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Efficacy of Selected Biopesticides as Protectants Against *Dermestes maculatus* on Smoked *Clarias gariepinus* and *Oreochromis niloticus* in Wukari Metropolis, Taraba State

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Abstract

Fish is an affordable source of animal protein and is increasingly utilized to address nutritional deficiencies in tropical regions; however, post-harvest losses caused by insect infestation remain a major challenge to its preservation and utilization. This study aimed to assess the repellent effects of selected biopesticides against adult *D. maculatus* on smoked fish and to determine their effects on weight loss in smoked fish infested with the pest. Three newly emerged adult insects were introduced into transparent containers containing fish samples admixed with powders of *C. annuum*, *P. guajava* leaves, and *C. papaya* leaves at concentrations of 5.0 g, 7.0 g, and 10 g per 15 ± 5 g of fish. The results showed that the highest mean percentage repellency of adult *D. maculatus* on smoked catfish was recorded with 10 g of *C. annuum* powder, yielding 99.92 ± 0.00%, whereas the lowest mean percentage repellency was observed with 5 g of *C. papaya* powder, with a value of 0.08 ± 0.00%. Overall, *C. annuum* powder at all tested concentrations demonstrated the greatest repellent effect, while *C. papaya* showed the lowest repellency among the three plant treatments. The findings further indicated that, for most observation periods, increasing the concentration of plant treatment tended to reduce weight loss in tilapia, although this pattern was not entirely consistent; conversely, weight loss generally increased with longer storage duration at each treatment concentration. The study concludes that the tested biopesticides have potential as alternatives to synthetic pesticides for the control of *Dermestes maculatus* infestation in smoked fish, with *C. annuum* showing the greatest promise for enhancing protection and reducing post-harvest losses.

Keywords: Biopesticides; *Dermestes maculatus*; Fish Preservation; Repellent Activity; Weight Loss

INTRODUCTION

Fish represents an economical source of animal protein, increasingly utilized to address nutritional deficiencies in tropical regions. Globally, fish consumption delivers essential nutrients to vast populations, thereby playing a pivotal role in dietary health (Uneke, 2015). In terms of amino acid profiles, fish protein surpasses many alternatives from animal origins and aligns closely with benchmarks from dairy, poultry, and red meat products. As a cost-effective dietary staple, it remains vital for nutritional enhancement in nations like Nigeria, where carbohydrate-heavy diets predominate (Ayeloja et al., 2015). Beyond nutrition, fish supports livelihoods for countless individuals engaged in capture, preparation, and commerce near aquatic ecosystems (Alhaji et al., 2024).

Nevertheless, post-harvest degradation poses challenges in warm climates, driven by microbial activity, enzymatic breakdown, and pest interference if processing is delayed. In Nigeria, such losses affect 30–40% of harvested fish stocks, prompting reliance on techniques like solar drying and thermal smoking (Akintayo *et al.*, 2022). Among these, smoking predominates in tropical settings due to its multifaceted benefits: extending shelf stability, imparting appealing sensory attributes, exerting antimicrobial and antioxidant properties, reducing acidity, enhancing visual appeal, expediting moisture removal, and countering deteriorative factors. Despite these advantages, stored smoked fish often suffers nutritional depletion from pervasive insect damage (Ayeloja *et al.*, 2016). Stored smoked fish incurs considerable economic and qualitative damage from arthropod invasions during transit and warehousing, especially in moisture-laden environments where conventional dehydration techniques inadequately inhibit moisture regain. Such vulnerabilities often manifest as outbreaks from coleopterans, including *Dermestes maculatus*, resulting in up to

30% mass reduction under suboptimal conditions. In Nigeria, arthropod assaults represent the foremost threat to dried fish integrity, with projections indicating annual losses of approximately 50% in commercial yields near the Niger and Benue riverine hubs (Alhaji *et al*., 2024).

Arthropod proliferation on dehydrated fish alters its aesthetic and textural properties, often rendering it friable and commercially unviable. Such incursions diminish available stock volumes for end-users, elevating market prices and exacerbating protein shortages among low-income groups. Safeguarding dried fish against pests is thus essential, given fish's foundational contributions to nutritional stability, economic viability, and occupational prospects. Overreliance on conventional synthetic agents for pest mitigation fosters resistance, introduces residual contaminants into comestibles, escalates operational expenses, pollutes habitats, and poses occupational risks (Oppert *et al*., 2010).

