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Biopesticide value of *Uapaca corbisieri* and *Sterculia oblonga* plants against *Dermestes maculatus* DeGeer (Coleoptera: Dermestidae) infestation in smoked-dried fish *Clarias gariepinus* Burchell

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Abstract Fish merchants and consumers face severe deterioration and damage of smoked-dried fish due to *Dermestes maculatus* (Coleoptera: Dermestidae) infestation. This study evaluates the potential of *Sterculia oblonga* and *Uapaca corbisieri* plant powder as natural alternatives to synthetic fumigants for controlling *D. maculatus* infestation and minimising damage to smoked-dried *Clarias gariepinus* fish. The powders were separately admixed at concentrations of 5.0, 7.5 and 10.0% w/w per 20 g of dried fish. Results showed that *U. corbisieri* and *S. oblonga* powder at different concentrations evoked significant ($P<0.05$) larval mortality compared to the untreated fish as the concentration increased. Similarly, the application of *U. corbisieri* powder significantly ($P<0.05$) inhibited adult emergence compared to the control, whereas adult emergence inhibition rate was non-significant between the samples treated with different concentrations of *S. oblonga* powder. Feeding activity of *D. maculatus* larvae on smoked dried fish treated with *U. corbisieri* was significantly affected compared to *S. oblonga* powder-treated fish. Untreated fish samples suffered significant weight loss compared with samples treated with plant powders, revealing insecticidal potential of these two plant powders. Their adoption can be encouraged and developed as a biopesticide to reduce the use of synthetic chemicals for the protection of *C. gariepinus* smoked fish against *D. maculatus* infestation by some merchants. Further study is recommended to determine the chemical constituents of the plant materials that are responsible for their insecticidal activity. In addition, the toxicity of the plant

powder should be evaluated to determine the safe consumption of treated fish.

Keywords: Biopesticide, inhibition rate, insecticidal effect, larval feeding activity, quality deterioration

1 Introduction

Fish is widely accepted and readily available as a dietary protein source on most people's menus, regardless of their socioeconomic status, age, or religious background. When compared to other dietary protein sources like meat, eggs, and legumes, fish is an excellent source of digestible essential nutrients required for the maintenance of a healthy human body (Marimuthu *et al*. 2012). Consuming fish is important for human nutrition because it is an inexpensive and easily accessible source of dietary protein for many people worldwide (Mufutau 2012) and for those who cannot afford the rising costs of animal protein sources like beef (Adesina *et al*. 2016, Sujita *et al*. 2019, Selamoglu and Naeem 2023).

One of the most popular methods for preserving fish in developing countries, Nigeria in particular is smoke-drying it. This improves flavour and utilisation (Salaudeen and Osibona 2018), makes fish products more readily available all year round, and makes handling easier during marketing and transit (Inusa *et al.* 2022). However, a significant obstacle to the preservation and storage of smoke-dried fish is insect pest infestation, which can cause significant degradation and quality losses.

Dermestes maculatus, commonly known as Hide beetle (Coleoptera: Dermestidae) causes significant damage to smoked-dried fish globally. It feeds and thrives on smoked fish, and its larval stages account for approximately 90% of infestations, which leads to losses in quantity and quality as well as changes in the fish's appearance that render it unfit for consumption, reduce its nutritional value, and decrease its market value (Johnson and Esser 2000, Adesina *et al*. 2016). Fish infested with *D. maculatus* are similarly vulnerable to microbial attack (Emmanuel 2019).

In the absence of viable alternatives, fish merchants use synthetic fumigants and insecticides to reduce these post-storage losses. However, health concerns arising from such chemical use have made it necessary to find alternatives such as biopesticides (Abolagba *et al*. 2011, Jose and Adesina 2014, Jatau *et al*. 2024). Plant powders with insecticidal, antifeedant, and repellent capabilities have been established by several researchers to be effective in controlling *D. maculatus* on smoke-dried *C. gariepinus* (Adedire and Lajide 2000, Olayinka-Olagunju 2014, Abdullahi *et al*. 2016, Olori-Oke and Onyeonoro 2019, Koomson *et al.* 2022).

