

Improving the efficiency of two local baits used for the control of the German cockroach, *Blattella germanica* (L.), (Dictyoptera: Blattellidae)

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Abstract: Two mixtures (ethanol extract of taro plant leaves + roasted peanut, coriander oil, fresh coriander leaves, fresh zucchini fruit and cockroach faeces at ratio of 1:1:1:1:0.1, respectively, and ethanol extract of taro plant leaves + peppermint oil at ratio(1:1) were added to two commercial cockroach baits (Siko Biko and Ixon) and evaluated against a dulst of the German cockroach, *Blattella germanica* (L.) under laboratory conditions. The efficacy of the tested baits was conducted through two different bioassays, no-choice and choice assays. The choice assay considered the effect of alternative food (white bread) on efficacy of the baits. The bioassays also considered the effects of ageing the baits for seven days on their effectiveness. All the assays were conducted in special glass arenas (45 × 25 × 25 cm). Results showed a significant increase in the attractiveness and efficacy of the improved baits against adult males and females. Baits mixed with the 1st mixture were significantly more efficient than baits mixed with the 2nd mixture. All tested baits attracted and killed more males than females. Ageing of the original and improved baits for seven days affected their attractiveness and efficacy, but the improved baits were more effective against the tested cockroaches than the original baits.

Keywords: efficiency, local baits, German cockroach control

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I. Introduction

Cockroaches are found in houses, hospitals, food service establishments, warehouses, offices, storage areas and restaurants and remain one of the most economically and medically important pests (Shariffard *et al.* (2016). Poisoned baits have largely displaced other methods for controlling German cockroaches (Anaclerio & Molinari 2012). In comparison with residual sprays, baits are target specific and allow easy application; thus, they are recognized as a safer alternative than liquid sprays (Tee & Lee 2014). Baits also have advantages of long residual activity and less environmental pollution, so they can be selectively used in sensitive areas, such as premises used for the preparation of food, hospitals and kindergartens (Gondhalekaret *et al.* 2011). When the active ingredient is incorporated into palatable bait, cockroaches readily consume a lethal dose from a single meal, which may prevent the development of physiological resistance through reducing exposure to sub lethal doses of insecticides (Zhu *et al.* 2016).

A number of important factors are critical in developing baits and baiting systems such as a suitable active ingredient, a readily acceptable bait matrix and an understanding of the biology of the pest. It has been documented that cockroaches can develop bait aversion to inert ingredients in the bait base after extensive use of baits and the bait base must be modified to maintain its effectiveness. Bait manufacturers can counter the control failure problem by introducing new baits containing either different bait bases or different active ingredients (Silverman and Bieman 1993). Modifications of the inert ingredients in the Maxforce fipronil gel bait significantly improved its efficacy against the German cockroach which showed aversion behaviors to the original gel bait formulations (Wang *et al.* 2004). Ahmad & Suliyat (2011) found that mixing gel baits having the same amount of fipronil (0.03%) with different attractants (chicken liver, honey-banana, cow blood and cockroach faeces) influenced its efficiency against the German cockroach under laboratory conditions. When cockroach baits are placed close to harborage, they are usually in direct competition with other food and water resources. The disparities between the nutritional quality of baits and the foods that are naturally available could profoundly impact the management of German cockroach infestations (Koet *et al.*, 2016). Therefore, baits need to out-compete other sources of dry food as well as other moisture sources so cockroaches will consume them (Appel, 2003). The present study is a trial for improving the efficiency of two commercially local baits by adding safe natural products proved to be of attractive and/or toxic for the German cockroach in our laboratory.

II. MATERIALS AND METHODS

Tested insects and rearing technique:

Insecticide-susceptible strain of the German cockroaches, *Blattella germanica*, was reared under constant laboratory conditions of temperature and humidity (27 ± 2 °C and $65 \pm 5\%$ RH). Wooden frames ($50 \times 30 \times 30$ cm) (with a glass upper side) covered with muslin were used as rearing cages. Each cage was provided with corrugated papers for shelter. The insects were provided with an unlimited supply of food (white bread) and water (pieces of cotton soaked with water) (Durier and Rivault, 2000).

Tested baits

Two baits (SikoBiko and Ixon) were purchased from local distributors. SikoBiko bait is manufactured by Top Bottling Company and detergent trade. Kilo 22 (Egypt Alex Agricultural, road -Sndion -Qalioub-Qaliobia), while Ixon (47% boric acid) is manufactured by MisrDetergents, Egypt.

