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Effectiveness of particle size of selected plant materials as protectants of stored *Clarias gariepinus* against D*ermestes maculatus* infestation

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Abstract

The focus of this study was to determine the efficacy of the different particle sizes of the powder of three plant materials, African Nut-meg (*Monodora myristica*), Black pepper (*Piper guineense*) and dry bud of Cloves (*Eugenia aromatica*) in the control of *Dermestes maculatus* infestation on stored dried African mud catfish, *Clarias gariepinus.* Each plant material was pulverized, sieved into 0.5 mm and 0.4 mm particle-sizes, rubbed at 5 g of powder onto the body of 55 g dried fish and placed in Kilner jar in triplicates. The weight loss, adult / larvae emergence and adult mortality of treated fish were determined. The results showed that 0.4 mm particle size of the powder of *P. guineense* and *E. aromatica* prevented the infestation of *D. maculatus* as demonstrated by low fish weight loss, low level of adult / larvae emergence and high mean value of adult insect mortality. Higher number of larvae emergence and weight losses were recorded in the fish exposed to 0.5 mm of each plant powder and 0.4 mm of *M. myristica*. The study revealed that stored catfish could be treated with smooth particle sizes of *Piper guineense* and *Eugenia aromatica,* and can significantly serve as protectants of smoked *C. gariepinus* against *Dermestes maculatus* infestation.

Keywords: *Dermestes maculatus*; *Monodora myristica*; *Piper guineense*; *Eugenia aromatica*; *Clarias gariepinus*

1. Introduction

The culture of the African catfish, *Clarias gariepinus* is an important source of food, income and jobs for people around the world. The consumption of fish provides an important nutrient to a large number of people worldwide and this makes it a very significant contribution to human nutrition [1, 2]. As many developing nations aim for food security for their expanding populations, there is a need to preserve fish products which are a major contributor of animal protein (from good quality fish) in order to ensure availability of food and prevent malnourishment. The phenomenon of fish preservation is enunciated by the simple principle of making fish unfavourable for the growth of spoilage organisms.

The availability of the quality of fish depends on the proper preservation of fish. A major way to bring an improvement in this aspect of aquaculture is by the use of certain preventive techniques which are less toxic and support the supply of essential nutrients. Dried fishes are readily attacked by several species of pests or insects, mainly *Dermestes* and *Necrobia* species. These pests are generally associated with dried fish, especially during storage, transportation and marketing. *Dermestes maculatus* commonly known as Hide beetle also destroys many other storage products including dried meat, dried blood, and leather and tobacco leaves [3]. The rate at which a fish spoils does not only depend on microbes, enzymes and fat oxidation but also affected by insect pests, especially in cured fish during storage [4]. A number of simple high temperature preservation techniques suitable for small-scale preservation in the tropics, such as, sun drying and smoking exists. However, in spite of the desirable effects of smoke on fish quality, high incidence of insect pest infestation has been reported to cause substantial losses in the nutritive value of fish during storage [5,6]. Smoked *C. gariepinus* is highly susceptible to insect infestation mainly by hide beetle (*Dermestes maculatus*). Attack on

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smoked catfish by *D. maculatus* significantly reduces the quantity and quality of fish flesh destined for both human consumption and economic purpose [7]. The damage caused by hide beetle on stored fish has triggered several efforts to reduce losses of quality and nutrient by the use of insecticide and pesticide which has not been fully adopted due to the hazardous nature of such chemical to health and toxicity at high doses to users. Ashamo and Ajayi (2003) [8] recommended the use of paper carton and aluminum foil as good packaging material but the author noted that any tiny hole in the plastic or foil through which flow of air can pass will nullify it effectiveness as insect can pass in and be sustained on the stored fish.

The uncertainty and hazards of chemical use and ineffectiveness of paper carton for packing of stored fish has elicited alternative strategies of controlling fish damage. One of such promising methods is the use of plant derived pest control agents. Many Nigerian medicinal plants and spices have been cited as pest control agents of stored grain, legumes and smoked fish [9, 10,6,11]. Fresh fishes are highly perishable and there is, therefore, the need for preservation in order to prevent their spoilage. In many developing countries, the common preservative methods are drying, smoking, chilling and brining but the most prominent method of fish preservation in Nigeria is smoke drying [12].