Sterculia oblonga Mast. (Synonym *Eribroma oblonga*) is a member of the Malvaceae family and also known as Yellow Sterculia, Oroforofo in Yoruba, and Okoko in Edo. It is a type of tree that is commercially exploited for its timber in the tropical rainforests of West and Central Africa. While the leaves and bark are used in traditional medicine to treat a variety of ailments, the seeds are edible and taste like

peas (Bosch and Louppe 2008, Tropical Plants Database 2026). Gas chromatography-mass spectroscopy (GC-MS) analysis of essential oil/extracts of *S. oblonga* shows that the plant contains various compounds ranging from simple to very complex compounds such as tannins, flavonoids, alkaloids, cyanide, lipids, phenol, and oxalate (Ezeonu and Ejikeme 2016, Frank and Emmanuel 2021, Nkom *et al*. 2024).

Uapaca corbisieri De Wild. also called Wild Mahogany or Wild Mango is a flowering plant species in the Phyllanthaceae family native to tropical and subtropical regions of Africa. The leaves and bark are used to treat various ailments such as fever, malaria, and dysentery (Breteler 2013), management of inflammatory diseases like rheumatism and joint pains, as well as purgative, gastrointestinal troubles, anti-abortive and skin-related diseases like leprosy, and eczema (Bouquet and Debray 1974). Plants in the *Uapaca* genus are rich in bioactive secondary metabolites such as diterpenes, fatty acids, cyclopentones, quinic acid, oxalic acids, triterpenes, saponins, flavonoids and tannins which contribute to the fruits' astringency, medicinal, anti-inflammatory and potential anti-cancer properties (Nyasse *et al*. 2009, Tebbal *et al*. 2025). GC-MS analysis conducted by Gervais *et al.* (2022) revealed the presence of lupeol, betulin, betulinic acid, β-amyryl acetate, physcion, quercetin, rutin, β-sitosterol, and β-sitosterol-3-O-β-D-glucopyranoside in *U. corbisieri*. The presence of these compounds sums up the effective use of the plant in many pharmacological applications and may serve as promising sources for future biopesticide applications.

Consequently, the goal of this research is to evaluate the potential of *Sterculia oblonga* and *Uapaca corbisieri* plant powder as natural alternatives to synthetic fumigants and insecticides for controlling *D. maculatus* infestation and minimising harm to smoked-dried *Clarias gariepinus* fish.

2 Material and Methods

The study was carried out under ambient conditions of 32 ± 2 °C temperature, 75 ± 5% relative humidity, and 12-hour dark/light photoperiods at the Department of Fisheries and Aquaculture Laboratory, Rufus Giwa Polytechnic, Owo, (5° 12' N and 5° 36' E), Ondo State, Nigeria.

2.1 Processing of plant materials

The stem bark of *Uapaca corbisieri* and *Sterculia oblonga* was collected from their natural habitat at Ilu Titun in Okitipupa (6° 57' N and 4° 56' E), Ondo State, and Ikere Ekiti (7°30′N and 5°14′E), Ekiti State. After washing the plant materials in clean water to remove any dirt, they were allowed to air dry for three weeks. After that, the plant materials were ground into a fine powder using a mortar and pestle, and sieved through a 0.2mm mesh size sieve to obtain a fine powder (Jatau *et al*. 2024). Each powder was then stored in a separate plastic container with a tight-fitting lid and kept under ambient laboratory conditions until needed.

2.2 Culturing of *D. maculatus Larvae* and processing of smoked-dried fish sample

The first supply of *D. maculatus* larvae of different ages was obtained from naturally infested smoke-dried catfish from fish vendors in Owo, Ondo State, Nigeria. In a Kilner jar with muslin cloth covering to allow air circulation, *D. maculatus* larvae were reared in ambient conditions keeping other insects from entering or escaping (Amulejoye and Maulu 2024). In order to produce a new generation of emerging adults, adult insects from the stock culture were placed on freshly disinfested smoked dried fish after two weeks, and newly hatched larvae from mass rearing were used for the bioassay. Water-soaked cotton wool was placed at the bottom of the jar to provide water requirements for oviposition (Emmanuel 2019).