Control measures against insect infestation of dried and smoked fish include the use of chemical insecticides such as dichlorvos, DDT and heptachlor to keep away insects and other pests. These pesticides have induced the development of pests' resistance, leading to the applications of higher pesticide doses. Numerous studies on both human and laboratory animals provide strong evidence of the toxic potential of exposure to pesticides residue. Therefore, risk characterization of pesticides in environmental samples, foods and dietary products is an important step and a vital tool in the assessment of food safety risk (Abolagba *et al.,* 2015).

Insect pests such as *Dermestes maculatus* and *Necrobia rufipes* are insect pests that destroy smoked fish during storage just as microbes, enzymes and fat oxidation accelerates rates of spoilage. *Dermestes maculatus*, is a very important pest of smoke-dried fish as it destroys the flesh of stored fish. However, efforts to reduce losses through insect infestation by the use of synthetic insecticides and pesticides have not been fully adopted due to the hazardous nature of these chemicals to health and toxicity at high doses to users. In order to eliminate much of these problems, many researchers are now working on plant based insecticides which are biodegradable, environment friendly, cheap, available and affordable to fish processors thereby justifying the use of plant based insecticide in this study (Ayeloja *et al*., 2016). Thus this research is to evaluate the Efficacy of selected biopesticides as Protectants to control *Dermestes maculatus* of Smoked African Catfish, *Clarias gariepinus* and Tilapia fish, *Oreochromis niloticus.*

MATERIALS AND METHODS

Study site

The study was carried out in Federal University Wukari, In the Department of Biological Sciences Laboratory. Wukari has a Latitude 7^0 15'N and longitude $9^0$47'E. It has an annual rainfall of about 150 mm – 200 mm with a mean temperature in October. (Taraba State Government diary, 2007).

Collection and preparation of protectants

Sniper insecticide (Dichlorvos) for the investigation was purchased from a chemical store in Wukari. Capsicum annuum fruit was purchased from Wukari market, Taraba State, Nigeria. Fresh Psidium guajava (guava) leaves and Carica papaya (paw-paw) leaves were collected from the premises of Federal University Wukari, Taraba State. These plant leaves were brought into the laboratory (Department of Biological Sciences, Federal University Wukari Taraba State, Nigeria) for identification by a Plant Taxonomist Mr Okoh Obeya Peter. The plant leaves and C. annuum (pepper) fruit were washed thoroughly with cleaned water, air-dried in the laboratory for three weeks. Each of the plant leaves and C. annuum (pepper) fruit were then pulverized into fine powder using pestle and mortal. The powder was further sieved to pass through 2mm mesh screen. The fine powders were kept separately inside an air tight sample containers at ambient laboratory condition of 27^0C to retain their freshness before application. The sniper insecticide was inside the container till the time of application (Ileke, 2021).

Preparation of sample

Fresh fish samples of *Clarias gariepinus* (African catfish) and *Oreochromis niloticus* (Tilapia fish) were purchased from Wukari fish market. The fishes were cleaned by putting them in a warm water, to remove any adhering contaminant from the fishes. Killings were done by hitting the head of the fish with a heavy object several times. Fish samples were dissected and the stomach contents removed (guts i.e. intestine, eggs). Fish samples were washed thoroughly with clean water to remove blood stains, after which they were hanged to drain off water.

Samples of fresh C. gariepinus and O. niloticus (50g weight each) were smoked using a traditional rectangular smoking kiln. Heat and smoke were generated by burning of charcoal from log of wood (different species). And smoking of the samples were been carried out separately in a single batch with the Catfish (Clarias gariepinus) at the bottom and at the top and Tilapia fish respectively. Smoking of the fish samples was done repeatedly for (3) three days to ensure the samples were well smoked. After smoking, the samples were packed into a polythene bag to reduce pest/microbial infestation (Umar et al., 2021).

