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Comparison of methods of repelling mosquitoes

C.F. Curtis & N. Hill

London School of Hygiene and Tropical Medicine, Keppel St., London WC1E 7HT, U.K.

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Abstract

Comparisons were made with human subjects of repellency of free flying *Anopheles gambiae* using soaps containing deet and permethrin or permethrin alone. The reduction in biting did not differ statistically significantly between these two forms of repellent soap. Some mosquitoes which touched the permethrin soap layer without biting died within the next day. The soap with deet was compared with the same amount of deet in a commercially available stick or as a liquid. Only in the latter form did the repellent show resistance to being washed off by cold water.

Electrically heated vaporizing mats containing bio-allethrin were shown to be more effective than smouldering coils containing natural pyrethrins, in that there was more complete prevention of biting, and more rapid knock-down and kill. Operation of the vaporizing mat caused deposition of insecticide on the room surfaces.

Introduction

There is no doubt of the effectiveness against mosquitoes of soap containing di-ethyl toluamide (deet) and permethrin (Simmons, 1985; Yap, 1986), of electrically heated vaporizing mats containing volatile pyrethroids (Chadwick & Lord, 1977), and of smouldering coils containing natural pyrethrins (Chadwick, 1975). However, a number of questions about their performance remained to be answered: (i) how does the performance of a given quantity of the soap compare with that of the same quantity of the active ingredient as a liquid or in a commercially available mosquito repellent? (ii) does the repellent effect remain if the soap is used like ordinary washing soap and is rinsed off? (iii) does permethrin in soap (with or without deet) kill significant numbers of the mosquitoes which contact it? (iv) what is the persistence of a vaporizing mat and how does its performance compare with that of a smouldering mosquito coil? This paper reports answers to these questions.

Methods and materials

All experiments were carried out with female *Anopheles gambiae* s.s. belonging to three of the strains reared in this laboratory. The mosquitoes were aged 3-6 days when used and had not been previously fed. Counted numbers of the mosquitoes were released into a mosquito-proof room of volume 13 m³.

For testing deet and/or permethrin on the skin a single human subject stood in the room with bare lower legs and feet and he allowed the mosquitoes to bite freely for 8 min, after which all the mosquitoes were collected up and sorted into those which had blood fed and

those which had not. The categories were held separately for 24 h with access to glucose solution and mortality was then scored.

The soaps tested were made by Simmons Nominees Pty. Ltd., Chadstone, Victoria, Australia. The composition of the soap is specified by Simmons (1985) and contained either 1% permethrin or 0.5% permethrin and 20% deet. To test a soap the subject rinsed his legs with cold water, allowed 10 min for them to dry, carried out a mosquito test with untreated legs, wetted the legs and applied the soap, spreading the lather all over the lower legs and feet, and then allowed 10 min for them to dry before carrying out a further mosquito test. In one series of tests the legs were then rinsed under a cold water tap before 10 min drying and carrying out another mosquito test. Tests were also conducted with liquid deet and a commercially available 'Autan' stick which contains 33% deet. In these tests the legs were washed and dried before the initial control test and the repellent was then applied to the dry legs and feet. The amounts of liquid deet and 'Autan' applied were aimed to contain approximately the same amount of deet as the tests with the soap containing deet. The liquid deet was dissolved in 8 ml of 70% alcohol which is sufficient to wet the legs and feet. On any one day only one repellent preparation was tested, so as to leave time for residues to be lost from the subject's skin before the next test.

For the tests of a smouldering mosquito coil and vaporizing mat two human subjects with bare lower legs and feet stood in the test room and collected mosquitoes with aspirators as soon as the insects landed on their skin. The time when knock-down began was noted. Eight minutes after releasing the mosquitoes, all of them, whether knocked down or not, were collected into cups with netting tops and, after another 7 min. The cups were removed from the test room and held with access to glucose for 24 h, after which mortality was noted.

The brand of coil tested is sold by Thames Laboratories, Isleworth, U.K., under the trade name 'Z stop' and is reported to contain 0.25% natural pyrethrins. The brands of vaporizing mat tested were 'Buzz-off' (Travel International Products, London W1X 7RT) and 'Spira' (Travel Accessories, Lutterworth, U.K.). In both cases the mat contains 42 mg of bioallethrin and it is heated on a 6-7 Watt heating plate.

