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Effect of Mating Disruption in Leather Beetle, *Dermestes maculatus* on Biological Activities and Nutritional Quality of Infested Smoked Catfish, *Clarias gariepinus*

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Abstract

Mating between male and female leather beetle, *Dermestes maculatus* infesting smoked catfish, *Clarias gariepinus* was disrupted in this study. The effects of disruption on pest biological activities and nutritional quality of fish after pest infestation were determined using standard methods. Mating disruption technique of 2:1 (♂: ♀); where the males were removed after 24 h of mating had the highest number of survived adults. Number of developed larvae (156.80 and 167.50) was significantly higher on treatments 1:2 and 2:1 (♂: ♀) in which males were removed after 48 h and 24 h, respectively. Frass weight generated by the beetle was higher in the mating disruption treatment 2:1 (♂: ♀) in which the male insects were removed at 24 h. Mating disruption technique 1:1 (♂ : ♀) in which male was removed after 144 h of mating, had higher ash content (5.307%) whereas, the least ash content (3.622%) was recorded in mating disruption treatment 1:1 (♂ : ♀) and the male was removed after 120 h. Moisture content (29.05%) was significantly higher on mating disruption technique 1:1 (♂: ♀) where the male was removed after 144 h. Mating disruption resulted into different number of offspring of *D. maculatus* and different degree of loss of minerals. These give unequivocal signal that mating disruption can affect biological activities and nutrient quality. Therefore, the use of physical mating disruption technique can be applied to *D. maculatus* control to reduce their (adults and larvae) biological impact on smoked fish and ensure quality and sufficient fish for human use.

Keywords: Mating disruption, nutritional quality, *Dermestes maculatus*, biological impact, smoked fish.

INTRODUCTION

Smoked fish, *Clarias gariepinus* Burchell is consumed by many families in different parts of the world for palatability and health benefits (Lale and Sastawa 1996; Odeyemi *et al*., 2000; Azam *et al.*, 2014; Onoja *et al*., 2018). It is high in poly saturated fatty acids which are important factors in lowering blood cholesterol level (Azam, *et al*., 2014). Infestation by the leather beetle, *Dermestes*

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maculatus De Geer (Coleoptera: Dermestidae) impinges on the quality and quantity of stored catfish available for human use. The smoked catfish has no major nutritional difference when compared with the fresh form. Fish is smoked and kept dry to extend its storability. Smoking enhances loss of moisture that helps to improve nutritional quality by concentrating beneficial constituents in fish (Ajao, 2012; Tahir *et al*., 2020).

Dermestes spp. and *Necrobia rufipes* have been implicated in the infestation of Egyptian mummies (Adams, 1990), museums (Linnie and Keatinge, 2000), smoked fish and poultry products (Geden and Hogsette, 2001) and stored cocoons of silk-worm *Bombyx mori* (Sahaf, 2007). Haines and Rees (1989) reported that *D. maculatus* is a major insect pest of smoked African catfish where both adults and the larvae attack the product and inadvertently cause fragmentation. Huge quantitative losses of up to 50% and invariably, qualitative losses are recorded (Odeyemi et *al*., 2000; Fasakin and Aberejo, 2002).

It has been shown that the life cycle of *D. maculatus* (from egg to adult-emergence) is about 5 to 7 weeks under optimal conditions (Archer and Elgar, 1998; Jones *et al.*, 2006). In leather beetle, pheromones are secreted by males through a gland located at the base of the abdomen. These secretions biologically attract the female insects. Male and female *D. maculatus* mate multiple times and females have the capacity to lay eggs within 24 hours of first mating (Zakka *et al*. 2013). Larvae of this species metamorphose through 5–11 instars and number of instars increase with adverse conditions. Adults can disperse to other food sources by flying (Jones *et al.*, 2006) and this makes infestation easy. The life span of the adults is between 4 and 6 months. Larval development in *D. maculatus* does not signal any visible morphological change but increase in size occurs. Development period of 31 days was observed on *C. gariepinus*, while average of 42.75 days was noticed on mixed substrates (Zakka *et al.*, 2013). Processed fish is readily attacked by several species of *Dermestes* such as *D. frischi, D. attah* and *N. Rufipes* (Don-Pedro 1989).