Collection, Culture and Maintenance of *Dermestes maculatus*

Adult D. maculatus were obtained from 5kg heavily infested dried Clarias gariepinus and Oreochromis niloticus purchased from fish sellers at Wukari market, Taraba State. The infested samples were taken in a sealed transparent plastic container with cover to the Department of Biological Sciences, Federal University Wukari (FUW). The insects were sorted, identified, and confirmed by entomologist of the Department, using the observable morphological features with the aid of hand lens (Nasiru et al., 2022). Un-infested smoked dried C. gariepinus, O. niloticus and the experimental jars were disinfested in an oven at 60^0C for 60 minutes to kill all possible insect pests and their eggs that might be present. Twenty pairs of identified beetles were then introduced into six different rearing containers, containing 100g of disinfested smoked dried fish sample and water-soaked cotton wool to serve as source of food as well as meeting the water requirement for oviposition, respectively. The rearing containers were then covered with muslin cloth, to prevent escape or entrance of unwanted insects. The set up was then kept in an incubator at a temperature of 28^0C ± 2^0C and 65% ± 5% relative humidity (R.H) for a period of two weeks to allow oviposition and larval emergence. Adults were then removed after 14 days of oviposition (egg laying) period. The freshly laid eggs (24 hours) were used for hatchability or emergence of larvae and newly emerged larvae (0-3 days) were used for the investigation. The same containers used for production of eggs and larvae were kept under same condition for adults Dermestes maculatus that were been used for the experiment.

Data collection

Repellency test of plant powder

Rectangular containers (18cm×12cm×10cm) were used for the repellent test. The dried fishes were thoroughly admixed with C. annuum (pepper), P. guajava (guava leaves) and C. papaya (pawpaw) leaves powders each at concentrations 5.0g, 7.0g and 10.0g per 15±5g of dried fish. Three newly emerged adult of D. maculatus were introduced. The treated fish was placed at one end of the container and the control fish (untreated fish) was placed at the other end. Three (3) newly emerged adults of Dermestes maculatus were introduced into separate transparent containers, containing the treated fish with control and were replicated thrice separately for the two samples. Similar experiment was laid using 5ml concentrated sniper insecticides, diluted with water and applied at 5ml, 7ml and 10ml per 15±5g of dried fish. Each placed in different labeled container and allowed to air dry for 60 minutes. The repellency of protectants to adults D. maculatus were determined by counting the number of adults that moved away from the treated fish after 24 hours exposure period in an experimental rectangular glass containers (Folasade et al., 2015).

Effects of selected biopesticides as protectancts on Weight loss (depreciation) of Fish Infested with D. maculatus

Three (3) newly emerged adult insects were introduced into the transparent containers after admixed fish samples with *C. annumm* (pepper), *P. guajava* (guava) leaves and *C papaya* (paw-paw) leaves powders each at concentrations 5.0g, 7.0g and 10g per 15±5g of fish. Each of the experimental containers was replicated thrice separately for the two samples, covered with muslin cloth, were kept in an open air shelf in the laboratory at room temperature. The control experiments have same number of insects without natural or chemical protectants treatment. Similar experiment was laid using 5ml concentrated sniper insecticides, diluted with water and applied at 5ml, 7ml and 10ml per 15±5g of dried fish. Each placed in different labeled container and allowed to air dry for 60 minutes. Three (3) newly emerged adults of *D. maculatus* were introduced into separate transparent containers, containing the treated fish and were replicated thrice, separately for the two samples. The fish weights were been monitored and recorded every two weeks for 56 days (2, 4, 6 and 8 weeks) after treatment. The percentage weight losses were been calculated as follows:

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

Data Analysis

All data were subjected to Analysis of Variance to determine any significant difference among treatments. Significant means were separated using New Duncan Multiple Range Test (NDMRT) was employed at 5% level of probability using SPSS version 29.0.

RESULTS

Effects of Plant Powder on Repellency of Adult *D. maculatus* from Smoked Fish

Results of repellency are presented in Table 1. The highest percentage mean repellency of D. maculatus adult on smoked Tilapia fish is 66.67 ± 0.00% when each of 10g C. annuum powder, 10g P. Guajava leaves powder and 7g C. papaya leaves powder is applied. The lowest percentage mean repellency among the three plant treatment is 33.33 ± 0.00% when each of 5g C. annuum powder and 7g P. guajava leaves powder is applied.

One-way analysis of variance statistical technique showed that there is significant percentage mean difference (F=5.180, P<0.01) among the treatments concentrations. Duncan Multiple comparison techniques showed that the potency repellent for each of 7g C. papaya leaves powder, 10g P. Guajava leaves powder and 10g of C. annuum powder is significantly greater than those for each of 5g P. Guajava leaves powder, 5g C. annuum powder.

