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Development of *Dermestes maculatus* (DeGeer, 1774) (Coleoptera, Dermestidae) on Different Fish Substrates

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Abstract

The development of *Dermestes maculatus* (DeGeer) on four smoked fish substrates [Trigger fish (*Balistes capriscus)*, Catfish (*Synodontis sp.*), African catfish (*Clarias gariepinus*) and Nile Tilapia (*Oreochromis niloticus*)] were investigated as completely randomized design under laboratory temperature of 30^{o}C, relative humidity of 65±5% and a light: darkness regimen of 12:12 hours. Females laid eggs within 24 hours of copulation. The numbers of eggs laid and the period between larval instars were not significantly different ($P > 0.05$). Mean total egg laying period varied from 18 days on *B. capriscus* to 30 days on *Synodontis sp.* with about 75% of eggs laid on days 13, 15, 15 and 17 for *O. niloticus*, *B. Capriscus*, *C. gariepinus*, and *Synodontis sp*., respectively. Hatching started 48 hours after copulation on all fish substrates. The mixed fish substrate (comprising all species) gave the longest ($P < 0.05$) developmental period of 42.75 days. Except *C. gariepinus* which recorded five larval instars, all others gave six instars. The total development period of *D. maculatus* from egg → larva → pre-pupa → pupa → adult emergence on the fish substrates decreased in the order *Synodontis* > *O. niloticus* > Mixed > *C. gariepinus* > *B. capriscus.*

Keywords*: Dermestes Maculatus*, Developmental Period, Emergence Pattern, Fish Substrates, Copulation.

1. Introduction

Fish has remained an important source of food and income to many people in the developing world including Africa where as much as 25% of the population depend on it (Essuman, 1992). It is a very rich source of good quality protein in diets of man (Amusan and Okorie, 2001; Fasakin and Aberejo, 2002; Azam *et al*., 2004; Aderolu and Akpabio, 2009). Don-Pedro (1989) concurs that during storage, transportation and marketing, dried fish is readily attacked by several species of insects notably *D. maculatus*, *D. frischii*, *D. ater* and *Necrobia rufipes*. FAO (1990) reported that *Dermestes spp.* and *N. rufipes* were major pests of smoked fish, poultry products (Geden and Hogsette, 2001), museums (Linnie and Keatinge, 2000), Egyptian mummies (Adams, 1990) and stored cocoons of silk-worm *Bombyx mori* (Sahaf, 2007). Lale and Sastawa (1996) and Odeyemi *et al.* (2000) recorded about 50% losses during the storage of smoked fish products due to deterioration. The losses have been attributed to net reductions in the amount of nutrients available to the consumer (nutritive quality) resulting to declining consumer acceptability and market prices (economic losses) or both quantitative and qualitative losses (Odeyemi *et al*., 2000; Atijegbe, 2004). Thus, the experiment was designed to investigate the developmental processes of *D. maculatus* on substrates from four species of smoked fish with the aim of understanding the biology of the pest for effective and efficient management measures against losses caused by the pests in stored fish products.

2. Materials and Methods

The studies were carried out between October 2004 and May 2005 under controlled temperature (30ºC), relative humidity (65±5 %) and light-to-darkness regimen of 12:12 hours. Smoked fish from four species of fish – the Trigger fish (*Balistes capriscus* Gmelin*)*, Catfish (*Synodontis* sp.), African catfish (*Clarias gariepinus* Burchel) and Nile tilapia (*Oreochromis niloticus* Linnaeus) – were purchased from Madina and Makola local Markets in Accra, Ghana and used for the experiment. Treatments were arranged as completely randomized design (CRD), replicated four times and kept on open air shelves. The life cycle of the pest was determined on each food medium and appropriate records taken as outlined below.

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2.1. Rearing of D. Maculatus

Several unsexed adults of *D. maculatus* obtained from naturally infested smoked fish materials served as sources of the pests. The glass jars and cured fish species- *B. capriscus* (Trigger fish), *Synodontis sp.* (Catfish), *C. gariepinus* (African catfish) and *O. niloticus* (Nile Tilapia) used for the experiment were heat-sterilized at 60ºC for one hour in a hot-air Gallenkamp oven in the laboratory to kill all insect pests that may be present. The experimental bottles had their lids opened and sealed with 4 cm diameter mesh to facilitate aeration of the culture and placed on inverted Petri dishes submerged in white oil on shallow trays to keep out mites and other insect pests. Adult *D. maculatus* were then transferred into sterilized jars containing the disinfested smoked fish from *B. capriscus*, *Synodontis sp.*, *C. gariepinus* and *O. niloticus* species to initiate new colonies of the parent stock for rearing the pests. The insect pests were fed on the four different fish substrates.

