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Full Length Research

Effects of Salt Treatment on the Development of *Dermestes Maculatus* in Smoked Fish

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ABSTRACT

Dermestes maculatus infestation is a major threat to the quality of smoked fish. It results in reduced nutritional value and economic losses. This study explores the effect of salt treatment on the development of *D. maculatus* in smoked Catfish (*Clarias gariepinus*) and Tilapia (*Oreochromis niloticus*). The study was conducted in the Volta Region of Ghana. Fish samples were purchased from five major processing sites (Kpando, Kwame Krom, Dambae, Abutuase, and Jemeni). Salt content of smoked samples was determined using the Mohr method, while fresh fish sample were immersed in varying salt concentrations (0%, 5%, 10%, 15%, 20%, and 25%), smoked before exposure to adult *D. maculatus* under controlled laboratory conditions for 68 days. Results showed that salt concentrations in smoked fish samples ranged from 16.0% in Abutuase to 22.8% in Jemeni, exceeding WHO-recommended sodium limits. There was a significant reduction in egg laying as salt concentration increases. In Catfish, mean egg counts dropped from 58.3±42.7 at 0% to 11.3±16.3 at 20%, while in Tilapia, egg counts decreased from 20.3 ± 9.0 at 0% to 8.00±8.5 at 20%. Salt treatment was more effective in Tilapia, which recorded lower egg counts compared to Catfish. Although salt concentration did not significantly affect egg to larva development, it inhibited larva to adult emergence with 0.0% adult emergence recorded at 25% salt concentration in both species. Weight loss decreased with increase in salt levels, from 60.0% at 0% to 14.0% at 25% in Catfish. These findings confirm that salt is effective against *D. maculatus* infestation through inhibition of its reproductive capacity and limiting adult emergence. However, the high salt levels used may raise public health concerns.

Keywords: Beetle, infestation, Catfish, Preservation, Salting, Tilapia, Volta Region. Entomology

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INTRODUCTION

Fish is a major component of the human diet valued for its high-quality protein (Phogat et al., 2022). Fish serves as a staple food, source of income and employment in developing countries (Maulu et al., 2021; Patekar et al., 2023). Fish and fish product generate over $50 billion annually playing important role in international trade. The sector also contributes to supply of raw materials to other industries (Adedeji et al., 2012; Akinwumi et al., 2007).

African Catfish (*Clarias gariepinus*) and Nile Tilapia (*Oreochromis niloticus*) are among the widely consumed fish in many parts of Africa (Agbugui & Inobeme, 2023). These species are noted for their rapid growth and tolerance to harsh environmental conditions (Ahmed et al., 2022). Their availability in local markets makes them important for both subsistence and commercial fisheries (Kumar & Lal, 2024). *Dermestes* play a minor role in disease transmission but are known to breed on any form of animal protein.

This makes them serious pests in locations such as hide warehouses, tanneries and other facilities that handle animal-based products (Shuaibu et al., 2022). Dried fish products are vulnerable to deterioration when infested by beetles from the genera *Dermestes* and *Necrobia* (Tunaz & Uygun, 2004). *Dermestes maculatus* is known for infesting smoked fish due to its capacity to survive in dry conditions (Oke et al., 2014). Such infestations result in reduction of nutritional quality and economic losses (Ugwu et al., 2008; Bob-Manuel & Ukoroije, 2020). These damages are caused by the feeding and boring habits of the late instar larvae. They destroy the edible portion of dried fish and reduce it to frass and bones within a matter of weeks (Baba et al., 2014).

According to Ufele et al. (2015) smoked fish stored for long periods are prone to insect infestations. Post-harvest losses are estimated at 10% to 35% of the global fish catch due to inadequate handling during processing and storage. Oke et al. (2014) reported that the nutritional value of catfish is at risk during storage due to infestations by *D. maculatus*. Lale and Sastawa (1996) reported that in Nigeria, *D. maculatus* alone is responsible for 13–17% losses in dried fish during long-term storage.

A significant portion of the rural population in the Volta Region engaged in small-scale fishery operations. which play a vital role in supporting livelihoods through employment and access to source of protein (Tsado et al., 2021; Iboyi et al., 2021). Fish caught in the region is preserved through smoking and transported to distant markets for commercial sale. However, studies have shown that smoked fish transported over long distances is highly susceptible to beetle infestation during storage and marketing stages (Idris & Omojowo, 2013). These losses are heightened when the moisture content of the fish is low. This creates an ideal condition for beetle proliferation and damage.

