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Comparing *Dermestes maculatus* (DeGeer) infestation of cured tropical freshwater fishes [*Oreochromis niloticus* (Linnaeus) and *Clarias gariepinus* (Burchell)]

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Abstract: A multiple choice test was used to determine the rate of infestation of *D. maculatus* on two cured fish species of commercial importance. All the treatments had three replicates and were arranged in randomized complete block design. The infested and non-infested dried fish were subjected to a taste panel of four to evaluate the texture and taste quality of the fish before and after infestation. Percentage weight loss of the fish was also determined 30 days post infestation. A skewed 32% weight loss in *C. gariepinus* compared with 24.4% in *O. niloticus* was recorded. The study revealed that *D. maculatus* infestation rate (number of adults and larvae per fish specimen) was more in *C. gariepinus* than *O. niloticus*. Quality (taste and texture) damage was significantly greater in *C. gariepinus* than *O. niloticus* ($p<0.05$). The study also reveals that the entomo-fauna may feed on any material that has animal steroids. The effect of the pest infestation is discussed in the context of taste and texture characteristics, substrate fragmentation and frass weight. There is imperative need to develop appropriate pro-poor control measures which will minimize economic losses due to *D. maculatus* infestation of stored fish and fish products in the tropics.

Keywords: *Dermestes maculatus*, Cured Fish, *Oreochromis niloticus*, *Clarias gariepinus*, Freshwater Fish

1. Introduction

Fish is one of the cheapest animal protein sources consumed over millennia and it is being used increasingly to correct protein deficiency in diets in the tropics [1]. In Africa, where animal protein is scarce and expensive, with average intake considered low, cured fish, is used to increase household protein intake [2] since, it is comparable, if not a better, source of protein. Essuman [3] reported declining fish consumption in West Africa over the last decade. This stems from the inability of the production sector to meet the soaring demand of an ever increasing population, coupled with the demand-supply gap created by post-harvest losses.

FAO [4] reported that cured fish can suffer considerable loss of weight due to feeding damage caused by insect pest. Up to 50% loss can result due to beetle infestation over several months. From processing throughout storage shelf-life, fish is vulnerable to insect pests belonging to 3 families, namely, Calliphoridea, Sarcophagidae (blowflies) and Dermestidea (beetle) [5, 6]. *Dermestes maculatus* is cosmopolitan and the most preponderant insect pest of dried fish in sub-Saharan Africa [6,7]. Pest damage can cause fragmentation of cured fish; and this can lead to quantitative loss of the smaller fragments and loss of value due to quality reduction, visual quality loss due to contamination by live or dead pests, or by their cast skins and frass. Lale *et al.* [8] estimated 20 - 50% deterioration of smoked fish products during storage arising from microbial and insects' pest infestation in the tropics. More so, Esser *et al.* [9] put physical and financial losses in Indonesia at between 10 and 50% and 25 and 90%, respectively, for the fish species they investigated. Huss [10] stated that reduction in post harvest losses could add another 20-30 million tonnes in the cured fish sector.

Insects infest cured fish during and after processing, especially in the tropics and subtropics. *D. maculatus* occurs widely in stored produce especially those of animal origin, but the species infestation and damage to dried fish has not been studied in sufficient detail. This study was aimed at investigating under controlled conditions, *D. maculatus* infestation load and associated losses of two cured fish species of commercial importance in the Niger Delta, Nigeria, namely, *Clarias gariepinus* and *Oreochromis niloticus*. It is envisaged that the result would provide valuable information that will guide the development of appropriate control measures for hide beetle infestation of cured fish.

2. Materials and Methods

Fish species and processing: Samples of two commercially important and highly relished fish species, *O. niloticus* and *C. gariepunus* were bought from Choba market, Rivers State, Nigeria and smoked using a local smoking kiln. The fishes were arranged on drying tray (chicken wire mesh) placed over an open-air smoking kiln. Clean fresh plantain leaves were used to cover the fish on the tray to enhance smoke circulation and drying.