About 1000 g of the sterilized fish substrates were then conditioned for 2 days under ambient laboratory conditions with about 600 g of each substrate later poured into a series of 1-litre jars. About 20 unsexed adults of *D. maculatus* were introduced into each jar and their offspring allowed developing up to the pupa stage. The adults were sieved out after fourteen days of oviposition to ensure that offspring of relatively same age were obtained as pure F_1 *D. maculatus*. The pupae were then transferred from each of the substrates into separate sub-culture bottles containing each pure fish substrates. The rearing cultures were left undisturbed over a long period of time but pupae were isolated from each substrate at 7-day intervals and introduced into separate test tubes prior to adult emergence to ensure that adults were 47 days old before sexing them and kept unmated until required. The males are distinguished from the females by their possession of a deep depression and brush of hairs on the 4th abdominal sternite (Imai *et al*., 1990). On emergence, the adults were placed in test tubes containing similar fish substrates to the ones on which they were bred and maintained under same conditions.

2.2. Egg Laying Bioassay

The experimental bottles were sterilized in a Gallenkamp oven, as described above, to obtain the number of egg(s) laid per female per day. Each fish species was then carefully dissected using entomological scissors and compacted with rubber band as in whole fish substrates. A male and a female adult *D. maculatus* (each 47-day old) were then introduced into separate tubes containing each fish species to serve both as food and oviposition medium and incubated for 30 days. Water was provided as soaked cotton wool and insects were allowed to drink for five minutes while egg count was done. The jars were monitored twice daily for the presence of eggs using hand lens and any egg seen was counted and removed using soft brush after which the medium was returned to its original position.

2.3. Larval Development

Larval instars were examined after collecting and placing eggs laid on each fish substrate from each of the experimental jars into glass tubes for incubation. On hatching, the larvae were separated into individual tubes of 2.2 cm × 15 cm dimensions containing 10 g of each fish species and kept under observation for their development. Duration of each larval instar was determined on each substrate by the presence of exuviate after each moult. All larvae were derived from eggs laid by individuals maintained on smoked fish substrates used in determining the number of eggs laid.

2.4. Pupal Period

The pre-pupal stage occurs when the last instar larva becomes almost C-shaped, shortened and remains non-motile for some days, while the pupal stage is what follows immediately. Pupae were removed and placed individually in clear tubes and held under laboratory conditions until adult emergence. The sexes, length and pupal periods were recorded for each emerged adult.

Data collected on eggs laid, developmental pattern, larval instars, prepupal and pupal durations were transformed using square roots of $\sqrt{(x+1)}$ and analysed using Genstat software version 5 Release 3.2 (Lawes Agricultural Trust, 1995) and subjected to analysis of variance at 95% level of significance and significant means were separated using LSD at 0.05 error limit.

3. Results

3.1. Pattern of oviposition by D. maculatus on four different fish substrates

Eggs laid on each fish species were random but gradually increased in number during the first week and subsequently declined with time. About 75% of eggs were laid on *Synodontis* by day 17 while the same level was reached on *C. gariepinus* and *B. capriscus* by day 15 and on *O. niloticus* by day 13 (Figure 1). Maximum egg laying periods were recorded on *Balistes sp*. and *Synodontis sp*. in 30 days while the minimum egg laying period recorded on *O. niloticus* was 18 days. The maximum recorded number of eggs laid in a batch per day was 28 on *O. niloticus* and a minimum of a single egg per day was recorded on all the fish substrates.

3.2. Total Eggs Laid By D. Maculatus Within 30 Days on Different Fish Substrates

The total number of eggs laid on the different fish substrates over 30 days was not statistically significant ($P > 0.05$, F Prb. = 0.275). The highest mean number of eggs was, however, laid on *O. niloticus* (151±33.67) and the lowest were on *B. capriscus* (103±43.5) with *Synodontis sp.* (132±31.11) and *C. gariepinus* (117±14.39) as intermediates (Table 1).

