Efficacy and Toxicity of 20 Commercial Aerosol Insecticide Brands to *Anopheles gambiae* Mosquitoes in Lagos State.

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ABSTRACT

Aim: This study was conducted with a focus on assessing the susceptibility of the *Anopheles gambiae* mosquitoes in Lagos state to twenty commercial aerosol insecticides brands.

Study design: An entomological survey and a conventional bioassay.

Place and Duration of Study: The study was carried out between May and December 2025 in the Department of Zoology and Environmental Biology, Lagos State University, Nigeria.

Methodology: Entomological surveys were conducted in the urban and rural areas of Lagos state using 105 structured questionnaire to understand the public opinion on the use of aerosol insecticides in controlling mosquitoes. The efficacy of the twenty aerosol insecticides was assessed using a conventional bioassay on adult *Anopheles gambiae* by exposing twenty adult *Anopheles* mosquitoes to 0.5ml of each of the insecticides; after the bioassay, Probit 1.5 software was used to determine the lethal concentrations of the insecticides that can knockdown and bring about mortality of 50% and 99% of exposed insects.

Results: Findings revealed that about 96.19% residents of Lagos State prefer aerosol insecticides to other forms of vector control; while 3.81% do not use aerosol at all. The study further revealed that all aerosol insecticides marketed in Lagos State contained pyrethroids as the active ingredient, and *Anopheles gambiae* populations in the State remained susceptible to them, though toxicity levels varied. The most toxic was found to be Specimen A while the least toxic is V. All twenty test aerosol insecticides were able to cause 100% mortality in twenty exposed *Anopheles gambiae* mosquitoes after 60 minutes exposure period.

Conclusion: The study discovered that aerosol insecticides are both the first choice of Lagos State residents and is equally effective at controlling *Anopheles gambiae* mosquitoes. It is therefore suggested that pyrethrum based aerosol insecticides should be used in place of other toxic chemical insecticides; while putting into consideration safety precautions during and after use.

Keywords: *[Anopheles gambiae, Lagos state, Aerosol insecticides, Pyrethroid insecticides lethal concentrations knockdown }*

INTRODUCTION

Mosquitoes are important insects because they serve as vectors to various parasites and pathogens, with *Plasmodium* parasite which causes malaria being the most virulent. They have also been referred to as the most dangerous animal on earth because of the high mortality they cause in humans [1]. The disease, malaria is a great burden to countries in Sub-Saharan Africa because of the effectiveness of the *Plasmodium* pathogen due to its high transmission and prevalence rate [2]. As of 2018, out of the 228 million global cases that was reported by World Health Organization (WHO) 90% were from sub-Saharan Africa [3]. Among the mosquito species, one of the most effective vector that transmits the malaria parasite is the *Anopheles* mosquitoes. These *Anopheles gambiae* complex is found in many countries including Nigeria where it is endemic [4-6].

According to a report by the Nigerian Demographic and Health Survey, [7] Nigeria accounts for a quarter of the worldwide malaria burden with children and pregnant women bearing the brunt of the effect. Some States even

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have half the children population suffering from this disease. Malaria remains the country's biggest health challenge [8].

To fight back against malaria worldwide, vector control using chemical insecticides has been the most used method [9]. Four classes of chemical insecticides are being used in controlling mosquito species and this has been the popular approach for a long time [10]. They include the use of carbamates, organochlorines, organophosphates, and pyrethroids, and their use was largely successful between the years 2000 to 2015; coupled with new diagnostic methods and drugs, it reduced the worldwide mortality [11]. In Africa, the major application of these insecticides at homes and residential buildings involves sleeping under long-lasting insecticide nets (LLINs) and indoor residual sprays (IRS) while other methods include burning coils or rubbing repellants on the body [12-13].

