Monitoring the toxicity of dry wood termites using three plant powders in laboratory culture

Ojianwuna, C.C. and Enwemiwe, V.N.

ABSTRACT

In order to model a suitable control alternative for subterranean termites and termites infesting wooden furniture and cabinets where consumables are likely stored, this present study monitored the efficacy of three plant powders at different doses (0.50-1.50g) against the dry wood termite, *Cryptotermes cavifrons* Banks (Blattodea). Plant materials were locally prepared into powders and assigned to 20 wood termites in 5g substrates of sand and stick. The culture was set up in triplicates and lethal concentrations were determined by Probit analysis. The plant powder could not exerted 100% mortality, but the highest mortality was recorded in *Dennettia tripetala* (1.50g) on stick (mean= 8.33±0.80). All concentration of *D. tripetala* on sand and stick caused mortality within 0 to 48 hours after exposure and compared favorably with Permethrin which recorded the highest mean time mortality on sand at 0-24 hrs after exposure. The lowest LC_{50}value (0.75 and 0.79g/g) corresponded to Permethrin and *D. tripetala* on sand and stick respectively. This results suggest that best concentrations of pepper fruit powder can be adopted as potential alternative to chemical powders.

Key words: Keywords: Efficacy, *Cryptotermescavifrons*, botanical powders, control measures

MS History: 00.02.2020 (Received)-00.04.2020 (Revised)- 16.07.2020 (Accepted)

Citation: Ojianwuna, C.C. and Enwemiwe, V.N. 2020. Monitoring the toxicity of dry wood termites using three plant powders in laboratory culture. *Journal of Biopesticides,* 13(2): 150-158.

INTRODUCTION

The dry wood termite, *Cryptotermes cavifrons* Banks (Isoptera: Kalotermitidae) are sometimes mistaken for white ants due to the morphological similarities. Their destructive nature is widespread affecting agricultural products, forest trees, furniture and any wood byproduct. However, the distribution of species may be beneficial causing recycling, soil upturn for improved fertility, food derivatives (Wang *et al.*, 2009). As long as the material contains cellulose, it would be a tasty consumable by termites. Termites has been reported by Vasconcelles (2010) and Materu *et al.* (2013) to predominantly infest tree species, and plants in grass and forested areas. According to report by Ugbomeh *et al.* (2019), the damages caused by termites has been severely targeted on younger tree plants than the older ones and in many cases starting from the root and spreading to the terminal tip. Leaves and seeds of *Moringa oleifera, Garcinia kola, Gmelina arborea* and *Moringa lucida* have been used for the management (Okweche *et al.*, 2015).

The destruction caused by termites cannot be quantified. It has been reported by Abdullah *et al*. (2014) that the biodegradation of wood by termites is a serious problem for wood utilization. Termite species are distributed in various continental regions of the world except Antarctica and its diversity records has triggered damages accompanied by the symbiotic bacteria, and associated microbes (Ohkuma and Brune, 2011). To justify the spread of termites, 37 species has been recorded in an Atlantic forest in Northern Brazil with Nasutiterminae being the dominant group (Vasconcelles, 2010). In homes and forested sites in India and on grazing lands in semi-arid Nakasongola in Uganda, five and sixteen species has been recorded (Wang *et al.*, 2009; Mugerwa *et al.*, 2011). According to a Nigerian study by Ogedegbe and Eloka (2015), five termite species have been recorded. Even arboreal termite nests has been observed on *Mangifera indica*, *Irvingia gabonensis*, *Cola nitida* among others (Echezona *et al.*, 2012).