Sterilization of jar and insect culture: All the jars used were subjected to thermal sterilization. Larvae of *D. maculatus* were obtained from heavily infested dried fish bought from the same market and kept in 1-L culture jar and allowed to develop on smoked fish substrates in the laboratory. The emerging pupae were removed and placed individually in a clean plastic tube and held under laboratory conditions until metamorphosed adults *D. maculatus* emerged using the methods described in Zakka *et al.* [11] and Akinwumi [1].

Multiple Choice and Selective tests: To determine the relative rate of infestation of both fish species by *D. maculatus,* multiple-choice test was carried out. In test F, a sample of cured *C. gariepinus* and *O. niloticus* were kept separately each in two clean Kilner jars and placed horizontally with their open ends facing a centrally located Petri-dish containing 10 pairs of *D. maculatus.* This enabled the beetles to have uninterrupted access to the cues from both fish samples. In test B, the two clean Kilner jars having separately the fish samples were placed horizontally with their closed ends facing the beetle stocked Petri-dish so as to obscure the attractive odour emanating from the different fish species. Each treatment had three replicates and these were arranged in randomized complete block design. At the end of the 30 days experiment, the fish specimens in the multiple-choice test were dissected and *D. maculatus* (larvae and adults) were isolated and counted.

Determination of physical characteristics of fish samples
Moisture content: The moisture contents of the exposed fish samples were determined before and at the end of the experiment. The sample of fish was dried in an oven at a temperature of 60 ^{0}C for one hour and the weight of water lost calculated [11].

Texture and taste: Infested and non-infested fish were subjected to organoleptic taste. A panel of four (4) people was constituted to evaluate the texture and taste of the fish.

The texture and taste of the fish samples was evaluated using the following model in Table 1:

Table 1. *Taste and textural quality ranking model*

Texture		Taste	
Quality	**Score**	**Quality**	**Score**
Firm	3	Good	3
Fairly firm	2	Acceptable	2
Brittle	1	Poor	1
Powdery	0	Unacceptable	0

Weight loss: Percentage weight loss was determined by direct weighing method in which the initial and final weights of each fish substrate were recorded and the percent weight loss calculated [12].

Percentage Economic fish loss was calculated as

$$\%\,\text{loss} = \frac{(\text{W1} - \text{W2})\text{g x } 100}{\text{cost price of individual fish}}$$

Where W1 is the initial weight of each fish sample, and W2 is the final weight of the fish after infestation.

3. Results

Table 2 shows the rate of infestation by adults and larvae of *D. maculatus* on the cured fishes. The T-test analysis shows significant difference between the number of adult beetles /100g of *O. niloticus* in both treatments. However, the result shows no significant difference (P>0.05) between the number of larvae/100g of *O. niloticus* in both treatments (F and B) and the combinations. The result of the rate of infestation by *D. maculatus* on *C. gariepinus* is also shown in the same table. The T-test analysis shows that the number of adult beetles /100g of *C. gariepinus* in both treatment F and B varied (P<0.05) but did not vary between the number of larvae/100g of cured *C. gariepinus.*

Table 2. *Rate of infestation of adult and larvae of D. maculatus on cured fish (O. niloticus and C. gariepinus)*

Fish species/treatment	No. of Adult/100g of fish sample	No. of Larvae/100g of fish sample
O. niloticus (F)	21.19	38.11
O. niloticus (B)	19.69	20.32
C. gariepinus (F)	15	58
C. gariepinus (B)	3	17
t-value	6.93	1.08
P(T<=t) two-tail	0.02	0.39
*t-value	13	1.88
*P(T<=t) two-tail	0.005	0.20

(F) = cured fish kept horizontally with their open ends facing a centrally placed petri dish containing10 pairs of *D. maculatus.*
(B) = cured fish kept horizontally with their closed ends facing *D. maculatus* stocked in Petri dish; to interfere with cues emanating from the different fish species.

Table 3 shows the percentage weight loss of the fish species at the end of the experiment due to insect activity. The T-test result shows that there was no significant difference between the percentage weight loss and frass weight in *O. niloticus* in both treatments F and B (P>0.05)

(Figure 1). By contrast, the result shows significant difference between %weight loss in *C. gariepinus* in treatment F and B (P>0.05) (Figure 2). The % frass weight caused by *D. maculatus* feeding activities was not significant in *C. gariepinus* between treatment F and B (P>0.05).