Aerosol insecticide application involves the spraying of liquid insecticides in small droplets or particles, usually ranging in size between 0.1 and 50μm [14]. This method of insecticide application is more efficient and effective compared to other application methods, and this is mainly because aerosol insecticides can cover a wider surface area. When the droplets are deposited on surfaces, insects in hiding or that were not in contact with the insecticide during the application would eventually be affected when they come in contact with those surfaces due to diffusion [15]. Among the four major classes of chemicals used for insect pest control, pyrethroids are the most commonly used in aerosol insecticides because they are inexpensive and exhibit high toxicity to insects while remaining relatively safe to non-target organisms. [16].

Unfortunately, due to the success recorded, their ever-increasing use has caused mosquitoes to develop genetic, enzymatic, and behavioral resistance to all four major classes of insecticides, especially to the pyrethroids [17-18]. Specifically, the mosquitoes now avoid treated nets and surfaces sprayed with insecticides, begin feeding on humans early rather than late at night, and developed knock-down resistance mutation [19]. This resistance to the control measures has made the success achieved so far stalled in some places, while in others it has been reversed [20].

Thus, there is a need to continually monitor mosquito resistance to insecticides, as this is one of the focal points of the World Health Organization in its fight against malaria [21]. The elimination of malaria in Nigeria would not be possible without knowledge of the level of mosquito resistance and how efficient commercial insecticides are against them. Currently, there is little data on the susceptibility of mosquitoes to various control measures in southwestern Nigeria. This present study was therefore conducted with a focus on assessing the susceptibility of the *Anopheles gambiae* mosquitoes to twenty commercial aerosol insecticides used for their control. This research is aimed to evaluate the effectiveness and susceptibility of aerosol insecticides brands from Lagos Markets on *Anopheles gambiae*

MATERIALS AND METHODS

Study site

The research was carried out in Lagos State, which is one of the malaria-endemic states in Nigeria within the months of May and December 2025 at the Department of Zoology and Environmental Biology, Lagos state University. Lagos is usually recognized as Nigeria's economic hub and the country's most populated state. It sits between 6°27'14.65"N latitude and 3°23'40.81"E longitude in Nigeria's south western area, on the shore of the Gulf of Guinea. Lagos has a tropical climate that is hot all year, with a dry season from November to March and a wet season from April to October, with yearly rainfall totaling over 2,000 millimeters. Water bodies and wetlands cover 40% of the state's total land mass.

Fig 1. Map of Lagos State, Nigeria

Fig 2. Wooden houses built on of top the Lagos Lagoon

Collection of aerosol insecticides

For this study, twenty different brands of aerosol insecticides were chosen based on their broad availability to the public. Two aerosol insecticides were acquired for each brand, and a total of forty insecticides were purchased from the Lagos market located at old trade fair complex along Badagry express way Lagos State.

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Mosquito collection

Anopheles gambiae larvae used for the study were obtained from Entomological Laboratory of Nigeria Institute of Medical Research (NIMR), at Yaba, Lagos. They were fed yeast and maintained in the laboratory at 27±1ºC and 85% relative humidity. The emerged adults were placed in a glass netted life cage measuring 50cm by 50cm and were fed 10% glucose soaked in cotton wool and blood meal from swiss mice in this experiment.

Data collection through survey

A total of 105 structured questionnaires were designed and administered across four different locations in the state for data collection; they were distributed in the following places: Ajah, Ikorodu, Iyana Iba, and Ojo as the four communities are semi- urban towns. Twenty-five questionnaires were distributed in three study sites while thirty was distributed in Ojo area. Random sampling technique was adopted for the study where five households were randomly picked from five streets in each area of study to make a of total twenty -five households while thirty households were used at Ojo town. The purpose was to collect information from respondents on knowledge, usage and insecticide brands available in Lagos State markets.

Bioassay

Measured doses of each brand of aerosol insecticide was measured from the brand using neonate syringe and were exposed to 20 adult mosquitoes in 50 by 50 cm glass aluminum cage. The number knocked down and killed after 10, 30 and 60 minutes exposure were recorded with stopwatch. All mosquitoes knockdown were carefully transferred into separate clean holding cups. Mortality was determined after 24 hours exposure.

