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Damages of Dermestidae and Cleridae on smoked and dried *Cyprinus carpio* (Cyprinidae) and *Clarias gariepinus* (Clariidae) during storage

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ABSTRACT

Fish is an important source of protein, mineral salts, and fatty acids essential for human nutrition. To ensure permanent availability to feed a hungry population, this very highly perishable commodity is transformed and stored. However, during storage, the dry fish suffer significant quantitative and qualitative losses due to insect pests. To characterize the damage of these pests, a study was conducted at the laboratory on two species of smoked and dried fish (*Cyprinus carpio* Linnaeus, 1758 and *Clarias gariepinus* Burchell, 1822) free from any chemical treatment, and infested by three species of ichthyophagous insects (*Dermestes frischii* Kugelann 1792, *Dermestes maculatus* De Geer 1774, and *Necrobia rufipes* De Geer 1775). For this purpose, 100g of dried fish were introduced into a jar to scarce each of the three pests. Three replications were made and observed for 90 days in the laboratory. The weekly follow-up of the damage is made, and the kinetics of the losses are observed and snapped. Weight losses are accessed; in addition, emerging insects were extracted, identified, and counted. It appears from these investigations that the genus *Dermestes* is the most noxious to all dried fishes. After 90 days of storage, D. *frischii* causes a loss of 50.57% of the fish, *D. maculatus* 53.42%, and *N. rufipes* 31.57% of weight losses. The emergence of adults does not differ significantly for all fishes. The weight loss index on smoked fish shows that *D. frischii* has a level of 40%, *D. maculatus* at 38%, and *N. rufipes* at 22%. In their appearance, damages of *Dermestes* differ from those of *N. rufipes*. Larvae of *N. rufipes* destroy inner parts, mostly dried flesh whereas *Dermestes* are eating both skin and flesh. Damages of insect pests observed are both affecting the quantity and the quality of this precious commodity, which become a lost as food. It is therefore necessary to consider methods for the control of these pests.

Keywords: Pests, weight loss index, dry fish, storage, damages.

RESUME

Dégâts de Dermestidae et de Cleridae, insectes ravageurs, sur *Cyprinus carpio* (Cyprinidae) et *Clarias gariepinus* (Clariidae) fumés et séchés pendant le stockage

Le poisson est une source importante de protéines, des sels minéraux et d'acides gras essentiels pour l'alimentation. Afin d'assurer une disponibilité permanente pour nourrir une population affamée, cette denrée très périssable est transformée et stockée. Cependant, au cours du stockage, les poissons secs subissent d'importantes pertes quantitatives et qualitatives dues aux insectes ravageurs. Pour caractériser les dégâts de ces ravageurs, une étude a été menée au laboratoire sur deux espèces de poissons fumés et séchés (*Cyprinus carpio* Linnaeus, 1758 et *Clarias gariepinus* Burchell, 1822) indemnes de tout

traitement chimique et infestés par trois espèces des insectes ichtyophages *Dermestes frischii* Kugelann 1792, *Dermestes maculatus* De Geer 1774 et *Necrobia rufipes* De Geer 1775. A cet effet, 100g ont été pesés et introduits dans un bocal avec trois répétitions pour chacun de trois ravageurs et observés pendant 90 jours en condition contrôlée au laboratoire. Le suivi hebdomadaire des dégâts est fait et la cinétique des pertes observée et photographiée. Il ressort de ces investigations que les dermestes causent plus des dégâts sur toutes les formes de poissons. Au terme de 90 jours de stockage, 50,57% du poids des poissons sont perdus suites aux attaques de *D. frischii*, 53,42% à celles de *D. maculatus* et 31,57% à *N. rufipes*. L'émergence des adultes de ravageurs ne diffère pas significativement sur tous les poissons. L'indice de perte de poids est très élevé pour les *Dermestes*, 40% pour *D. frischii* et 38% pour *D. maculatus* contre 22% chez *Necrobia*. A leurs aspects, les dégâts des *Dermeste* ne sont pas semblables à ceux des *Necrobia*. Les larves de *N. rufipes* détruisent les parties internes, particulièrement la chair, tandis que les dermestes mangent à la fois la peau et la chair. Les dégâts des insectes ravageurs observés affectent à la fois la quantité et la qualité de cette denrée précieuse, qui devient une denrée perdue. Il est donc nécessaire d'envisager les méthodes de lutte pour le contrôle de ces ravageurs.