Results of repellency are showed in Table 1. The percentage mean repellency of adult D. maculatus for each treatment concentration when applied on smoked Catfish. The highest percentage mean repellency of D. maculatus adult on smoked Catfish is 10g of C. annuum with a value of 99.92 ± 0.00%. The lowest percentage mean repellency of D. maculatus adult on smoked Catfish is 5g of C. papaya with a value of 0.08 ± 0.00%. The table showed that generally, C. annuum powder at all concentrations has the largest percentage mean repellency while C. papaya has the lowest percentage mean repellency among the three plant treatments.

One-way analysis of variance statistical technique showed that there is significant percentage mean difference (F=10.184, P<0.01) among the treatments concentrations. Test showed that the potency repellent of 10g *C. annuum* powder is significantly greater than those for each of 10g *C. papaya* leaves, 7g *P. guajava* leaves powder and 5g *C. papaya* leaves powder. The potency repellent for each of 10g *P. guajava* leaves powder, 7g *P. guajava* leaves, 5g *P. guajava* leaves powder, 7g *C. annuum* powder, 5g *C. annuum* powder is significantly greater than those for each of 7g *C. papaya* leaves powder and 5g *C. papaya* leaves powder. The potency repellent for 10g *P. guajava* leaves powder is significantly greater than potency repellent of 5g *C. papaya* leaves powder.

Table 1: Percentage (%) repellency of *D. maculatus* adult on smoked Tilapia and Cat fishes at Wukari

Treatment	Tilapia Fish	Cat Fish
A 5.0	33.33 ± 0.00bc	77.75 ± 11.08ef
A 7.0	55.56 ± 11.11cd	77.75 ± 11.08ef
A 10.0	66.67 ± 0.00d	99.92 ± 0.00f
B 5.0	33.33 ± 0.00bc	77.75 ± 11.08ef
B 7.0	55.56 ± 11.11cd	77.75 ± 11.08ef
B 10.0	66.67 ± 0.00d	77.75 ± 11.08ef
C 5.0	44.44 ± 11.11bcd	0.08 ± 0.00a
C 7.0	66.67 ± 0.00d	22.25 ± 11.08ab
C 10.0	55.56 ± 11.11cd	44.44 ± 11.11bcd
D 5.0	0.08 ± 0.00a	33.33 ± 0.00bc
D 7.0	22.25 ± 11.08ab	55.56 ± 11.11cde
D 10.0	33.36± 19.22bc	66.67 ± 0.00de
	F=5.180 (P<0.01)	F=10.184 (P<0.01)

A 5.0 =5g of C. annuum (pepper) leaves powder, A 7.0 = 7g of C. annuum (pepper) leaves powder, A 10.0 = 10g of C. annuum (pepper) leaves powder, B5.0 = 5g of P. Guajava (guava) leaves powder, B7.0 = 7g of P. guajava (guava) leaves powder, B10.0 = 10g of P.guajava (guava) leaves powder, C 5.0 = 5g of C. papaya (pawpaw) leaves powder, C 7.0 = 7g of C. papaya (pawpaw) leaves, C 10.0 = 10g of C . papaya (pawpaw) leaves powder, D 5.0 = 5ml of Dichlorvos, D 7.0 =7ml of Dichlorvos, D 10.0 =10ml of Dichlorvos, Control = No treatment. 0% and 100 is transformed into 0.08% and 99.92% using $\left(\frac{1}{4n}\right)$ *and* $\left(100 - \frac{1}{4n}\right)$ *transformations.*

Effects of Plant Powder on Weight Loss of Smoked Fish

Table 2 shows the percentage mean weight loss of smoked Tilapia fish for each treatment from two weeks to eight weeks. Results from the table showed that for most periods (weeks), as concentration of plant treatment increases, weight loss of the Tilapia fish decreases but not consistent. Also, for each concentration of plant treatment, as the weeks increase, the weight loss of the Tilapia fish increases. Comparing the highest concentration of the three plant treatments, when 10g of C. annum is applied, the weight loss of the fish increases from 3.2317 ± 0.8216 to 58.6591 ± 25.9946%. When 10g P. guajava leaves powder was applied, the weight loss of the fish increased from 2.375 ± 0.8179% to 45.859 ± 17.0312%. When 10g C. papaya leaves powder was applied, the percentage weight loss of the fish increased from 3.7097 ± 1.0011% to 70.7645 ± 11.4339%.

