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Comparative efficacy of mosquito coils on *Anopheles stephensi* (Liston), *Aedes aegypti* (Linn.) and *Culex quinquefasciatus* (Say) (Diptera: Culicidae)

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ABSTRACT

A study was conducted to assess the knockdown and adulticidal efficacy of d-trans allethrin (0.1%) and d-allethrin (0.2%) mosquito coils under laboratory condition against *Anopheles stephensi* Liston, *Aedes aegypti* Linn. and *Culex quinquefasciatus* Say. These coils provided significant knockdown activity against the tested mosquitoes. KT_{50} and KT_{95} values indicated that *Ae. aegypti* was more susceptible to d-trans allethrin and *An. stephensi* was more susceptible to d-allethrin. *Cx. quinquefasciatus* was less susceptible to both the coils and needed longer time to be knocked- down. Mortality and revival rates after 24 h varied between the mosquito species. The highest mortality was recorded against *Ae. aegypti* (68.5%) followed by *Cx. quinquefasciatus* (55.5%) and *An. stephensi* (34.5%) respectively after 24 h of exposure to the coil fumes.

Introduction

Mosquitoes, the haematophagous insects, are responsible for the transmission of various dreadful human diseases from one person to another and WHO has declared the mosquito to be public enemy number one. Malaria kills more than 1 million people each year (WHO, 2008), and dengue fever affects an estimated 50 million persons annually (Farrar *et al*., 2007). Lymphatic filariasis (LF) affects about 30% of the global population (WHO, 2006[b]). Mosquito coil is the most commonly used household insecticide product in Asia. The worldwide consumption and usage of mosquito coils are increasing and the consumption in Asia constituted about 90%.

Pyrethroids are a class of chemicals that have proven to be very effective in controlling arthropods of medical and veterinary importance. They have a very low mammalian toxicity. Mosquito coils which contain pyrethroids have been shown to repel and disrupt the host-seeking activity of mosquitoes, followed by knockdown (MacIver 1964, Fales *et al*., 1968; 1971; Mace 1969; Teshima 1993), although the mortality of mosquitoes caused by mosquito coils may be low (Smith & Chadwick 1964; Smith and Obudho 1967; Smith *et al*., 1973; Mosha *et al*., 1989). Although pioneering studies have been reported on the performance of mosquito coils, only limited work has been done on knockdown and per cent mortality after exposure to the mosquito coils. This study was initiated to determine the efficacy of two mosquito coils containing either d-allethrin or d-trans allethrin against female mosquitoes of *An. stephensi*, *Ae. aegypti* and *Cx. quinquefasciatus* with reference to knockdown and mortality.

Materials and methods

Mosquito coils

Commercially prepared coils containing d-allethrin (d 1-3-allyl-2-methyl-4-oxo-2-cyclopentenyl d-sis trans chrysanthemate, 0.2% w/w) and d-trans allethrin (d 1-2-allyl-4-hydroxy-3-methyl-2-cyclopenten-1-ester of d-trans chrysanthemate monocarboxylic acid, 0.1% w/w) were used in this study. The inert ingredients in the coils were: wood flour (52.90%), coconut shell powder (35.00%) and starch (12.00%).

Mosquitoes

Adult female mosquitoes of *An. stephensi*, *Ae. aegypti* and *Cx. quinquefasciatus* were obtained from Rearing and Colonization Unit of Entomology Research Institute, Loyola college for knockdown study.

Experimental design

Experiments were done according to WHO guidelines 2009. A mosquito coil whose weight (18.5±0.1g) had been ascertained earlier with the help of a weighing balance was fixed on a stand, ignited and introduced into the Peet-Grady chamber (PGC) (180 cm x 180 cm x 180 cm).

Hundred numbers of 2-4 day old non-blood-fed female mosquitoes were released into the Peet-Grady chamber immediately, taking care to see that none of them escaped and the chamber door was closed tightly. Knockdown of the mosquitoes was recorded at 5 minutes intervals for up to 90 minutes. The burning coil was allowed to remain in the Peet-Grady chamber for 60 minutes during the test period, after which the coil was extinguished and removed. But the mosquitoes were allowed to remain in the chamber for 30 more minutes after removal of the coils, in order to study the effect of the smoke in the absence of the burning coil. In all the experiments the revival of the mosquitoes was observed during the 30 minutes period after removal of the coil. At the end of 90 minutes the knocked down mosquitoes were collected with the help of an aspirator and put in a clean ventilated jar with appropriate feed (10% sucrose solution). Criteria for knockdown were that the mosquitoes no longer maintained normal posture and were unable to fly or were on their backs. The recovery or mortality of the knocked down mosquitoes at the end of 24 h was monitored and recorded. After burning the first segment of a coil for 60 minutes, the last segment of the coil was used to repeat the above experiment against a new set of 100 female mosquitoes.

