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Bioefficacy of some oil-mixed plant derivatives against African mud catfish (*Clarias gariepinus*) beetles, *Dermestes maculatus* and *Necrobia rufipes*

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The efficacy of the separate mixtures of four tropical spicy and medicinal plants: *Dennettia tripetala* Baker (pepper fruit), *Eugenia aromatica* Hook (clove), *Piper guineense* (Schum and Thonn) (black pepper) and *Monodora myristica* (Dunal) (African nut-meg) and a household vegetable oil was evaluated under tropical storage conditions for the control and reproductive performance of *Dermestes maculatus* (De Geer) (hide beetle) and *Necroba rufipes* (De Geer) (copra beetle) on African catfish, *Clarias gariepinus* (Burchell). Each of the plant materials was pulverized into powder and applied as a mix of 1ml of oil and plant powder at 2.5, 5.0, 7.5 and 10.0g per 100g of dried fish, and allowed to dry for 6h. Each of the four oil-mixed powder treatments evoked significant ($p< 0.05$) mortalities of the two insects compared with the control (oil only) at 1, 3 and 7 days post treatment. The oil-powder mixture dosages did not prevent insect egg hatchability but while the emergent larvae on the treated samples died, the emergent larvae in the control survived into adults. The application of oil-mixed powders effectively suppressed the emergence of the larvae of the beetles. Similarly, each of the oil-powder mixtures significantly reduced weight loss in smoked fish that were exposed to *D. maculatus* and *N. rufipes* when compared to the control ($p< 0.05$). The results of this study suggest that the plant powders rather than the domestic oil demonstrated protective ability against the fish beetles and confirm the efficacy of the plant products as pest control agents.

Key words: oil-powder mix, plant products, fish preservation, fish beetles, catfish

Introduction

Fish is one of the cheapest sources of animal protein and other essential nutrients required in human diets. Fish is becoming increasingly important in the diet of a larger percentage of the populace worldwide because of its availability, palatability and health provisions (Azam *et al.,* 2004; Fawole *et al.,* 2007). With their high protein content, fish are a natural supplement to cereal,

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root, tuber and red meat staples in the human diet. However, fish are a very perishable commodity, more than cattle, sheep, and poultry, and get spoiled very easily even in temperate climates; therefore they must be preserved quickly after capture (Omojowo *et al*., 2009). One of such major ways of fish curring is smoking. Ward (1995) reported that 15% of the estimated 100 million tons of World fish production in 1989 was cured in one way or the other, and that one third of the cured fish was smoked.

The African catfish, *Clarias gariepinus* is the most popular, widely cultivated and mostly smoked fish in Nigeria (Awa and Alegbeleye, 1991; Aderolu and Akpabio, 2009). However, smoked *C. gariepinus* is highly susceptible to insect infestation, mainly by hide/leather beetle, *Dermestes maculatus* (De Geer) and copra/red-legged ham beetle, *Necrobia rufipes* (De Geer). Attack on smoked catfish by *D. maculatus* and *N. rufipes* significantly reduces the quantity and quality of fish flesh destined for both human consumption and economic purposes. Osuji (1974) reported that about 71.5% of dried fish infestation was caused by *D. maculatus*. In addition, adult *Dermestes* and *Necrobia* can fly and are thus easily dispersed to new sources of food where they cause food damage, and their infestation also predisposes the infested fish to microbial attack (Adedire and Lajide, 2000).

Because of the obvious food, economic and health implications of beetles in smoked fish, several attempts have been made to control them. Ashamo and Ajayi (2003) recommended the use of paper cartons and aluminium foils as good packaging materials but the authors noted that any tiny hole in the plastic or foil through which a flow of air can pass will nullify its effectiveness, as insects can pass in and be sustained on the stored fish. Cold treatment or freezing of dried fish at 6-12 ^{o}C can kill all developmental stages of insects (Boeke *et al*., 2001) but unreliable electricity supply or lack of the purchasing power makes the use of refrigerator undependable in poor resource-based communities. In addition, mouldiness, rancidity and texture sponginess of such frozen fish have been reported (Ashamo and Ajayi, 2003). UNDFW (1988) recommended the use of primiphos-methyl (under the trade name actellic) on dried fish because it does not leave any harmful residue when properly applied. However, for low resource and illiterate fish handlers in developing countries, availability, costs and right application can constitute major problems towards the use of synthetic pesticides (Boeke *et al*., 2001). This awareness has created worldwide interest in the development of alternative strategies, including the re-examination of using plant derivatives against agriculturally important insect-pests.