The main constraint in the efficient production and storage of dried fish is the infestation by Dermestid beetle, *Dermestes maculatus*. During storage, transportation and the marketing stage of dried fish, *D. maculatus* feeds on the fish and reduces them to powdery form. The members of genus *Dermestes* are known for their infestation of dried fish causing qualitative and quantitative damage. This genus accounts for about 71.5 % of dried fish infestation recorded in most of the producing areas with a substantial loss in dry weights of about 43 - 62.7 % from both larvae and adu1ts [13]. The female, after mating with male, lays eggs in batches with regular supply of water for drinking, they laid about 18 eggs per day and their life expectancy is 14 days at controlled laboratory condition. Egg and larvae development is affected by temperature and humidity. At 35 OC, developmental is fast and takes few days. The life cycle of *Dermestes maculatus* on either a carcass in dry-decay or in stored animal products requires approximately five to seven weeks under optimum conditions. The adults consume the remains of the carcass or the animal product. Once adults, the beetles can disperse to other food sources by flying. Adult beetles typically live between four to six months [15].

Due to the economic loss by fish mongers, the use of synthetic chemicals has been employed to protect their stock from insect infestation for lack of credible alternatives. Many synthetic chemicals, such as, pentachlorophenol (PCPs), polychlorinated biphenyls (PCBs), atrazine (S-triazines), organochlorines (OCs), organophosphates (Ops), and carbamates are no doubt effective against the pests of treated smoked fish, but some attendant problems such as insecticide resistance, lack of technical-know-how, high cost of purchase, and mammalian toxicity are better imagined than real [15]. The serious limitations (such as human health hazards, high cost of purchase, development of highly resistant strains etc.) offered by the use of highly persistent chemicals as fish preservatives have elicited interests on seeking alternative methods of controlling post-harvest fish damage. One of such promising areas is in the use of plant-derived pest control agents. The extracts and powdery form of many medicinal plants and spices have been cited as pest control agents for stored grains, legumes and smoked fish [6, 16, 17, 18, 19, 20, 21, 22, 23, 24]. However, the effectiveness of the particle size of the powder of such herbs against dry fish insects and pests has not been widely documented. Hence, the major objective of the present study was to evaluate the effectiveness of the particle sizes of Africa Nut-meg (*Monodora myristica*), Black pepper (*Piper guineense*) and Dry bud of cloves (*Eugenia aromatica*) in the control of *Dermestes maculatus* infestation on dried, *C. gariepinus*. The study evaluated weight loss in dried *C. gariepinus* treated with the different particle sizes of the plant powder, investigated larvae and adult emergence in *D. maculatus* infested fish treated with different particle sizes of plant powder and evaluated the adult mortality in *D. maculatus* infested fish treated with different particle sizes of the plant powder.

2. Material and methods

2.1. Collection and preparation of plant materials

The fresh seed of black pepper (*Piper guineense*), African nut-meg (*Monodora myristica*) and dry bubs of clove (*Eugenia aromatica*) were purchased in local herbal stores at Okusa market Akungba Akoko in Akoko South West of Ondo State. Nigeria. The plant materials were washed with clean tap water, dried in an electric oven to a constant weight at 80 OC for 2 h, ground thoroughly in an electric kettle grinder and sieved through different holes of 0.4 mm and 0.5 mm mesh sizes. 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.

2.2. Collection of *Dermestes maculatus*

The adult and larvae of *Dermestes maculatus* were obtained from heavily infested dried *Clarias gariepinus* purchased from fish sellers at Okusa market, Akungba-Akoko, Ondo State, Nigeria. The larval and adult stages of this pest were disengaged from the head of the fish and placed in two (2) plastic containers covered with muslin cloth. In the laboratory, the insect pests were placed in another set of two (2) transparent plastic whose open ends was covered with muslin cloth provided with uninfected dried fish and soaked cotton wool.

2.2.1. Insect culture and maintenance

Several males and females of *D. maculatus* were obtained and maintained in transparent plastic covered with muslin cloth under laboratory conditions and kept at temperature 30±2 OC and relative humidity 70±5 %. New generations (cultures) were prepared by removing adults of each insect from a stock culture and placing them on fresh uninfected fish, then removing the parent adults after 2-3 weeks oviposition period. Water was supplied with pieces of soaked cotton wool as the beetle requires water to lay egg.