Attack on smoked catfish by *D. maculatus* significantly reduces the quality and quantity of fish flesh that should ideally be consumed by human beings and used for other economic purposes (Singh *et al*., 2018). According to Osuji (1974), about 71.5% of dried fish infestation was caused by *D. maculatus*. From analysis, *D. maculatus* adults easily disperse to new sources of food where they infest, and predispose the infested fish to microbial attack (Adedire and Lajide, 2000). Therefore, control of *D. maculatus* infestations of smoked cat fish by disrupting the mating activities of the males and females is vital for global economic sustainability in the fish industry. The objectives of the present study were to (i) identify the most suitable physical mating disruption technique in *D. maculatus* infestations of smoked catfish, (ii) determine the effects of mating disruption on the biological activities of the insect pest, and (iii) ascertain the effects of mating disruption on nutritional quality of fish after pest infestation.

MATERIALS AND METHODS

Experimental Site and Specimens

This experiment was conducted in the Crop Protection Laboratory of the Department of Crop and Soil Science, Faculty of Agriculture, University of Port Harcourt, Rivers State, Nigeria, with the Coordinates: 4°49′27″N 7°2′1″E/4.82417°N 7.03361°E, latitude: 4.7848, longitude: 7.0055. *Dermestes maculatus* was obtained from an

open market in Borokiri, Port Harcourt, Rivers State, Nigeria while *Clarias gariepinus* was obtained from an open market in Choba, Port Harcourt, Rivers State, Nigeria. The work bench was sterilized using 70% ethanol and cotton wool to prevent microorganisms from infecting the work. Kilner jars and samples of *C. gariepinus* were heat sterilized using an open flame from a stove before the experiment.

Insect Culture

A culture was set up to ensure adequate number of insects. The culture was left undisturbed over a long period of time while pre-pupae and pupae were isolated from each substrate at 3-4 days intervals and introduced into separate test tubes prior to adult emergence of similar age and kept unmated before sexing them when needed for the experiment (Zakka *et al*., 2013). The males were distinguished from the females by their possession of a deep depression and brush of hairs on the 4th abdominal sternite (Imai *et al*., 1990). The F1 generation of 1-2 d old were used for the experiment.

Sample Preparation and Bioassay

Fresh *Clarias gariepinus* fish of about 36-49 g were purchased from the open market in Choba and used for the experiment. The fish was washed thoroughly and weighed using a standard weighing balance. It was then dried at a Section in the Choba open market using a local Oven for 2 d, and sun dried for a day, after which it was heat-sterilized using an open flame from a stove. The fish samples were weighed with a sensitive weighing balance to ascertain the weight of the fish before infestation. The standardized fish samples were allotted into an already sterilized and tagged Kilner jars where they were infested with copulating male and female *D. maculatus* in varying ratios as shown in Table 1. The experimental design was Completely Randomized Design (CRD) with seven treatments and replicated three times where *D. maculatus* adults were allowed to mate and the females left to lay eggs while the males were removed at various times as physical mating disruption techniques as shown in Table 1. A control was designated. On the 35th day of infestation, the number of live adult *D. maculatus*, number of dead adult *D. maculatus*, number of larva, number of pupa, weight of frass (g) and percent weight loss of fish were evaluated.

Table 1: Physical mating disruption techniques employed for the study

Treatment serial numbers	Male : Female	Mating disruption techniques (hours)*
1	2:1	24 (1day)
2	1:2	48 (2 days)
3	1:1	72 (3days)
4	1:1	96 (4days)
5	1:1	120 (5days)
6	1:1	144 (6days)
7	3:2	168 (7days)

*Hours after which males were removed.

Determination of Proximate and Mineral Contents of the Smoked Catfish Samples

Proximate analyses were carried out on both infested and uninfested cured catfish to ascertain the level of nutrient loss attributable to *D. maculatus* infestations under different mating disruption techniques. The standard analytical methods of AOAC (1990) described in Onwuka (2005) were used to determine ash, moisture, protein and lipids present in the fish samples. Potassium and sodium were determined by flame photometry while calcium, magnesium and iron contents were determined by atomic absorption spectrometry (Onwuka, 2005).