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After the completion of each test, the inner wall surfaces of the Peet-Grady chamber were thoroughly cleaned with detergent and water to remove any toxic residue present. The chamber was then air dried with an exhaust fan before the onset of the next test. The bioassay experiments were repeated three times using coils of both d-allethrin and d-trans allethrin formulations against three different mosquito species.

Statistical analysis

Median knockdown time KT_{50} and KT_{95} were analyzed by using probit analysis software (Probit Program version 1.5). The upper, lower fiducial limits and Regression equations were also calculated.

Results

Knockdown activity against *Ae. aegypti*

All the three species of mosquitoes viz., *An. stephensi*, *Ae. aegypti* and *Cx. quinquefasciatus* were found to be knocked down when exposed to both d-trans allethrin and d-allethrin mosquito coils. However the effect varied among the three species tested.

When the first segment of d-trans allethrin mosquito coil was tested against *Ae. aegypti*, the minimum and maximum KT_{50} values were found to be 5 and 10 minutes, while the minimum and maximum KT_{95} values were 15 and 20 minutes respectively. The last segment of the same coil gave a minimum and maximum KT_{50} value of 5 minutes and the minimum and maximum KT_{95} values of 10 and 30 minutes respectively against *Ae. aegypti*. The d-allethrin coil recorded minimum and maximum KT50 values of 10 and 20 minutes and minimum and maximum KT_{95} values of 20 and 70 minutes respectively when the first segment of coil was tested against *Ae. aegypti*. When the last segment of the same coil was tested against *Ae. aegypti*, the minimum and maximum KT_{50} values were 5 and 10 minutes and the minimum and maximum KT_{95} values were 30 and 70 minutes respectively.

Knockdown activity against *An. stephensi*

A minimum and maximum KT_{50} value of 10 minutes and minimum and maximum KT95 values of 20 and 30 minutes were obtained when the first and last segments of d-trans allethrin mosquito coils were tested against *An. stephensi*. A minimum and maximum KT_{50} value of 10 minutes and minimum and maximum KT_{95} values of 20 and 25 minutes were obtained with the first segment of d-allethrin coil, while a minimum and maximum KT_{50} value of 10 minutes and minimum and maximum KT_{95} value of 20 minutes were obtained with the last segment of the same coil against *An. stephensi*.

Knockdown activity against *Cx. quinquefasciatus*

When the first segment of d-trans allethrin mosquito coil was tested against *Cx. quinquefasciatus*, minimum and maximum KT_{50} values of 25 and 30 minutes, while a minimum and maximum KT_{95} value of 60 and 70 minutes were obtained. When the last segment of the same coil was tested against the same mosquito, a minimum and maximum KT_{50} value of 20 minutes and minimum and maximum KT_{95} values of 60 and 75 minutes were obtained.

The first segment of d-allethrin coil against *Cx. quinquefasciatus* gave minimum and maximum KT_{50} value of 30 minutes and minimum and maximum KT_{95} values of 80 and 90 minutes, while the last segment of the same coil gave minimum and maximum KT_{50} values of 20 and 30 minutes and minimum and maximum KT_{95} values of 60 and 80 minutes respectively.

Mortality after 24 hours

The mean mortality percentage of *Cx. quinquefasciatus*, 24 hours after exposure to the first and last segments of d-trans allethrin mosquito coil, was found to be 32.5 and 55.5 respectively. Likewise the mean mortality percentage of *Cx. quinquefasciatus*, 24 hours after exposure to the first and last segments of d-allethrin mosquito coil, was found to be 32 and 41.5 respectively. The first and last segments of d-trans allethrin mosquito coil against *An. stephensi* gave a mean mortality percentage of 34.5 and 24 respectively, while the first and last segments of d-allethrin mosquito coil against the same mosquito gave a mean mortality percentage of 25 and 33 respectively. The mean mortality percentage of *Ae. aegypti*, 24 hours after exposure to the first and last segments of d-trans allethrin mosquito coil, was found to be 19 and 25 respectively. Likewise the mean mortality percentage of *Ae. aegypti*, 24 hours after exposure to the first and last segments of d-allethrin mosquito coil, was found to be 56 and 68.5 respectively.