Mots-clés : Ravageurs, indice de perte, poisson sec, stockage, dégâts.

INTRODUCTION

Fish is an important staple source of nutrients and animal proteins for the local population in sub-Saharan Africa (FAO, 2006; Tamgno et al., 2021). Smoked, as well as dried fishes, are part of the traditional food with great protein importance for the worldwide population (Ayuba and Omeji, 2006; Okonta and Ekelemu, 2005). In sub-Saharan Africa, fish is considered a foodstuff of first necessity (Gamane et al., 2016); it covers around 22% of protein intakes of animal origin accessible to low-income households where the price of meat is not the cheaper (FAO, 2016).

Fish is a very perishable foodstuff, especially in tropical and hot climate areas where refrigeration techniques are not common and especially not always available (Gamane et al., 2016). Due to constraints related to the preservation of fish after fishing, only a small quantity is sold fresh, a large part being subject to the artisanal transformation such as smoking and drying to allow actors to keep the finished product as long as possible (Ikenweiwe *et al*., 2010; Babarinde et al; 2016a). This transformation of fishery products which are both foodstuff and goods is an important tool for alleviation of undernourishment and poverty reduction (FAO, 2009). In rural areas in Cameroon and according to agro-ecological zones, virtually all fish caught are either dried or smoked. Those smoked fish are very nutritive and contain unsaturated fatty acids, liposoluble vitamins, essential minerals as well as proteins containing essential amino-acids fundamental for humans (Ozogul & Balikci, 2013). Fish, apart from its nutritive value, is a major source of employment and business for millions of people living near water via harvesting, manipulation, processing, and distribution (Bene & Heck, 2005; Al-Jufaili & Opara, 2006; Mufutau, 2012).

Despite the transformation, dried fish remains a commodity that can be lost during storage because of depreciation caused by pests (Tamgno et al., 2020; 2021). Conducted studies show that in sub-Saharan Africa, Dermestidae and Cleridae are the most harmful insect families to fish storage (Folorunso et al., 2006). Losses can be complete if no protection is made (Ndrianaivo et al., 2016). These losses are at the same time quantitative and qualitative (Ndrianaivo et al., 2016, Sameza et al., 2016; Tekou Ngunte, 2018). Hence the purpose of this study aims at characterizing the damage of the different fish-eating pests *D. maculatus*, *D. frischii*, and *N. rufipes* on two fish species *Cyprinus carpio* Linnaeus, 1758 and *Clarias gariepinus* Burchell, 1822 smoked and dried to determine to most harmful pest. In addition, these fish species mostly dried and/or smoked in the northern part of Cameroon are abundant in stocks and markets and also vulnerable to pests attacks.

MATERIAL AND METHODS

Two smoked and dried fishes *C. Carpio* and *C. gariepinus*, free of any insecticidal protective treatment were bought at Pouss market (10°50'50'' North, 15°03'20''East) in Maga Subdivision, Mayo-Danay Division, Far North Region of Cameroon. From the quantity collected, an amount of 100g was weighed and introduced into a jar where each of the three pests *D. frischii*, *D. maculatus*, and *N. rufipes* were introduced for rearing in the laboratory. For this purpose, in each jar, three couples were inoculated. Three replications were made for each dried fish. The experimental set so made was kept in controlled condition in the laboratory for a delay of 90 days. Weekly controls were made for the record weight losses and the observation of damages on fishes through pictures. The taking of fish weight was made from the beginning, until the end of the manipulation; the number of emerging individuals is established for each substrate. Pictures were taken by a Samsung Galaxy A10 pro camera.

Determination of fish weight loss

After 90 days of storage, the stock put in observation in the flask was extracted and weighed. Dead or alive, in adults or at the larval stage, all insects were also extracted and counted per species. After estimation of the loss rate, the weight loss index was calculated by reporting weight loss during the storage period to the number of individuals that emerged at the end of that same delay. This weight loss index is expressed by the following formula:

Loss index (%) = (LR / emergence after 90 days) x 100.
The loss rate was determined using the formula:
Loss rate (%) = {(IW - FW) / PI} * 100.
IW : Initial Weight ; FW : Final Weight and LR : Loss Rate.