The result showed there was a significant difference ($F = 59.067$, $P < 0.01$) of percentage mean weight loss across time (weeks). Also, there is significant interaction effect between treatment applied and time (weeks) ($F = 2.057$, $P < 0.01$). Generally, the percentage mean weight loss of the smoked Tilapia fish increases significantly as time (weeks) increases, and there is interaction effect of the treatments and time. Test showed significant mean differences among the treatments. The mean weight loss of 10g *P. guajava* performed better than *C. annuum* while *C. annuum* performed better than *C. papaya* under 2 weeks of exposure. The mean weight loss of 10g *C. papaya* performed better than *P. guajava* while *P. guajava* performed better than *C. annuum* under 4 weeks of exposure. The mean weight loss of *P. guajava* performed better than *C. annum* while *C. annuu*m performed better than *C. papaya* under 6 weeks of exposures. The mean weight loss of *P. guajava* performed better than *C. annum* while *C. annuum* performed better than *C. papaya* under 8 weeks of exposures.

Table 2: Percentage (%) Weight loss of Smoked Tilapia by D. *maculatus* adult

Treatment	2 Weeks	4 Weeks	6 Weeks	8 Weeks
Control	8.83 ± 0.86^{b}	54.29 ± 5.76^{b}	79.06 ± 1.05^{c}	90.93 ± 1.39^{d}
A 5.0	3.24 ± 1.35^{a}	37.00 ± 17.89^{ab}	66.13 ± 9.46^{bc}	78.77 ± 4.93^{bcd}
A 7.0	5.03 ± 1.98^{a}	17.26 ± 8.91^{ab}	31.83 ± 12.58^{abc}	37.76 ± 14.98^{ab}
A 10.0	3.23 ± 0.82^{a}	45.21 ± 20.01^{ab}	55.20 ± 25.58^{abc}	58.66 ± 25.99^{abcd}
B 5.0	3.55 ± 1.36^{a}	23.58 ± 12.09^{ab}	43.36 ± 21.89^{abc}	52.24 ± 21.64^{abcd}
B 7.0	4.97 ± 1.63^{a}	38.00 ± 21.76^{ab}	38.63 ± 21.45^{abc}	41.40 ± 21.95^{abc}
B 10.0	2.38 ± 0.82^{a}	24.41 ± 17.36^{ab}	37.95 ± 17.14^{abc}	45.86 ± 17.03^{abcd}
C 5.0	2.78 ± 1.17^{a}	47.87 ± 18.16^{ab}	69.46 ± 11.51^{c}	85.52 ± 4.11^{cd}
C 7.0	2.56 ± 0.61^{a}	20.61 ± 14.49^{ab}	66.61 ± 8.61^{bc}	76.85 ± 8.64^{bcd}
C 10.0	3.71 ± 1.00^{a}	21.69 ± 5.73^{ab}	57.21 ± 14.65^{abc}	70.76 ± 11.43^{bcd}
D 5.0	3.90 ± 0.35^{a}	7.47 ± 2.07^{a}	12.80 ± 4.55^{a}	16.69 ± 2.81^{a}
D 7.0	5.28 ± 0.63^{a}	8.39 ± 1.88^{a}	18.34 ± 8.27^{ab}	19.89 ± 8.09^{a}
D 10.0	5.02 ± 1.31^{a}	7.22 ± 1.84^{a}	15.29 ± 7.42^{a}	15.91 ± 8.02^{a}

For Hours: F = 59.067 (P < 0.01)

For Hours and Treatment: F = 2.057 (P > 0.05)

A 5.0 = 5g of C. annuum (pepper) leaves powder, A 7.0 = 7g of C. annuum (pepper) leaves powder, A 10.0 = 10g of C. annuum (pepper) leaves powder, B5.0 = 5g of P. guajava (guava)leaves powder, B7.0 = 7g of P. guajava (guava)leaves powder, B10.0 = 10g of P. guajava (guava)leaves powder, C 5.0 = 5g of C. papaya (pawpaw) leaves powder, C 7.0 = 7g of C. papaya (pawpaw) leaves, C 10.0 = 10g of C. papaya (pawpaw) leaves powder, D 5.0 = 5ml of Dichlorvos, D 7.0 =7ml of Dichlorvos, D 10.0 =10ml of Dichlorvos, Control = No treatment.