The testing room is fitted within a Vent-Axia extractor fan. This was operated during part of the testing period with the coil and vaporizing mats. A 3 cm aperture was opened on the opposite side of the room, when the fan was on, so as to create a moderate through draught.

Results and discussion

Almost all the *An. gambiae* which attempted to bite did so on the lower legs and feet of the standing human subjects within 3 or 4 min of release. Thus the method of baring and treating only the lower legs and feet and recording biting for 8 min give a repeatable measure of the avidity of a particular batch of mosquitoes in biting in the presence or absence of repellent.

Tables 1 and 2 show two series of trials with soaps. Ordinary toilet soap had no repellent effect, but the same dosage of soap containing permethrin or permethrin and deet were

repellent. The mean numbers of bites were less in each trial with the latter than the former but in neither case was the difference statistically significant. With the permethrin soap there was considerably reduced survival, not among the mosquitoes which had bitten and taken blood meals, but in those which had only made fleeting contact with the treated legs. Thus skin treated with permethrin soap may be considered as a 'baited insecticide'. From a human community point of view it would be better to reduce the vectorial capacity of a population of mosquitoes by killing some of those which attempt to bite, rather than diverting them from people who can afford to use repellents to those who cannot.

Table 2 shows that about 0.4 gm of deet was more effective as a repellent if applied as a liquid than in soap of from an 'Autan' stick. Even after washing in cold water, the deet which had been applied as a liquid was moderately effective, but the repellency of the soaps and the 'Autan' stick had been completely removed. The results of Frances (1987) showed more prolonged effectiveness of deet as a liquid rather than in a soap formulation with permethrin, but in this paper the weight of deet soap applied was not reported. Some people may consider the removability of the soaps formulations by washing as an advantage, since liquid deet on the skin dissolves certain plastics when one touches them; furthermore some individuals show adverse reactions to deet (Heick *et al.*, 1980; Miller, 1982).

Table 3 shows the results of comparative tests with a burning pyrethrum coil and a 'Buzz-off' vaporizing mat. The latter was more effective, as shown by the fact that there was a larger reduction in the number coming to bite, knock-down of the mosquitoes commenced sooner after their release and their survival after 24 h was lower. After the vaporizing mat had been operating for 2 ½ h, none of the mosquitoes released succeeded in coming to bite, knockdown occurred within half a minute of release and all the mosquitoes subsequently died. Running the extractor fan reduced the insecticidal effect but did not eliminate it, even after running the fan for many hours. It was only after scrubbing the walls and ceiling that mosquitoes released into the room could once more survive and bite normally. Similar evidence for deposition of insecticide on surfaces was encountered in testing the 'Spira' vaporizing mat and this device gave results which resemble in all respects those shown in Table 3 (b).

Table 1. Comparison of ordinary toilet soap, soap with 1% permethrin and soap with 20% deet and 0.5% permethrin. Results are shown in terms of numbers and % of mosquitoes (*An. Gambiae* released into a room) which fed (F) within 8 min on the bare legs and feet of a human subject or remained unfed (UF). Also shown are the number of the fed and unfed mosquitoes which survived 24 h, the overall % survival and the percentages fed and survived with soap, corrected for the control values with mosquitoes from the batch of mosquitoes on the same day in the absence of soap. The weight of soap (gms) applied to the legs and feet is shown, obtained by weighing the dry soap bar before and after application. Figures in the same column followed by different letters differ statistically significantly (χ^2 test).

Control	With soap				
	Mosq.	Survival	Gms	Mosq.	Survival
<i>Toilet soap</i>					
No. F	41	39		41	39
No. UF	58	55	1.41	58	56
	--	--		--	--
Total	99	94		99	95
%	41.4%	94.9%		41.4% a	96.0% a
Corr.%	100%	100%		100%	101.1%
<i>Permethrin soap</i>					
No. F	48	48		13	12
No. UF	52	47	1.36	87	57
	--	--		--	--
Total	100	95		100	69
%	48%	95.0%		13% b	69.0% b
Corr. %	100%	100%		27.1%	72.6%
<i>Permethrin & deet soap</i>					
No. F	30	26		4	3
No. UF	30	30	1.48	56	5
	--	--		--	--
Total	60	56		60	55
%	50%	93.3%		6.7% b	91.7% a
Corr. %	100%	100%		13.3%	98.3%

Chadwick and Lord (1977) gave evidence that the output of pyrethroid from a vaporizing mat declines after a few hours of use. However, as shown in Table 3, on day 2 of the trial when the mat had been heated for a total of 9 hours it was still emitting highly insecticidal vapour. The deposition of insecticide on surfaces should enhance the efficient and economical functioning of vaporizing mats in small rooms, and also perhaps in aircraft which require disinsection to avoid accidental transport of disease vectors (Curtis & White, 1984). It should seem wise to remove or cover food before operating a mat to avoid deposition of pyrethroid on the food.