Determination of the pest's emergence rate

To evaluate the abundance of pest's species that emerged, counting of all emerging insects was made at all the stages and for all the species at any check-up during the period of observation. For this purpose, living and dead individuals, larvae, and adults were counted.

Data analysis

The results obtained presented in means and standard deviation were submitted to the one-way ANOVA using Statgraphic version 5.0 software. In post-test, the procedure of Duncan, at a 5% probability level, allowed group values in significantly different classes.

RESULTS

After 90 days of infestation and observation in storage conditions, pests' damage provoked a weight loss of the dry fish put in observation. Going from an initial weight of 100 g for all the fish species, it appeared to a final weight of 50.53 g at the end of the storage for the fish infested by *D. frischii*; 46 g for those infested by *D. maculatus*, and then 64.96 g for those infested by *N. rufipes* (Figure 1).

Evolution of weight losses of fish under observation

Weight losses observed depend on pests. Thus, 50.57% of the weight is lost in 90 days due to *D. frischii*, 53.42% to *D. maculatus*, and 31.57% to *N. rufipes* (Figure 1). Species of the genus *Dermestes* are more destructive, causing greater fish weight loss than that of the genus *Necrobia*. Losses due to those pest species combine both feeding activities of larvae and adults and the decaying process of the fish due to the presence of exuviates and the action of the microorganisms. Ichthyophagous insects induce fish weight loss, for they lay eggs, grow and grow more quickly thereafter.

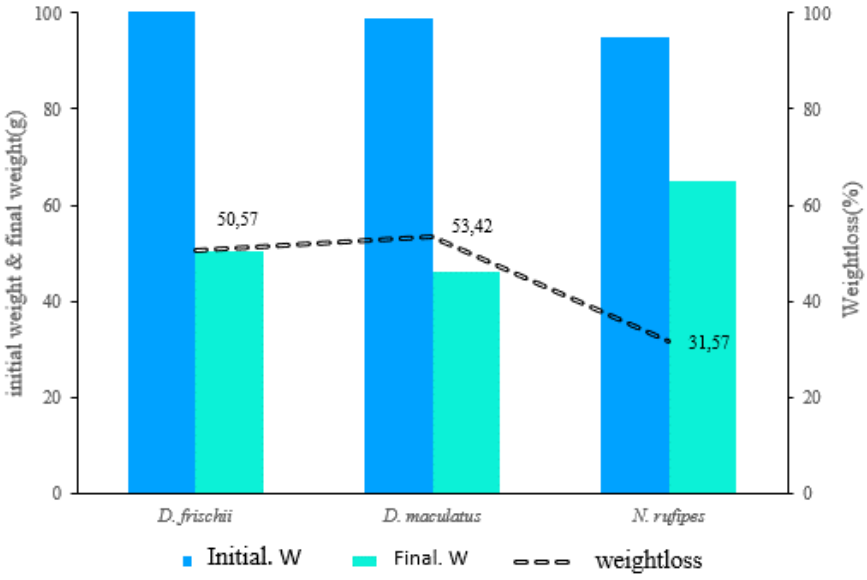

Figure 1. Weight loss rate after 90 days of infestation with *Clarias gariepinus* and *Cyprinus carpio*

On the two fish species tested, the two pests lead to losses shown in the gradual weight loss from the seventh week of observation. However, of the two pest species, smoked catfish are highly susceptible to pests compared to the others (Figures 2, 3). After 11 weeks of infestation, 80% of the weight of these fish is lost. Weight losses of smoked fish are more important than those of dried fish.

