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Effects of selected phytochemicals as protectants of smoked catfish, *Clarias gariepinus* against Hide Beetle, *Dermestes maculatus*

Akintayo Lanre Adeyekun [1, *], Felix Olusegun Akinwumi [1], Olaposi Idowu Omotuyi [2, 3], Olawale Stephen Akinmoladun [1], Lola Adedayo Awoniyi [1], Boluwaji Temidayo Aregbesola [1], Evelyn Magret Animpuye [1] and Mutahali Olawale Apalowo [1]

[1] *Department of Animal and Environmental Biology, Adekunle Ajasin University, Akungba-Akoko, Nigeria.*
[2] *Department of Pharmacology and Toxicology, College of Pharmacy, Afe Babalola University, Ado-Ekiti, Nigeria.*
[3] *Molecular Biology and Molecular Simulation Centre (Mols & Sims), Ado-Ekiti, Nigeria.*

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Abstract

This study investigated the mortality and phytochemical constituents of Lemon, Pepper fruit, Black Pepper and African Nutmeg on smoked catfish infested with Hide Beetles. Disinfested dried catfish were thoroughly rubbed with the powder of the plants at 5.0 g, 7.5 g and 10.0 g per 100 g of dried fish; newly emerged adult Beetles were introduced and kept in separate muslin covered transparent containers. Each experimental set-up was in triplicate and carried out at ambient temperature of 28 °C and 32 °C, and 65-70% observed humidity. Adult mortalities and weights of the fish were monitored and recorded for 4 weeks. 0.5ml of ethyl acetate was introduced to 0.2 g of plant powders using micropipette in order to extract oil and left for 48 hours for total extraction. Phytochemical analyses were carried out on the extracted oil using Gas Chromatography/Mass Spectrometry. Nutmeg, Pepper fruit and Black Pepper powders caused significantly higher mortalities in both adults and larvae of the beetle at all concentrations than Lemon powder. The studies revealed the possible bioactive ingredients in the selected botanicals and showed that the plant products can be used as insecticides to effective protection against the insect pest of smoked fish during storage.

Keywords: Dried fish; Botanical; Hide beetle; Bioactive; Phytochemicals

1 Introduction

Phytochemicals are bioactive compounds produced by plants [1], functioning in resisting fungi, bacteria and other infections [2]. Some phytochemicals have been used as insecticides and others in traditional medicine [3]. It has been estimated that there are more than 4000 known phytochemicals [4;5;6] and are classified by protective function, physical characteristics and chemical characteristics [1] having the potential to ameliorate diseases, such as, cancer, stroke, metabolic syndrome and those caused by microorganisms [6]. Potential phytochemicals in freshly harvested plant foods are often destroyed or removed by local and modern processing techniques. For this reason, industrially processed foods likely contain fewer phytochemicals and may thus be less beneficial than unprocessed foods [6]. The absence or deficiency of phytochemicals in processed foods may contribute to increased risk of preventable diseases [6]. Ibrahim and Fagbohun [7], stated that the most important of these bioactive compounds of plants are alkaloids, flavonoids, tannins, and phenolic compounds. Alkaloids, terpenoids and saponins are significant because they ensure plants survival against insects attack [3; 8] and thus can be used to protect other organic substances.

* Corresponding author: Akintayo Lanre Adeyekun
Department of Animal and Environmental Biology, Adekunle Ajasin University, Akungba-Akoko, Nigeria.

