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EFFICACY OF BITTER APPLE (*Citrullus colocynthis* L. Schrad) FRUIT EXTRACT ON *Dermestes maculatus* DeGeer AND ORGANOLEPTIC PROPERTIES OF SMOKE - DRIED NILE TILAPIA (*Oreochromis niloticus* Linnaeus, 1758)

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ABSTRACT

Post - harvest losses of smoke - dried fish caused by insect infestation, particularly the hide beetle (*Dermestes maculatus* DeGeer), pose a severe threat to food security and fish trade in sub - Saharan Africa. This study evaluated the insecticidal efficacy of bitter apple (*Citrullus colocynthis* L. Schrad) fruit extract at concentrations of 0 g (control), 50 g, 100 g and 150 g against *D. maculatus* in smoke - dried Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758), and determined the organoleptic properties of treated fish. Forty (40) specimens of *O. niloticus* were dipped in four treatment solutions and smoke - dried in a modified drum kiln. Eighty (80) adult *D. maculatus* were introduced and monitored over 21 days. Results showed that the 150 g extract caused the highest adult mortality (25.00) and larval mortality (21.50) and completely suppressed the emergence of new adults and larvae. Sensory evaluation by 25 panelists revealed that fish treated with 100 g extract scored highest for appearance (60%), aroma (64%) and texture (60%), while the untreated control scored highest for taste acceptability (48%). The declining taste scores at higher concentrations are attributed to the characteristic bitterness of cucurbitacins present in *C. colocynthis*. These findings indicates that *C. colocynthis* fruit extract is a promising, eco - friendly and low - cost alternative to synthetic insecticides for protecting smoke - dried fish during storage while maintaining acceptable organoleptic quality at moderate application levels.

Keywords: Bio – Insecticide, Food Security, Hide Beetle; Post – Harvest Losses, Synthetic Insecticides.

1.0 INTRODUCTION

Fish is one of the most affordable and nutritionally rich sources of animal protein globally, contributing to food and nutrition security, particularly in developing nations (Maulu *et al.,* 2021). In Nigeria, fish accounts for approximately 75% of daily dietary animal protein for rural populations. However, fish is highly perishable in tropical environments where elevated temperature and humidity accelerate spoilage immediately after harvest (Ayeloja and George, 2016). Post - harvest losses of fish globally range from 10 – 35% by weight, with losses in small-scale fisheries reaching 40 – 50% of the national catch (Ufele *et al.,* 2015). In Nigeria, De Young *et al.* (2011) estimated that the country produces 150,000 tons of fish annually, of which 40% is lost due to poor handling and storage. Lale *et al.* (2000) documented 20 – 50% deterioration of smoke - dried fish products in the tropics due to combined microbial and insect pest infestation. Alhassan *et al.* (2012) reported that smoking is one of the most widely practiced traditional preservation techniques in sub - Saharan Africa and also that smoke - dried fish remains highly vulnerable to insect infestation during storage. The hide beetle, *Dermestes maculatus* DeGeer (Coleoptera: Dermestidae), is the most economically significant insect pest of stored smoke-dried fish in Nigeria and across sub-Saharan Africa (Chris *et al.,* 2014),

causing up to 50% weight loss (Odeyemi *et al.,* 2000; Kemabonta *et al.,* 2013). Its larvae feed within the fish flesh, causing severe fragmentation, quality deterioration and contamination with cast skins and frass (Zakka *et al.,* 2009; Uneke, 2015). Bala *et al.* (2018) noted that *D. maculatus* larvae are especially destructive to stored dried animal matter. Conventional synthetic insecticides have been used to manage *D. maculatus* infestations; however, their abuse has resulted in acute and chronic toxicity, skin irritation, blindness and fatalities among fish handlers and consumers (Akunne *et al.,* 2014). There is therefore an urgent need for safe, effective and affordable alternatives.

Botanical insecticides derived from plant extracts are biodegradable, generally safe for humans and culturally acceptable in local communities. Bitter apple (*Citrullus colocynthis* L. Schrad), a member of the family Cucurbitaceae, is a drought-resistant perennial vine indigenous to arid zones of northern Africa, the Middle East and Asia (Hussain *et al.,* 2014).

The fruits are rich in cucurbitacins, alkaloids, flavonoids, saponins and tannins with documented insecticidal, antimicrobial and antioxidant properties (Niroumand *et al.,* 2016; Kapoor *et al.,* 2020). Despite its wide distribution in northern Nigeria and known insecticidal potential, information on the application of *C. colocynthis* fruit extract as a protectant for smoke - dried fish against *D. maculatus* remains scarce. This study therefore aimed to investigate the efficacy of bitter apple (*C. colocynthis*) fruit extract on *D. maculatus* and organoleptic properties of smoke - dried Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758).