Figure 1. *Frass and remnant of O. niloticus sample; and larvae of D. maculatus post infestation.*

Figure 2. *Frass and remnant of C. gariepinus sample; and larvae of D. maculatus post infestation.*

Table 3. *Percentage weight loss of fish specimens and % frass weight of samples of O. niloticus and C. gariepinus infested by D. maculatus*

Fish species/treatment	% weight loss	% frass weight
O. niloticus (F)	24.42	11.54
O. niloticus (B)	16.52	9.76
C. gariepinus (F)	31.81[a]	20.87
C. gariepinus (B)	18.91[b]	11.84
t-value	1.21	0.44
P(T<=t) two-tail	0.35	0.701
*t-value	3.88	1.87
*P(T<=t) two-tail	0.060	0.20

[a-b] in the same column are significantly different; (F) = exposed fish samples in containers kept horizontally with their open ends facing a centrally placed Petri-dish containing 10 pairs of *D. maculatus.*
(B) = exposed fish samples in containers kept horizontally with their closed ends facing the Petri-dish so as to reduce interference of cues emanating from different fish species.

Table 4 shows mean values recorded for texture and taste of the infested fish samples. The values recorded for *O. niloticus* were 2.25 and 2.63 for taste and texture, respectively. In contrast, *C. gariepinus* had 1.1 and 1.3 for taste and texture, respectively. The results also indicate that while infested *O. niloticus* were still fairly firm, *C. gariepinus* samples were brittle and considerably fragmented. The taste value shows that *O. niloticus* was still in acceptable edible state while *C. gariepinus* had a poor taste.

Table 4. *Quality (Texture and Taste) of fish samples (O. niloticus and C. gariepinus) infested with D. maculatus*

Fish species/treatment	Taste	Texture
O. niloticus	2.25	2.63
C. gariepinus	1.1	1.3

Table 5 indicates a negative correlation between the number of adult beetle and weight loss of the fish species (r = -0.038). Also a negative relationship was calculated between the texture of the fish species and weight loss of the fish species. A highly significant value was observed between the % weight loss of the fish species and the weight loss of the fish species (r = 0.945**). The texture of the fish species and the weight loss were negatively correlated with high significance (P<0.01). A negative correlation was observed between the %weight loss of the fish species and the number of adult (r = -0.150). A high correlation was observed between frass weight and the number of larvae (r = 0.754) and the correlation was highly significantly (P<0.01). Negative relationship was observed between texture of the fish and the number of larvae found in the fish species (r = -0.499). The correlation was high and positively significant (P<0.05) between the % weight loss and frass weight (0.687*). Also, a negative correlation was recorded between texture and frass weight of the fish species. The texture and the % weight loss of the fish species were negatively correlated. Negative value was also observed between the texture, taste and the % weight loss of the fish species.

Table 6 shows the economic losses due to infestation of the different fish species caused by *D. maculatus.* The estimated loss in Nigerian naira per kilogramme of infested fish was #253.60k for *C. gariepinus* and #204.70k for *O. niloticus,* representing 25.36% and 20.47% losses, respectively.

Table 5. *Correlation coefficient matrix showing the interrelationship between the Indices (weight losses, number of adult beetle, number of larvae, frass weight, % weight loss, taste and texture of the fish species)*

	Wt Loss	No. Of Adults	No. Of Larvae	Frass Wt	%Wt loss	Texture After
Wt Loss						
No. Of Adults	- 0.033					
No. Of Larvae	0.329	0.180				
Frass Wt	0.541	0.307	0.754**			
%Wt loss	0.945**	- 0.150	0.524	0.687*		
Texture After	- 0.018	0.075	-0.499	- 0.628*	- 0.392	

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Table 6. *Economic losses due to D. maculatus infestation of C. gariepinus and O. niloticus.*