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In Nigeria, fishes constitute a major source of food and income for many citizens because they are highly nutritious animal. containing protein and other essential classes of nutrients. Iwalewa [9] reported that fisheries and aquaculture remain important sources of food, nutrition, income and livelihoods for millions of people globally. The high cost of beef has made low income earners to patronize fish as an alternative source of cheaper animal protein [10]. In addition, the demand for smoked fish abroad has remained constant throughout the years [11; 12]. However, fishes are susceptible to post–harvest deterioration because of high tropical temperatures, microorganisms and pests, if not quickly consumed [13]. Nigeria accounts for 30 – 40% post – harvest losses of landed catches of fish [13]. and for this reason, landed catches of fish are subjected to a variety of processing methods, mainly, fish smoking and drying [13]. A major source of damage in stored smoked fish is insect infestation by especially the hide beetle, *Dermestes maculatus* (De Geer) which attacks cured fish and significantly reduces the quantity and quality of fish flesh meant for human consumption and economic purposes [14]. Therefore, the control of *D. maculatus* infestation of smoke – dried fish is vital for economic sustainability in the fish industry worldwide. Several plant oils, as well as, powders tested against insect pests of smoke-dried fish were effective as protectants [15; 16; 17]. The toxicological studies of plant oils to economic pest like *D. maculatus* would expand the range of tools available for pest management and also establish larvicidal prospects of plant oil in the management of *D. maculatus* infestation of smoke-dried fish. This could provide the much needed replacement of the use of synthetic chemicals to protect human food and stem the dangers associated with the misuse of chemicals in edible fish protection. African nut-meg, *Monodora myristica* (Gaertn.) is a highly economical tree used for various trado-medical and consumable reasons. *Piper guineense* (Schumach) known generally as Black pepper, is a spice plant used for culinary, medicinal, cosmetic and insecticidal activities [18]. *Citrus limon* (Osbeck) generally known as Lemon is a main sources of essential oil, which is extensively studied for its potential uses in the food industry [19; 20; 21]. *Dennettia tripetala* (G. Baker) commonly known as Pepper fruit) is widely consumed by the inhabitants of West Africa due to its distinctive spicy taste and for its varied traditionally medicinal values.

The major aim of this study was to establish the bio-preservative properties of the four eco – friendly plant products against *D. maculatus* on one of the commercially important smoked fish, *Clarias gariepinus.*

2 Material and methods

The experiment was carried out in the Laboratory of the Department of Animal and Environmental Biology, Adekunle Ajasin University, Akungba Akoko Ondo State, Nigeria (7.480235° N; 5.740943° E), at ambient temperature of between 25 – 30 °C.

2.1 Collection of Plant Materials

Fresh fruits of Lemon (*Citrus limon*), dry fruits of African nut-meg *(Monodora myristica*) and dry seeds of black pepper *(Piper guineense*) were purchased at the local herbal stores in Ikare Akoko, Ondo State Nigeria. Dry pepper fruit *(Dennettia tripetala*) were obtained from Erekesan Market in Akure, Ondo State, Nigeria.

2.2 Preparation of Plant Powder

The plant materials were washed with clean tap water, dried in electric ovens to a constant weight at 40^{o}C for 8h, ground thoroughly using 5.0 HP electric grinder and sieved through a 40 holes/mm2 mesh screens. The plant powders were kept in separate sterile plastic containers with a tightly fitted lid at ambient laboratory conditions until further experimental analyses.

2.3 Collection, Culture and Maintenance of *Dermestes maculatus*

Adult insects were obtained from 5kg heavily infested dried *Clarias gariepinus* purchased from fish sellers at Ikare main market, Ikare-Akoko, Ondo State. The insects were disengaged from the tissues and kept in transparent plastic containers covered with muslin cloth at 30±2 °C. and 70±5% relative humidity in the laboratory. New generation (culture) was prepared by removing adult insects from a stock culture, placing them on fresh uninfected fish for 2-3 weeks oviposition period. Water was supplied to the insects using soaked cotton wool.

2.4 Preparation of Fish Samples

Fresh fish samples of *Clarias gariepinus* (African catfish) were collected at the fish farm of the Department of Animal and Environmental Biology, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria. The fresh fish samples were thoroughly washed with tap water to remove any adhering contaminants and drained using hand towel and weighed. The samples were dissected and guts removed. Samples of *C. gariepinus* with average weights of 400g were smoked using a traditional rectangular smoking kiln. The maximum smoking duration was four hours at 80 °C. The

samples were further kept in the electric oven at 80 °C. temperature for more than five hours in order to reduce their moisture content to less than 10%.