Plant-derived materials are more readily biodegradable, less toxic to mammals, retard the development of resistance, easy and cheap to produce by farmers and small-scale industries as crude, or partially purified extracts. It was reported that when dried fish was mixed with leaf, bark, seed powder, or oil extracts of selected plants, there was mortality of beetles, reduced oviposition rate, suppression of adult emergence and reduced fish damage rate (Okorie *et al.*, 1990; Adedire and Lajide, 2000; Okonkwo and Okoye, 2001; Fasakin and Aberejo, 2002; Anyaele and Amusan, 2003).

In Nigeria, merchants rub groundnut oil or other vegetable oils on dried fish but only scanty information is available on whether such practices are protective or merely cosmetic. The present research was carried out to determine the action of four plant products separately mixed with one of the commercially important domestic oils in Nigeria against *D. maculatus* and *N. rufipes* on smoked catfish. The effect of the oil-mixed treatments on egg, larva and adult of the two beetle species was investigated. The study also examines the reproductive performance of the beetles on treated smoked *C. gariepinus*.

Materials and methods

Dry fruits of pepper fruit *(Dennettia tripetala)*, *black* pepper (*Piper guineense*) and African nut-meg *(Monodora myristica)* and the dry buds of clove (*Eugenia aromatica*) were purchased in local herbal stores in Akure, Nigeria.

Each of the plant materials was washed with clean tap water, dried in an electric oven to a constant weight at 40^{o}C for 8h, ground thoroughly in an electric 5.0 HP electric grinder and sieved through a 40 holes/mm^2 mesh screen (Adedire and Lajide, 2000). Each of the plant powders was kept in a separate sterile plastic container with a tightly fitted lid and kept at ambient laboratory conditions until use.

Executive Chef (from Soyabean, *Glycine max* L. Merr.) was obtained from a local supermarket in Akure, southwestern Nigeria. Powder-oil mixture was prepared in the ratio of 1ml of oil to powder dosages of 2.5, 5, 7.5 and 10g.

Samples of smoke-dried African mud catfish, *Clarias gariepinus* were obtained from a fish market in Akure, Nigeria. All samples were weighed and disinfested by heat treatment in the Gallenkamp oven at 60^{o}C for 1h and allowed to cool at room temperature.

The initial source of *D. maculatus* and *N. rufipes* culture was obtained from naturally infested smoked catfish, *C. gariepinus* collected from a dried fish market in Akure, Nigeria. Insect culture methods as described by Don-pedro (1985) and Adedire and Lajide (1999) were used. Several males and females of either *D. maculatus or N. rufipes* were obtained and maintained separately in Kilner jars covered with muslin cloth under laboratory conditions and kept at temperature 30±2^{o}C and relative humidity 70±5%. All bioassay jars were disinfected using the standard procedure by heat treatment in a Gallenkamp drying cabinets at 70°C for 1h and allowed to cool at room temperature. New generations (cultures) were prepared by removing adults of each insect species from a stock culture, placing them on fresh uninfested fish, then removing the parent adults after 2-3 weeks oviposition period. Water was supplied with pieces of soaked cotton wool.

Disinfested dried fish was thoroughly rubbed with the mixture of 1ml of oil and plant powders at 2.5, 5.0, 7.5 and 10.0g per 100g of dried fish, and allowed to dry for 6h. Six newly emerged adults (0–24h) of *D. maculatus* and *N. rufipes* respectively were introduced into separate plastic jars (80mm depth and 100mm in diameter) containing the treated fish. Each experimental set-up was in triplicate and was carried out at the ambient temperature 28–32°C and relative humidity 65–70%. Similar jars, also in triplicates, containing adult fish rubbed with oil only and beetles were used as control experiments. The caps of the plastic jars were perforated and covered with muslin cloth so as to prevent escape of the beetle or entry of other insects while allowing aeration for the beetles. Adult mortality was monitored and recorded at 1, 3, and 7 days after treatment and the percentage mortality was calculated as follows:

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

20 freshly laid eggs of *D. maculatus* and *N. rufipes* respectively were introduced into separate jars containing dried fish 6h after treatment with the mixture of 1ml of oil and plant powders at 2.5, 5.0, 7.5 and 10.0g /100g fish. The jars were covered with muslin cloth and left on the shelf. Similar jars containing dried fish rubbed with oil only and same number of eggs served as the control experiments. Tests were in triplicates for each treatment per insect species and were carried out at ambient temperature and relative humidity. Observation for hatching and recording of the emergent larvae were made at 21days after treatment, and the number of such larvae was expressed as percentage hatchability / larva emergence as follows:

$$\text{Mean \% hatchability} = \frac{\text{mean number of eggs hatched} \times 100}{\text{meanmean number of eggs introduced}}$$

Each plant material at concentration of 2.5, 5.0, 7.5 and 10.0g mixed with 1ml of oil was rubbed onto the body of 100g dried fish and placed in a Kilner jar (300 cm^3). Twenty newly emerged (up to 24 h old) adults each of *D. maculatus* and *N. rufipes* were introduced into each jar 6h later and covered with muslin cloth. Wet cotton wool was supplied in the jar to induce oviposition. A control experiment consisted of same number of insects exposed to dried fish rubbed with oil only. Each treatment was in triplicate and carried out at ambient temperature and relative humidity. Eggs laid on the fish by each of the beetles were counted every 24h for 18 days. Daily observations were also made up till 34 days after treatment for adult emergence. The number reaching larval and adult stages was recorded and expressed respectively as follows:

$$\text{Mean \% larval emergence} = \frac{\text{mean number of emergent larvae in treated sample} \times 100}{\text{mean number of eggs laid in untreated sample}}$$

$$\text{Mean \% adult emergence} = \frac{\text{mean number of emergent adult in treated sample} \times 100}{\text{mean number of emergent larvae in untreated sample}}$$

Six newly emerged (up to 24h old) adults of each insect species were introduced to plastic jar 6h after coating fish samples with the mixture of 1ml of oil and each of the plant powders at 2.5, 5.0, 7.5 and 10.0g per 100g of fish. Each of the experimental jars was in triplicate, covered with muslin cloth and was then stored on the shelf for 90 days at 28-32^{o}C and relative humidity 65-70%. Control experiments consisted of same number of insects exposed to fish coated with oil only. Weight loss was monitored and recorded at 30, 60 and 90 days after treatment. Percentage weight loss was calculated as the difference between the initial and final weight of fish, divided by the initial weight and multiplied by 100; that is:

$$\text{Mean \% weight loss} = \frac{\text{mean initial} - \text{mean final} \times 100}{\text{mean initial}}$$

Results presented are meaning values of each determination ± standard error of mean (SEM). Analysis of variance was performed by one-way ANOVA procedures (SPSS 11.0 for Windows). Differences between the mean values of the treatments were determined by Tukey's Test and the significance was defined at $p<0.05$.

Results

The effects of the oil-mixed powder treatments on the adults of *D. maculatus* and *N. rufipes* are shown in Table 1 and Table 2 respectively. There were significant differences in the effects of each of the four oil-mixed powder treatments on the mortality of the two insects compared to the control ($p< 0.05$). There were relatively low mortality rates, less than 30% of both *D. maculatus* (Table 1) and *N. rufipes* (Table 2) at 1 day after treatment (DAT). At 3DAT, mortality rates generally increased and a total kill of the two test insects was observed at the end of the experimental period. However, all the beetles survived on the untreated (oil only) fish samples.

Table 1. Effect of oil–mixed powder treatment on mortality (%) of adult *Dermestes maculates.*