From the Ulede market in Owo, Ondo State, smoke-dried fish samples of *C. gariepinus* (without the head region) weighing roughly 20g each were purchased. The samples had no obvious signs of an adult or larval *D. maculatus* infestation. To destroy any hidden insect pest development stage, the fish samples were disinfested in a Gallen Kamp hot air oven at 100°C for 30 minutes, and then allowed to cool at ambient temperature to prevent mould growth (Adesina *et al*. 2015).

2.3 Larvicidal Activity of *U. corbisieri* and *S. oblonga* powder

About 20g of the sterilised smoke-dried fish was separately weighed into 250ml plastic containers. Different amount of (1.0, 1.5 and 2.0g) of *U. corbisieri* and *S. oblonga* powders, corresponding to 5.0, 7.5 and 10.0% w/w respectively were separately admixed manually and moderately shaken for 2 min to guarantee uniform mixture. Fish samples were then coated with the plant powders (Adesina *et al*. 2016) and then stabilized for 5 to 10 min. Ten *D. maculatus* larvae (1-3 day old) were sieved from the culture and introduced into each plastic container of fish samples coated with plant powders, and were tightly covered to prevent the escape and entry of insects (Adesina *et al*. 2011, Ito and Utebor 2018). The control experiment was equally set up with untreated fish without the addition of plant powers or any form of protectants. The number of dead larvae was recorded at 12, 24, 48 and 72 h after infestation to determine the mortality rate of *D. maculatus* larvae. Larvae that refused to respond to pin probing at the abdomen were considered dead.

% larva mortality = (number of dead larvae / number of introduced larvae) x 100

At 35-day post infestation, the number of emerged adults from treated and untreated samples was counted and used to determine adult emergence inhibition rates (IR) (Kundu *et al*. 2007).

$$\% \text{ IR} = [(Cn - Tn)/Cn] \times 100$$

where, Cn = number of insects in the control, and Tn = number of insects in treated.

The percentage weight loss was determined at the end of the experiment by reweighing the fish samples after sieving out the plant power along with the insect frass (Adesina *et al*. 2016), as follows.

% weight loss = [(initial weight - final weight)/ initial weight of fish sample] x 100

Damage assessment was carried out on treated and untreated fish using the feeding deterrence index.

Feeding Deterrence Index: FDI = [(WC – WT)/(WC + WT)] × 100

where, WC= Final weight of sample in control and WT = Final weight of sample in treated.

2.4 Experimental design and statistical analysis

All the treatments were replicated three times and arranged in a Completely Randomised Design (CRD). Before analysis, data in percentages were arcsine transformed to ensure normalisation and homogenization of the data (Asiry and Zaitoun 2020). Data were subjected to analysis of variance using Microsoft Excel 2016 software package (Adesina *et al*. 2011) and where means were found to be significant, these were separated using Duncan Multiple Range Test at 5% level of significance ($p<0.05$), and the results were interpreted accordingly. The mean value ± SE was presented for all the data.

3 Results

3.1 Larval mortality of *D. maculatus*

Statistically, the result in Table 1 showed that application of the *U. corbisieri* and *S. oblonga* powder at different concentrations had a significant ($P<0.05$) effect on the mean percentage larval mortality of *D. maculatus* in treated smoked dried fish over the period of exposure, post infestation. At the highest concentration of 10% plant powders, larval mortality above 50% was achieved 12 h post infestation. While the lowest mortality was observed from the lowest concentration. Across the treatments, the result also showed that mortality increased as the concentration of *U. corbisieri* and *S. oblonga* powders increased from 5% to 10% (Table 1). However, at 48h post infestation, nonsignificant larval mortality was noticed in samples treated with 5 and 10% *S. oblonga* powders.

Table 1: Percentage mortality of *D. maculatus* larvae exposed to different concentrations of *Uapaca corbisieri* and *Sterculia oblonga* powder.