Data analysis

Adult *Anopheles* that were unresponsive and stationary when softly stroked with the bristles of a brush were documented as dead. Environmental protection agency (EPA) Probit analysis was used to calculate lethal concentrations of 50% and 99% (LC_{50} and $LC_{99)}$ values, and percentage mortality was calculated by dividing the number of deaths by the number introduced *100 after correction of mortality.

RESULTS AND DISCUSSION

Survey

Questionnaire survey response was used to establish the most prevalent form of mosquito control strategy employed by inhabitants of Lagos. The findings showed that majority of respondents preferred aerosol insecticide to long-lasting insecticide nets and other types of control (Figure 3). While some used combination of controls, such as application of aerosol and still sleeping under long-lasting insecticide nets (LLINs)

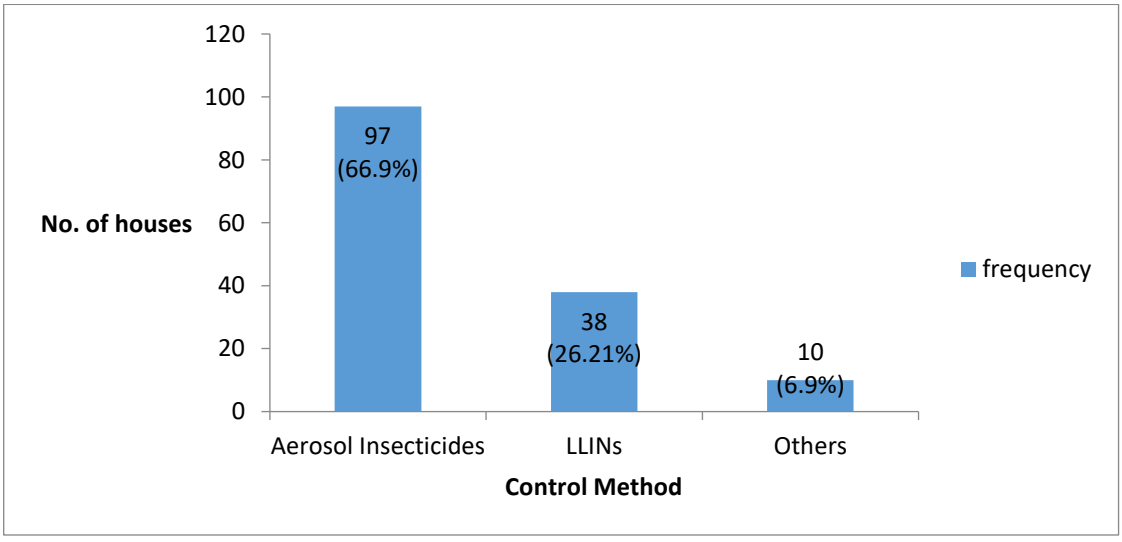

Fig 3: **Preference of Respondents to Aerosol insecticides compared to LLINs and other forms of control**

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This could be because aerosol insecticides are affordable and instantly bring about mortality and knockdown of mosquitoes, which could bring relieve from discomfort and nuisance caused by these insects [10]. Also, most aerosols can control wide range of household insect pests unlike other forms of control [12, 22]. This may be the reason why it has high acceptability and most preferred as recorded from respondents as shown in Figure 3. Though respondents claimed that it is not highly effective compared to other forms of control (figure 4) but because it is convenient to use and able to kill other insect pests (figure 5).