Plant material	Concentration (1mL/g/100g fish)	Post treatment period (Day)		
		1	3	7
D. tripetala	0 (oil only)	0±0	0±0	0±0
	2.5	22±6.0^{b}	67±6.0^{ab}	100±0^{b}
	5.0	6±6.0^{a}	67±6.0^{ab}	89±6.0^{a}
	7.5	22±6.0^{b}	56±6.0^{a}	100±0^{b}
	10.0	28±6.0^{b}	72±6.0^{ab}	100±0^{b}
E. aromatica	0 (oil only)	0±0	0±0	0±0
	2.5	6±6.0^{a}	11±6.0^{a}	50±6.0^{a}
	5.0	11±6.0^{ab}	39±6.0^{b}	78±6.0^{b}
	7.5	16±6.0^{b}	56±6.0^{c}	78±6.0^{b}
	10.0	22±6.0^{cd}	61±6.0^{cd}	100±6.0^{c}
P. guineense	0 (oil only)	0±0	0±0	0±0
	2.5	11±6.0^{a}	33±6.0^{a}	72±6.0^{a}
	5.0	17±6.0^{a}	44±6.0^{b}	67±6.0^{a}
	7.5	28±6.0^{b}	67±6.0^{cd}	100±0^{b}
	10.0	28±6.0^{b}	72±6.0^{d}	94±6.0^{b}
M. myristica	0 (oil only)	0±0	0±0	0±0
	2.5	11±6.0^{a}	39±6.0^{a}	67±6.0^{a}
	5.0	17±6.0^{a}	50±6.0^{b}	83±6.0^{bc}
	7.5	28±6.0^{b}	56±6.0^{bc}	83±0^{b}
	10.0	22±6.0^{ab}	61±6.0^{c}	94±6.0^{bc}

Tabulated results are means of three replicates±SEM. Values in the same column carrying different superscripts are significantly different ($p<0.05$) by Tukey's Test.

The effects of oil-powder mixtures on the percentage mean egg hatch of insects on smoked fish are presented in Tables 3 and 4. The results showed that eggs did hatch on both the treated and untreated samples. It was observed that as the concentration of the dosages decreased, increasing numbers of larvae emerged from the eggs that were introduced to both the treated fish and the control. However, while the emergent larvae on the treated samples died within a few hours, the emergent larvae in the control (oil only) survived into adults.

There were significant differences ($p< 0.05$) between the average emergent insect larvae in the treated fish and the control (oil only). The results in Table 5 show that the emergence of the larvae of *D. maculatus* was significantly suppressed in smoked fish that were protected by each of the oil-powder treatments at 18DAT in comparison to the control. Table 6 shows that topical application of oil-mixed powders effectively suppressed the emergence of the larvae of *N. rufipes*. The results in the Table indicate that the number of the emergent larvae in the protected fish significantly differed from the emergent larvae in the control ($p< 0.05$). The results in Tables 5 and 6 showed that a few numbers of larvae emerged but observation revealed that there was no F_1 adult emergence in the treated samples because all larvae died within 3 days after emergence.

Table 2. Effect oil-mixed powder treatment on mortality (%) of adult *Necroba rufipes*.

Plant material	Concentration (1mL/g/100g fish)	Post treatment period (Day)		
		1	3	7
D. tripetala	0 (oil only)	0±0	0±0	0±0
	2.5	$17±6.0^{ab}$	$44±6.0^{a}$	$78±6.0^{a}$
	5.0	$6±6.0^{a}$	$56±6.0^{b}$	$94±6.0^{b}$
	7.5	$6±6.0^{a}$	$56±6.0^{b}$	$78±6.0^{c}$
	10.0	$22±6.0^{b}$	$61±6.0^{bc}$	$89±6.0^{b}$
E. aromatica	0 (oil only)	0±0	0±0	0±0
	2.5	$11±6.0^{a}$	$39±6.0^{a}$	$89±6.0^{a}$
	5.0	$17±6.0^{ab}$	$56±6.0^{b}$	$89±6.0^{a}$
	7.5	$22±6.0^{b}$	$50±6.0^{b}$	$89±6.0^{a}$
	10.0	$17±6.0^{ab}$	$39±6.0^{a}$	$89±6.0^{a}$
P. guineense	0 (oil only)	0±0	0±0	0±0
	2.5	$22±6.0^{a}$	$39±6.0^{a}$	$83±6.0^{a}$
	5.0	$17±6.0^{a}$	$50±6.0^{b}$	$89±6.0^{ab}$
	7.5	$22±6.0^{a}$	$56±6.0^{b}$	$94±0^{ab}$
	10.0	$28±6.0^{a}$	$72±6.0^{c}$	$100±0^{b}$
M. myristica	0 (oil only)	0±0	0±0	0±0
	2.5	$6±6.0^{a}$	$28±6.0^{a}$	$61±6.0^{a}$
	5.0	$22±6.0^{b}$	$67±6.0^{b}$	$94±6.0^{b}$
	7.5	$17±6.0^{bc}$	$56±6.0^{c}$	$89±0^{b}$
	10.0	$11±6.0^{c}$	$44±6.0^{b}$	$72±6.0^{a}$

Tabulated results are means of three replicates±SEM. Values in the same column carrying different superscripts are significantly different ($p<0.05$) by Tukey's Test

Table 3. Egg hatchability at 21 DAT in *Dermestes maculates* eggs treated with oil-mixed powder.