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) and significantly different means were separated using least significant difference (LSD) at $\alpha = 0.05$. Probability values of < 0.05 were considered significant.

RESULTS

The effects of physical mating disruption on the biological activities of *D. maculatus* reared on smoked *C. gariepinus* are shown in Table 2. Where mating disruption technique of 2:1 (♂: ♀) and the males removed after 24 h of mating had the highest adult beetles alive (2.0) whereas the other mating disruption techniques showed non-significant ($p > 0.05$) difference in values (1.0 throughout) obtained for the other disruption and mating techniques. Same result was obtained for adult beetle dead after the experiment. Number of larval development was higher on physical mating disruption techniques 1:2 and 2:1 (♂ : ♀) where males were removed after 48 h and 24 h respectively though not significantly different from the other treatment combinations except mating disruption technique 1:1 with male removed after 144 hours. Mating disruption technique 1:1 with male removed after 144 h was not significantly different from the other 1:1 treatment combinations and treatment combination 3:2 with males removed after 168 h. Similar result was obtained for pupal emergence under different treatment combinations. Frass weight generated by the beetle at the end of the experiment was highest in the physical mating disruption technique 2:1 (♂: ♀) where the male skin beetles were removed at 24 h though not significantly ($P > 0.05$) different from the other treatment combinations, however, the least frass was recorded in the 1:1 (♂: ♀) mating disruption technique with the male removed after 144 h of mating. Fish loss was highest in the 1:1 (♂: ♀) mating disruption technique where males were removed after 144 h whereas loss was least in the 3:2 mating disruption technique.

Table 2: Mating disruptions and levels of biological activities of the leather beetle, *D. maculatus* unrestricted by smoked catfish, *C. gariepinus*

Treatment (♂ : ♀)	Mating disruption technique (hours)	ABA	ABD	No. larva	No. pupa	Frass weight (g)	% weight loss
2: 1	24	2.00^{a}	3.00^{a}	156.80^{a}	27.75^{a}	11.25^{a}	37.00^{b}
1:2	48	1.00^{b}	0.00^{b}	167.50^{a}	15.75^{a}	10.75^{a}	42.25^{b}
1:1	72	1.00^{b}	0.00^{b}	111.20^{ab}	3.75^{ab}	6.75^{a}	61.50^{ab}
1:1	96	1.00^{b}	0.00^{b}	92.00^{ab}	2.25^{bc}	5.75^{a}	75.75^{a}
1:1	120	1.00^{b}	0.00^{b}	125.50^{ab}	4.00^{ab}	9.50^{a}	49.25^{ab}
1:1	144	1.00^{b}	0.00^{b}	65.80^{b}	2.25^{bc}	5.50^{a}	78.50^{a}
3:2	168	1.00^{b}	0.00^{b}	130.50^{ab}	5.75^{ab}	9.25^{a}	32.75^{b}

Keys: ABA – Adult beetle alive; ABD - Adult beetle dead.
Means followed by the same letters within column were not significantly different by LSD at $\alpha = 0.05$. In all cases, df = 6,14, $P < 0.05$.

Proximate compositions of smoked cat fish infested by *D. maculatus* after different physical mating technique are shown in Table 3 and significant differences ($P < 0.05$) occurred. The mating disruption technique 1:1 (♂: ♀) where male was removed after 144 h of mating had higher ash content and the least ash content was recorded in mating