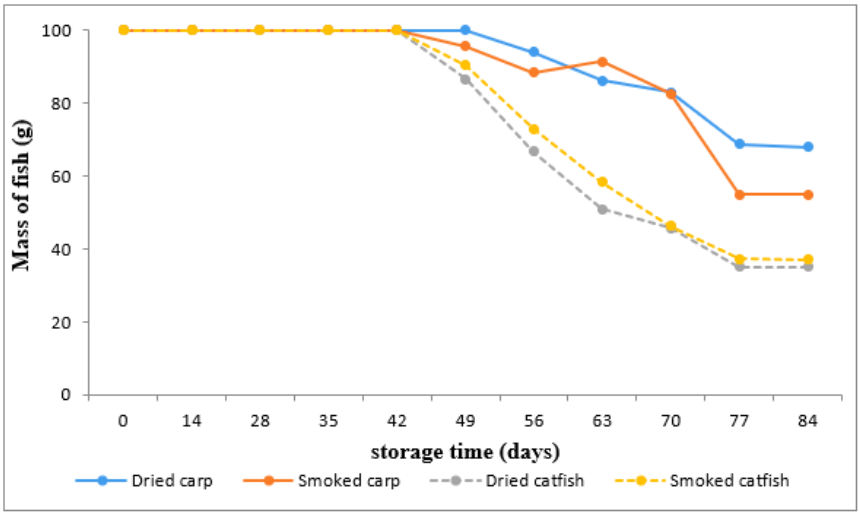

Figure 2. Evolution of the mass of carp, *Cyprinus carpio* and catfish, *Clarias gariepinus* infested by *Dermestes maculatus* after 90 days of infestation

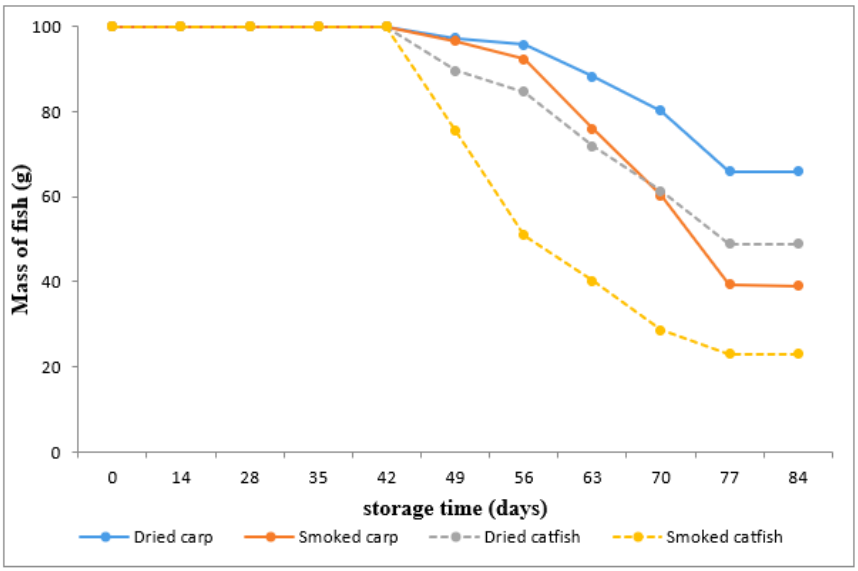

Figure 3. Evolution of the mass (g) of carp, *Cyprinus carpio* and catfish, *Clarias gariepinus* during 90 days of infestation by *Dermestes frischii*.

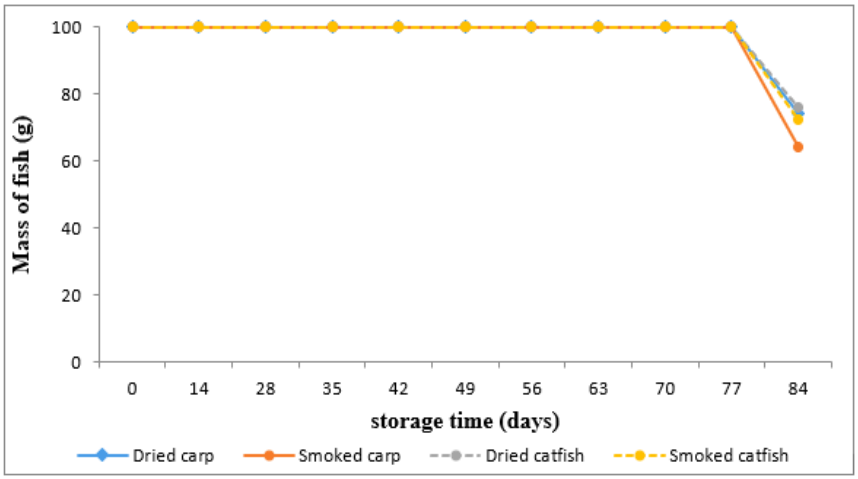

Figure 4. Evolution of the mass of carp, *Cyprinus carpio* and catfish, *Clarias gariepinus* infested by *Necrobia rufipes* after 90 days of infestation

Two weights were considered with Necrobia: the fish weight before infestation (initial weight) that did not almost vary up to the 77th day of observation, and the weight after 90 days (final weight) obtained after having dried the fish on the stove for 10 min to eliminate moisture, then weighed. Weight losses were observed on all the substrates (Figure 4). Apart from the adult, which is the free form, these pest larvae develop themselves inside the fish they damage, thus creating moisture that increases the fish weights.