	Uapaca corbisieri				*Sterculia oblonga*			
Conc.	12 h	24h	48h	72h	12 h	24h	48h	72h
0%	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}
5 %	23.85 ± 3.85^{b}	42.29 ± 3.66^{b}	52.86 ± 3.93^{b}	57.00 ± 3.65^{b}	16.92 ± 2.93^{b}	47.71 ± 3.85^{b}	50.94 ± 5.85^{b}	53.07 ± 5.45^{b}
7.5%	30.00 ± 1.51^{c}	53.15 ± 2.51^{c}	57.00 ± 1.34^{c}	61.22 ± 3.84^{c}	40.08 ± 2.01^{c}	45.00 ± 3.91^{c}	50.77 ± 0.00^{b}	59.71 ± 6.18^{c}
10%	54.78 ± 2.01^{d}	60.01 ± 3.33^{d}	63.93 ± 4.27^{d}	68.85 ± 4.69^{d}	50.92 ± 1.34^{d}	53.78 ± 2.01^{d}	59.01 ± 3.84^{c}	66.15 ± 2.71^{d}

Means (± SE) with shared alphabet along the column showed no significant difference at $p<0.05\%$ using Duncan's multiple range test (DMRT).

3.2 *Dermestes maculatus* larval emergence inhibition rate

Larval emergence inhibition rates show that fish samples treated with *U. corbisieri* powders recorded a significant reduction of larval emergence, with 10% treated samples having the maximum inhibition rate (35.05%), and the untreated control had the highest larval emergence rate (61.77%). The inhibition rate revealed a dose-dependent response (Table 2). In comparison, a non-significant larval emergence inhibition rate was noticed between the samples treated with different concentrations of *S. oblonga* powder. However, the emergence of larval was significantly inhibited in treated samples compared to untreated (Table 2).

Table 2: *Dermestes maculatus* larval emergence inhibition rate from smoked dried fish treated with *Uapaca corbisieri* and *Sterculia oblonga* powders.

Concentration (%)	*Uapaca corbisieri*	*Sterculia oblonga*
0	61.77± 1.75 ^{a}	55.17 ± 5.39 ^{a}
5	54.27 ± 5.56 ^{b}	48.00 ± 7.19 ^{b}
7.5	48.16 ± 6.73 ^{c}	48.00 ± 7.19 ^{b}
10	35.05 ± 7.75 ^{d}	47.93 ± 6.98 ^{b}

Means (± SE) with shared alphabet along the column showed no significant difference at $p<0.05\%$ using Duncan's multiple range test (DMRT).

3.3 Feeding deterrence index of *Dermestes maculatus* larvae on smoked dried fish

Dermestes maculatus feeding deterrence index revealed a dose-dependent response to the plant powders application, which increased with increasing concentration (Table 3). The treatments significantly deter feeding activity of larvae on smoked dried fish treated with 10% plant powders, exhibiting the highest feeding deterrence index (66.32% and 38.59%) and the untreated fish recording the lowest feeding deterrence index (11.95% and 12.37%). Fish samples treated with *U. corbisieri* powder outperformed *S. oblonga* (Table 3).

Table 3. Feeding deterrence index of smoked dried fish treated with *Uapaca corbisieri* and *Sterculia oblonga* powders.

Concentration %	*Uapaca corbisieri*	*Sterculia oblonga*
0	11.95 ± 2.34 [a]	12.37 ± 2.80 [a]
5	24.94 ± 2.26 [b]	14.80 ± 2.37 [b]
7.5	34.19 ± 1.75 [c]	28.39 ± 1.92 [c]
10	66.32 ± 4.11 [d]	38.59 ± 3.86 [c]

Means (± SE) with shared alphabet along the column showed no significant difference at p<0.05% using Duncan's multiple range test (DMRT).

3.4 Percentage weight loss of smoked dried fish

Result presented in Table 4 show that the untreated fish sample suffered significant weight loss compared to samples treated with various concentrations of the two plant powders. Those exposed to 10% plant powder experienced the least percentage weight loss. *Uapaca corbisieri* powder at 5 and 7.5% and *S. oblonga* powder at 7.5 and 10% do not record significant weight loss, respectively.

Table 4. Percentage weight loss of smoked dried fish treated with *Uapaca corbisieri* and *Sterculia oblonga* powders.

Concentration %	*Uapaca corbisieri*	*Sterculia oblonga*
0	11.95 ± 5.43 [a]	12.37 ± 3.68 [a]
5	7.18 ± 4.62 [b]	9.81 ± 2.13 [b]
7.5	5.86 ± 3.42 [b]	6.90 ± 3.49 [c]
10	2.42 ± 2.42 [c]	5.48 ± 2.80 [c]

Means (± SE) with shared alphabet along the column showed no significant difference at p<0.05% using Duncan's multiple range test (DMRT).