Concentration	**Plant material**			
(1mL/g/100g of fish)	***D. tripetala***	***E. aromatica***	***P. guineense***	***M. myristica***
Control (oil only)	83.5±2.5[a]	91.5±2.5[b]	88.5±2.2[bc]	90.0±2.5[bc]
2.5	85.0±2.5[a]	83.5±2.2[a]	81.5±2.4[a]	85.0±2.5[a]
5.0	81.5±2.7[a]	81.5±2.6[a]	78.5±2.6[a]	88.5±2.2[a]
7.5	73.5±2.2[b]	78.5±2.2[b]	61.5±2.2[a]	78.5±2.7[b]
10.0	58.5±2.2[a]	78.5±2.2[c]	55.0±2.5[a]	66.5±2.6[b]

Tabulated results are means of thee replicates±SEM. Values in the same row carrying different subscripts are significantly different (p<0.05) by Tukey's Test.

Table 4. Egg hatchability at 21 DAT in *Necroba rufipes* eggs treated with oil-mixed powder.

Concentration	**Plant material**			
(1mL/g/100g of fish)	***D. tripetala***	***E. aromatica***	***P. guineense***	***M. myristica***
Control (oil only)	87.0±2.0[a]	93.0±2.2[b]	93.0±2.0[b]	87.0±2.2[a]
2.5	67.0±2.2[a]	77.0±2.2[c]	90.0±2.5[d]	73.0±2.2[b]
5.0	60.0±2.5[a]	73.0±2.5[c]	87.0±2.2[d]	67.0±2.2[b]
7.5	53.0±2.3[a]	70.0±2.2[c]	77.0±2.2[d]	63.0±2.2[b]
10.0	47.0±2.0[a]	70.0±2.5[c]	70.0±2.5[c]	57.0±2.3[b]

Tabulated results are means of thee replicates±SEM. Values in the same row carrying different subscripts are significantly different (p<0.05) by Tukey's Test.

Table 5. Larvae Emergence in number at 18DAT in *Dermestes maculates* infested fish treated with oil-mixed powder treatment.

Concentration	**Plant material**			
(1mL/g/100g of fish)	***D. tripetala***	***E. aromatica***	***P. guineense***	***M. myristica***
Control (oil only)	146.33±3.1[c]	151.67±2.9[b]	136.67±2.4[a]	155.67±2.5[b]
2.5	0.67±0.31[a]	0.67±0.31[a]	0.33±0.16[a]	0.67±0.31[a]
5.0	0±0	0±0	0±0	0±0
7.5	0±0	0±0	0±0	0±0
10.0	0±0	0±0	0±0	0±0

Tabulated results are means of thee replicates±SEM. Values in the same row carrying different subscripts are significantly different (p<0.05) by Tukey's Test.

The effects of oil-mixed powder treatment on weight loss in *D. maculatus* and *N. rufipes* infested fish are shown in Table 7 and Table 8 respectively. Each of the oil-powder mixtures significantly reduced weight loss in smoked fish that were exposed to *D. maculatus* (Table 7) and *N. rufipes* (Table 8) when compared to the control ($p < 0.05$). However, while there was notable general prevention of weight losses in *D. tripetala*, *E. aromatica* and *P. guineense* treated fish at all concentration levels, fish samples treated with *M. myristica* did not have a corresponding reduction in weight loss at the lower concentrations (2.5g and 5.0g).

Table 6. Larvae Emergence in number at 18DAT in *Necroba rufipes* infested fish treated with oil-mixed powder treatment.