disruption technique 1:1 (♂: ♀) where the male was removed after 120 h. Other mating techniques were significantly different from each other except for treatment 2:1 and 1:1 (♂: ♀) were mating was disrupted after 24 and 72 h respectively which were not significantly different from each other. Moisture content was significantly higher (29.05%) on physical mating disruption techniques 1:1 (♂: ♀) where the male leather beetle was removed after 144 h and the least moisture content (17.21%) was recorded in the control. Other mating disruption techniques were significantly ($P < 0.05$) different from each other except between treatments 1:1 and 1:1 (♂: ♀) where males were removed after 72 and 120 h, respectively and between treatments 1:2 and 1:1 (♂: ♀) where males were removed after 48 and 96 h respectively. Protein content was significantly higher in uninfested smoked fish and physical mating disruption 1:1 (♂ : ♀) where male was removed after 96 h and the least protein content was recorded in mating disruption technique 3:2 and 2:1(♂ : ♀) where the males were removed after 168 and 24 h of mating respectively. Lipid content was significantly higher in uninfested smoked fish while the least lipid content was recorded in mating disruption technique 1:2 (♂: ♀) where the male skin beetle was removed after 48 h of mating. Mating disruption techniques 1:1 (irrespective of hours after male was removed) were not significantly different from each other. Minerals composition of smoked cat fish infested by *D. maculatus* after different physical mating technique is shown in Table 4 and significant differences were observed. The result showed that the physical mating disruption 1:1 (♂: ♀) where male was removed after 120 h had the highest K value and this was followed by uninfested smoked catfish. Sodium value was significantly higher on smoked catfish where physical mating disruption techniques 3:2 and 1:1 (♂ : ♀) with males removed after 168 and 96 h of mating respectively were adopted and the least sodium value was recorded in mating disruption technique 1:1 (♂ : ♀) and the male was removed after 120 h of mating. Calcium was significantly higher in uninfested smoked catfish while the least was recorded in infested smoke catfish where mating disruption technique 1:1 and the male was removed 72 h of mating. Similar result was obtained for magnesium and iron, except that they occurred in lowest amount in mating disruption 1:1 where the male was instead removed 96 h after mating.

Table 3: Proximate composition of smoked cat fish infested by *D. maculatus* after different physical mating technique

Treatment (♂ : ♀)	Mating disruption technique (hours)	Ash (%)	Moisture (%)	Protein (%)	Lipid (%)
2: 1	24	4.616^{c}	27.35^{b}	53.375^{e}	2.70^{d}
1:2	48	4.277^{d}	23.03^{e}	59.063^{bc}	1.30^{e}
1:1	72	4.679^{c}	24.45^{d}	59.500^{bc}	4.40^{c}
1:1	96	4.927^{b}	23.47^{e}	61.250^{a}	4.30^{c}
1:1	120	3.622^{f}	25.04^{d}	59.938^{ab}	4.40^{c}
1:1	144	5.307^{a}	29.05^{a}	56.875^{d}	4.40^{c}
3:2	168	3.756^{e}	26.51^{c}	52.500^{e}	5.40^{b}
Control*		4.920^{b}	17.21^{f}	61.250^{a}	18.70^{a}

*Un-infested smoked cat fish

Means followed by the same letters within column were not significantly different by LSD at $\alpha = 0.05$. In all cases, df = 7,16, $P < 0.05$.

Table 4: Mineral composition of smoked cat fish infested by *D. maculatus* after different physical mating technique

Treatment (♂ : ♀)	Mating disruption technique (hours)	K (mg/kg)	Na (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Fe (mg/kg)
2: 1	24	284.00^{g}	499.05^{b}	322.45^{e}	280.65^{g}	65.80^{d}
1:2	48	307.50^{e}	463.20^{c}	727.50^{b}	897.95^{c}	86.65^{c}
1:1	72	262.60^{h}	495.80^{b}	169.45^{h}	605.45^{d}	199.30^{a}
1:1	96	333.00^{d}	517.60^{a}	292.35^{g}	189.15^{h}	47.70^{g}
1:1	120	729.45^{a}	275.50^{d}	686.00^{c}	1735.00^{a}	59.65^{e}
1:1	144	291.50^{f}	490.45^{b}	246.15^{f}	524.84^{e}	64.20^{d}
3:2	168	345.00^{c}	521.70^{a}	347.45^{d}	487.20^{f}	51.00^{f}
Control*		597.45^{b}	292.50^{d}	1327.50^{a}	1046.50^{b}	111.40^{b}

*Un-infested smoked cat fish

Means followed by the same letters within column were not significantly different by LSD at $\alpha = 0.05$. In all cases, df = 7,16, $P < 0.05$.

DISCUSSION

According to Archer and Elgar (1999), *D. maculatus* males attempt to mount and copulate with the females on encountering them without courtship. This could be attributed to the facts that both produce sex pheromone (Rakoswki and Cymborowski, 1986; Jaskulska *et al*., 1987). Contrary to what was reported in *Coleophora deauratella* where physical mating disruption technique controlled the mobile adult stage by preventing or delaying mating (Baker and Heath, 2005), such has been utilized in disrupting chemical communication between male and female insects (Howse *et al.*, 1998) and thereby preventing mating among and between the species.