Attractiveness of the tested fresh baits:

Attractiveness was conducted in glass arenas ($45 \times 25 \times 25$ cm), with upper side screened with perforated plastic sheet to avoid insect escaping, according to the method of Anaclerio and Molinari (2012). Two shelters made of cardboard egg carton were placed in two opposite corners inside the test arena, and insects (adult males or un-gravid females) were left 24 hours in the arena to adapt before the bioassay was carried out. To ensure that introduced cockroaches would remain in this shelters rather than aggregation elsewhere in the arena the egg carton was placed in the cockroach colony for 7 days, a procedure that results in the deposition of aggregation pheromone on the egg carton (Ishii, 1970 and Buczkowskiet al., 2001). To verify the attractiveness of the bait, a drop of it (~0.2 g) was placed in the middle of a cardboard sticky trap (7.5×7.5 cm cardboard covered with rat glue) located in the center of the arena. An empty sticky trap was used as control in separated replicates (in each bioassay only one sticky trap was put in the arena). The assessment of the catches was carried out after 5 days. Three replicates were carried out for each product, for each sex and for the control (20 individuals /arena) in conditions that were the same as rearing.

Efficacy of the tested fresh baits: Efficacy trials were conducted in the test arenas according to a modified method of Wang et al., (2004) under conditions that were the same as rearing. Twenty adult male and twenty adult female cockroaches were counted and placed in separate arenas. Cockroaches were acclimated in the arenas for one day before bait introduction with a piece of cotton soaked with water on one side of the arena and a harborage made of a piece of cardboard egg carton at the opposite end. After the acclimation period, two bioassay techniques were accomplished: -**No-choice experiments:**

One gram of the bait was placed on a glass slide and introduced at the arena side opposite the harborage. The control arena was provided with white bread only. Three replicates were carried out for each treatment. Mortality of cockroaches was checked after 7 days. Cockroaches were considered dead if they could not run away when flipped over with a pair of forceps.

Choice experiments:

This bioassay design considered the effect of alternative (competitive) food source (white bread) on baits efficacy. One gram of the bait was placed on a glass slide and introduced at the arena side opposite the harborage. Each arena also received one gram of white bread as alternative food. The control arena was provided with white bread only. Three replicates were carried out for each treatment. Mortality of cockroaches was checked after 7 days.

Effect of aging of baits on its effectiveness: Aging of baits was conducted according to a modified method of Nalyanyaet al., (2001); about 1 gm of each bait was placed on a glass slid and left for 7 days at 27 ± 2 °C and $65 \pm 5\%$ RH. The toxicity and attractiveness of the aged baits were repeated as the same of fresh baits.

Improving the effectiveness of the selected baits: Improvement of baits effectiveness against adult male and female of *B. germanica* was carried out by adding two different mixtures to each bait separately. The first mixture (FM) composed of 4% of taro plant leaves crude ethanol extract + 5% of the attractive mixture (1:1:1:1:0.1 of coriander oil, crushed roasted peanut, fresh crushed coriander leaves, fresh crushed zucchini fruits and cockroaches feces, respectively), while the second mixture (SM) contained 4% of taro plant leaves crude ethanol extract + 0.1% of peppermint oil/ total weight of each bait. After adding one of the two mixtures, toxicity and attractiveness of the four new baits (SikoBiko + FM, SikoBiko + SM, Ixon + FM and Ixon + SM) were re-tested as described before in the form of fresh baits and after aging for seven days.

Statistical analysis:

The statistical significance of differences between individual means was analyzed with using SPSS statistical analysis one way (ANOVA, version 20-32bit) program followed by Duncan's test. The LT₅₀ values were obtained by LT₅₀ program (version 6.0.0).

III. RESULTS

Improving the efficiency of Siko Biko baits against adult male and female of *B. germanica*:

Before and after addition of the two mixtures, attractiveness of adult male and female cockroaches to SikoBiko bait is shown in Table (1).

The addition of the first or second mixture to SikoBiko bait significantly increased its attractiveness. SikoBiko baits mixed with the first mixture attracted significantly more insects than baits mixed with the second mixture. The cumulative attractiveness after five days of original SikoBiko was 36.65% and 26.6% for males and females, respectively, while it increased to 88.33% and 80.0% and to 76.6% and 66.6% for males and females when combined with the first and second mixtures, respectively.