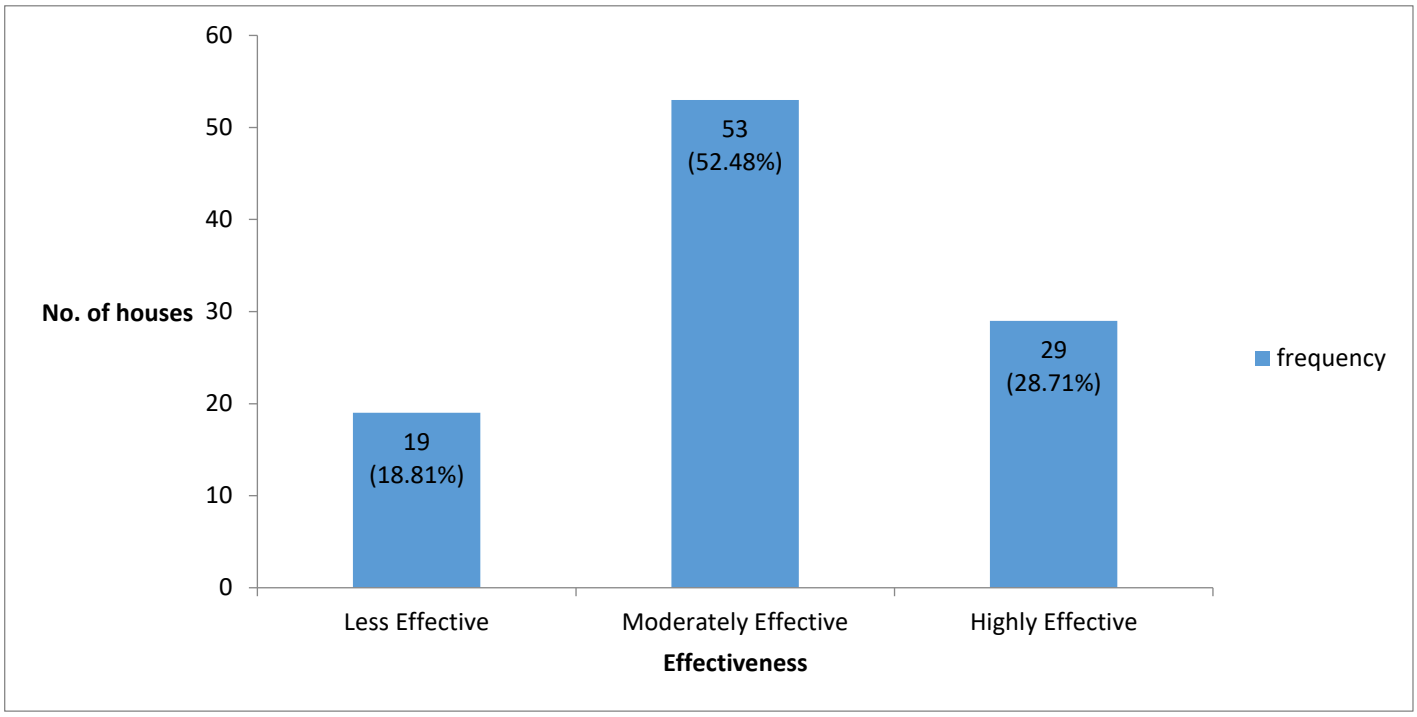

Fig 4: **Respondents comparative effectiveness of Aerosol insecticides to *Anopheles gambiae.***