2.3. Preparation of fish samples and smoking

Fresh samples of C. gariepinus were obtained at the fish farm of Department of Animal and Environmental Biology, Adekunle Ajasin University, Akungba-Akoko, Nigeria. The fresh fish were weighed and thoroughly washed with tap water to remove any adhering contaminants and drained with towel. The fish samples were dissected with a knife, the guts were removed and rinsed with clean water to remove the stained blood. The samples were stored in a clean bowl prior to smoking. Samples that were thoroughly rinsed with clean tap water were smoked using the modern rectangular smoking kiln. The maximum smoking duration was eleven hours and the fish was periodically turned at thirty minutes intervals to prevent charring and the fire was moderated to prevent case hardening. The maximum temperature in the smoking chamber was 80 OC. After eleven hours of smoking, the smoked fish samples were kept in an open container and later taken to the laboratory for further drying using an electric oven at 80 OC for thirty minutes in order to reduce their moisture content below 10 %.

2.4. Investigation of plant particle-size on adults *Dermestes maculatus*

Uninfected dried fish was thoroughly rubbed with the plant powder of particle size 0.4 mm and 0.5 mm at 5 g per 55 g of dried fish respectively. Three newly emerged adults (0-24 h) of *D. maculatus* were introduced into separate plastic jars containing the treated fish. Each experiment was carried out at the ambient temperature 28-32 OC and relative humidity 65- 70 %. 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 and survival were monitored and recorded at weeks 1, 2, 3, 4, 5, 6 and 7 respectively after treatment and the percentage mortality was calculated as follows:

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

2.5. Investigation of plant particle size on developmental performance of *Dermestes maculatus*

Each plant particle-sizes of 0.5 mm and 0.4 mm at 5 g respectively were rubbed on the body of 55 g dried fish and placed in a Kilner jar (300 cm3). Three newly emerged adults *D. maculatus* were introduced into each jar and covered with muslin cloth. Wet cotton wool was supplied in the jar to induce oviposition. Eggs laid on the fish by each of the beetles were observed and counted after treatment for larvae and adult emergence. The number of larval and adult emerge were counted and recorded.

2.6. Investigation of plant particle-size on weight of dried fish infested with *Dermestes maculatus*

Three newly emerged adults of the insect were introduced to plastic jar 6 h after coating fish samples treated with different plant particle-size of 0.5 mm and 0.4 mm at 5 g per 55 g of fish. Each of the experimental jars was covered with muslin cloth and was stored in the shelf for 52 days at 28-32 OC and relative humidity 65-70 %. The weight loss was monitored and recorded at week 1, 2, 3, 4, 5, 6 and 7 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:

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

2.7. Statistical analysis

Data were subjected to one-way ANOVA procedures (SPSS 11.0 windows). Difference between the mean values of the treatment were determined by Duncan Test and the significance was defined at P < 0.5.

3. Results and discussion

There were significant differences (p<0.05) in the weight loss of fish sample treated with 0.4 mm of *Monodora myristica* (0.73±1.26) compared to *Piper guineense* and *Eugenia aromatica* which recorded no weight loss (0.00±0.00) in week one (Table 1). There was no significant difference in the fish sample treated with 0.5 mm of *P. guineense* and *E. aromatica* from week one to week seven as high weight losses were recorded while 0.5 mm of *M. myristica* showed high weight loss from week two to week seven. The highest weight loss (9.67±8.34) was recorded in 0.4 mm particle size treatment of M. myristica at week 7 while the lowest was recorded in 0.4 mm of *Piper guineense* at weeks 1, 3 and 5 and *Eugenia aromatica* at the 1st, 4th and 5th weeks. The emergence of the larvae of *Dermestes maculatus* was influenced by the powder of *Monodora myristica* as shown in Table 2. There was no emergence of larvae at weeks 1 and 2 in all smoked fish protected with *M. myristica.* At the 3rd week post-treatment, the highest larval emergence (9.33±5.13) was recorded in the fish protected with 0.5mm particle size of *E. aromatica.* At weeks 4, 6 and 7, there were significantly higher (p<0.05) larval emergence in 0.5mm particle size of the treatments when compared with samples treated with 0.4mm particle plant size of the same treatment at same week. It is therefore inferential that 0.4mm particle size of *P. guineense* and *E. aromatica* were highly effective for the inhibition of larvae emergence in stored *C. gariepinus.*

Table 1 Weight Loss (%) in Infested Smoked *Clarias gariepinus* Protected with Different Plant Particle Sizes