4 Discussion

Dermestes maculatus infestation in smoked-dried fish contributes to the economic losses and reduces the market value of the dried fish. It is essential to protect smoked - dried fish from that infestation to guarantee the food quality and prevent dietary protein deficiency in the human diet.

A laboratory study was conducted to evaluate the toxicity of *U. corbisieri* and *S. oblonga* plant powder against *D. maculatus* larvae in smoked dried fish, *C. gariepinus*. The resultant high mortalities of larvae observed on smoked dried fish treated with the two plant powders could be due to the high toxic effect of these products on the larvae. Fasakin and Aberejo (2002) attributed the insecticidal properties of most plant material to its active constituent. The present findings demonstrated that, as compared to the untreated control, all tested concentrations of the plant powder resulted in noticeably higher larval mortality, with mortality escalating with increasing powder concentration and exposure time. The study's observation regarding mortality is consistent with Sabra and Mehana's (2015) findings, which claimed that mortality is a key mechanism

limiting the damage caused by *D. maculatus* infestation to smoked-dried fish preservation and storage. The active components in the various plant species may be responsible for the observed mortality. The larvicidal activity found in this study supports the argument put forth by Rubabura *et al*. (2014), in which the volatile phytochemical constituents of plant-based products that exhibit insecticidal potentials are frequently linked to their bioactivity. These compositions penetrate insects' bodies and interfere with their physiological processes. The duration of the insect's exposure to the active ingredients in the various test plant materials, which had a high tendency to interfere with the insect's behaviour, physiological activities, biochemical processes, morphology, and metabolic pathways, may have contributed to the plant powder superior efficacy in controlling *D. maculatus* infestation when compared to the control (Rahman *et al*. 2003, Rattan 2010).

In addition to the possible obstruction of the larval spiracles, which impedes normal respiration and causes suffocation and eventual death, the observed mortality in this study may also be partially attributable to the incapacity of the larvae to detoxify plant toxins while they are feeding, particularly during the first to fourth larval stage. This aligns with the position of Philip-Attah (2019) and Odeyemi *et al*. (2000). Furthermore, the plant powders may have antifeedant properties that prevent larvae from feeding, leading to many starving, and dead larvae. Unrestricted voracious devouring habit of the larvae is the cause of the substantial weight loss that was observed in the control treatment. However, the negligible weight loss noticed in the treated samples could be attributed to both possible antifeedant attributes of the plant powders, and the high larval mortality rate.

The capacity of the plant powders to drastically hinder larval emergence and induce feeding deterrence strongly suggests the presence of physical interfering agents. Plant powder may contain some toxic bioactive compounds that have a detrimental effect on the insects' ability to survive, inhibiting the developmental phases of insects, as seen by the notable decrease in larval emergence. A decrease in larval emergence was caused by the plant powder's insect-repelling properties and higher dosages. This was further supported by findings of Akinwumi *et al*. (2006).

5 Conclusions

This study indicated that *U. corbisieri* and *S. oblonga* were toxic against larvae of *D. maculatus,* causing mortality within the shortest duration of application when compared with the untreated control, and significantly deterred feeding activity, inhibited adult emergence and reduced dried-fish weight loss. Based on findings, the use of *U. corbisieri* and *S. oblonga* powders should be encouraged and developed as biopesticides at a small-scale level to reduce the use of synthetic chemicals for the protection of *C. gariepinus* fish against *D. maculatus* infestation. Further study is recommended to determine the chemical constituents of the plant materials that are responsible for their insecticidal activity. In addition, the sensory evaluation and the

toxicity of the plant powders should be carried out to determine the treated fish palatability and toxicity effect (if any) when consumed.

Authors Contributions

Titilayo E. Mobolade-Adesina conceptualisation, design, execution, data collection. Jacobs M. Adesina, validation, supervision and original draft preparation. Raut M. Ankush reviewed and edited the manuscript. Ucheoma M. Anaele, data analysis and interpretation and Anike T. Bashar, execution/investigation and data collection. All authors reviewed and approved the final manuscript.

Competing interests

The authors disclosed no conflict of interest in the course of this research.

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