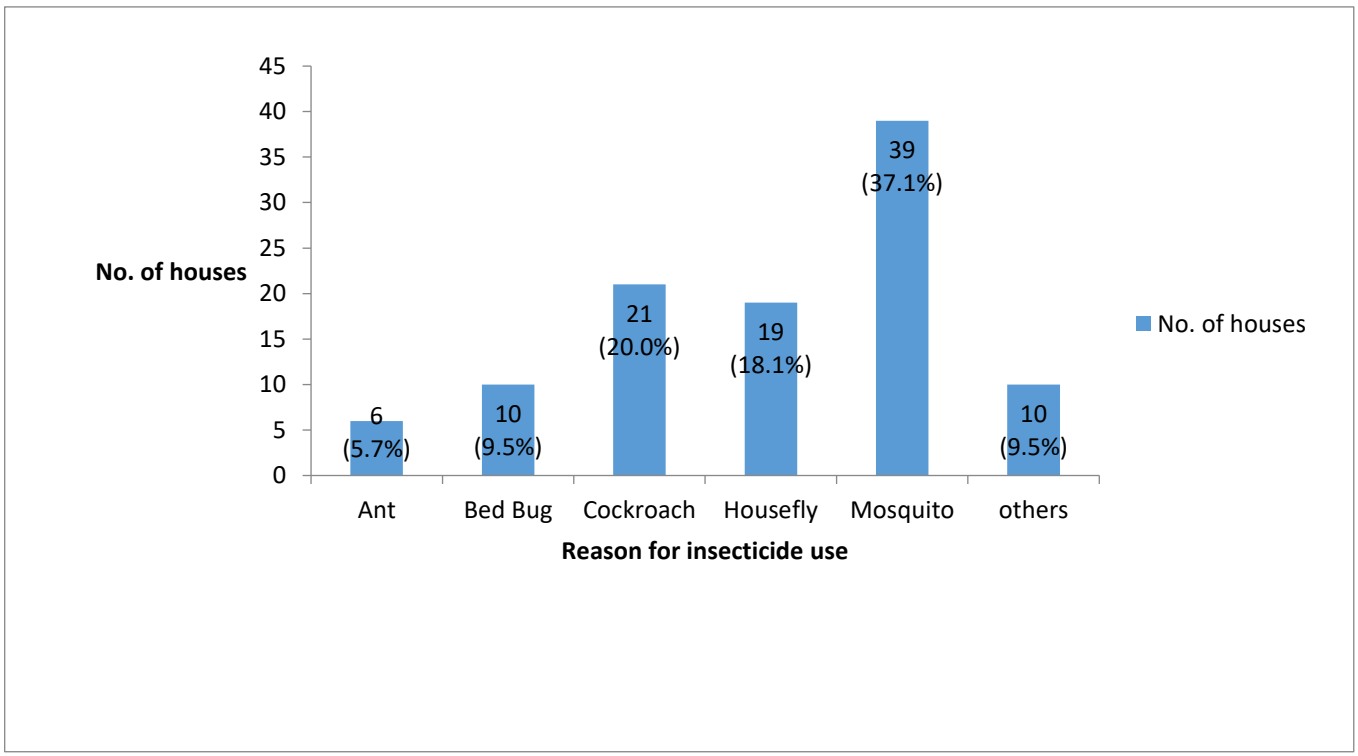

Fig 5: **Respondents insect control targets**

Table 1 showed the brands of aerosol insecticides that are being used by respondents and frequency of use. The choice of brands used by people was influenced by factors such as effectiveness, cost, fragrance, and availability and their usage frequency was majorly determined by their costs.

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Table 1: most widely used brand of insecticide in Lagos State, Nigeria

Specimen of insecticide (any kind) most used (n =101)	Number of Houses	Total (%) or Mean (SD)
None used	4	3.98
Specimen A	28	27.72
Specimen B	12	11.88
Specimen C	11	10.89
Specimen D	11	10.89
Specimen E	6	5.94
Specimen F	5	4.95
Specimen G	4	3.96
Specimen H	4	3.96
Specimen I	4	3.96
Specimen J	3	2.97
Specimen K	3	2.97
Specimen L	2	1.98
Specimen M	2	1.98
Specimen N	2	1.98
Specimen O	1	0.99
Specimen P	1	0.99
Specimen Q	1	0.99
Specimen R	1	0.99