Results also showed that aging of baits for seven days decreased its attractiveness to both sexes. Addition of the 1st or the 2nd mixture resulted in a significant increase in SikoBiko attractiveness to both sexes. The greatest cumulative attractiveness after five days was achieved for males fed SikoBiko mixed with the first mixture (63.66%), while addition of the second mixture attracted 30.0% of the tested males. The percentage attractiveness of SikoBiko bait mixed with the first mixture to females was 43.33%, while it was 10.0% and 35.0% for original SikoBiko bait and SikoBiko bait mixed with the second mixture, respectively.

Table 1: Comparative attractiveness of improved and original SikoBiko baits against adults of *B. germanica* after the investigation period (5 days) days at 27 ± 2 °C and 65 ± 5% RH.

Baits	Attractiveness (mean% ± SE)			
	Fresh baits		Aged baits	
	♂	♀	♂	♀
SikoBiko	36.6 ± 0.6 ^b	26.6 ± 0.3 ^c	16.6 ± 0.3 ^c	10.0 ± 0.5 ^c
SikoBiko + **	80.0 ± 1.1 ^a	66.6 ± 1.1 ^b	30.0 ± 0.5 ^b	35.0 ± 1.1 ^b
SikoBiko + *	88.3 ± 0.3 ^a	76.6 ± 0.8 ^a	63.6 ± 0.8 ^a	43.3 ± 0.8 ^a

N: 3 replicates for each treatment, percentage mortalities in the same column followed by the same superscript are not significantly different (ANOVA) followed by Duncan's test, p < 0.05.

** = Second mixture (4% taro plant ethanol extract + 0.1% peppermint oil).

* = First mixture (4% taro plant ethanol extract + 5% attractive mixture).

Attractive mixture = 1:1:1:1:0.1 of roasted peanut, coriander oil, fresh coriander leaves, fresh zucchini fruits and cockroach feces.

Comparative efficacy of improved and original SikoBiko baits in no-choice assay:

A synergistic action was obtained when SikoBiko baits were mixed with the 1st or 2nd mixture against adults of *B. germanica* in no-choice assay (Table, 2). Mortalities recorded for insects fed on the two new baits were significantly different compared to that of insects fed on original SikoBiko baits. The obtained data also indicated that SikoBiko baits mixed with the 1st mixture was significantly more toxic to both sexes than SikoBiko baits mixed with the 2nd one, and males were more susceptible than females. Fresh SikoBiko baits mixed with the 1st mixture was able to kill half of the tested males in less than one day (LT₅₀, 0.8). When tested as a mixture with original SikoBiko bait, the second mixture reduced its LT₅₀ value from 2.8 to 1.1 days for males and from 6.3 to 3.3 days for females.

Aging of baits for seven days reduced the toxicities of improved and original SikoBiko baits against the tested insects. Regarding the effect of the two mixtures on original aged SikoBiko baits, a significant increase in the toxicity of original aged SikoBiko baits was observed after adding the 1st or the 2nd mixture against both sexes. SikoBiko baits mixed with the 1st mixture recorded the lowest values of LT₅₀ (1.6 days) for males compared with that of SikoBiko baits mixed with the second mixture (4.5 days) and that of original SikoBiko (7.1 days). Females treated with SikoBiko baits mixed with the 1st mixture was 4.2 days and 6.7 days for females treated with SikoBiko bait mixed with the 2nd mixture.

Table (2): Comparative efficacy of improved and original SikoBiko baits against adults of *B. germanica* after the investigation period (7 days) at 27 ± 2 °C and 65 ± 5% RH inno-choice assays.

Baits	Fresh baits						Aged baits					
	♂			♀			♂			♀		
	Mortality % ± SE	LT ₅₀ (Days) ± SE	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days) ± SE	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days) ± SE	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days) ± SE	Slope ± SE
SikoBiko	83.3 ± 1.7 ^b	2.8 ± 0.1	7.2 ± 0.1	60.0 ± 1.1 ^c	6.3 ± 0.1	0.2 ± 0.3	33.3 ± 0.8 ^c	7.1 ± 1.2	0.5 ± 0.5	15.0 ± 0.5 ^c	8.3 ± 1.5	0.7 ± 0.5
SikoBiko + **	100 ^a	1.1 ± 0.1	5.1 ± 1.7	73.3 ± 0.3 ^b	4.7 ± 0.2	0.1 ± 0.1	73.3 ± 1.2 ^b	4.5 ± 0.0	8.6 ± 2.0	60.0 ± 0.5 ^a	6.7 ± 0.1	0.1 ± 1.4
SikoBiko + *	100 ^a	0.8 ± 1.3	3.6 ± 0.1	88.3 ± 0.6 ^a	0.2 ± 2.1	3.3 ± 1.0	93.3 ± 0.8 ^a	1.6 ± 0.0	6.3 ± 1.4	76.6 ± 0.8 ^a	4.2 ± 0.1	0.1 ± 0.0