Fish traders in the Volta Region apply salt to smoked fish to protect fish from beetle infestations. This traditional method has shown some level of protection against beetle attack (Shuaibu et al., 2022). However, there is limited evidence about the impact of varying salt concentrations on beetle development in this region. Therefore, the present study aims to evaluate the effects of different salt concentrations on the development of *D. maculatus* in smoked fish.

MATERIALS AND METHODS

Study Area

This study was carried out in Volta Region of Ghana, located in the eastern part of the country. The region lies between latitudes 5°45′N and 8°45′N and longitudes 0°15′E and 0°15′W. The Volta Region falls within the tropical climatic zone and experiences a bimodal rainfall pattern. The major raining season run from April to July and the minor raining season from September to November. Average annual rainfall ranges between 1,100 mm and 1,500 mm. Temperatures ranges between 22°C and 32°C.

Sample Collection

Fresh and smoked fish samples of African Catfish (*Clarias gariepinus*) and Nile Tilapia (*Oreochromis niloticus*) were purchased from five distinct fish processing sites in the Volta Region of Ghana. These include; Kpando, Kwame Krom, Dambae and Abutuase. The collected samples were then transported to the laboratory for analysis.

Laboratory Analysis

Determination of percentage salt concentration in smoked fish samples

Fish samples from different processing sites were taken to the Food Research Institute Laboratory, Accra and percentage salt concentration were determined by using the Mohr's method of salt analysis as describe by Karl et al. (2002).

Preparation of Fresh Fish Sample

Fresh African catfish (*Clarias gariepinus*) and Nile tilapia (*Oreochromis niloticus*) were purchased from Madina Market, Accra. Each species was immersed for four hours in different concentrations of brine (0%, 5%, 10%, 15%, 20% and 25% in g/mL). Samples were arranged in single layers separated by iron bars in a traditional smoking kiln and smoked at approximately 70–80°C for 8 hours (Atiejegbe, 2004).

Rearing of Dermestes maculatus

Several pairs of D.maculatus were obtained from infested fish obtained from Makola and Adabraka markets. Smoked Catfish (C. garienpinus) were Sterilized in Galemkamp oven for one hour at 60ºC to kill all the pests present (Atiejegbe 2004). The sterilized fish were placed in a series of one-litre jars and 20 pairs of D maculatus (male and female) were introduced into the jars. The adults were sieved out after 14 days so as to obtain cohort of approximately the same age. (Atiejegbe, 2004). This culture was left undisturbed until adults emerged.

Experimental Setup of D. maculatus on Fish

Salt-treated smoked fish samples (six concentrations

(0%, 5%, 10%, 15%, 20%, 25%) were each divided into three replicates, yielding 18 experimental units per fish species. A single pair of adult *D. maculatus* was introduced into each jar. Jars were placed on laboratory shelves in a completely randomized design. The experiment lasted 68 days, covering the full developmental cycle of *D. maculatus* (Atiejegbe, 2004), under controlled insect-rearing conditions at the Stored Product Laboratory, ARPPIS, University of Ghana, Legon (30 ± 2 °C and 70 ± 5% RH). At the end of the period, all insects were sieved and counted. Oviposition was assessed by egg counts per replicate. Development from egg to adult was monitored, and percentage emergence at each stage was recorded.

Weight Loss

Percentage weight loss was determined by using differences in weights of fish between the start and the end of the experiment (68 days). The percentage loss was then calculated using the formulae be

$$\frac{W1-W2}{W1+W2} \times 100$$

STATISTICAL ANALYSIS

Descriptive statistics, including mean, standard deviation and percentage, were calculated using Microsoft Excel. Analysis of variance (ANOVA) was employed to determine the level of significance among level of salt concentration using GENSTAT.

RESULTS

The percentage concentration of salt in smoked fish sampled from various processing sites is shown in Table 1. Jemeni recorded the highest mean salt concentration of 22.8 ± 0.3% (22.5–23.1%). While the lowest concentrations were observed in fish samples from Abutuase with a mean salt concentration of 16.0 ± 0.4% (15.5–16.4%).

Table 1: Percentage concentration of sodium chloride (NaCl) in smoked fish samples from various processing sites

Location	Mean (±SE) (Max-Min)
Jemeni	22.8 ± 0.30 (23.07 - 22.5)
Kwame Krom	20.2 ± 0.1 (20.3 - 20.06)
Kpando	16.0 ± 0.40 (16.4 - 15.6)
Dambae	21.4 ± 0.1 (21.5 - 21.2)
Abutuase	16.0 ± 0.4 (16.4 - 15.5)

The data presented in Table 2 show the mean number of *Dermestes maculatus* eggs laid on fish samples treated with varying salt concentrations. The 0% salt concentration (control) recorded the highest mean egg count (20.3 ± 9.0) in Tilapia and 58.3 ± 42.7 in Catfish. For Tilapia, egg production at 10% (12.3 ± 2.5), 15% (9.7 ± 8.5) and 20% (8.0 ± 8.5) salt concentrations was significantly lower ($p<0.05$) than the control. Catfish treated with 10% (20.3 ± 5.5), 15% (10.7 ± 11.0) and 20% (11.3 ± 16.3) salt concentrations showed significant ($p < 0.05$) lower egg counts compared to the control group (0%).