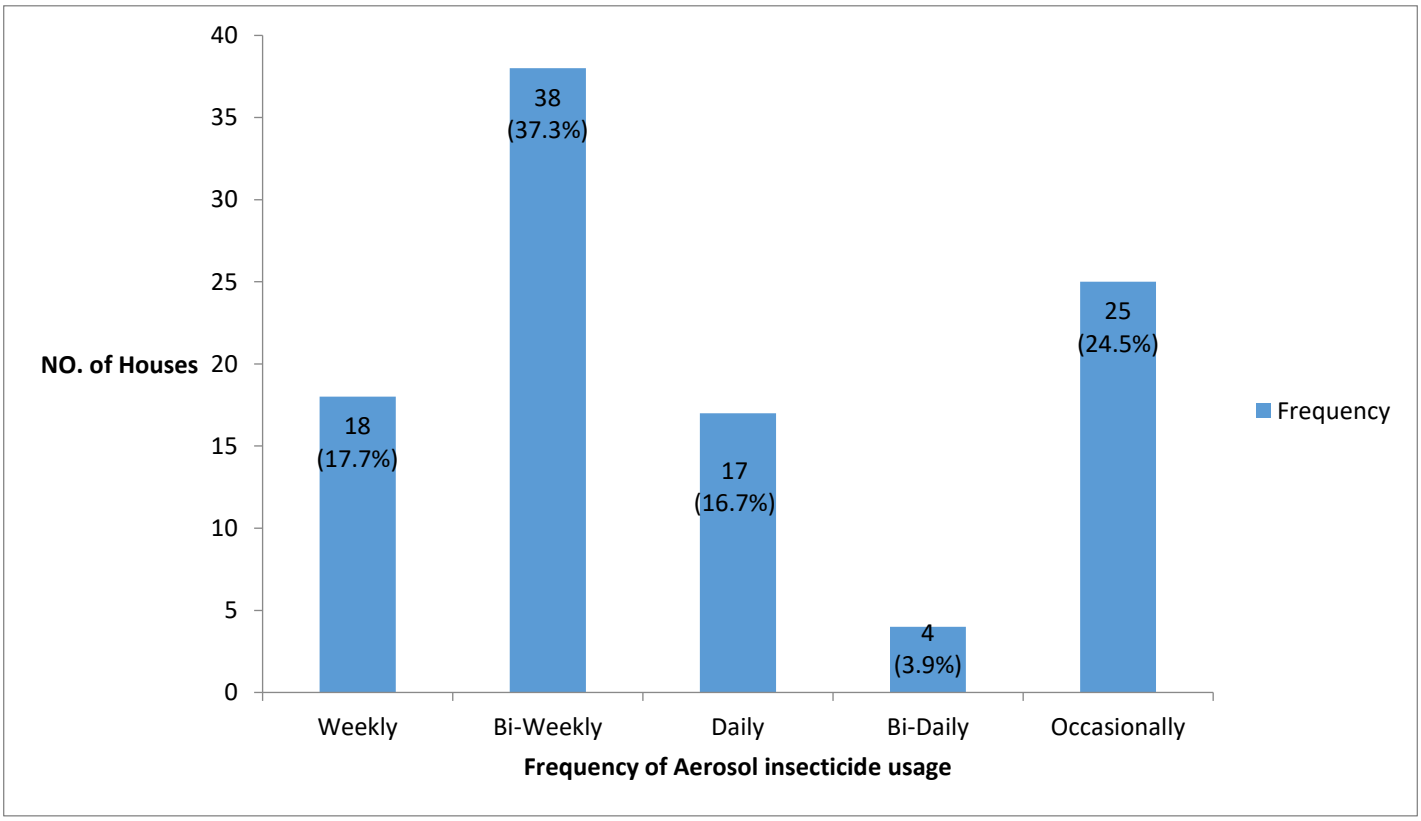

Fig 6: **Frequency of use of aerosol insecticide by Lagos residents.**

Insecticide origin and composition

The origin and composition of sampled aerosol insecticides were taken into consideration and it was discovered that all the twenty brands were pyrethroid based insecticides. Tables 2, 3, and 4 showed information about the origin and composition of the insecticides. A notable addition to aerosol insecticides manufactured in China is fragrance and from the survey, we found that the public believed they were safer because of their pleasant smell.