The damages caused by termites has led to the adoption of chemical, non-chemical method and integrated approach in their control (Ibrahim and Adebote, 2012). Biological insecticides are generally control specific. Insecticide derivatives from plants are non-chemical alternative due to their availability in the environment, friendliness and vast potential on any insect species especially the dry wood termite. The plant materials in this study have been reported in with promising results in insect pest management (Ukeh *et al.*, 2009, Ukeh *et al.*, 2010, Okpako *et al.*, 2013, Adesina *et al.*, 2015). *Aframomum melegueta* (alligator pepper), *Dennettia tripetala* (pepper fruit) and *Zingiber officinale* (ginger rhizome) are popular plants that are used as spices for food in Nigeria. So the chances of food poisoning would be low when applied on wooden cabinets infested by dry wood termites. Although, the efficacy study using plant materials on dry wood termites was reported by Okweche *et al.* (2015) but it was not a substrate-based experiment. The rationale for a substrate-based set up is to evaluate the efficacy of plant materials in a cryptic species like dry wood termites that present themselves hidden in wooden household furniture while carrying out their destructive activities. Similarly, the use of sand as substrate is to model a non-contact efficacy for subterranean termite species. Hence, the need to design a study on monitoring the efficacy of plant powders: *A. melegueta*, *D. tripetala* and *Z. officinale* in the control of the dry wood termites in laboratory condition.

MATERIALS AND METHODS

Study Area

This present experiment was conducted at the Entomology Laboratory, Department of Animal and Environmental Biology, Delta State University, Abraka, Delta State, Nigeria (5° 47' N and 6° 6' E) under ambient temperature of 28±2°C, 73±2% RH and 12:12hrs photoperiod L:D.

Insect and Material Collection

The termite population for this study was obtained from some infested wood furniture at Oria-Abraka, Nigeria (5^0 44’ 46N and 6^0 7’ 43E). The species were collected by destroying the infested furniture using cutlass and axe. The termites were identified as *Cryptotermes cavifrons* using standard identification by Edwards and Mill (1986). They were transferred into 350 x 350 transparent glass jars covered with muslin clothes of mesh sized 0.5 mm. Wood from the furniture was added to the container to serve as food for the species. Wood relating to the furniture obtained from Oria-Abraka, Delta State was equally identified and authenticated as *Polyalthia longifolia* (voucher no: 276) from the Herbarium of the Department of Botany, Delta State University, Abraka, Nigeria.

Plant Collection and Preparation

The seeds of alligator pepper *A. melegueta* (0.01%), African pepper fruit (*D. tripetala*) and high volatile oil ginger (*Z. officinale*) were used for the studies. The plant materials were air dried in the laboratory and were made into powder using mortar and pestle. The powders were packed into 350 x 350 glass jars with tight lids and stored in a laboratory until they were required for use. Permethrin (0.6% in composition commonly known as Rambo™), served as positive control to the experiment, and was obtained from a pharmaceutical store at Abraka. Woods of *P. longifolia* were cleaned, air dried and stored for the study. The sand collected from a termitarium and wood were used as substrate for the experiment and to acclimatize the wood termites for four days.

Toxicity Bioassay

Powders of *A. melegueta*, *D. tripetala*, *Z. officinale* and Permethrin were evaluated at different concentrations in gram (0.5, 1.0, and

1.5g) as adopted with modifications from Okweche *et al.* (2015). The experimental insect and test powders were placed in 350 mL glass jars. The treatments were introduced on 5g of sand and stick which served as substrates for different treatment exposure. Twenty *Cryptotermes cavifrons* were introduced into each plastic containers, covered to prevent entry and exist of insects. The treatment was replicated three times. Mortality was scored at 24 hrs interval (24, 48, 72 and 96 hrs) post treatment exposures. Insects were considered dead with failure to respond to gentle pressure using a forceps and then with finger.

Data Analysis

Mortality data was presented in means and the percentage mortality corrected using Abbot's formula (Abbot, 1925). The mean mortality data were then subjected to Analysis Of Variance (ANOVA) and percentage mortality subjected to Probit Analysis for determination of 50% lethal concentrations (LC_{50}) and 95% (LC_{95}) and associated statistics using XLSTAT software version 2019. The goodness of fit was also determined. Percentage Probit mortality was significant at 5% probability level between tested powders.

RESULT

Mortality

The result of this study showed that the botanical powders had significant effects on the mortality of the termite species at various levels of concentration and exposure time. The mean mortality of 1.00g Permethrin (0.6% composition: Rambo™) on stick is directly proportional to *A. melegueta* 1.50g, Permethrin 0.5g on stick is proportional to *Z. officinale* 0.5g on stick and *D. tripetala*0.5g on sand, Permethrin 0.5g on sand is proportional to *Z. officinale* 1.00g on stick and sand. The proportionality between the plant powders was not significantly different (*P> 0.05*). The highest mortality was recorded in *D. tripetala* 1.50g on stick while the lowest was recorded in *A. melegueta* 0.50g on sand (Table 1). Similarly, percentage probit mortality was highest on all the tested plant powders on stick compared to those recorded on sand while percentage probit mortality was highest on sand compared to those recorded on sticks in the permethrin group.