As far as mean mortality percentage at 24 hours after coil exposure was concerned, the highest value was obtained with d-trans allethrin mosquito coil against *Ae. aegypti* followed by *An. stephensi* and *Cx. quinquefasciatus*. The highest mean mortality percentage was obtained with d-allethrin mosquito coil against *Cx. quinquefasciatus* followed by *Ae. aegypti* and *An. stephensi.*

Discussion

Smoke from burning plant materials and mosquito coils have been used in mosquito management all over the world, predominantly in Asia, Africa and the Western Pacific. Mosquito coils are prominent mosquito management tools in Asia. The efficiency of a coil is evaluated based on percentage of repellency and knockdown potential against mosquitoes. The active ingredients like pyrethroids improve the limited effect of the simple smoke particles contributing to the bioefficacy of coils. The active ingredients mainly consist of ingredients which, by prolonged exposure, knockdown or kill the mosquitoes and other flying insects. Mosquito coils containing synthetic pyrethroids seem to have better efficacy compared to those with natural pyrethrins and other groups of organic insecticides. Pyrithroids are potent contact insecticides which produce rapid knockdown of household pests (mosquito, housefly, lice, and cockroach) and parasites of dogs and cats. Pyrethroids are distinctly less toxic to humans and other mammals (WHO, 1988). The safety benefit has led to the widespread acceptance and utilization of pyrethroids to control insects of medical importance (Lindsay, 1989). The active ingredient (3% w/w d-allethrin) is the most commonly used component in mosquito coils worldwide.

In the present study, KT_{50} values showed that *Ae. aegypti* was more susceptible than *An. stephens*i and *Cx. quinquefasciatus* to the coil containing d-trans allethrin (Table 3). This finding was similar to the earlier findings (MacIver, 1964, Chadwick, 1975, Yap and Chung, 1987; Adanan *et al*., 2005). *An. stephens*i was more susceptible than *Ae. aegypti* and *Cx. quinquefasciatus* to the coil containing d-allethrin (Table 2). This result corraborates with the findings on deltacide (deltamethrin 0.5% w/v, S- bioallethrin 0.71% w/v & piperonyl butoxide 8.9% w/v) was effective against *An. stephensi* when tested in the form of ULV cold aerosol (Srinivasan and Kalyanasundaram, 2006). Earlier reports (Amalraj *et al*., 1987) showed that continuous burning of a mat or coil for 10 hours led to the knockdown of more than 60% of all the three vector species but mortality was not consistently above 60% in all the three vector species. In our study the revival rate varied between the mosquito species. Highest revival was observed in *Cx. quinquefasciatus* compared to the other two species. (McIver, 1964) suggested that the larger body size of *Cx. quinquefasciatus* when compared to *Ae. aegypti* probably contributes to its increased tolerance.

The biting activities of all three mosquito species were totally reduced when exposed to these coils. Similar findings were reported on field trials of several formulations of mosquito coil in a suburban squatter area in Penang, Malaysia (Yap *et al*., 1990). They demonstrated that the mosquito biting activity can be reduced by more than 70% when coils containing either d-allethrin (0.20% and 0.3W w/w) or d-trans allethrin (0.1W and 0.15% w/w) were used. Other reports using different formulations of chemicals demonstrated behavioural response and insecticide resistance against the mosquito coils (Ujihara *et al*., 2004, Asidi *et al*., 2005).

We recorded high mortality in 2-4 days old *Ae. aegypti* (68.5%) than in other two species after exposure to d-allethrin coils (Table 1). Similar findings were reported earlier in *Ae. aegypti* (David and Bracey, 1947), *An. stephensi* (Rowland and Hemingway, 1987), *Ae. aegypti* and *Cx. quinquefasciatus* (Yap *et al*., 1996), houseflies (Simanton and Miller, 1937). The burning duration for these coils was eight hours which was reported to be similar to other studies done in Tanzania with pyrethroid coils (Mosha *et al*., 1992).

Conclusion

The knockdown efficacy of the first and last segments of d-trans allethrin coil was the highest against *Ae. aegypti* followed by *An. stephensi* and *Cx. quinquefasciatus*. The knockdown efficacy of the first and last segments of d-allethrin coil was highest against *An. stephensi* followed by *Ae. aegypti* and *Cx. quinquefasciatus*. These results showed that *Ae. aegypti* was more susceptible to d-trans allethrin and *An. stephensi* was more susceptible to d-allethrin.

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Table 1 Mean KT_{50} and KT_{95} (in minutes) and Mortality (%) of d-trans allethrin and d-allethrin mosquito coils against *An. stephensi, Ae. aegypti* and *Cx. quinquefasciatus* adults

Test mosquito	Test coil	Time Point (Hours)	KT_{50} (mins)	KT_{95} (mins)	Mortality (%)
Anopheles stephensi	d-trans allethrin	0	10	35	34.5
		8	10	25	24
	d-allethrin	0	10	22.5	25
		8	10	20	33
Aedes aegypti	d-trans allethrin	0	7.5	17.5	19
		8	5	20	25
	d-allethrin	0	15	45	56
		8	7.5	50	68.5
Culex quinquefasciatus	d-trans allethrin	0	27.5	65	32.5
		8	20	67.5	55.5
	d-allethrin	0	30	85	32
		8	25	70	41.5