Table 3 shows the percentage mean weight loss of smoked Catfish for each treatment from two weeks to eight weeks. Results from the table showed that for most periods (weeks), as concentration of plant treatment increases, weight loss of the Catfish decreases but not consistent. Also, for each concentration of plant treatment, as the weeks increase, the weight loss of the Catfish increases. Comparing the highest concentration of the three plant treatments, when 10g of C. annum was applied, the weight loss of the fish increases from 1.1457 ± 0.581% to 75.0758 ± 12.3774%. When 10g P. guajava leaves powder was applied, the weight loss of the fish increased from 2.2961 ± 0.2560% to 66.0987 ± 15.2294%. When 10g C. papaya leaves powder was applied, the percentage weight loss of the fish increased from 2.9648 ± 1.6032% to 67.5582 ± 12.6932%.

The result showed there was a significant difference (F = 83.014, P < 0.01) of percentage mean weight loss across time (weeks). But the interaction effect between treatment applied and time (weeks) is not significant (F = 2.730, P < 0.01). Generally, the percentage mean weight loss of the smoked Catfish increases significantly as time (weeks) increases, and there is interaction effect of the treatments and time. Test showed significant mean differences among the treatments. The mean weight loss of 10g *C. annuum* performed better than *P. guajava* while *P. guajava* performed better than *C. papaya* under 2 weeks of exposure. The mean weight loss of 10g *C. papaya* performed better than *P. guajava* while *P. guajava* performed better than *C. annuum* under 4 weeks of exposures. The mean weight loss of *P. guajava* performed better than *C. papaya* while *C. papaya* performed better than *C. annuum* under 6 weeks of exposure. The mean weight loss of *P. guajava* performed better than *C. papaya* while *C. papaya* performed better than *C. annuum* under 8 weeks of exposure.

Table 3: Percentage (%) Weight loss of Smoked Cat fishes by D. *maculatus* adult

Treatment	2 Weeks	4 Weeks	6 Weeks	8 Weeks
Control	3.81 ± 0.95[a]	69.19 ± 3.76[c]	81.50 ± 2.58[b]	89.34 ± 1.88[c]
A 5.0	2.42 ± 0.87[a]	26.38 ± 3.95[abc]	43.80 ± 11.45[ab]	56.41 ± 7.54[bc]
A 7.0	2.80 ± 0.48[a]	36.42 ± 17.21[abc]	61.86 ± 15.45[b]	67.72 ± 12.17[bc]
A 10.0	1.15 ± 0.58[a]	58.07 ± 14.27[bc]	69.30 ± 13.39[b]	75.08 ± 12.38[bc]
B 5.0	2.09 ± 0.56[a]	31.38 ± 27.87[abc]	35.93 ± 26.30[ab]	40.57 ± 25.61[ab]
B 7.0	1.21 ± 0.28[a]	41.62 ± 22.38[abc]	46.83 ± 20.45[ab]	54.84 ± 17.36[bc]
B 10.0	2.20 ± 0.26[a]	50.88 ± 18.31[abc]	62.71 ± 14.93[b]	66.00 ± 15.23[bc]
C 5.0	3.40 ± 1.00[a]	58.37 ± 25.51[bc]	63.51 ± 21.85[b]	70.84 ± 17.34[bc]
C 7.0	2.23 ± 0.20[a]	62.56 ± 22.78[c]	67.69 ± 19.70[b]	76.54 ± 13.15[bc]
C 10.0	2.96 ± 1.60[a]	38.40 ± 14.81[abc]	64.03 ± 12.02[b]	67.56 ± 12.69[bc]
D 5.0	3.40 ±1.66[a]	5.66± 3.05[ab]	6.79 ± 4.17[a]	13.62 ± 5.25[a]

Treatment	2 Weeks	4 Weeks	6 Weeks	8 Weeks
D 7.0	0.95 ± 0.55[a]	2.79 ± 0.90[ab]	4.03 ± 1.10[a]	5.58 ± 1.36[a]
D 10.0	0.94 ± 0.54[a]	1.88 ± 0.01[a]	2.82 ± 0.55[a]	4.39 ± 0.31[a]