Table 2: Mean±SD of *Dermestes maculatus* Eggs Laid at Different Salt Concentrations

Salt Concentration (%)	Tilapia (Mean ± SD)	Catfish (Mean ± SD)
0	20.3 ± 9.0[a]	58.3 ± 42.7[a]
5	41.3 ± 34.0[b]	39.0 ± 19.3[ab]
10	12.3 ± 2.5[ac]	20.3 ± 5.5[bc]
15	9.7 ± 8.5[ac]	10.7 ± 11.0[c]
20	8.0 ± 8.5[c]	11.3 ± 16.3[c]
25	9.7 ± 2.9[c]	27.0 ± 45.9[abc]

[a b c-] Means within the same column with different superscripts differ significantly (P< 0.05)

Table 3 detailed the percentage emergence of developmental stages of *Dermestes maculatus*. For Catfish, 25% salt concentration recorded 56.8% larval emergence but no adults (0.0%). Similarly, at 15% salt levels where neither larvae nor adults emerged (0.0%). At 10% and 5%, larval emergence was 41.0% and 43.3% respectively, but adult emergence was low (1.6% and 15.8%). The highest adult emergence was recorded at 20% (76.5%) despite moderate larval emergence (23.5%). While the control (0%) showed the highest larval emergence (97.7%) and adult emergence (25.1%).

Table 3: Percentage Emergence of Developmental Stages of *Dermestes maculatus* from Smoked Catfish and Tilapia at Different Salt Concentrations

Salt Concentration (%)	Catfish Eggs	Catfish Live Larvae (%)	Catfish Live Adults (%)	Tilapia Eggs	Tilapia Live Larvae (%)	Tilapia Live Adults (%)
0	175	97.7%	25.1%	61	18.0%	16.4%
5	127	43.3%	15.8%	124	0.0%	0.0%
10	61	41.0%	1.6%	37	8.1%	0.0%
15	32	0.0%	0.0%	29	58.6%	0.0%
20	34	23.5%	76.5%	24	75.0%	29.2%
25	81	56.8%	0.0%	29	44.8%	0.0%

For Tilapia, 15% and 25% salt concentrations recorded larval emergence of 58.6% and 44.8% respectively, but no adults emerged (0.0%). At 20%, both larval and adult emergence were highest, with 75.0% and 29.2% respectively. At 10%, no adults emerged (0.0%) despite some larval presence (8.1%). At 0%, adult emergence was 16.4% with a lower larval emergence of 18.0%.

Results of weight loss are presented in Figure 1. Interspecies comparison revealed that there was a significant difference (P <

0.05) in weight loss between Tilapia and Catfish across the different salt concentrations. Intra-species comparison show that weight loss also varied significantly ($P < 0.05$) across treatment levels in both fish. In Catfish the highest weight loss was recorded at 0% (60.0%) while the lowest was observed at 25% (14.0%). In Tilapia, the highest weight loss was observed at 5% (22.7%), while the least was recorded at 20% (2.8%).