The analysis of result showed that each physical mating disruption technique resulted into different number of progenies of *D. maculatus* as observed in mating disruption technique 2:1 and 1:2 (♂: ♀) left to mate for 24 and 48 h respectively resulting to higher larvae and pupae was at variance with earlier report by McNamara *et al*. (2008) that males exhibit preference, discriminating against mated females in preference for virgins. Eady *et al*. (2000) reported that copulation of males with the same sexual partner may suggest their incapability of recognizing previous sexual partners and the fact that females inseminated by multiple males laying more eggs implies a function of polyandry. Bateman (1948) also reported that male reproductive success increases with additional copulation. In this report even where males were twice the number of females and vice versa, higher progenies over those where the sexes were in equal proportion and were allowed to mate for longer period were observed which contrast to the previous reports. The selection of mate may then suggest that it is determined by female species of *D. maculatus* and since some insects even among the coleopterans are known to be parthenogenetic (which was beyond the scope of this study). It may then be as Archer and Elgar (1999) reported that males initiate mating while the females exhibit some degree of choice and can either accept or reject copulation advances by either walking away, resisting by bucking, kicking at the genitals of the males and/or

rolling over while remaining calm for suitor to allow mating. However, benefits of females copulating with multiple males were highlighted by previous studies to include increasing fertility (Walker, 1980), high male parental care (Davies, 1992), courtship feeding (Thornhill and Alcock, 1983), deriving nutrients from the ejaculatory (Gwynne, 1984), and reduction of infanticide (Hrdy, 1977). Others are genetic diversity and compatibility (Keller and Reeve 1994; Zeh and Zeh, 1997), production of viable and attractive offspring (Kempenaers *et al*. 1992; Olsson *et al*. 1994) and efficient sperm fertilization (Keller and Reeve, 1995).

Frass weight generated by all stages of development of *D. maculatus* in the physical mating disruption technique adopted showing higher index in where the number of both adults and larvae of the beetle were higher may be attributed to the fact that both stages of the beetle feed and the higher the number; the higher frass generated and the higher weight loss of the substrates. This assertion was earlier propounded by Rustin and Munro (1984) and Haines and Rees (1989) that *D. maculatus* is a cosmopolitan and a major pest of cured fish and these workers observed continuous feeding by adults and larva thereby causing up to 50% quantitative and qualitative losses of the edible fish during storage (Odeyemi *et al*., 2000; Fasakin and Aberejo, 2002). Ekeh *et al.* (2008) described hide beetle as a highly destructive pest of protein-based food which include smoked fish, dried meat and blood meal and any material containing steroids which could range from leather goods to poultry feeds and allied produce. Therefore its management is an essential component of any effort to increase food production and thus ensure food security.

Dermestes maculatus developing on all substrates where different physical mating disruption techniques were employed resulting to different level of mineral composition and proximate depreciation may suggest the assertion propounded earlier that the beetle has high preference to animal steroid. Lale (2002) reported that skin beetle feeds on wide variety of animal protein-rich diet while Ikeme (1991) and Ande *et al*. (2012) stated that nutritional requirements of both adult and larvae of *D. maculatus* are similar. From the results, the rate of food consumption, development, emergence, fecundity and fertility were proportionate to the loss in the available nutrients consumed. This suggests that protein content and other minerals and vitamins depreciated higher in the smoked fish which supported higher progenies. Proteins, minerals and vitamins might have been utilized during egg-laying and other development processes by both the adult beetle and their F_1 progenies. Similar result was obtained by Johnson and Esser (2005) that carnivorous beetles such as skin beetle need a good supply of protein, vitamins and minerals for optimum growth.

In conclusion, the physical mating disruption techniques yielded different number of progenies of *D. maculatus.* The selection of mate may be determined by female species of *D. maculatus* and there was evidence of parthenogenesis and therefore the use of physical mating disruption technique can be applied in the control of *D. maculatus* to reduce their biological impact on smoked cat fish and to ensure the availability of quality and sufficient smoked cat fish for human use.

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