2.0 MATERIALS AND METHODS

2.1 Study Area

The study was conducted at the Research and Teaching Farm, Department of Fisheries, University of Maiduguri, Borno State, Nigeria (latitudes 10°43′N – 0°14′N; longitudes 10°15′E – 13°17′E), an area characterized by a semi - arid climate with pronounced dry and rainy seasons (Lale *et. al*., 2000).

2.2 Collection and Preparation of Bitter Apple (*C. colocynthis*) Fruit Extract

Mature fruits of *C. colocynthis* as shown in Plate I, were collected from the University of Maiduguri campus during the rainy season. The plant was identified and authenticated by a taxonomist at the Department of Biological Sciences, University of Maiduguri, and a voucher specimen was deposited at the University Herbarium. The inner pulp was separated, seeds removed and the extract prepared at three concentrations: 50 g, 100 g and 150 g, each dissolved in 1,500 mL of water. A control treatment containing 0 g extract (water only) was also prepared.

Plate I: *C. colocynthis* Plant

2.3 Fish Procurement and Preparation

Forty (40) *O. niloticus* (of average weight 300g) were procured from Gamboru fish market, washed, de-scaled and de-gutted. Fish were assigned to four treatment groups (n = 10 per group), immersed in the respective extract solution for one hour, drained on a wire mesh and smoke-dried in a 400-litre modified drum kiln at 45–85°C until completely dried (Tiamiyu *et. al*.,2020).

2.4 Insect Bioassay

Eighty (80) adult *D. maculatus* were obtained from fish sellers at Baga market. Ten adults were introduced into each of two replicates per treatment in ventilated plastic containers. Counts of dead adults, dead larvae, remaining adults, remaining larvae, newly emerged adults and newly emerged larvae were conducted at 7, 14 and 21 days. Insect mortality was calculated as: Insect Mortality = Initial Number of Insects − Number of Survived Insects. The experiment was arranged in a Completely Randomized Design (CRD).

2.5 Organoleptic Assessment

Sensory evaluation was conducted by a panel of 25 assessors for four attributes: appearance, aroma, texture and taste, scored using a 9-point hedonic scale: Extremely Liked (EL), Liked Very Much (LVM), Liked Moderately (LM), Liked Slightly (LS), Neither Liked nor Disliked (NLND), Disliked Slightly (DS), Disliked Moderately (DM), Disliked Very Much (DVM) and Extremely Disliked (ED). Results are expressed as percentage frequencies of panelist responses.

2.6 Statistical Analysis

Data on insect mortality counts were subjected to one-way Analysis of Variance (ANOVA). Treatment means were separated using the Least Significant Difference (LSD) test at $p < 0.05$.

3.0 RESULTS

3.1 Effects of *C. colocynthis* Fruit Extract on *D. maculatus* in Smoke - Dried *O. niloticus*

Effects of *C. colocynthis* fruit extract on *D. maculatus* in smoke - dried *O. niloticus* are presented in Table 1. Dead adult counts increased with extract concentration. The 150 g treatment recorded the highest dead adult count (25.00),

significantly higher ($p < 0.05$) than the 100 g (17.00), 50 g (8.00) and control (5.00) treatments. No significant difference ($p > 0.05$) was observed between the control and the 50 g treatment for dead adults; however, both differed significantly from the 100 g and 150 g treatments. Dead larval counts followed the same trend. The 150 g treatment yielded the highest dead larval count (21.50), followed by 100 g (15.50), 50 g (8.00) and the control (2.00), with all treatment levels differing significantly from one another ($p < 0.05$). Remaining adults were highest in the control (8.50) and declined progressively to 5.50, 2.50 and 0.50 at 50 g, 100 g and 150 g respectively ($p < 0.05$). Remaining larval counts were highest in the control (6.00), followed by 50 g (5.00), 100 g (1.50) and 150 g (0.50). Newly emerged adults were highest in the control (4.50) and absent in the 150 g treatment (0.00). Likewise, newly emerged larvae were most numerous in the control (4.00) and absent in the 150 g treatment (0.00), indicating complete suppression of reproduction at that concentration.