The mean emergence for the three pests does not show a significant difference on the different substrates tested (p=0.33; F=1.19; df=3). The fried catfish is the best substrate for the development of two Dermeste with 265.67±105.31 and 214±34.07 as numbers respectively for *D. maculatus* and *D. frischii*. The smoked carp is the substrate that further allows *N. rufipes* growth with 87.67±42.44 individuals that emerge, against 21.33±7.09 obtained from dried catfish (Table 1).

Determination of the abundance of emerged pests

Table 1. the abundance of pest emergence depending on the feeding source (fish)

Feeding source		*D. frischii*	*D. maculatus*	*N. rufipes*
Carp	dried	110.67±36.46	145.33±51.59	32.50±25.29
	smoked	163.33±78.50	189±31.24	87.67±42.44
Catfish	dried	214±34.07	265,67±105.31	21.33±7.09
	smoked	151,33±35.55	168,67±62.69	46.33±32.39

Determination of loss indices due to pest species

Table 2. Index (%) of fish losses caused by the three insect pests

Feeding source		*D. frischii*	*D. maculatus*	*N. rufipes*
Carp	dried	33.65±14.42 [a]	28.38±5.91 [a]	33.50±16.17 [a]
	smoked	39.33±12.50 [a]	48.31±7.67 [b]	38.33±7.09 [a]
Catfish	dried	50.35±4.04 [ab]	62.14±14.27 [b]	25.33±12.66 [a]
	smoked	75.36±20.65 [b]	62±9.08 [b]	32.33±6.65 [a]

In the column, the numbers followed by the same letter do not differ significantly at the 5% level after an ANOVA (F = 1.90; df = 3).

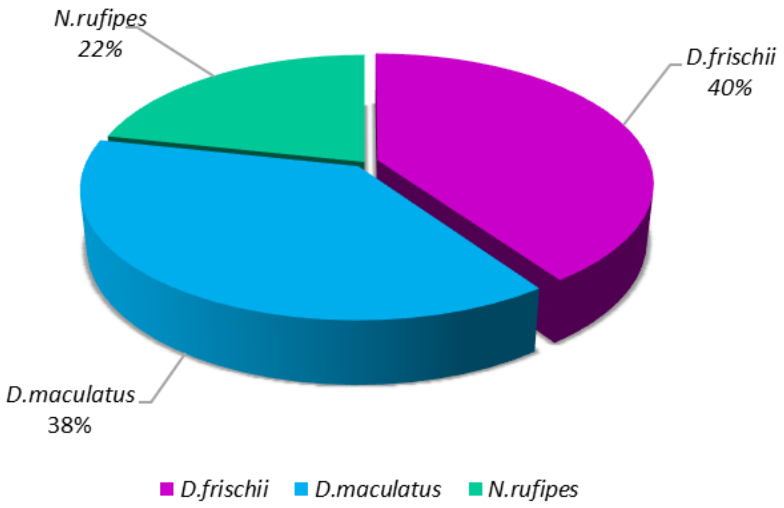

Figure 5. Loss index (%) of dry carp, *Cyprinus carpio* and catfish, *Clarias gariepinus* due to pest insects

Regarding the weight loss index obtained with *D. frischii*, the results show, at a threshold of 5%, a significant difference (P>0.05) between the weight loss indices of smoked catfish and those of carp dried and smoked. However, there is no significant difference between the weight loss indices of smoked and fried catfish. With *D. maculatus*, there is a significant difference (p> 0.05) between the indices of weight loss of dried carp and the indices of loss of other types of fish (Table 2). There is no significant difference at the 5% level between the different weight losses due to the activities of *N. rufipes* during storage. Weight loss is the result of damage caused by the depreciation of fish flesh or partial or complete consumption of fish tissue. The loss of the catfish in the dried and smoked forms is greater for the two *Dermestes*. The fish weight loss index varies with the loss rate and the abundance of individuals who emerged from fish. The weight loss index is very high for *Dermestes*, 40% for *D. frischii*, and 38% for *D. maculatus* while a great abundance of emergences is observed with *Necrobia* with 22% of the loss. A low abundance of population brings about a great weight loss, then leading to an increase of the loss index of that pest.