N: 3 replicates for each treatment, percentage mortalities in the same column followed by the same superscript are not significantly different (ANOVA) followed by Duncan's test, p < 0.05.

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** = Second mixture (4% taro plant ethanol extract + 0.1%peppermint oil).

* = First mixture (4% taro plant ethanol extract + 5% attractive mixture).

Attractive mixture = 1:1:1:0.1 of roasted peanut, coriander oil, fresh coriander leaves, fresh zucchini fruits and cockroach feces

Comparative efficacy of improved and original SikoBiko baits in choice assay:

Regarding the effect of the two mixtures on the efficacy of fresh original SikoBiko bait against adult male and female cockroaches (Table, 3), a significant increase in the toxicity of original SikoBiko baits was observed against the tested insects.SikoBiko baits mixed with the 1st and 2nd mixtures killed 78.3% and 66.6% of the tested females. Both of the improved baits killed 100% of the tested males in less than seven days.

The results also showed reduction in LT₅₀ values of SikoBiko baits by adding either the 1st or 2nd mixture. SikoBiko baits mixed with the 1st mixture recorded the lowest LT₅₀ values (0.4 and 3.1 days for males and females, respectively) compared with the highest values observed for original SikoBiko baits (4.8 and 5.5 days for males and females, respectively).

Results of the efficacy of aged original and improved SikoBiko baits against the tested insects revealed that toxicity of SikoBiko bait was significantly increased by the addition of the 1st or the 2nd mixture for both sexes. According to LT₅₀ values, aged SikoBiko bait mixed with the 1st mixture was the most acceptable and the fastest working bait (2.4 and 4.8 days for males and females, respectively) compared with aged SikoBiko bait mixed with the 2nd mixture (5.8 and 6.8 days, respectively) and original aged SikoBiko bait (8.0 and 9.0 days, respectively).

Table (3): Comparative efficacy of improved and original SikoBiko baits against adults of *B. germanica* after the investigation period (7 days) at 27 ± 2 °C and 65 ± 5% RH in choice assays.

Baits	Fresh baits						Aged baits					
	♂			♀			♂			♀		
	Mortality % ± SE	LT ₅₀ (Days) ± SE	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days) ± SE	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days) ± SE	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days) ± SE	Slope ± SE
SikoBiko	76.6 ± 2.4 ^b	4.8 ± 0.2	0.1 ± 0.1	53.3 ± 2.4 ^c	5.5 ± 1.3	0.5 ± 0.5	26.6 ± 0.3 ^c	8.0 ± 1.5	0.8 ± 0.5	11.6 ± 0.3 ^c	9.0 ± 1.5	0.8 ± 0.4
SikoBiko + **	100 ^a	1.2 ± 1.1	0.0 ± 2.5	66.6 ± 1.2 ^b	4.9 ± 0.1	8.9 ± 3.4	51.6 ± 0.3 ^b	5.8 ± 1.2	0.5 ± 0.5	40.0 ± 0.5 ^b	6.8 ± 0.2	6.2 ± 0.4
SikoBiko + *	100 ^a	0.4 ± 0.1	3.3 ± 0.7	78.3 ± 0.3 ^a	3.1 ± 0.1	8.3 ± 1.4	76.6 ± 1.2 ^a	2.4 ± 0.4	7.1 ± 3.2	68.3 ± 0.6 ^a	4.8 ± 0.1	5.1 ± 0.1

N: 3 replicates for each treatment, percentage mortalities in the same column followed by the same superscript are not significantly different (ANOVA) followed by Duncan's test, p < 0.05.

** = Second mixture (4% taro plant ethanol extract + 0.1%peppermint oil).

* = First mixture (4% taro plant ethanol extract + 5% attractive mixture).

Attractive mixture = 1:1:1:1:0.1 of roasted peanut, coriander oil, fresh coriander leaves, fresh zucchini fruits and cockroach feces.