Treatment	Particle Size (mm)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
M. myristica	0.4	0.4 0.73±1.26^{h}	0.72±1.26	1.11±0.96	0.0±0.0	1.13±0.97	1.32±1.17	9.67±8.34
	0.5	0.5 0.00±0.00^{a}	0.58±1.01^{a}	0.51±0.88^{b}	2.02±0.60^{c}	0.00±0.00^{a}	2.06±0.63^{b}	2.03±1.76^{ab}
P. guineense	0.4	0.4 0.00±0.00^{a}	1.23±0.06^{ab}	0.00±0.00	0.40±0.69	0.00±0.00	0.40±0.69	1.25±0.06
	0.5	0.5 0.69±1.20^{b}	2.59±1.37^{bc}	0.72±1.26^{bc}	0.59±1.03^{b}	1.23±1.70^{b}	0.74±1.28^{a}	0.64±1.11^{a}
E. aromatica	0.4	0.4 0.00±0.00^{a}	1.03±0.91^{ab}	0.37±0.64	0.00±0.00	0.00±0.00	0.52±0.90	0.85±0.75
	0.5	0.5 0.59±1.03^{b}	3.14±0.48^{c}	0.45±0.78^{b}	0.46±0.79^{b}	1.64±0.23^{b}	1.09±0.98^{ab}	0.56±0.97^{a}

All values are reported in Mean±SD. Values in the same column carrying different superscripts are significantly different (p<0.05)

Table 2 Larvae Emergence in *Dermestes maculatus* Infested Fish Treated with Different Plant Particle Sizes

Treatment	Particle Size (mm)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
M. myristica	0.4	0.00±0.00	0.00±0.00	4.00±6.93^{b}	6.00±6.0^{abc}	4.00±4.0^{ab}	0.00±0.00^{a}	0.00±0.00^{a}
	0.5	0.00±0.00	0.00±0.00	5.33±4.61^{bc}	9.82±8.18^{bc}	4.67±4.16^{ab}	3.33±5.77^{abc}	0.67±1.15^{ab}
P. guineense	0.4	0.00±0.00	0.00±0.00	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
	0.5	0.00±0.00	0.00±0.00	0.00±0.00^{a}	1.33±2.31^{ab}	0.00±0.00^{a}	1.00±1.73^{ab}	2.00±3.46^{ab}
E. aromatica	0.4	0.00±0.00	0.00±0.00	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
	0.5	0.00±0.00	0.00±0.00	9.33±5.13^{c}	0.00±0.00^{a}	1.00±1.73^{ab}	0.66±1.15^{ab}	0.00±0.00^{a}

All values are reported in Mean±SD. Values in the same column carrying different superscripts are significantly different (p<0.05)

Table 3 Adult Emergence in *Dermestes maculatus* Infested Fish Protected with Different Plant Particle Sizes

Treatment	Particle Size (mm)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
M. myristica	0.4	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	3±3.60^{b}	1.67±2.89^{ab}
	0.5	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.67±1.15b	2.33±1.15^{a}	2.67±0.58^{b}
P. guineense	0.4	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00^{a}
	0.5	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00^{a}
E. aromatica	0.4	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00^{a}
	0.5	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	2.00±1.00^{a}	0.00±0.00^{a}

All values are reported in Mean±SD. Values in the same column carrying different superscripts are significantly different ($p<0.05$)

Table 4 Adult Mortality in *Dermestes maculatus* Infested Fish Treated with Different Plant Particle Sizes

Treatment	Particle Size (mm)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
M. myristica	0.4	0.00±0.00	0.0±0.00^{a}	0.00±0.00^{a}	22.22±19.24^{b}	11.11±19.2^{ab}	0.00±0.00^{a}	33.33±57.7^{b}
	0.5	0.00±0.00	0.0±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
P. guineense	0.4	0.00±0.00	0.0±0.00^{a}	11.11±19.2^{ab}	72.22±25.45^{c}	66.67±57.7^{abc}	0.00±0.00^{a}	0.00±0.00^{a}
	0.5	0.00±0.00	0.0±0.00^{a}	0.00±0.00^{a}	22.22±19.24^{b}	0.00±0.00^{a}	11.11±19.2^{b}	100±0.00^{c}
E. aromatica	0.4	0.00±0.00	11.11±19.2^{b}	22.22±19.2^{ab}	66.67±28.87^{c}	66.67±57.7^{abc}	0.00±0.00^{a}	0.00±0.00^{a}
	0.5	0.00±0.00	0.0±0.00^{a}	0.00±0.00^{a}	22.22±19.24^{b}	77.78±38.49^{bc}	0.00±0.00^{a}	0.00±0.00^{a}