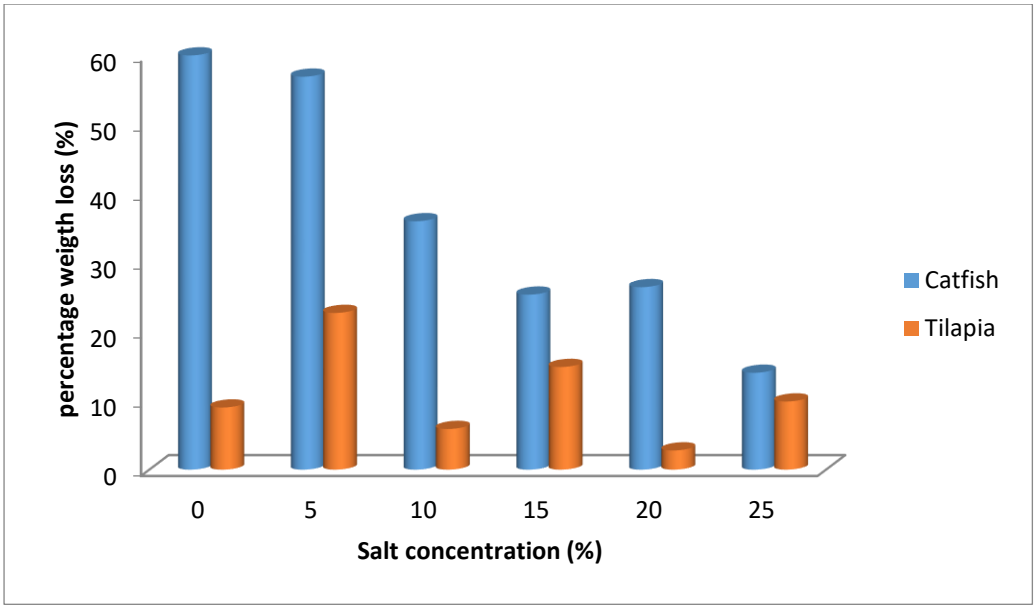

Figure 1: Salt concentration and weight loss in both fish species.

DISCUSSION

In this study the salt concentration in smoked fish sampled across the regions ranged from 16.0% in Abutuase to 22.8% in Jemeni. These values exceeded the recommended levels (2.0%) for sodium in smoked products by World Health Organization (Mozaffarian et al., 2014). This value is higher than values (1.3–2.6%) reported by Rybicka et al. (2022) in Portugal in smoked mackerel. Suprapto et al. (2022) found 10% salt concentration in stingray fish as the ideal concentration
require to balance microbial stability and quality. Nie et al., (2023) observed that smoked tilapia processed with 1% salt retained sensory properties and food safety. These differences might be as result of variation in processing methods, salt application duration, fish species and regional taste preferences. Hypertension and cardiovascular diseases are major public health concern of high salt levels in smoked product.

The study also revealed that increasing salt concentration hindered the reproductive capacity of *D. maculatus* in both Tilapia and Catfish. Egg production reduces significantly ($p < 0.05$) as salt concentration increased. This finding is consistent with Shuaibu et al. (2022), who reported a dose dependent reduction in egg viability when *D. maculatus* was exposed to varying concentration of salt. Similarly, Osuji (1975) revealed that salt treatment led to decreased fecundity and egg

viability in storage pests. Abolagba et al. (2015) confirmed that salt (NaCl) effectively inhibits egg deposition by *D. maculatus* on smoked fish. Contrarily, Esser (1988) states that Chrysomya *megacephala* could still oviposit on fish with relatively high salt content. This implies that salt possesses ovicidal properties that disrupt the reproductive behaviour of *D. maculatus*.

In this study Tilapia recorded fewer eggs at each concentration level. This implies that salt treatment was more effective in Tilapia than Catfish. This species related response might be due to differences in muscle texture, water content or skin permeability. Khairani et al. (2021) reported that Tilapia has more compact stratum compactum and a higher density of mucus cells than *C. gariepinus.* This feature could make Tilaipa tissue less susceptible to *D. maculatus* infestation.

Salt concentration did not affect the transition from egg to larva. In this study there was high emergence rates of larva in both species at higher salt levels. This indicates the physiological adaptations such as egg membrane resistance and the ability of early larvae to withstand osmotic stress. However, the larva to adult metamorphosis was impede by salt with 25% NaCl eliminating adult emergence entirely. This consistent with Osibona and Gafar (2018), who reported that salt treatment reduced microbial and fungal growth during storage of smoked *C. gariepinus*. Onyuka et al. (2013) revealed that the adults and eggs of *Dermestes* beetles were dead on the dried fish treated with 30% salt concentration. Lekahena (2020) noted that higher salt concentrations reduced insect infestation and preserved Mackerel quality. Salt interferes with hormonal regulation, moulting process and metabolic transitions required for pupation and adulthood in *Dermestes*.

Generally, there was reduction in weight loss of fish as salt concentration increase especially Catfish. This might be because fish with higher salt concentration harbour more larva stages. Baba et al. (2014) reported that the late instar larvae of *D. maculatus* are highly destructive due to their feeding and boring habits. They degrade the edible portions of dried fish and ultimately reduce them to frass and bones within weeks. Salt ability to reduce water level in fish tissue might also contributed to weight loss during storage.

In conclusion, this study further confirm that salt is potent in insect control and spoilage prevention. It also shows that salt application must be balanced with health guidelines. Although traditional smoking practices in Africa exceed modern sodium guidelines, they respond to preservation challenges in region with limited preservation infrastructure.

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