Table 1. Total number of egg laid on different fish substrates within 30 days

Fish substrates	Total eggs laid ±SE*	Range (eggs/day)
O. niloticus	151±33.67	1-28
Synodontis sp	132±31.11	1-20
C. gariepinus	117±14.39	1-19
B. capriscus	103±43.51	1-18

3.3. Larval Instars of D. Maculatus on Different Fish Substrates

There were 6 larval instars of *D. maculatus* on all the fish substrates except on *C. gariepinus* substrates where only 5 instars were recorded (Table 2). The mean duration (in days) of the various larval instars on the different fish substrates was not statistically significant ($P > 0.05$, F Prb. = 0.287) without a clear trend in larval developmental periods on the substrates over 50 days. While larval development on *O. niloticus* had uniform periods except in the 6th larval instar, those on *Synodontis* and *B. capriscus* had the highest number of days recorded in the 2nd larval instar and least in the 6th instar. However, on *C. gariepinus* the highest period was recorded in the 5th instar. When placed on mixed substrates, there was generally a progressive increase in duration in each subsequent larval instar (Table 2). The mean duration of larval instars was highest in the 2nd instar (range: 6-12 days) followed by the 5th instar (range: 4-11 days), and the least duration was recorded on the 6th larval instar.

Table 2. Mean duration (days) of larval instars of *D. maculatus* on the different fish substrates

Fish species	Duration (days) of larval instars ±S.E*						
	1	2	3	4	5	6	Total
O. niloticus	5.75±0.48	5.75±0.48	5.75±0.48	5.75±1.03	5.25±0.48	7±0.00	35.25
Synodontis sp	6.75±0.75	10±0.82	5.25±0.48	6.00±0.91	6.5±0.65	5±0.00	35.75
C. gariepinus	5.00±0.00	7.25±0.25	5.75±0.25	5.00±0.00	8.00±0.00	-	31.00
B. capriscus	5.75±0.48	9.00±0.41	5.75±0.48	6.00±0.71	5.25±0.48	5.5±0.35	37.25
Mixed subs.	5.00±0.00	6.50±0.29	7.25±0.48	6.50±0.65	9.00±1.35	8.5±0.35	42.75

*Values are means of four replicates ± SE. (Standard error)

3.4. Developmental Periods of Pre-Pupa and Pupal Stages of D. Maculatus

Statistical analysis showed significant differences ($P < 0.05$, F Prb. = 0.083) in the mean period between pre-pupa and the emergence of external adults. *O. niloticus* recorded higher pre-pupal period while the least pre-pupal period was recorded on mixed substrates. The results further showed significant difference ($P < 0.05$, F Prb. = 0.083) in pupal period with *B. capriscus* recording the least from the other fish substrates (Table 3).

Table 3. Mean period of development from pre-pupa to adult emergence of *D. maculatus* on different fish substrates

Fish species	Developmental period ± SE*			
	Pre-Pupa	Range	Pupa	Range
O. niloticus	12.75^{a}±1.65	9-16	9.00^{a}±1.29	6-10
Synodontis sp	11.00^{ab}±1.08	8-13	9.50^{a}±0.96	8-12
C. gariepinus	8.75^{bc}±1.11	6-9	7.50^{a}±0.65	6-9
B. capriscus	8.00^{c}±0.82	9-12	6.75^{b}±1.38	5-10
Mixed substrates	7.25^{c}±0.48	6-8	8.00^{a}±1.08	6-11
LSD 2.73				

Means with the same superscripts in the same column are not significantly ($P > 0.05$) different.

However, the cumulative developmental periods of *D. maculatus* from pre-pupa to pupa on the various fish substrates did not show any significant differences ($P > 0.05$, F Prb. = 0.135) (Table 4). The total development period of *D. maculatus* from egg → larva → pre-pupa → pupa → adult emergence on the fish substrates decreased in the order *Synodontis* > *B. capriscus* > *O. niloticus* > *C. gariepinus*.