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Table 2. Aerosol Iinsecticide made in Nigeria and their composition

Specimens	Place of manufacture	Class of insecticide	Group	Percentage composition (%)
Specimen B	Nigeria	Imiprothrin Prallethrin Cyfluthrin	Pyrethroid Pyrethroid Pyrethroid	0.05 0.05 0.015
Specimen F	Nigeria	Prallelthrin Permethrin Tetramethrin	Pyrethroid Pyrethroid Pyrethroid	0.05 0.12 0.20
Specimen E	Nigeria	Imiprothrin d-phenothrin	Pyrethroid Pyrethroid	0.02 0.03
Specimen C	Nigeria	Tetramethrin Deltamethrin d-allethrin	Pyrethroid Pyrethroid Pyrethroid	0.150 0.015 0.250
Specimen D	Nigeria	Transfluthrin	Pyrethroid	0.20
Specimen Z	Nigeria	Tetramethrin Beta-cypermethrin	Pyrethroid Pyrethroid	0.4 0.15
Specimen O	Nigeria	Cyfluthrin Prallelthrin Imiprothrin	Pyrethroid Pyrethroid Pyrethroid	0.015 0.05 0.05
Specimen S	Nigeria	Transfluthrin Permethrin	Pyrethroid Pyrethroid	0.15 0.23

Table 3. Aerosol Insecticide made in China and their composition

Specimens	Place of manufacture	Class of insecticide	Group	Percentage composition (%)
Specimen T	China	Tetramethrin Phenothrin Transallethrin	Pyrethroid Pyrethroid Pyrethroid	0.20 0.20 0.20
Specimen M	China	Tetramethrin Cypermethrin Esbiothrin	Pyrethroid Pyrethroid Pyrethroid	0.03 0.17 0.63
Specimen U	China	Esbiothrin Permethrin	Pyrethroid Pyrethroid	0.3 0.25
Specimen N	China	Dimefluthrin Cyphenothrin Beta-cypermethrin Tetramethrin	Pyrethroid Pyrethroid Pyrethroid Pyrethroid	0.55 0.45 0.55 0.45
Specimen V	China	Tetramethrin Permethrin	Pyrethroid Pyrethroid	0.4 0.4
Specimen G	China	Tetramethrin Phenothrin d-transallethrin	Pyrethroid Pyrethroid Pyrethroid	0.2 0.2 0.2
Specimen A	China	D-Allethrin Imiprothrin Cypermethrin	Pyrethroid Pyrethroid Pyrethroid	0.2 0.1 0.2

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Table 4. Aerosol Insecticide made in other countries and their composition

Brand name	Place of manufacture	Class of insecticide	Group	Percentage composition (%)
Specimen R	England	Esbiothrin Permethrin	Pyrethroid Pyrethroid	0.3 0.25
Specimen X	Korea	Phthalthrin Permethrin	Pyrethroid Pyrethroid	0.200 0.667
Specimen P	spain	Permethrin Tetramethrin d-phenothrin	Pyrethroid Pyrethroid Pyrethroid	0.25 0.20 0.01
Specimen Y	Spain	Permethrin tetramethrin	Pyrethroid Pyrethroid	0.20 0.20
Specimen K	Turkey	Permethrin Teramethrin	Pyrethroid Pyrethroid	0.20 0.20

Toxicity test

Bioassay tests on *An. gambiae* mosquitoes with twenty aerosol insecticides were tested against 0-2 days old adults at varying concentrations of 0 to 5mls in $50cm^2$ by $50cm^2$ rearing boxes The effectiveness of the insecticides was determined by adult mortality after 30 and 60 minutes of observation. Table 5 shows observed mortalities while Table 6 reveals their lethal concentration levels at 50% and 99% at 30 mins. The knockdown effect on mosquitoes differed based on the brand of insecticides. It was observed that Specimen A showed highest toxicity to mosquitoes while V® showed least toxicity (Table 5). Also, the imported brands were more toxic to mosquitoes when compared to others brands from Nigeria. (Table 5).

Table 5. Table showing the percentage mortality of the *Anopheles gambiae* to 5ml of the insecticides.