2.5 Investigation of Plant Powders on *Dermestes maculatus* Adults

The dried fishes were thoroughly rubbed with the plant powders at 5.0 g, 7.5 g and 10.0 g per 100 g of dried fish. Four (4) newly emerged adults of *Dermestes maculatus* were introduced into separate transparent plastics containing the treated fish. Each experimental set-up was in triplicate and was carried out at 28–32 °C. and 65–70% relative humidity. Similar transparent containers in triplicates were prepared for smoked fish without any plant powder treatment as control experiments. The cover of the transparent containers was perforated and covered with muslin cloth for aeration purposes. Adult mortality was monitored and recorded for 1, 2, 3, and 4 weeks after treatment and the percentage mortality was calculated as follows:

$$\text{Mean \% adult mortality} = \frac{\text{Mean number of dead insects}}{\text{Mean number of adult insects introduced}} \text{X} \quad 100$$

2.6 Investigation of Plant Powder on Weight of Fish Infested with *D. maculatus*

Four (4) newly emerged adult insects were introduced to the transparent containers for 6hours after coating fish samples with the plant powders at 5.0 g, 7.5 g and 10 g per 100 g of fish. Each of the experimental containers was in triplicate, covered with muslin cloth and left for 30 days at 28-32 °C. and 65-70% relative humidity. The control experiment had same number of insects without any plant powder treatment. The insect weights were monitored and recorded at 1, 2, 3, 4 weeks after treatment. The percentage weight loss was calculated as follows:

$$\text{Mean \% weight loss} = \frac{\text{Mean initial} - \text{Mean Final}}{\text{Mean initial}} \text{X} \quad 100$$

2.7 Extraction of Plant Materials

Ten grams (10 g) of ground plant sample was soaked in 80ml of 70% ethyl acetate. The mixture was stirred for 5 hours and filtered using Whatmann No. 1 filter paper and funnel. The filtrate was transferred into a tightly corked conical flask. 80ml of 70% methanol was added to the residue from the first mixture and shaken intermittently for 4 hours and filtered. The filtrate was transferred into another conical flask. 80ml of 70% ethyl acetate was again added to the residue from the second mixture, the mixture was filtered and the filtrate was kept in a conical flask overnight. The filtrates in the conical flasks were pooled together and concentrated by evaporating under vacuum with the use of rotary evaporator operated at 40 °C., and the concentrate was dried using an air pump. 1.2 g of the ethyl acetate extract (crude) was reconstituted in 100 ml distilled water and partitioned using 100 ml (3×) ethyl acetate. The fractions were concentrated using rotary evaporator operated at 40 °C.

2.8 Gas Chromatography/Mass Spectrometry (GC/MS) Analysis

GC/MS analysis was carried out at the Shimadzu Training Center for Analytical Instruments and Environmental Technical Department, Lagos (using Agilent Technology model 7890A GC/MS, MSD = 5975C (detector) Agilent Technologies, Injector: 7683B Series, Initial temperature was 100 °C held for 2 minutes, final temperature was 270 °C. at the rate of 10 °C./min, 1µl of the various fractions of the extract was injected. Temperature of heater was 250°C, pressure was 3.2652 psi, mode type slit less, column type (HP 5MS: 30 m x 320 µm x 0.25 µm) and carrier gas (Helium, 99.99% purity, flow rate = 1.4963 ml/min; average velocity = 45.618 cm/s). The constituent compounds were determined by comparing their retention times and mass weights with those of standard samples obtained by gas chromatography, as well as, the mass spectra.

Data were subjected to analysis of variance (ANOVA) test and the means were separated by Duncan new multiple test using Statistical Analysis System software version 5.0.1.

3 Results

3.1 Effects of Plant Powders on the Mortality of the Adult Fish Beetles

At the end of the first week, there was no *Citrus limon* induced mortality of *Dermestes maculatus* while there were 25% and 33.33% mortalities at the end of the 2nd and 3rd weeks respectively (Table 1). The total mortality was slightly but not significantly different from the control group (25%), as recorded in Table 1. For *Monodora myristica* after the first week, 25% mortality was recorded in the group treated with 75g, while the group treated with 10 g had zero mortality.

