 208:721–735

Woodruff, L.C. (1938). Observation on cockroach reproduction .J. Kansas Ent.Soc. 11(3):94-96.

Yamamoto, I. (1996). Neonicotinoids-mode of action and selectivity. *Agrochemical Japan* 68: 1-14.