All values are reported in Mean±SD. Values in the same column carrying different superscripts are significantly different ($p<0.05$)

There was no adult insect emergence in the fish protected with 0.4 mm and 0.5 mm particle sizes of the powder of *P. guineense* from week 1 - 7 (Table 3). There was emergence of adult in sample treated with 0.4 mm particle size of P. guineense, *E. aromatica* and *M. myristica* at weeks 1, 2, 3 and 4. At week 5, only the treatment with 0.5 mm particle size of *M. myristica* had adult emergence (0.67±1.15) which increased till 7th week. The result in Table three showed that the emergence of adult was significantly inhibited in the samples treated with 0.4 mm particle size of *P. guineense* and *E. aromatica*.

The percentage adult mortality was significantly affected by the particle size of the treatments (Table 4). At week 2, treatment with 0.4 mm particle size of *E. aromatica* showed the highest percentage mortality when compared to other treatments. Also, there were significantly ($p<0.05$) higher percentage mortality of adult in samples treated with 0.4 mm particle size of *M. myristica* (22.22±19.24), *E. aromatica* (66.67±28.87) and *P. guineense* (72.22±25.45) at week 4 in comparison to the adult mean mortalities in the samples treated with 0.5 mm particle sizes of the same treatment. This indicated that the smaller particles of the plant powder were more effective in the control of the fish pest.

The study compared the effectiveness of the particle sizes of three selected plant materials, black pepper (*Piper guineense*), dry bud of cloves (*Eugenia aromatica*) and Africa nut-meg (Monodora myristica) in the control of *Dermestes maculatus* in stored *Clarias gariepinus*.

The resulting low weight loss, low larvae emergence, low adult emergence and high level of adult mortality observed in 0.4mm particle size of *M. myristica, P. guineense* and *E. aromatica* used to protect *C. gariepinus* could be as a result of the advantage of good coverage on surfaces and ease of attachment to an insect's legs and body offered by the particle size. Also, the active ingredient in the smaller particles could be picked up easily than the larger ones when inhaled, thereby causing the death of the insects.

Lale [25] reported that *P. guineense* contains piperine and chavicine, the active ingredients that are toxic to the insect pest. Adedire and Lajide [26] reported that the plant materials in the Family Annonaceae to which *Monodora myristica* belongs, possess some form of insecticidal properties against the eggs of cowpea, Bruchid, and that they are also capable of suppressing the various developmental instars of *Callosobrunchus maculatus.*

The toxicity and repellence of the different botanical materials in the control of *D. maculatus* have been evaluated [6, 27, 16, 28, 19]. The insecticidal property of any plant would depend on the active constituents of the plant material [29]. According to Lale [30], the mortality of adult and larvae are two common mechanisms which have been observed as the basis for low damage insect pest to stored product with plant materials.

In this study, there were significant differences in the insecticidal effectiveness of the 0.5mm and 0. 4mm.sizes of the the plant powder. The results obtained in this study agree with the findings of Adedire and Lajide, [31] and Longe [32] who reported that *E aromatica* powder had significant contact and fumigant action against *Callosobruchus maculatus*. The findings are also similar to Akinneye [33] who reported that the inability of the egg to hatch to larval might be due to the fact that the powders inhibit gaseous exchange between the egg and external environment. The 0.4 mm particle size of *M. myristica, P. guineense* and *E. aromatica* caused significant adult mortalities of *D. maculatus* in the first 3 weeks of the protection by the plant powder, thus indicating a probable safe control method that can prevent the infestation of stored *C. gariepinus* by *D. maculatus.*

4. Conclusion and recommendation

The results obtained in this study showed that stored catfish can be effectively protected with 0.4 mm particle size of *P. guineense* and *E. aromatica* against the attack of *D. maculatus*. The protective and toxic effects of the powder in addition to the local availability make the plant materials a more attractive bio-preservatives in the management of post-harvest losses in stored fish, thereby preventing protein malnutrition and enhancing food security.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest declared.

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