Fish species	%weight loss of fish sample	Estimated loss/kg of infested fish(g)	Cost (#)	Estimated loss/kg of infested fish (#)
C. gariepinus	25.36	253.6	1000	253.6
O. niloticus	20.47	204.7	800	204.7

4. Discussion

The study revealed that cured fresh fish kept in jars placed with their open ends facing each other had more larvae of *D. maculatus* thus suggesting that the beetle could preferentially select suitable substrate even when cues from different substrates abound [11,13]. According to Corbet [14], the ability to select chemical cues is passed from the larval stage to the adult. These cues trigger recognition of a substrate and so influence selection by the adult. *C. gariepinus* proved to be a more suitable substrate for *D. maculatus* development. Zakka *et al*. [15] reported that *C. gariepinus* flesh was a more preferred substrate for *D. maculatus* infestation than *O. niloticus*. This suggests superiority in nutritional composition as *D. maculatus* larvae prefer substrates with high lipid content [16].

The high weight loss in *C. gariepinus* (32%) and 24.4% in *O. niloticus* after 30 days infestation is at variance with the findings of Golob *et al.* [17] who recorded 19% dry weight and 12% on wet weight basis, in stored fish. The weight loss incurred could partly be due to the differences in length of the experiment, fish type and other factors. Awoyemi [18] assessed fish loss and reported that by 60 days the exposed fishes were reduced to mere frass and bones. It could be explained that the higher weight loss suffered by *C. gariepinus* was due to higher level of infestation (that is higher number of larvae). Traditionally cured fish are capable of sustaining significant losses, both in quality and value. This is because both the adult and larvae feed on infested fish samples, causing large quantitative losses of edible material, and there is also fragmentation of the remaining product [19, 20].

D. maculatus feeds on any material that has animal steroids [12, 21]. However, when exposed to various animal steroid sources the insect tends to show preference to a particular species. The comparatively high weight loss, detectable change in taste and significantly higher frass generated in *C. gariepinus* samples suggest the species flesh was a more suitable substrate than *O. niloticus* for the growth and development of *D. maculatus*. Zakka *et al*. [15] and Zakka *et al.* [11] observed that *C. gariepinus* had the highest suitability index, while Lale *et al.* [8] also recorded high infestation levels on *C. gariepinus* than on *Tilapia sp.*

Generally, the results may not be linked to the positioning of the fish samples or chemical cue emanating from them because there were little or non-significant difference between most of the treatments. It is plausible that protein and lipid contents are the key infestation determinants. According to Samish *et al*. [16], *D. maculatus* prefers diets higher in lipid and protein content, which would be unsaturated for other insect. Osuji [22] screened 30 samples for the presence of insect pests in four fish species (*Clarias sp, Citharinus sp, Heterotis sp,* and *Synodontis sp*) and found that the infestation load correlated to the lipid content of the fishes. *Clarias* sp with a mean of 82 individual insects per 100g (lipid content 16.4%) had significantly higher number of insect pests. It is known that *D. maculatus* develops more effectively on fish with higher fat contents.

Based on the number of adult *D. maculatus* that emerged from the fish substrates, *C. gariepinus* proved to be a more suitable substrate. Nevertheless, the high infestation rate (number of adults and larvae) of *D. maculatus* in both fish species is an indication that the insect constitutes serious threat to stored fish products [18, 23].

The present study showed a considerable loss of both fish substrates leading to fragmentation and loss of quality. This is attributable to extensive feeding habit of *D. maculatus* on fish substrates and the presence of the exuvia [24]. Atijegbe [25] evaluated quality loss during storage, noting that damage severity may be partly a function of moisture and the lipid contents of the fish at the time of storage. The 25 % weight loss recorded compares favourably with previous records. Lale and Sastawa [8], Odeyemi [24], and Atijegbe, [25] assessed the value and extent of quantitative losses of different fish species and reported 50-100 % quantitative and qualitative losses depending on storage length, salt content and climatic conditions. From the variables assessed, *C. gariepinus* is a more suitable substrate for *D. maculatus* development than *O. niloticus,* and overall, *D. maculatus* infestation can lead to quantum loss in both commercially important freshwater fishes.

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