Table 2. Tests as in Table 1, with the addition of tests after rinsing the legs in cold water and with the addition of tests of liquid deet applied in alcohol solution and of an 'Autan' stick.

Control	Treated				Washed		
	Mosq.	Surv.	Gm: (gm deet)	Mosq.	Surv.	Mosq.	Surv.
<i>Toilet soap</i>							
No. F	38	37	2.43	37	36	45	43
No. UF	22	18	(0)	23	20	15	15
	--	--		--	--	--	--
Total	60	55		60	56	60	58
%	63.3%	91.7%		61.7% a	93.3% a	75.0% a	96.7%
Corr. %	100%	100%		97.5%	101.8%	118.5%	105.4%
<i>1% Permethrin soap</i>							
No. F	27	26	2.07	13	11	27	27
No. UF	13	13	(0)	27	18	13	12
	--	--		--	--	--	--
Total	40	39		40	29	40	39

%	65.0%	97.5%		32.5%	72.5%	67.5% a	97.5%
Corr. %	100%	100%		48.2%	74.4%	100%	100%
<i>0.5% Permethrin & 20% deet soap</i>							
No. F	26	26	.09	9	8	25	25
No. UF	14	13	(0.42)	31	30	15	15
	--	--		--	--	--	--
Total	40	39		40	38	40	40
%	65.0	97.5%		22.5% b	95.0% a	62.5% a	100%
Corr. %	100%	100%		34.6%	97.4%	96.1%	102.6%
<i>Liquid deet</i>							
No. F	46	46	0.36	4	4	12	12
No. UF	14	14	(0.36)	56	54	48	47
	--	--		--	--	--	--
Total	60	60%		60	58	60	59
%	76.7%	100%		6.7% c	96.7%	20.05B	98.3%
Corr. %	100%	100%		8.7%	96.7%	26.1%	98.3%
<i>Autan stick (33% deet)</i>							
No. F	52	51	1.11	18	18	33	32
No. UF	8	8	(0.37)	42	41	26	25
	--	--		--	--	--	--
Total	60	59		60	59	59	57
%	86.7%	98.3%		30.0% b	98.3% a	55.9% a	96.6%
Corr. %	100%	100%		34.6%	100%	64.5%	98.3%

In the trials referred to in Table 3 the mosquitoes were collected as soon as they came to bite. In still air the vaporizing mat prevented all the mosquitoes coming to bite but the coil did not do so. In a trial in which the mosquitoes were given the opportunity to take blood (as in the soap trials), some succeeded in taking a partial meal in the presence of the coil. Apart from the lower effectiveness of the coil, the smoke from it in still air caused smarting of the eyes; there was no such discomfort with the vaporizing mat.

Table 3. Tests of pyrethrum coil and a 'Buzz-off' vaporizing mat: at the times indicated batches of mosquitoes were released and those coming to bite within 8 minutes were counted. In the test with the vaporizing mat the room surfaces were scrubbed between days 2 and 3, and before the device was switched on on day 2 the mat had already been heated for 9 hours.

	Time for which device had been operating (day 1)						---	(day 2)		---	(day 3)
	zero control	10 min	½ h	2 ½ h	3 ½ h	4 ½ h		zero	1 h		zero
Running time (h) of extractor fan	0	0	0	0	½	1 ½	19	0	0	19	0
<i>(a) Test of coil</i>											
No. biting from 100 released	58	41	31	25	46	50		60	-		-
No. biting as % of control	100%	71%	53%	43%	79%	86%		103%	-		-
Time (min) knock down began	None	2	2	2	2	3		none	-		-
24 h survival as % of control	100%	81%	25%	40%	59%	69%		97%			
<i>(b) Test of vaporizing mat</i>											
No. biting from 50 released	41	12	0	0	0	4		24	4		44
No. biting as % of control	100%	29%	0	0	0	10%		58%	10%		107%
Time (min) knock down began	None	3	½	½	½	¾		4	¾		None
24 h survival as % of control	100%	27%	2%	0	0	0		50%	0		98%

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