TREATMENT	NO	% MORTALITY AT 10 MINS	% MORTALITY AT 30 MINS	% MORTALITY AT 60 MINS
CONTROL	20	0	0	0
Specimen T	20	90	100	100
Secimen B	20	100	100	100
Specimen M	20	50	100	100
Specimen U	20	70	100	100
Specimen F	20	90	100	100
Specimen R	20	100	100	100
Specimen X	20	80	90	100
Specimen E	20	70	80	100
Specimen P	20	60	100	100
Specimen N	20	80	100	100
Specimen Y	20	80	100	100
Specimen V	20	50	70	100
Specimen C	20	90	100	100
Specimen D	20	70	100	100
Specimen G	20	90	100	100
Specimen A	20	100	100	100
Specimen Z	20	70	80	100
Specimen K	20	80	90	100
Specimen O	20	100	100	100
Specimen S	20	80	90	100

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Table 6. Table showing the lethal concentration of the insecticides at 30 minutes on *Anopheles gambiae*.

TREATMENT	NO	LC_{50}	95% CI	LC_{99}	95% CI
Specimen T	20	1.201	0.296 – 1.804	10.371	5.188 – 265.285
Specimen B	20	0.563		3.379	-
Specimen M	20	1.055	0.125 - 1677	10.999	5.160 –956.806
Specimen U	20	2.028	0.596 – 3.255	32.604	10.188 – 331426.873
Specimen F	20	0.665	0.000 – 1.287	8.929	4.027 – 1376442.875
Specimen R	20	0.749	0.018 -1.153	3.222	1.981 – 373.259
Specimen X	20	0.701	**	66.854	**
Specimen E	20	1.261	**	61.291	**
Specimen P	20	0.895	0.014 – 1.553	12.323	5.232 – 30448.727
Specimen N	20	0.539	**	33.844	**
Specimen Y	20	1.427	0.026 – 2.351	32.224	9.192 – 1766343168.000
Specimen V	20	2.335	**	338.340	**
Specimen C	20	0.703	0.006 – 1.250	6.250	3.255 – 1871.004
Specimen D	20	0.659	0.000 – 1.338	12.095	4.760 - 2067.000
Specimen G	20	0.475	**	7.531	**
Specimen A	20	0.410	**	3.056	**
Specimen Z	20	1.066	**	140.154	**
Specimen K	20	0.338	**	137.134	**
Specimen O	20	0.572	0.000 – 1.248	11.109	4.381 – 1000.000
Specimen S	20	0.338	**	137.139	**

(**) This denotes that the values are less than 0.0001 hence negligible

According to the work of [9], one of the main causes of insecticide resistance in mosquitoes is exposure of these chemicals to mosquitoes in farming practices and little dose pick up from the wild. This could be the reason for the high *Anopheles gambiae* resistance to these pyrethroid insecticides. This observation aligns with two independent works carried out in Lagos state where it was observed that the mosquito populations were less susceptible to pyrethroid insecticides [23-24].

CONCLUSION

In conclusion, the results of this study have shown that all the 20 brands of aerosol insecticides were highly effective against *Anopheles gambiae* as 100% mortality was recorded in all brands at 60 minutes; though, knockdown speed differs amongst the brands. while there is a growing concern about the resistance of malaria vectors to pyrethroid insecticides, it is still the first choice of mosquito control insecticide among Lagos eestate inhabitants. The reason is that these pyrethroid aerosol insecticides are cheap, fast, easy to use, available and still effective in the control of various insect vectors within the state. It was discovered from this work that the local population of *Anopheles gambiae* in the State are still susceptible to these insecticides. Also, contrary to the belief by the populace; the pleasant-smelling aerosol insecticides were as toxic as foul-smelling ones. Also further studies should be carried out in a households to ascertain the level of aerosol insecticides effectiveness in Lagos homes.

It is important to note that the results obtained from the laboratory studies may differ from household use conditions because of some factors such as ventilation, aerosol deposition, user behaviour, mode of spraying and other related factors which may influence end results in the households.

Competing Interests

Authors have declared that no competing interests exist.

Authors' contributions

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