None of the plant powder tested was able to exert 100% adult mortality, but the best concentration (1.50g) of *D. tripetala, Z. officinale, A. melegueta* caused above 50% mortality on stick and compared favorably with Permethrin. The percentage probit kill is in the descending order of *D. tripetala* 1.50g on stick to Permethrin 1.50g on sand to 1.50g of Permethrin and *D. tripetala* on stick to 1.50g of *D. tripetala* on sand to Permethrin 1.00g on sand to 1.5g of *Z. officinale* on stick to 1.5g of *A. melegueta* on stick to 1.50g of *Z. officinale* on sand and so on (Table 1).

Exposure Time Records

The highest mean time mortality was recorded in 1.50g of Permethrin on sand at 0-24hrs after exposure while the lowest mean time mortality was recorded in 1.50g of *A. melegueta* and 0.50g of Permethrin at 60-72 hrs respectively. All concentration of *D. tripetala* on sand and stick caused mortality within 0 to 48hrs after exposure and compared favorably with permethrin.

The differences between the time mortality records for minimum concentrations and best concentrations (1.67%) in all the tested powders were not significant except in 1.00g and 1.5g of permethrin on sand, 1.50g of permethrin on stick which occurred within 24hrs, 1.00g and 1.50g of *D. tripetala* on sand and stick respectively which occurred within 24hrs, 1.00g of *A. melegueta* which occurred within 48hrs and 1.50g of *Z. officinale* on sand and stick respectively which occurred within 48hrs (Table 2). Time mortality in *Z. officinale* and *A. melegueta* occurred from 0-72hrs after exposure. The differences were not significant except for *Z. officinale* on stick at 36-48hrs. Mortality in 0.50g of *D. tripetala* on sand occurred only within 0-24hrs (Table 2).

Table 1.Mortality records and Probit kill of *Cryptotermes cavifrons* due to exposures to various concentration of plant powders on stick and sand

Treatment	Conc. (g)	Substrate	Log dose	Mean ± SE mortality	Probit mortality (%)
Permethrin (control)	0.50	Stick	-0.30	2.33 ± 0.80^{ab}	42.6
		Sand	-0.30	3.67 ± 0.80^{abcd}	46.2
	1.00	Stick	0.00	4.67 ± 0.80^{bcde}	49.4
		Sand	0.00	5.67 ± 0.80^{bcde}	52.8
	1.50	Stick	0.18	6.33 ± 0.80^{cde}	53.3
		Sand	0.18	7.67 ± 0.80^{de}	56.6
A. melegueta	0.50	Stick	-0.30	2.00 ± 0.80^{ab}	41.5
		Sand	-0.30	1.67 ± 0.80^{ab}	40.3
	1.00	Stick	0.00	4.00 ± 0.80^{abcd}	47.8
		Sand	0.00	3.33 ± 0.80^{abc}	45.8
	1.50	Stick	0.18	3.50 ± 1.00^{abcd}	51.5
		Sand	0.18	4.67 ± 0.80^{bcde}	49.1
Z. officinale	0.50	Stick	-0.30	2.33 ± 0.80^{abc}	42.0
		Sand	-0.30	2.67 ± 0.80^{abc}	40.2
	1.00	Stick	0.00	3.67 ± 0.80^{abcd}	48.5
		Sand	0.00	3.67 ± 0.80^{abcd}	46.8
	1.50	Stick	0.18	4.75 ± 0.69^{bcde}	52.2
		Sand	0.18	5.33 ± 0.80^{bcde}	50.7
D. tripetala	0.50	Stick	-0.30	3.00 ± 0.80^{abc}	44.2
		Sand	-0.30	2.33 ± 0.80^{abc}	42.4
	1.00	Stick	0.00	5.67 ± 0.80^{bcde}	53.3
		Sand	0.00	4.33 ± 0.80^{bcde}	49.1
	1.50	Stick	0.18	8.33 ± 0.80^{e}	58.7
		Sand	0.18	6.33 ± 0.80^{cde}	52.9

Means of the same superscript letter do not differ significantly between tested powders ($p<0.05$) using Turkey test.