Attractiveness of improved and original Ixon baits:

It is noticed from data in Table (4) that the percentage attractiveness of fresh Ixon bait significantly increased after the addition of the 1st or 2nd mixture. Ixonbaits mixed with the 1st mixture were more attractive to the tested insects than Ixon baits mixed with the 2nd one. Attractiveness of the improved baits after 5 days were 55.0 and 43.3% for males and females, respectively) which was significantly more than that of original Ixon baits (28.3% and 8.3% for treated males and females, respectively).

In case of aged baits, the cumulative attractiveness of aged Ixon bait was very low where it attracted only 10.0% and 1.66% of males and females, respectively). Ixonbaits mixed with the 1st mixture attracted insignificantly more insects than baits mixed with the 2nd mixture. Aged Ixon mixed with the 1st mixture attracted 41.6% and 28.33% of males and females, respectively, while Aged Ixonbaits mixed with the 2nd mixture attracted 30% and 21.66% of males and females, respectively.

Table (4): Comparative attractiveness of improved and original Ixon bait against adults of *B. germanica* after the investigation period (5 days) days at 27 ± 2 °C and 65 ± 5% RH.

Baits	Attractiveness (mean% ± SE)			
	Fresh baits		Aged baits	
	♂	♀	♂	♀
Ixon	28.3 ± 0.6 ^b	8.3 ± 0.3 ^b	10.0 ± 0.5 ^c	1.6 ± 0.3 ^b
Ixon + **	55.0 ± 0.5 ^a	41.6 ± 0.6 ^a	30.0 ± 1.1 ^b	21.6 ± 0.3 ^a
Ixon + *	55.0 ± 0.0 ^a	43.3 ± 0.6 ^a	41.6 ± 0.3 ^a	28.3 ± 0.3 ^a

N: 3 replicates for each treatment, percentage mortalities in the same column followed by the same superscript are not significantly different (ANOVA) followed by Duncan's test, p< 0.05.

** = Second mixture (4% taro plant ethanol extract + 0.1%peppermint oil).

* = First mixture (4% taro plant ethanol extract + 5% attractive mixture).

Attractive mixture = 1:1:1:1:0.1 of roasted peanut, coriander oil, fresh coriander leaves, fresh zucchini fruits and cockroach feces.

Efficacy of improved and original Ixon baits against *B. germanica* in no-choice assay:

Results of the toxicity of fresh and aged Ixon baits against adult male and female cockroaches before and after adding the two mixtures are summarized in Table (5). Both mixtures had a synergistic effect on the original Ixon toxicity against the tested insects. The cumulative mortality of insects fed on original fresh Ixon bait (16.6% and 10.0% for males and females, respectively) increased to 68.3% and 53.3% for males and females, respectively, after adding the 1st mixture and to 65.0% and 46.6% for treated males and females, respectively, after adding the 2nd mixture.

According to the LT₅₀ values, Ixonbaits mixed with the 1st mixture had the lowest time 4.8 and 5.3 days for treated males and females, respectively followed by that obtained from Ixon baits mixed with the 2nd mixture (5.2 and 6.2 days for males and females, respectively) compared to that of original Ixon baits (8.6 and 8.7 days for males and females, respectively).

Results also indicated that aging of improved and original baits for seven days reduced its toxicity against adult male and female. The cumulative mortalities of aged original Ixon baits fed insects were very low and recorded only 8.3% and 6.6% of males and females, respectively. While it increased to 45.0% and 31.6% of males and females, respectively, after adding the 1st mixture to original Ixon baits and to 31.6% and 26.6% of treated males and females, respectively, after adding the 2nd mixture to original Ixon baits.

Ixonbaits mixed with the 1st mixture recorded the lowest values of LT₅₀ (6.8 and 7.2 days for males and females, respectively) compared with that of Ixonbaits mixed with the second mixture (7.2 and 8.0 days for males and females, respectively) and that of original Ixon baits (11.0 and 11.7 days for males and females, respectively).

Table (5): Comparative efficacy of improved and original Ixon baits against adults of *B. germanica* after the investigation period (7 days) at 27 ± 2 °C and 65 ± 5% RH in no-choice assays.