33.33% mortality was recorded in the group treated with 7.5 g in the second week and in the group treated with 10 g 50% mortality was recorded. In the third week, 33.33% mortality rate was recorded in the group treated with 10 g. The total mortality for the group treated with 7.5 g and 10 g was 50% and 75% respectively and were significantly different from the control group which had 25% mortality rate (Table 2). 7.5g concentration *Piper guineense* powder recorded 25% percentage mortality of insect while 10.0 g was 50% during the first week. 100% mortality in 7.5 g concentration and 50% mortality in fish treated with 10.0 g concentration was observed during the second week. The mortality effect of the powder of *Piper guineense* was significantly different when compared to the control group which had mortality of 25%. There was total mortality in the treated group while the untreated control group had a total mortality of 25% as observed on Table 3. Table 4, showed the effects of the powder of *D. tripetala* on adults of *D. maculatus* on *Clarias gariepinus.* In the Table in week one, 25% mortality of the adult insect was recorded in the fish that was treated with 5 g powder of *D. tripetala* while in the group treated with 7.5 g, 75% mortality was recorded. While 33.33% insect mortality was recorded in the group treated with 5 g in the second week, the total mortality in the groups with 5 g and 7.5 g powder treatments were 50% and 75% in weeks 3 and 4 respectively, and were significantly different from the control group (25%).

3.2 Effects of Plant Powders on the Weight of the Adult Fish Beetles

After treatment with *Citrus limon,* the Relative Weight Loss (RLW) (10.20%) in week one was higher in the fish exposed to 15g powder treatment when compared with the control group, although, the RWL value (4.22%) in group treated with 10g was significantly lower than that of the control group (Table 5). In week two (2), the RWL (2.87%) in group treated with 10g powder was higher than that of the control group (1.38%). In week four, there were significant weight losses in the group exposed to both 10 g and 15 g powder treatments. The treated fish in 10 g and 15 g treatments lost 7.181% and 4.08% of their weights respectively, while the control was reduced by 0.89% as reported in Table 5. After treatment with *Monodora myristica* the Relative Weight Loss in week one was significantly higher in fish treated with 10 g powder when compared with the group exposed to 7.5 g and the control. In week 2, group 10.0 g powder treatment had the lowest RWL (0.65%) when compared with the group rubbed with 7.5 g powder and the control (Table 6). At the end of week one, there was a significant difference in the Relative Weight Loss (RWL) in the fish groups treated with *Piper guinneense* powder. The 7.5 g and 10.0 g treatment groups had RWL 6.81% and 9.67% respectively, and were statistically different to the control (11.72%). In week two, treatment 10.0 g had the lowest relative weight loss (RWL) which was 0.27. While in week 4, the Relative Weight Loss of treatment (control) was 0.89% and that of group treatment 10.0 g was 0.81% as reported on Table 7. Table 8 showed the effect of powder of *Dennettia tripetala* on the weight of smoked *Clarias. gariepinus* and there was a significant difference in the Relative Weight Loss (RWL) in group treated with 5.0 g and 7.5 g when compared with the control group. In week one, the Relative weight loss in the control group (11.72%) was higher when compared with the group treated with 5 g and 7.5 g. 5 g and 7.5 g in week one had 4.66% and 9.40% respectively. The lowest Relative weight loss (RWL) was observed in the fourth week with the group treated with 5 g had having 0.46%.

3.3 Phytochemical Compounds Present in the Plant Materials

Table 1 Effects of *Citrus limon* Powder on Mortality of *Dermestes maculatus* on Smoked *Clarias gariepinus*

	Week 1			Week 2			Week 3			Week 4		
Powder Conc (g)	No of insect introduced	No of dead insect	% of dead insect	No of insect remaining	No of dead insect	% of dead insect	No of insect remaining	No of dead insect	% of dead insect	No of insect remaining	No of dead insect	% of dead insect
7.5	4	0	0	4	0	0	4	0	0	4	0	0
15	4	0	0	4	1	25	4	1	33	4	1	0
Control	4	0	0	4	0	0	4	1	25	4	0	0

Tables 9, 10, 11 and 12 showed the gas chromatography mass spectrometry analyses of the phytochemical compounds present in *Citrus limon* with Decane having the highest proportions and Phenol, 2,6-bis (1,1-dimethylethyl) recording

the lowest. *Monodora myristica* had alpha Phellandrene having the highest proportion and Hexadecanoic acid the lowest. In *Piper guinneense,* alpha.-Guaiene had the highest proportion and 1H-Cycloprop[e]azulen-4-ol was the lowest. Benzoic acid was recorded as the highest occuring phytochemical in *Dennettia tripetala* and 1-6-octadien-3-ol as the lowest.