Table 1: Effects of *C. colocynthis* Fruit Extract on *D. maculatus* in Smoke - Dried *O. niloticus*

Parameters	0g (Control)	50g	100g	150g	SEM
Dead Adult	5.00^{c}	8.00^{c}	17.00^{b}	25.00^{a}	2.23
Dead Larvae	2.00^{d}	8.00^{c}	15.50^{b}	21.50^{a}	1.69
Remaining Adult	8.50^{a}	5.50^{ab}	2.50^{bc}	0.50^{c}	1.22
Remaining Larvae	6.00^{a}	5.00^{a}	1.50^{b}	0.50^{b}	1.11
Newly Emerged Adult	4.50^{a}	2.50^{b}	0.50^{c}	0.00^{c}	1.61
Newly Emerged Larvae	4.00^{a}	2.00^{bc}	0.50^{c}	0.00^{c}	1.24

Means with the Same Superscript on the Same Row Are Not Significantly Different ($p < 0.05$).
Key: SEM = Standard Error of Mean

3.2 Organoleptic Characteristics of Smoke - Dried *O. niloticus* Treated with Different Concentrations of *C. colocynthis* Fruit Extract

The organoleptic characteristics of smoke - dried *O. niloticus* treated with different concentrations of *C. colocynthis* fruit extract (% of panelist responses; n = 25) are presented in Table 2. For appearance, 60% of panelists extremely liked fish treated with 100 g extract, compared with 52%, 48% and 44% for the 50 g, 150 g and control treatments respectively. The 100 g treatment also received the highest extremely liked ratings for aroma (64%) and texture (60%). A small proportion (4%) of panelists disliked slightly the aroma of 150 g-treated fish. For taste, the untreated control (0 g) received the highest extremely liked rating (48%), followed by 100 g (40%), 50 g (36%) and 150 g (28%). Negative taste responses were recorded across extract-treated groups: 12% of panelists disliked moderately the taste of 100 g-treated fish and 8% disliked very much the taste of 50 g-treated fish. The 150 g treatment received the highest proportion of neither liked nor disliked responses for taste (20%), indicating that the extract's bitterness adversely affected taste perception at higher concentrations.

Table 2: Organoleptic Characteristics of Smoke - Dried *O. niloticus* Treated with Different Concentrations of *C. colocynthis* Fruit Extract (% of Panelist Responses; n = 25)

Trt	Attribute	EL	LVM	LM	LS	NLND	DS	DM	DVM	ED
0g	Appearance	44	28	12	16	0	0	0	0	0
50g	Appearance	52	36	8	4	0	0	0	0	0
100g	Appearance	60	32	4	0	4	0	0	0	0
150g	Appearance	48	36	12	4	0	0	0	0	0
0g	Aroma	40	28	20	12	0	0	0	0	0
50g	Aroma	44	36	12	4	4	0	0	0	0
100g	Aroma	64	12	16	4	0	0	0	0	0
150g	Aroma	44	24	16	8	4	4	0	0	0
0g	Texture	52	40	8	0	0	0	0	0	0
50g	Texture	40	28	12	8	12	0	0	0	0
100g	Texture	60	20	8	8	4	0	0	0	0
150g	Texture	56	16	12	0	4	3	0	0	0
0g	Taste	48	20	8	12	4	12	0	0	0
50g	Taste	36	20	12	16	0	8	0	8	0
100g	Taste	40	20	16	8	0	4	12	0	0
150g	Taste	28	20	16	12	20	4	0	0	0

Key: EL = Extremely Liked; LVM = Liked Very Much; LM = Liked Moderately; LS = Liked Slightly; NLND = Neither Liked nor Disliked; DS = Disliked Slightly; DM = Disliked Moderately; DVM = Disliked Very Much; ED = Extremely Disliked; Trt = Treatment

4.0 DISCUSSION

4.1 Effects of *C. colocynthis* Fruit Extract on *D. maculatus* in Smoke - Dried *O. niloticus*

The clear dose - dependent insecticidal activity of *C. colocynthis* fruit extract on adult and larval stages of *D. maculatus* is consistent with its phytochemical composition. The major bioactive compounds — cucurbitacins, alkaloids, flavonoids, saponins and tannins disrupt insect nervous and digestive systems upon contact or ingestion and cause respiratory failure by blocking spiracles, leading to paralysis and death (Hussain *et al.,* 2014; Niroumand *et al.,* 2016; Kapoor *et al.,* 2020; Ahmed *et al.,* 2021). The highest adult mortality of 25.00 at the 150 g concentration is consistent with insecticidal effects reported by Rawi *et al.* (2011), who found that the methylene chloride extract of *C. colocynthis* caused significant mortality in *Spodoptera littoralis* larvae. Ahmad *et al.* (2021) confirmed contact toxicity of the same plant against adult ectoparasitic lice, indicating its broad-spectrum insecticidal activity across taxonomic orders. The dead larval