Characterization of pests' damage

Dermestes damage differs from those of *Necrobia* by the fact that *Dermestes* spoils fish outward and reduces fish into flour while *Necrobia* provokes damage inside the fish. Damage caused by the two *Dermestes* is identical. They start by making openings on the skin of healthy fish and crumbling the flesh into small pieces. As time passes, the flesh is consumed and the quantity of the fodder flour increases in the stock as well as moisture content, which leads to mold development in the stock, resulting in the change of color and smell of fish. In the end, all the flesh is consumed, and only fish spots, fodder flours, exuviate, dead insects, and excrement are observed in the stock (Plates 1 & 2).

The evolution of damage due to *Necrobia* is identical on all substrate forms. Clean fish put in observation were infested by the *N. rufipes* pest. Three months later, signs of attacks shown by holes were observed. Larvae develop inside fish by depreciating the flesh of these; fish have once broken allowing us to observe larvae buried in the flesh and inside the fish almost empty (Plate 3). In addition to the losses in quantity due to these pests, the qualitative loss has been observed by the change of color and unpleasant odors that the fish releases. The losses observed are at the level of the flesh, and skin, from outside inside with a large amount of fodder flour in the stock caused by *Dermestes* and inside with a small amount of fodder flour in the stock for *Necrobia*. Heavy moisture is observed in almost all stocks of the fish put in observation, especially on the dried condition fish.