Table 2 Effects of *Monodora myristica* Powder on Mortality of *Dermestes maculatus* on Smoked *Clarias gariepinus*

	Week 1			Week 2			Week 3				Week 4	
Powder Conc (g)	No of insect introduced	No of dead insect	% of dead insect	No of insect remaining	No of dead insect	% of dead insect	No of insect remaining	No of dead Insect	% of dead insect	No of Insect remaining	No of dead insects	% of dead insect
7.5	4	1	25	3	1	33.33	2	0	0	2	0	0
10	4	0	0	4	2	50	2	1	22.22	1	0	0
Control	4	0	0	4	0	0	4	1	25	3	0	0

Table 3 Effects of *Piper guineense* Powder on Mortality of *Dermestes maculatus* on Smoked *Clarias gariepinus*

		Week 1		Week 2			Week 3		Week 4			
PowderConc (g)	No. of insect introduced	No. of dead insect	% of dead insect	No. of insect remaining	No. of dead insect	% of dead insect	No. of insect remaining	No. of dead insect	% of dead insect	No.of insect remaining	No. of dead insect	% of dead insect
7.5	4	1	25	3	3	100	0	0	0	0	0	0
10.0	4	2	50	2	1	50	1	1	100	0	0	0
Control	4	0	0	0	0	0	4	1	25	3	0	0

Table 4 Effects of *Dennettia tripetala* Powder on Mortality of *Dermestes maculatus* on Smoked *Clarias gariepinus*

	Week 1			Week 2			Week 3			Week 4		
Powder Conc (g)	No of insects introduced	No of dead insects	% of dead insect	No of Insects remaining	No of dead insects	% of dead insect	No of Insects remaining	No of dead insects	% of dead insect	No of Insects remaining	No of dead insects	% of dead insect
7.5	4	1	25	3	1	33	2	0	0	2	0	0
10	4	0	0	4	0	0	0	0	0	0	0	0
Control	4	0	0	4	0	0	4	1	25	3	0	0

Table 5 Weight Loss in Smoked *Clarias gariepinus* protected with *Citrus limon*

Powder Conc (g)	Week 1		Week 2		Week 3		Week 4	
		RWL (%)		RWL (%)		RWL (%)		RWL (%)
10	4.6667±1.6414[a]	4.22	2.8333±1.5899[a]	2.87	1.1000±0.2645[a]	1.15	6.6667±2.0002[a]	7.81
15	12.3333±0.8819[b]	10.20	2.1000±0.3055[b]	1.94	1.2333±0.7333[b]	1.13	4.4100±2.9464[b]	4.08
0.0 (Control)		11.72		1.38		1.39		4.89

Mean values in columns with different superscripts as significantly different (P < 0.05) RWL: Relative Weight Loss

Table 6 Weight Loss in Smoked *Clarias gariepinus* protected with *Monodora myristica*

Powder Conc (g)	Week 1		Wk 2		Wk 3		Wk 4	
		RWL (%)		RWL (%)		RWL (%)		RWL (%)
7.5	3.6000±6.0918	9.93	3.2333±2.8846	3.58	1.0733±0.4676	1.30	2.9733±1.0248	3.59
10.0	16.7333±1.7524	15.42	-0.0667±0.4702	0.65	1.9467±1.0799	2.11	1.2267±0.8913	1.42
0.0 (Control)		11.72		1.38		0.39		0.89

Mean values in columns with different superscripts as significantly different (P < 0.05) RWL: Relative Weight Loss.

Table 7 Weight Loss in Smoked *Clarias gariepinus* protected with *Piper guineense*

Conc(g)	Week 1		Week 2		Week 3		Week 4	
		RWL (%)		RWL (%)		RWL (%)		RWL (%)
7.5	7.333±1.6823[a]	6.81	0.3333±0.133[a]	0.32	0.5257±0.242[a]	0.53	0.4367±0.331[a]	0.44
10.0	11.333±1.881[b]	9.67	0.2533±0.786[b]	0.27	0.2533±0.123[b]	0.23	0.9800±0.574[b]	0.81
0.0 (Control)		11.72		1.38		0.39		0.89

Mean values in columns with different superscripts as significantly different (P < 0.05). RWL: Relative Weight Loss.