Concentration	**Plant material**			
(1mL/g/100g of fish)	***D. tripetala***	***E. aromatica***	***P. guineense***	***M. myristica***
Control (oil only)	85.0±2.1[b]	76.67±1.9[a]	82.0±2.3[b]	68.67±1.7[a]
2.5	0±0	0.33±0.16[a]	0±0	1.00±0.27[a]
5.0	0±0	0.67±0.31[a]	0±0	0±0
7.5	0±0	0±0	0±0	0±0
10.0	0±0	0±0	0±0	0±0

Tabulated results are means of three replicates± SEM. Values in the same row carrying different subscripts are significantly different ($p<0.05$) by Tukey's Test.

Discussion

In this study, there were significant differences between the effects of the oil-mixed powders against adult insect mortality, egg hatchability, larval emergence and weight loss in smoked *C. gariepinus* that was protected against *D. maculatus* and *N. rufipes* infestation in comparison to the control. There was no indication that the use of the domestic oil only on the smoked fish either inhibited insect mortality or deterred larval emergence nor prevented fish weight loss. This implies that the protective effect of the oil-powder mixtures against the fish beetles could be adduced to the active ingredients in the plant materials rather than the effect of the domestic oil itself. Mortality rates in oil-mixed treatments were generally lower at 1DAT, suggesting that the application of oil might have acted as an impediment to insect-powder contact and or as a dilution factor to the active ingredients in the powders. However, there were subsequent increases in the mortality rates at 3 and 7DAT when the free surface oil had dried up. Don-Pedro (1989a) noted that when groundnut oil was aged 10days, it had no effect against insect eggs and that such oil-treated larva developed successfully into adults. This observation agrees with the finding in this work that treatment with oil-mixed powder did not prevent the eggs from hatching, although the entire emergent larva died within a few hours after exposure to the effects of the plant powders. There is less agreement on the effect of oil against the life cycle of insects. While Singh *et al.* (1978) reported that oils had no effect on mortality or longevity of adult bruichids, Haghtalab *et al.* (2009) recorded 80.83% and 86.66% mortalities of *Callosobruchus maculatus* on cowpea when treated with Hazelnut oil and Castor oil respectively. Pacheco *et al.* (1995) used refined soybean and crude castor oils to evaluate for the control of infestations of *C. maculatus* and *C. phaseoli* in stored chickpea (*Cicer arietinum*), and observed that both oils inhibited population growth of the two insect species but that Castor oil was more effective than soybean oil.

Table 7. Effect of oil-mixed powder treatment on weight loss (%) in *Dermestes maculates* infested fish.

Plant material	Concentration (1mL/g/100g fish)	Post treatment period (Day)		
		30	60	90
D. tripetala	0 (oil only)	41.83±1.0^{c}	57.70±1.12^{c}	69±76±1.62^{c}
	2.5	5.35±0.86^{b}	9.69±0.40^{b}	16.07±1.12^{b}
	5.0	2.74±1.11^{a}	6.17±0.30^{a}	9.13±1.12^{a}
	7.5	3.61±1.70^{a}	8.12±1.12^{b}	10.13±1.23^{a}
	10.0	3.47±1.33^{a}	7.06±0.69^{a}	11.02±1.10^{a}
E. aromatica	0 (oil only)	42.33±2.42^{b}	60.65±1.11^{b}	71.95±2.11^{d}
	2.5	4.41±1.47^{a}	3.79±2.86^{a}	7.83±2.44^{c}
	5.0	3.24±1.22^{a}	5.94±0.84^{a}	10.29±1.64^{ab}
	7.5	3.95±2.14^{a}	6.93±2.36^{a}	12.12±3.71^{c}
	10.0	4.40±2.34^{a}	6.30±1.92^{a}	8.53±2.12^{ab}
P. guineense	0 (oil only)	41.30±1.64^{c}	62.78±1.02^{c}	79.52±1.89^{b}
	2.5	2.32±0.98^{a}	5.42±0.82^{b}	8.92±0.96^{a}
	5.0	2.96±2.00^{ab}	5.61±1.88^{b}	9.28±1.52^{a}
	7.5	3.16±0.63^{a}	6.61±0.78^{ab}	9.55±0.94^{a}
	10.0	2.09±1.20^{ab}	6.21±1.66^{ab}	9.67±2.41^{a}
M. myristica	0 (oil only)	40.85±1.12^{c}	61.26±1.00^{d}	69.82±2.12^{d}
	2.5	18.36±1.47^{b}	25.04±2.22^{c}	30.43±1.66^{c}
	5.0	7.60±2.37^{a}	11.50±3.67^{b}	16.05±2.84^{b}
	7.5	7.76±1.33^{a}	13.65±0.68^{b}	18.54±1.10^{b}
	10.0	4.76±1.33^{a}	6.55±0.33^{a}	9.70±2.33^{a}

Tabulated results are means of three replicates±SEM. Values in the same column carrying different superscripts are significantly different ($p<0.05$) by Tukey's Test.