Toxicity Bioassay

The probit estimation of different plant powders exposed to *Cryptotermes cavifrons* at 96hrs post treatment period is shown in Table 3. *D. tripetala* on stick recorded the lowest LC_{50} and LC_{95} compared to Permethrin, the control. The lines of probit model were concordantly highest at 1.50g of Permethrin on sand and *D. tripetala* on stick while lowest at 0.50g of *A. melegueta* and *Z. officinale* on sand ($F= 5.97$; $P< 0.0001$), and *A. melegueta* alone on stick ($LC_{50} = 1.27$; $\chi^2 = 0.03$) .

DISCUSSION

Over three decades ago, the focus of studies involving plant materials has been increased drastically in association with different insect pests (Sharma 2010). This botanicals has been noted for their insecticidal potentials as well as protectants over varieties of products including stored grains (Ojianwuna *et al.*, 2016). A notable worth of wooden and agricultural products is being lost to insect pests in Nigeria and most especially the association of dry wood termites

Table 2. Time mortality records of *Cryptotermes cavifrons* on two substrates.

Treatments	Substrate	Conc. (g)	Mean time ± SE mortality (Hours) 0-24 h	36 -48h	60 -72h	84 -94h
Permethrin (control)	Sand	0.5	1.67 ± 0.35^{ab}	0.67 ± 0.35^{ab}	0.33 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.0	2.67 ± 0.35^{b}	0.67 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.5	5.00 ± 0.35^{b}	0.67 ± 0.35^{ab}	0.00 ± 0.43^{ab}	0.00 ± 0.35^{ab}
	Stick	0.5	1.00 ± 0.35^{ab}	0.33 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.0	1.67 ± 0.35^{ab}	1.33 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.5	3.67 ± 0.35^{b}	0.67 ± 0.35^{ab}	0.00 ± 0.62^{ab}	0.00 ± 0.35^{ab}
A. melegueta	Sand	0.5	0.33 ± 0.35^{ab}	0.67 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.0	0.67 ± 0.35^{ab}	1.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.5	1.33 ± 0.35^{ab}	2.00 ± 0.35^{ab}	0.33 ± 0.35^{ab}	0.00 ± 0.60^{ab}
	Stick	0.5	0.67 ± 0.35^{ab}	0.67 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.0	0.33 ± 0.35^{ab}	2.33 ± 0.35^{b}	1.67 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.5	1.33 ± 0.35^{ab}	1.67 ± 0.35^{ab}	0.00 ± 0.43^{ab}	0.00 ± 0.35^{ab}
Z. officinale	Sand	0.5	0.00 ± 0.35^{ab}	1.00 ± 0.35^{ab}	0.67 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.0	0.00 ± 0.35^{ab}	1.00 ± 0.35^{ab}	2.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.5	0.67 ± 0.35^{ab}	2.67 ± 0.35^{b}	0.67 ± 0.60^{ab}	0.00 ± 0.35^{ab}
	Stick	0.5	0.67 ± 0.35^{ab}	1.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.0	1.00 ± 0.35^{ab}	0.67 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.5	1.33 ± 0.35^{ab}	3.67 ± 0.35^{b}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
D. tripetala	Sand	0.5	1.67 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.0	2.33 ± 0.35^{b}	1.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.5	2.67 ± 0.35^{b}	1.67 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
	Stick	0.5	1.67 ± 0.35^{ab}	1.33 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.0	3.00 ± 0.35^{b}	3.00 ± 0.35^{b}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}
		1.5	3.67 ± 0.35^{b}	2.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}	0.00 ± 0.35^{ab}

Means of the same superscript letter do not differ significantly between tested powders ($p<0.05$) using Turkey test.