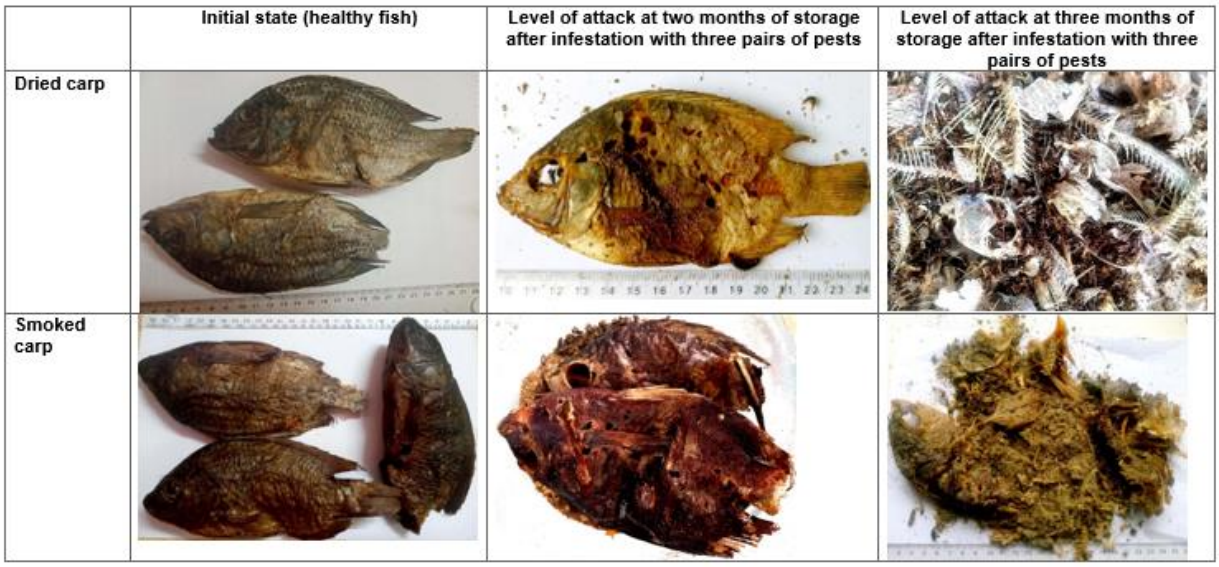

Plate 1. Dynamic of *Dermestes* damage on carp

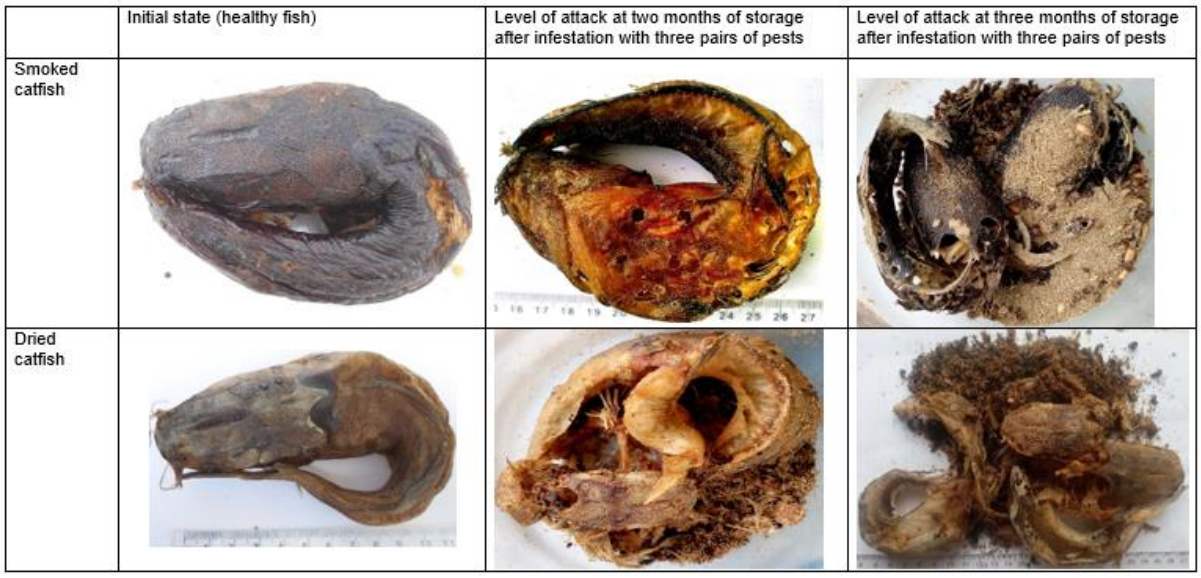

Plate 2. Dynamic of *Dermestes'* damage on catfish

Plate 3. Dynamic of the damages of *Necrobia* on fish (dried carp and smoked catfish)

DISCUSSION

Stored product insect pests are known in different agricu1tural products including smoked fish products (Wahedi & Kefas, 2013). Several authors (Babarinde et al., 2012; Onyuka and Ofulla, 2013; Zakka et al., 2013; Tamgno et al., 2021), reported the menace of insect pest infestation on smoked fish during storage. These insects lay eggs, develop, and multiply faster in fish. They not only reduce the quantity of poisons in stock but also deprive consumers of its nutritional qualities. Awoyémi (1991) examined the storability of different fish species over a period of 60 days and observed that they were reduced to mere frass and bones by *D. macu1atus*. Thus according to observations made in the laboratory over a period of 90 days on *C. carpio* and *C. gariepinus*, a rate of 50.57% of the mass of these fish are lost by *D. frischii*; 53.42% per *D. maculatus* and 31.57% per *N. rufipes* (Figure 1). These quantitative losses due to those pests result from a food reduction and can reach 50% of the stored quantity (FAO, 1981). Beetles led to significant quantitative and qualitative economic losses of stored products because they use this substrate for their development (Roesli et al., 2003; Gredilha et al., 2005).

Dermestes species cause a significant decrease in fish mass, they have more susceptibility for smoked catfish compared to dried catfish and smoked and dried carp (Figures 2 and 3). This observation therefore does not agree with the investigation carried out by Osuji (1973), indicating that insects preferred *Clarias* fish to all other available species of dried fish. The genus *Dermestes* is known for their infestation of dried fish causing qualitative and quantitative damage (Babarinde et al. 2016a). 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 (Osuji, 1974; Babarinde et al., 2012). Transformation methods could have effects on the sensitivity of fish as well as on their vulnerability to pests because smoking has an impact on the taste of fish and the smoked fish flesh is less hard than the dried. Apart from the adult, which is the free form, the larvae of *N. rufipes* develop themselves inside the fish they damage, creating moisture that increases the fish weights. According to Gredilha et al. (2005), the industrial standard of 12% moisture in the bags of animal provender offers suitable conditions for the proliferation of pests. The success of infestation by *N. rufipes* is linked to the environmental conditions provided to insects (Aluska et al., 2019).