For Hours: F = 83.014 (P < 0.01)

For Hours and Treatment: F = 2.730 (P < 0.01)

A 5.0 = 5g of C. annuum (pepper) leaves powder, A 7.0 = 7g of C. annuum (pepper) leaves powder, A 10.0 = 10g of C. annuum (pepper) leaves powder, B5.0 = 5g of P. guajava (guava)leaves powder, B7.0 = 7g of P. guajava (guava)leaves powder, B10.0 = 10g of P. guajava (guava)leaves powder, C 5.0 = 5g of C. papaya (pawpaw) leaves powder, C 7.0 = 7g of C. papaya (pawpaw) leaves, C 10.0 = 10g of C. papaya (pawpaw) leaves powder, D 5.0 = 5ml of Dichlorvos, D 7.0 =7ml of Dichlorvos, D 10.0 =10ml of Dichlorvos, Control = No treatment.

DISCUSSION

Effects of Plant Powder on Repellency of D. maculatus Adult

The repellent effects of *C. annuum* powder, *P. guajava* leaves powder and *C. papaya* leaves powder were significant p<0.05. They repelled *D. maculatus* from smoked Tilapia fish and Catfish, thereby preserving the fishes from the attacked by *D. maculatus*. The repellency increased with increased in concentrations of all the selected plant materials. In a study conducted using chili extract on flies, increasing concentration content provides promising results on the flies and cockroaches as repellants and insecticides Septiati *et al.*, (2022). This view is largely supported by Stoll (2000) who reported repellence as a major mechanism by which plant products control insect damage to stored produce. This repellent effect could be as a result of olfactory and gustory sensations which is in agreement with Egwunyenga *et al.* (1998) who also attributed the repellence of *D. maculatus* and *Necrobia rufipes* from admixed fish to olfactory and gustory sensations. The three plants material in this study showed different repellent activities, this may be as a result of the differences in the active compounds of the plants. The plant treatment used, have different efficacy from one another. This agrees with the finding of Ngamo *et al.* (2007) that the essential oils of different plants did not have same efficacy on the pests considered in their study and that the insects reacted differently to different oils. Results from this work showed guava leaves powder have repellent effects on *D. maculatus* adults. The study by Ling *et al.* (2022), reported there was a repellent effect of *Diaphorina citri* on Murraya plants with guava leaf extracts, it was attributed to the presence of volatile compounds. Bhadra and Singh (2023), pointed out that guava is also rich in flavonoids, which are also associated with plant protection. Díaz *et al.*, (2023); found that guava leaf extracts acted as repellents against *Anastrepha fraterculus* and *Bactrocera* sp.

Effects of Plant Powder on Weight Loss of Fishes

The result obtained from this research showed that, fishes stored without treatment stand high chances of been destroyed by *D. maculatus,* while there is reduction in the level of destruction by the insects, if protectants are being applied to the fishes. It has been reported by Akintayo *et al.*, (2022) 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 and thus can be used to protect other organic substances. In the results it was revealed, that weight loss in treated and untreated fishes tissues are used as indexes for calculating rate of fish damage during storage. It was observed in this research that, as the percentages weight loss in the fishes during storage was significantly increasing as the number of weeks increased. Previous study by Nta *et al.* (2019), reveals that certain plant oil extracts are effective in the prevention of *Dermestes maculatus* infestation of stored dried fish. The observation from this work agreed with Katamssadan *et al* (2015), who reported that long storage periods allowed insects more time to breed and destroyed the fish. This result is also in support with Medugu *et al.*, (2013), who worked on susceptibility of three fish species to *D. maculates* (Degeer: Coleoptera: Dermestidae) and *N. rufipes* (Degeer: Coleoptera: Cleridae) in Maiduguri and reported that there were significant differences in the mean percentage weight loss due to the activity of *D. maculates* and *N. rufipes* among fish species and that Clarias spp sustained the highest weight loss among the 3 species.

CONCLUSION

This finding showed that *Capsicum annuum*, *Psidium guajava* and *Carica papaya* repelled and prevented weight loss in fishes from *Dermestes maculatus*. Therefore, *C. annuum* powder, *P. guajava* leaves powder and *C. papaya* leaves powder could form the basis for a successful formulation and commercialization of biopesticides against *D. maculatus*.

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