count of 21.50 at the 150 g treatment is comparable to values reported by Adesina *et al.* (2014) using *Phyllanthus fraternus* extract against *D. maculatus* larvae on smoke-dried fish. The complete suppression of newly emerged adults and larvae in the 150 g treatment (0.00 for both) indicates disruption of the reproductive cycle of the pest, an ovicidal or oviposition-deterrent effect noted for other cucurbitaceous plant extracts in entomological studies. Comparing with other botanical insecticides tested against *D. maculatus* on smoke-dried fish: Okoronkwo *et al.* (2015) reported *Capsicum frutescens* extract caused mortality of 8 – 100% over five weeks but with no mortality after week five; National Research Centre (2021) found *Tithonia diversifolia* powder achieved 27.5 – 82.5% and *Vernonia amygdalina* achieved 20 – 77.5% larval mortality after 24 hours; while Akuque (2017) demonstrated that *Dennettia tripetala* powder achieved 15–85% larval mortality (Opara, 2020) and *Piper guineense* powder achieved 10 – 70% (Ufele *et al.,* 2015). The concentration-dependent mortality of *C. colocynthis* extract, culminating in complete reproductive suppression at 150 g, places it among the more efficacious botanical options documented to date. The observed decline in insecticidal effectiveness beyond 21 days of storage is consistent with the tendency of unformulated botanical extracts to degrade under tropical conditions. Lale *et al.* (2000) similarly reported that essential oil-based treatments lost efficacy during extended fish storage in the Lake Chad district. This underlines the need for future research into stabilized microencapsulated or nanoparticle-based formulations to prolong the bioactivity of *C. colocynthis* extract under field storage conditions.

4.2 Organoleptic Characteristics of Smoke - Dried *O. niloticus* Treated with Different Concentrations of *C. colocynthis* Fruit Extract

The superior organoleptic scores for appearance, aroma and texture recorded for fish treated with the 100 g extract are consistent with findings by Tiamiyu *et al.* (2020), who reported that smoke - dried *Clarias gariepinus* treated with natural spice extracts received significantly higher acceptability scores compared with untreated controls. Amuneke *et al.* (2020) likewise observed that ginger, bush pepper and Cameroon pepper significantly improved taste, customer acceptability and storage stability of *Heterotis niloticus*. Chinasa *et al.* (2022) reported that *Ocimum gratissimum* extract at 40% and 60% concentrations enhanced the eating quality and flavour of smoke - dried fish, demonstrating that plant extracts rich in phenolics and volatile compounds can improve sensory profiles. Similarly, Ihuahi *et al.* (2007) found that smoke - dried *C. gariepinus* treated with a 15% pepper and garlic paste mixture scored highest (80%) for texture and appearance. These findings support the dual functionality of *C. colocynthis* extract as both a pest protectant and organoleptic quality enhancer at optimal concentrations.

The superior aroma score for the 100 g treatment (64% extremely liked) compared with the control (40%) may be attributed to volatile terpenoids and phenolics in the extract that interact with smoke-derived compounds during drying. The antioxidant activity of *C. colocynthis* phenolics and flavonoids (Hussain *et al.,* 2014; Kapoor *et al.,* 2020) likely retards lipid oxidation during smoking and storage, preventing rancid off-flavours and maintaining fresh aroma and appearance. The declining taste acceptability at higher concentrations particularly the 20% neither liked nor disliked response in the 150 g treatment is directly attributable to the characteristic bitterness of cucurbitacins, which are perceptible at concentrations as low as parts per million (Hussain *et al.,* 2014). This trade - off between insecticidal efficacy and taste acceptability is an important practical consideration. The 100 g concentration represents the most practically viable treatment, offering effective suppression of *D. maculatus* alongside superior organoleptic scores for appearance, aroma and texture. Future studies should investigate whether post-treatment rinsing or co-application with taste-masking natural spices can mitigate bitterness without compromising insecticidal activity.

5.0 CONCLUSION

C. colocynthis fruit extract possesses significant, concentration-dependent insecticidal activity against *D. maculatus* in smoke - dried *O. niloticus*. The 150 g treatment produced the highest adult and larval mortality and completely suppressed the emergence of new insects. The 100 g treatment yielded the most favourable organoleptic profile across appearance, aroma and texture, while taste acceptability declined with increasing extract concentration due to cucurbitacin bitterness. These findings support *C. colocynthis* fruit extract as a viable, eco - friendly and affordable alternative to synthetic insecticides, with the additional advantage of enhancing the organoleptic appeal of smoke-dried fish at moderate application levels.

Further studies are recommended to: (i) isolate the specific insecticidal fractions of *C. colocynthis* fruit extract; (ii) assess residue safety for human consumption; (iii) evaluate long-term storage efficacy under field conditions; (iv) develop stabilized formulations to extend bioactivity; and (v) explore the application of *C. colocynthis* extract to other commercially important smoke - dried fish species and stored agricultural commodities.

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