Baits	Fresh baits						Aged baits					
	♂			♀			♂			♀		
	Mortality % ± SE	LT ₅₀ (Days)	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days)	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days)	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days)	Slope ± SE
Ixon	16.6 ± 0.3 ^b	8.6 ± 1.2	0.7 ± 0.4	10.0 ± 0.5 ^b	8.7 ± 1.7	0.2 ± 0.4	8.3 ± 0.3 ^c	11.0 ± 1.5	0.8 ± 0.4	6.66 ± 0.6 ^b	11.7 ± 1.4	0.7 ± 0.4
Ixon + **	65.0 ± 0.3 ^a	5.2 ± 0.1	0.1 ± 8.0	46.6 ± 0.8 ^a	6.2 ± 0.2	0.7 ± 0.1	31.6 ± 0.8 ^b	7.2 ± 1.4	1.8 ± 0.6	26.6 ± 0.3 ^a	8.0 ± 1.6	0.7 ± 0.6
Ixon + *	68.3 ± 0.5 ^a	4.8 ± 0.2	0.1 ± 0.1	53.3 ± 0.6 ^a	5.3 ± 2.3	1.1 ± 0.5	45.0 ± 0.0 ^a	6.8 ± 0.2	2.1 ± 2.1	31.6 ± 0.8 ^a	7.2 ± 0.2	0.1 ± 1.9

N: 3 replicates for each treatment, percentage mortalities in the same column followed by the same superscript are not significantly different (ANOVA) followed by Duncan's test, p < 0.05.

** = Second mixture (4% taro plant ethanol extract + 0.1%peppermint oil).

* = First mixture (4% taro plant ethanol extract + 5% attractive mixture).

Attractive mixture = 1:1:1:1:0.1 of roasted peanut, coriander oil, fresh coriander leaves, fresh zucchini fruits and cockroach feces.

Efficacy of improved and original Ixon baits against *B. germanica* cockroaches in choice assay:

No mortality was recorded for original fresh Ixon fed females, while it was verylow (3.3%) for males Table (6). On the other hand, the addition of the two different mixtures rendered fresh Ixon more toxic against the tested insects. Ixonbait with the 1stmixture was significantly more toxic than Ixon bait mixed with the 2nd mixture. Results also indicated that fresh Ixonbaits mixed with the 1stmixture had the lowest LT₅₀ values (6.1 and 6.6days for males and females, respectively), while the LT₅₀ ofIxon bait with the 2ndmixture was higher (6.4 and 7.3 daysfor males and females, respectively).

After aging for seven days, no mortalities were recorded for males or females fed on original Ixon bait. Addition of either the 1stor 2ndmixture to this bait led to an increase of its toxicity against the tested insects. The results alsoindicated that the cumulative mortalities of insects fed on aged Ixon bait mixed with the 1st mixture (35.0% and 26.6% of males and females, respectively) were significantly higher than those obtained from insects treated with aged Ixon bait mixed with the 2ndmixture (26.6% and 18.3% of males and females, respectively).

The LT₅₀ values of aged Ixon bait mixed with the 1stmixture was better (7.0 and 8.0 days for males and females, respectively) than those of aged Ixon bait mixed with the 2ndmixture (7.8 and 8.4 daysfor males and females, respectively, respectively).

Table (6): Comparative efficacy of improved and original Ixon baits against adults of *B. germanica* after the investigation period (7 days) at 27 ± 2 °C and 65 ± 5% RH in choice assays.

Baits	Fresh baits						Aged baits					
	♂			♀			♂			♀		
	Mortality % ± SE	LT ₅₀ (Days)	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days)	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days)	Slope ± SE	Mortality % ± SE	LT ₅₀ (Days)	Slope ± SE
Ixon	3.3 ± 0.6 ^b	12.8 ± 1.3	0.6 ± 0.	0 ^c	-	-	0 ^c	-	-	0 ^c	-	-
Ixon + **	48.3 ± 0.6 ^a	6.4 ± 1.3	0.5 ± 0.	30.0 ± 0.5 ^b	7.3 ± 1.2	0.5 ± 0.5	26.6 ± 0.8 ^b	7.8 ± 0.9	0.1 ± 0.2	18.3 ± 0.8 ^b	8.4 ± 1.4	0.7 ± 0.5
Ixon + *	51.6 ± 0.6 ^a	6.1 ± 0.1	0.1 ± 0.8	41.6 ± 0.3 ^a	6.6 ± 0.1	0.2 ± 0.4	35.0 ± 0.5 ^a	7.0 ± 2.6	0.1 ± 0.2	26.6 ± 0.8 ^a	8.0 ± 1.2	0.8 ± 0.5

N: 3 replicates for each treatment, percentage mortalities in the same column followed by the same superscript are not significantly different (ANOVA) followed by Duncan's test, $p < 0.05$.