Mean value (n =3 of 100 female mosquitoes per replicate)

Table 2 Bioefficacy of mosquito coils against *An. stephensi* adults

Test coil	Coil segment	Time point (h)	KT_{50} (mins)	Fiducial limits (Lower and Upper)	KT_{95} (mins)	Fiducial Limits (Lower and Upper)	Regression equation
d-trans allethrin	I	0	10	9.62 – 10.38	30	29.52 – 30.48	$Y=2.8528+2.6352 [\log_{10}(x)]$
		8th	10	9.67 – 10.33	30	29.58 – 30.42	$Y=2.5162+2.9126 [\log_{10}(x)]$
	II	0	10	9.63 – 10.37	40	39.46 – 40.54	$Y=2.5594+2.5579 [\log_{10}(x)]$
		8th	10	9.66 – 10.34	20	19.67 – 20.33	$Y=0.5346+5.7369 [\log_{10}(x)]$
d-allethrin	I	0	10	9.69 – 10.32	20	19.68 – 20.32	$Y=0.6091+4.8939 [\log_{10}(x)]$
		8th	10	9.67 – 10.33	20	19.64 – 20.36	$Y=1.7225+3.9134 [\log_{10}(x)]$
	II	0	10	9.64 – 10.36	25	24.59 – 25.41	$Y=1.9293+3.3855 [\log_{10}(x)]$
		8th	10	9.69 – 10.31	20	19.68 – 20.32	$Y=1.2397+4.4537 [\log_{10}(x)]$

Mean value (n =3 of 100 female mosquitoes per replicate); KT_{50} and KT_{95} (in minutes) of coil were estimated by using probit analysis.

Table 3 Bioefficacy of mosquito coils against *Ae. aegypti* adults

Test coil	Replication	Time point (Hrs)	KT_{50} (mins)	Fiducial limits (mins)	KT_{95} (mins)	Fiducial Limits (mins)	Regression equation
d-trans allethrin	I	0	5	4.765 - 5.235	15	14.68 – 15.32	$Y= 4.4852 + 1.8981 [\log_{10}(x)]$
		8th	5	4.869 – 5.131	30	29.59 – 30.41	$Y= 4.3919 +1.581 [\log_{10}(x)]$
	II	0	10	9.686 – 10.314	20	19.67 – 20.33	$Y=1.5468+4.0935 [\log_{10}(x)]$
		8th	5	4.551 – 5.449	10	9.52 – 10.48	$Y=3.0778+4.0759 [\log_{10}(x)]$
d-allethrin	I	0	10	9.700 – 10.30	20	19.7 – 20.3	$I=0.4946+5.1587 [\log_{10}(x)]$
		8th	5	4.88 – 5.120	30	29.58 – 30.42	$Y=4.5095+1.4666 [\log_{10}(x)]$
	II	0	20	19.33 – 20.67	70	68.73 – 71.27	$Y=1.8879+2.4235 [\log_{10}(x)]$
		8th	10	9.58 – 10.42	70	68.91 – 71.09	$Y=2.8394+1.9852 [\log_{!0}(x)]$

Mean value (n =3 of 100 female mosquitoes per replicate); KT_{50} and KT_{95} (in minutes) of coil were estimated by using probit analysis.

Table 4 Bioefficacy of mosquito coils against *Cx. quinquefasciatus* adults

Test coil	Replication	Time point (Hrs)	KT_{50} (mins)	Fiducial limits (mins)	KT_{95} (mins)	Fiducial Limits (mins)	Regression equation
d-trans allethrin	I	0	30	28.88 – 31.12	70	64.60 – 75.40	Y=2.349+1.746 [$\log_{10}$(x)]
		8^{th}	20	19.26 – 20.74	75	72 – 80	Y=2.797 + 1.734 [$\log_{10}$(x)]
	II	0	25	24.25 – 25.75	60	58.96 – 61.04	Y=1.772+2.424 [$\log_{10}$(x)]
		8^{th}	20	19.38 – 20.62	60	59.14 – 60.86	Y=1.907+2.510 [$\log_{10}$(x)]
d-allethrin	I	0	30	28.85 – 31.15	80	67.90 – 92.10	Y=2.394+1.707 [$\log_{10}$(x)]
		8^{th}	30	28.92 – 31.08	80	70.8– 89.20	Y=2.317+1.799 [$\log_{10}$(x)]
	II	0	30	29.1 – 30.90	90	82.74 – 97.27	Y=0.8+2.77 [$\log_{10}$(x)]
		8^{th}	20	19.48 – 20.53	60	59.37 – 60.63	Y=0.8353+3.463 [$\log_{10}$(x)]

Mean value (n =3 of 100 female mosquitoes per replicate); KT_{50} and KT_{95} (in minutes) of coil were estimated by using probit analysis.