Table 3. Probit estimations of different plant powders against *Cryptotermes cavifrons*

Treatments	Substrate	LC_{50}	95% CI interval Lower	Upper	LC_{95}	95% CI interval Lower	Upper	χ^2	Tabular Value
Permethrin	Sand	0.75	-2.61	1.40	4.54	1.93	11.21	0.23	3.84
	Stick	1.07	-0.99	1.54	5.94	2.60	12.87	0.01	3.84
A. melegueta	Sand	1.73	-0.32	5.08	16.25	1.96	22.26	0.004	3.84
	Stick	1.27	-0.56	2.66	8.23	2.65	15.66	0.03	3.84
Z. officinale	Sand	1.40	-0.30	3.25	8.92	2.83	16.18	0.02	3.84
	Stick	1.18	-0.71	2.13	7.02	2.68	14.25	0.95	3.84
D. tripetala	Sand	1.10	-0.89	1.72	6.27	2.63	13.31	0.15	3.84
	Stick	0.79	-1.97	1.76	2.99	2.15	7.36	0.39	3.84

χ^2: Goodness of fit. The tabular value of x^2 is 3.84 at probability level of 0.05.

with already-made furniture in homes (Abdullah *et al*., 2014). According to IPCC (2007), world temperature is most likely to increase by 3 and 6°C, respectively, thus, leading to increase in destructive activities of insects both in field conditions, stored and furnished wooden products. This increase in insect activities has prompted the use of plant protectants owing to the reports of various insecticide resistance (Gregory *et al.,* 2009; Sharma, 2010). Hence in this present study, different concentrations of plant powders of *A. melegueta, D. tripetala* and *Z. officinale* were tested against dry wood termites, *Cryptotermes cavifrons* in single forms on sand and stick for 96 hours exposure time. Our study was design as a modelled for the control of subterranean termites and those infesting wooden furniture and cabinets in houses.

The result of our study showed that mean mortality of the insect species were directly proportional to the concentrations of test powders. Higher concentrations caused higher mean mortalities and probit kills in dry wood termites. The highest mortality was recorded in 1.50g of *D. tripetala* on stick compared to the lowest in *A. melegueta* 0.50g on sand ($p < 0.05$). It was noted that the best concentrations (1.50g) of the other plant powders caused high mortalities of dry wood termites comparing favorably to the control. The result show that powders of *D. tripetala* contain insecticidal properties which is evident in the disruption of termite destructive activities on the stick and the tunnels in sands. The mortality records in best concentrations of the powders is linked to the insecticidal activities of the blend of (S)-2-heptanol, (S)-2-heptyl acetate and (R)-linalool in *A. melegueta*, blend of 1,8-cineole, neral and geranial in *Z. officinale* and linoleic acid ethyl ester, caryophyllene, 3-carene, phenyl ethyl alcohol, and cubebene in *D. tripetala* (Ukeh *et al.,* 2009; Iseghohi, 2015). The percentage mortality of dry wood termites were in the direct proportions of 1.00g of Permethrin on stick to *A. melegueta* 1.50g, Permethrin 0.5g on stick to *Z. officinale* 0.5g on stick and *D. tripetala* 0.5g on sand, Permethrin 0.5g on sand to *Z. officinale* 1.00g on stick and sand. This proportion corresponds to studies on flea beetles by Ilondu and Enwemiwe (2019).

None of the concentrations of the plant powders exerted 100% mortality but the best concentration (1.50g) of *D. tripetala* on stick ($p = 0.03$), and 1.50g of *Z. officinale* and *A. melegueta* on sand compared favorably with Permethrin, and caused above 50% mortality ($p = 0.01$). Although, the result of this study do not corroborate studies where similar botanical powders reported 100% mortality (Ukeh *et al.*, 2012; Umoetok *et al.,* 2013). It is suggestive that the effectiveness of the botanical powders and the control was not only compound dependent but also substrate-based. Thus, the higher insect mortality recorded on stick in this experiment may be as result of the inability of the termite to bore into the wooden substrate, which predicts that the powders inactivated normal activities of insects. Also, the powders may block spiracles and soft epithermal layer of insects and causing difficulty in breathing and related mortality attacks as suggested by Rajashekar *et al.* (2014) and Ilondu and Enwemiwe (2019).