Table 8 Weight Loss in Smoked *Clarias gariepinus* protected with *Dennettia tripetala*

Conc(g)	Wk. 1		Wk.2		Wk.3		Wk.4	
		RWL (%)		RWL (%)		RWL (%)		RWL (%)
5.0	5.1000±1.8735[a]	4.66	1.2333±0.5044[a]	1.24	1.0000±0.0000[a]	1.02	0.4667±0.5487[a]	0.46
7.5	10.0667±1.9099[b]	9.40	1.1000±0.8185[b]	1.15	1.1667±0.3333[b]	1.23	0.9333±0.5897[b]	0.98
0.0 (Control)		11.72		1.38		0.39		0.89

Mean values in columns with different superscripts as significantly different (P < 0.05) RWL: Relative Weight Loss

Table 9 Gas Chromatography/ Mass Spectrometer (GC/MS) Analyses Showing Compounds Present with the Highest Peak in *Citrus limon*

S/N	Compound name	Area	Mol weight (g/mol)
01	Decane	6.32	142
02	Undecane	4.80	156
03	Benzene, 1,2,4-trimethyl-	3.18	134
04	1,7,7-Trimethyl-2-vinylbicyclo[2.2.1]hept-2	3.49	162
05	Tridecane	3.72	212
06	Dodecane	3.84	170
07	Nonane	2.46	128
08	Cyclohexane, 1,1,3-trimethyl-2-(3-methylpe	2.56	210
09	Tridecane, 7-methyl-	2.06	198
10	2-methyltetracosane	2.22	352
11	trans-p-mentha-1(7),8-dien-2-ol	3.45	152
12	Carbonic acid, octadecyl propyl ester	2.38	356
13	Valeric acid, 4-phenyl-	3.82	178
14	Methylene	1.30	120
15	Decane, 4-methyl-	4.81	156
16	Phenol, 2,6-bis(1,1-dimethylethyl)-	1.25	206
18	Hexadonic aid	1.90	568
19	Naphthalene, decahydro-, trans-	3.29	138

Table 10 Gas Chromatography Mass Spectrometry Analyses Showing the Phytochemical Compounds Present in *Monodora myristica* with the Highest Peak

S/N	Compound Name	Area (%)	Molecular Weight (g/mol)
1	alpha.-Phellandrene	10.07	136
2	1,6-Octadien-3-ol	1.28	154
3	Naphthalene	5.21	204
4	1-Hydroxy-1,7-dimethyl-4-isopropyl-2,7-cyclodecadiene	9.28	222
5	Pyridine	17.03	183
6	Spathulanol	0.58	220
7	Limonene	0.64	136
8	Octadecanoic acid	2.60	298
9	Ethyl Oleate	12.93	296
10	Hexadecanoic acid	0.69	270

Table 11 Gas Chromatography Mass Spectrometry Analyses Showing the Phytochemical Compounds Present in *Piper guineense* with the Highest Peak

S/N	Compound name	Area (%)	Molecular Weight (g/mol)
1	Cyclohexane	5.26	204
2	Bicyclo	10.96	153
3	alpha.-Guaiene	19.94	204
4	Naphthalene	0.77	142
5	1H-Cycloprop[e]azulen-4-ol,	1.07	204
6	2,6,10,14-Hexadecatetraen-1-ol	2.09	332
7	Cyclohexanemethanol	1.63	222
8	1-Octadecanesulphonyl chloride	2.60	352
9	Cyclohexanol,	2.35	156
10	Decane	3.25	160
11	Undecane	2.71	156

Table 12 Gas Chromatography Mass Spectrometry Analyses Showing the Phytochemical Compounds Present in *Dennettia tripetala* with the Highest Peak

S/N	Compound name	Area (%)	Molecular Weight (g/mol)
01	d-menthol	1.53	156
02	1-6-octadien-3-ol	1.05	154
03	d-menthol	1.46	156
04	Formic acid	23.15	150
05	Benzoic acid	25.02	226
06	Caryophyllene	1.55	204
07	Phenol	1.42	164
08	Caryophyllene	1.53	204
09	Humulene	1.73	204