In 90 days three generations were obtained with the three pests, the population dynamics of these pests, and their damages increase with the generations. Dried catfish is the best substrate for *D. maculatus* and *D. frischii* development, while smoked carp is the substrate that further promotes of *N. rufipes* development (Table 1). Thus, the biology of pest depends on the nature of the substrate. Osuji (1974), found some evidence that different kinds of fish can vary in their susceptibility to being attacked by beetles. Moreover, the strong concentration of raw protein indicated in the product package (22%) could be beneficial to the infestation of pest insects (Aluska et al., 2019) and a high level of lipid content can increase sensitivity to insect infestation (Osuji, 1974). Weight loss is the result of damage caused by the depreciation of fish flesh or the partial or complete consumption of fish tissues by pests. Damage and weight loss are mainly caused by the feeding activity of larvae and adults (FAO, 1998), which leads to the decline of the product. These pests thus cause quantitative and qualitative losses marked by physical and chemical depreciation resulting in a reduction in nutritional value, appearance of unpleasant odors and a change in the taste of fish (Mckevith, 2004). The activities of these insects also increase the incidence of microorganisms and increase the production of their toxins which, for some, are one of the causes of foodborne deseases.

The fish weight loss index varies with the rates of loss and abundance of fish individuals. It is higher in *Dermeste* than in *Necrobia* (Figure 5). Other reports indicated that about 71.5 % of dried fish infestation in almost all production areas was caused by *D. maculatus* (Akinwumi et al. 2007) and 28 % by *N. rufipes* (Osuji, 1974). From this study, we can conclude that dried and smoked fish infestation by *D. maculatus*, *D. frischii*, and *N. rufipes* leads to a great loss in the quantity of the product. So, *Dermestes* provokes greater losses than *Necrobia*. *Dermest*es adults and larvae infest dried fish samples. The two stages provoke significant quantitative loss of edible matter and a fragmentation of the remaining product (Johnson & Esser, 2000; Babarinde et al., 2012; Babarinde et al; 2014). *Dermestes* and *Necrobia* have been observed as pests in dried fish (Mufutau 2012; Babarinde et al; 2012, Babarinde et al., 2016a; Babarinde, Sunnie-Ododo et al; 2016 b; Osuji, 1985; Tamgno et al., 2020). Beetles of the Dermestidae family invade fish in the early stages of drying and reproduce in dried products (Abolagba et al., 2015).

The damage of the *Dermestes* differs from that of *Necrobia in* that the *Dermestes* damage the fish to the outside and reduce the fish to flour while the *Necrobia* cause the damage inside fish (Plates 1, 2 & 3). In addition to the loss in quantity due to these pests, the qualitative loss was observed by the change in color and smell from the fish thus reducing its nutritional values. Johnson and Esser (2000) estimated between 25% and 75% of the nutritional value of fish lost during insect pest attacks. However, *Dermestes* and *Necrobia* have been observed as pests in dried fish (Babarinde et al; 2012). Beetles of the Dermestidae family invade fish in the early stages of drying and reproduce in dried products (Abolagba et al., 2015). The losses caused by insect infestation are important. They include physical, economic, and nutritional losses.

CONCLUSION

Observation of damages of the three pests: *D. maculatus*, *D. frischii* and *N. rufipes* on dried or smoked fish revealed quantitative losses due to the

activities of larvae which depreciate the fish flesh. *Dermestes* (*D. frischii* and *D. maculatus*) caused more fish weight loss than *Necrobia* (*N. rufipes*). Thus, 50.57% of the mass was lost in 90 days due to *D. frischii*; 53.42% due to *D. maculatus*, and 31.57% due to *N. rufipes*. The development of these pests on fish used as substrates was not the same. The abundance of emerged individuals was greater in the two species of *Dermeste*. There is no significant difference between the numbers of individuals emerging from the different substrates. As regards the weight losses, a significant difference was observed between the different substrates for the two species of *Dermestes*, but not significant for *N. rufipes*. The characterization of the damage observed in the three pests differs; the *Dermestes* were more voracious than the *Necrobia*. Thus, the infestation of insect pests causes addition to a weight loss of fish quality through smells and loss of nutrient matter and color change. To preserve this precious commodity for human consumption against insect pests, it is necessary to implement means of control that secures the consumers health.

Conflict of Interests

The authors have not declared any conflict of interests.

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