The mode of action of oils is yet to be confirmed but Don-Pedro (1989a) suggested that insect death caused by oils is due to anoxia or interference in normal respiration resulting in suffocation. Oils could act as anti-feedants or modify the storage micro-environment thereby discouraging insect penetration and feeding (Obeng-ofori, 1995). Weaver and Subramanyam (2000) noted that oils can also act as insect growth regulators (IRGs) by affecting metamorphosis. However, Don-Pedro (1989b) reported that adults of *D. maculatus* were not affected by the application of groundnut or traditional oil unless trapped in large oil droplets.

Table 8. Effect of oil-mixed powder treatment on weight loss (%) in *Necroba rufipes* infested fish.

Plant material	Concentration (1mL/g/100g fish)	Post treatment period (Day)		
		30	60	90
D. tripetala	0 (oil only)	12.98±1.10^{c}	25.52±1.12^{d}	39±52±1.62^{d}
	2.5	3.63±0.86^{b}	7.70±0.40^{c}	12.84±1.12^{c}
	5.0	3.70±1.11^{a}	3.70±0.30^{b}	6.94±1.12^{b}
	7.5	3.16±1.70^{a}	3.16±1.12^{a}	8.84±1.23^{a}
	10.0	2.92±1.33^{a}	2.93±0.69^{a}	9.93±1.10^{ab}
E. aromatica	0 (oil only)	11.39±3.78^{c}	60.86±3.44^{c}	37.53±2.88^{d}
	2.5	4.56±1.00^{b}	10.42±0.86^{b}	13.60±1.10^{c}
	5.0	3.57±1.00^{a}	6.01±1.22^{a}	10.52±2.17^{ab}
	7.5	4.54±1.19^{a}	7.29±1.36^{b}	12.12±3.71^{ac}
	10.0	4.40±2.34^{b}	6.30±1.44^{a}	9.35±1.88^{b}
P. guineense	0 (oil only)	13.40±1.00^{c}	25.38±0.78^{d}	38.70±0.40^{c}
	2.5	3.27±0.33^{b}	8.05±0.47^{c}	13.04±0.37^{b}
	5.0	2.38±0.33^{a}	6.14±2.00^{abc}	10.05±0.30^{b}
	7.5	3.54±1.00^{ab}	6.42±0.98^{b}	8.44±1.34^{a}
	10.0	2.26±1.00^{a}	4.90±1.20^{a}	7.71±2.11^{a}
M. myristica	0 (oil only)	13.64±0.67^{d}	28.41±0.87^{d}	40.49±1.00^{d}
	2.5	9.40±1.67^{c}	17.35±0.67^{b}	24.44±1.00^{c}
	5.0	11.92±1.44^{c}	17.49±1.37^{b}	21.98±1.55^{b}
	7.5	8.31±0.67^{ab}	15.44±1.00^{a}	18.89±1.33^{a}
	10.0	6.32±1.36^{a}	10.17±2.00^{c}	14.01±1.41^{b}

Tabulated results are means of three replicates±SEM. Values in the same column carrying different superscripts are significantly different ($p<0.05$) by Tukey's Test.

According to Stoll (1988), a relatively large amount of oil per unit weight of stored product is required to achieve insect control in fish because of the absorbent nature of fish muscle. Don-Pedro (1989b) put the quantity of the required oil at about 56mL/ kg of dried fish, as compared to 14mL/kg required of grain. This means that a large initial dose or repeated application of moderate dosages of oil will be required to effectively protect dried fish and therefore uneconomical and time consuming. The phenomenal increase in weight loss in the control (which was oil only) in this study supports this reasoning.

In conclusion, this work shows that the sprinkling of oil or the rubbing of oil onto the flesh of dried fish by some African fish handlers could be cosmetic, and may not confer a protecting ability against fish pests unless applied in large dosages. The study also supports the effectiveness of the powders of the four studied plant products as pest management agents.

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