4 Discussion

The research was conducted to evaluate the insecticidal efficacy of selected plant powders against the adult stage of fish beetle, *Dermestes maculatus* on smoked catfish, *Clarias gariepinus.* The resultant high mortality of adult stages of the beetle observed on dried fish treated with majority of the plant materials could be due to high toxic effects of the plant product on the adult stages of *Dermestes maculatus*. The insecticidal property of any plant material would depend on the active constituents of the plant material. It was reported that *Piper guineense* contains phytochemicals compounds which have insecticidal tendacies [22]. The phytochemicals found in *Monodora myristica* in this research, most especially, 1-Hydroxy-1,7-dimethyl-4-isopropyl-2,7-cyclodecadiene and Ethyl Oleate, Ethyl Oleate, had also been reported to have insecticidal tendacies [23; 24; 25]. *Dennettia tripetala* (G. Baker) commonly known as Pepper fruit) contains volatile oil constituent (phytochemicals) exhibited insecticidal activities [26; 27; 28; 29; 30].

It can therefore be deduced that these metabolites and others could have worked in a synergistic way with the fatty acid components of the oils to bring about the repellence and mortality of the larvae of *D. maculatus* observed in this study.

Fasakin and Aberejo [31], reported that pulverized plant materials from *Piper guineense* inhibited egg hatchability and adult emergence of *Dermestes maculatus* Degeer in smoked catfish (*Clarias gariepinus*) during storage.

Monodora myristica significant at $p<0.05$ excellently repelled the larvae of *Dermestes maculatus* from treated smoke–dried fish, *Clarias gariepinus* thereby preserving the fishes. This view is largely supported by various Researchers [17; 32; 33; 34]. This repellent effect could be as a result of olfactory and gustory sensations which is in agreement with Egwunyenga *et al*. [35]. Though the active principle responsible for mortality and repellency was not the main focus of this study but some compounds like monoterpenes, sesquiterpenes, β – caryophyllene, diterpenes alcohol (phytol), triterpenes and volatile terpenoids which are repellent to most insects [36] which were found in good proportions in the tested plants of this study could likely have been responsible for the resulting effects observed against the larvae of *D. maculatus*.

The result obtained from the study also revealed that the powder of *Dennettia tripetala* is effective in controlling the emergence of the adult and the destruction of the larval stages of the *D. maculatus* on smoked catfish. Previous studies showed that the powder and extracts of *Dennettia tripetala* inhibited adult emergence of storage insects [37]. The bioactive component of *Dennettia tripetala* had been noted to be 2-nitroethyl-benzene or beta-phenyl nitroethane [38]. This research revealed that the treatment with *Dennettia tripetala* powder caused the highest percentage mortality, as well as, reduced the numbers of adult emergence as seen by a previous researched article [31]. The efficacy of *Dennettia tripetala* powders and extracts on mortality in this work could be due to pharmacological properties, a depolarizing neuromuscular blocking of spiracles due to volatile component thus causing respiratory impairment, which probably affected their metabolism and consequently other systems of the body of the dermestid as observed by other researchers [39].

In this research it was also noted that *Citrus limon* had no significantly effective control of *D. maculatus* in smoked catfish in comparison with other tested plant extracts. The percentage of active ingredients in the essential oil from the natural samples depends on geographical distribution as well as the environmental conditions such as temperature, rainfall, altitude, hours of sunshine [40].

5 Conclusion

It should be noted that the studied plant materials contain some important bioactive components with pronounced mortality/repellant properties on *D. maculatus*.

Recommendations

- The oil of the tested plants could form the basis for a successful formulation and commercialization of biopesticides against *Dermestes maculatus*.
- The plant powders are recommended for fish processors for the control of *Dermestes maculatus* (except *Citrus limon* which was not significantly effective in the control of hide beetle in this study) pest of smoke-dried fish and serve as a good alternative to synthetic insecticides in food fish protection.
- Further studies on the effects of other unexploited plant products on insect pests particularly *Dermestes maculatus*, is recommended.

Compliance with ethical standards

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Disclosure of conflict of interest

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