It is confirmed that biological insecticides has the potentials of hindering the survival of the termites (Peterson and Ems-Wilson, 2003; Mao and Henderson, 2007). Hence, the high toxicity of dry wood termites recorded with the use of *D. tripetala* powders could be linked to their knockdown ability and resulting death. Ojianwuna *et al.* (2016) opined that extracts of *Z. officinale*, *D. tripetala* among other plant materials attained very high mortality within 24-72hrs of treatment exposure and their effectiveness were ascribed to the inability of the termites to build their moulds. To our best knowledge, this is a novelty study that involved treatment exposure of termite to different treatment concentrations using two substrates common to termites. The maximum probit kill was observed in 1.50g of *D. tripetala* on sand and stick. This is proportional to the control and it predicts that the application of *D. tripetala* powders in wooden cabinets where food are stored would reduce infestations of dry wood termites by 53-58% following results of probit mortality.

Similarly, the highest mean time mortality was recorded in 1.50g of Permethrin on sand at 0-24hrs after exposure and the lowest time mortality in 1.50g of *A. melegueta* and 0.50g of Permethrin at 60-72 hours respectively. The concentrations of *D. tripetala* on sand and stick caused mortality within 0 to 48 hours after exposure. Lowest time mortality was recorded in termites exposed to *A. melegueta* and *Z. officinale* on sand and stick respectively. Although, the finding of this study recorded below 60% mortality in *A. melegueta* and *Z. officinale* on sand and stick at 96 hours of exposure. This is not in agreement with the study of Okweche *et al.* (2015) which reported that *A. melegueta* effectively caused 95% mortality at 60 hours exposure time and 100% mortality in *Z. officinale* after 84 hours exposure time. The toxic properties of *Z. officinale, D. trepitala* powders against insects of stored products has been reported by Ukeh (2009) to be concentration and exposure time dependent. The results of this study is confirmed by the report of Abdullah *et al.,* 2014).

The effectiveness of the plant powders and control followed the order of Permethrin on sand to *D. tripetala* on stick to Permethrin on stick to *D. tripetala* on sand to *Z. officinale* on stick to *A. melegueta* on stick to *Z. officinale* on sand to *A. melegueta* on sand for lethal concentration of 50% and 95% respectively. Thus, revealing that the test powders on stick was more effective compared to other powders. Permethrin on sand, on the other hand, recorded the lowest $LC_{50}$and LC_{95}compared to the plant powders. This reveal that Permethrin on sand was the most effective. There was no lethal time records for the exposure period on sand and stick substrates. However, the probit mortality showed that a high concentration of the powders on stick is appropriate to effect high mortality in termite species. The reduced effect of the powders in the mortality of the insect could be due to the substrate used because substrate could obstruct contact toxicity. The result of this present study is in agreement with the findings of Ojianwuna and Surveyor (2017) and Krupal and Narasimhacharya (2017), Sumathi and Ramasubramanian (2013) and Suganthy (2013) in which biological insecticides were found to cause anti-insect activities. Our results is encouraging, following the on-going global search for protection of wood and materials attacked by termite species. The advantage of the three plant powders is their insecticidal ability on varieties of insect pests and inabilities to cause dangerous harm to human and the environment (Ilondu and Enwemiwe, 2019), since these plants are edible and considered food addictive. Further studies are underway to evaluate the efficacy of *A. melegueta* seed, *Z. officinale* rhizome and *D. tripetala* seed against dry wood termites under field conditions.

Based on the findings of this study, it can be concluded that *D. tripetala*, and to a lesser extent *Z. officinale*, served as alternatives bio-insecticides to commercialized insecticides on infested wooden cabinet where food are stacked and household furniture. This would limit the use of chemical insecticides which are already perceived to be costly and have a point use unlike the plant powders in this study which serve two point functions. Thus, killing the termites and acting as spice hence reducing poisoning of any kind.

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Department of Animal and Environmental Biology, Faculty of Science, Delta State University, Abraka, Delta State, Nigeria.

Ojianwuna, C.C. and Enwemiwe, V.N.*

Department of Animal and Environmental Biology, Faculty of Science, Delta State University, Abraka, Delta State, Nigeria

*Correspondence author

E-mail: enwemiwevictor@gmail.com

Orcid ID: http://orcid.org/0000-0002-2116-4448