** = Second mixture (4% taro plant ethanol extract + 0.1% peppermint oil).

* = First mixture (4% taro plant ethanol extract + 5% attractive mixture).

Attractive mixture = 1:1:1:1:0.1 of roasted peanut, coriander oil, fresh coriander leaves, fresh zucchini fruits and cockroach feces.

IV. DISCUSSION

The present results demonstrated that addition of improvement mixtures resulted in a significant and marked increase in baits efficacy against male and female cockroaches in the two bioassays (no-choice and choice assays). This may be attributed to the increase in bait's toxicity and/or attractively. Addition of taro plant leaves extract, *Colocasia esculenta*, to the baits may be the reason for the increased toxicity of the baits. The toxicological effects of taro plant against the German cockroach were reported by **Bakret et al., (2017)**. Many investigators recorded a toxic effect of Taro plant on many insect species as **Neerageet et al., (2013)** who found that taro plant has defense compound (α -amylases inhibitors) against *Callosobruchus chinensis*, *Tribolium castaneum*, *Corcyra cephalonica* and *Spodopteralittoralis* that interact with insect α -amylase causing insect mortality. Also, **El-Monairy (2015)** reported toxicological and histopathological effects of leaves extract of the plant on the immature stages of *Culex pipiens* mosquito.

Results of the present work indicated that the addition of luring mixtures increased the efficiency of the baits. The increase of trap attractively and efficiency may be attributed to the popular food products added to the original baits as coriander oil, crushed roasted peanut, fresh crushed coriander leaves, fresh crushed zucchini fruits peppermint oil and cockroaches feces. These materials proved efficient in luring male and female cockroaches. (**Ibrahim et al., 2017**).

Increasing the efficiency of cockroach baits by adding luring materials was reported by many other investigators as **Wang and Bennett, (2006)** who found that Sticky traps baited with bread, beer and peanut butter may have much greater efficacy than un-baited traps for monitoring and controlling German cockroach infestations. **Gore and Schal (2004)** found that aqueous solutions containing mixtures of boric acid and any of several inexpensive sugars as a phagostimulant which caused insects to consume lethal amounts of boric acid during the 24hrs exposure can provide rapid and effective kill of German cockroaches. **Wang and Bennett (2006)** compared the effect of Trapper roach attractant, NAF430 gel bait, and Invite lure in choice tests on sticky trap catches in simulated kitchens. All attractants significantly increased the number of cockroaches trapped in sticky traps compared with unbaited traps. Modifications of the inert ingredients in the Maxforce FC (0.01% fipronil) gel bait significantly improved the efficacy against the German cockroach which showed aversion behaviors to the original gel bait formulations **Wang et al., (2004)**. Laboratory tests of **Ahmad and Suliyat (2011)** showed that four gel baits having the same amount of fipronil (0.03%) but with different attractants (chicken liver, honey-banana, and cow blood and cockroach feces) greatly affected the time needed for killing cockroaches. Hundred % mortalities were achieved within 36 h with chicken liver, 48 h with honey-banana, 60 h with cow blood and 72 h with cockroach feces

Addition of cockroach feces to the baits in our study may be a major reason for the enhancement of trap efficiency. The ability of cockroach feces to increase the attractiveness and efficiency of the baits was reported by many investigators as **Miller and Koehler (2003)** who concluded that the addition of fecal extract with chlorpyrifos produced significantly greater mortality in young nymphs than chlorpyrifos alone or chlorpyrifos + methanol extract. Also, **Hui and Jintong (2004, 2005)** suggested that cockroach fecal extracts may increase the effectiveness of blatticide baits. Killing efficiency of the toxic baits was improved when mixed with the ethanol fecal extract of early and late nymphs (**Xiaoyan et al., 2010**). Moreover, traps placed nearest to cockroach aggregations places contain feces and exuviae capture more cockroaches (**Appel & Reid, 1992 and Weiyuan et al., 2011**).

The recorded decrease in LT50 values of the improved SikoBiko and Ixon baits may be due to accelerating of the effect of baits on the tested insects. Although aging of the improved SikoBiko and Ixon baits affected its attractiveness and efficacy, they were more effective against the tested cockroaches than the original baits.

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