Table 4. Mean development period (days) of pre-pupa and pupa of D. maculatus on different fish substrates

Developmental stages	Days± SE	Range
Pre-pupa	9.55±1.14	7.25-12.75
Pre-pupa	8.15±0.56	6.75-9.50
LSD	1.74	
Values are means of four replicates ±SE		

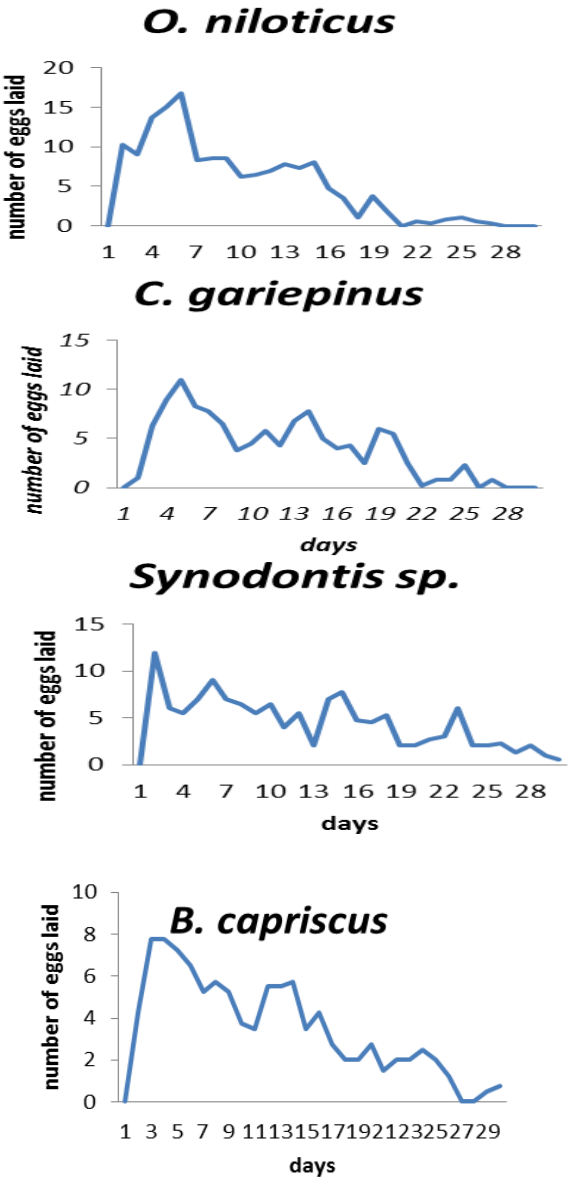

Figure 1. Oviposition pattern of *D. maculatus* on different fish substrates

4. Discussion

4.1. Oviposition in D. maculatus on fish substrates

The study revealed that in *D. maculatus* copulation occurred immediately the adults were paired and this could be explained as reported that both male and female *D. maculatus* produce sex pheromone (Rakoswki and Cymborowski, 1986; Jaskulska *et al*., 1987) which enhances communication and within 48 hours creamy white eggs were laid. The eggs laid were oval in shape and bluntly pointed at both ends as earlier reported (Archer and Elgar, 1999; Jones and Elgar, 2004; Ezenwaji and Obayi, 2004). The results of this study confirm the works of various researchers that *D. maculatus* females copulate within 30 minutes of pairing with the males initiating copulation (Archer and Elgar, 1999; Jones and Elgar, 2004).

Egg laying in *D. maculatus* per female within 30 days on each of the different fish substrates was random and varied. The egg laying capacity of the pest tested on different fish substrates followed the descending order: *O. niloticus* > *Synodontis* > *C. gariepinus* > *B. capriscus*. *O. niloticus* was thus the most suitable medium for egg laying on the four substrates tested and expected to carry the heaviest infestation in the field. These differences may be attributed to the fact that oviposition in insects on a specific host is determined by various factors that may determine its suitability or otherwise as a breeding medium, such as nutritional quality, host abundance (Jansen and Nylin, 1997; Barros and Zucoloto, 1999), morphology, environmental conditions, age and size of individual (Stejskal and Kucerova, 1996; Johnson and Kistler, 1987) and competition (Siemens *et al.*, 1991). The study showed that none of the fish substrates deterred egg laying, though some of the media proved to be better than others as more suitable for oviposition by *D. maculatus*.

Generally there was an initial increase in total number of eggs laid during the first week of oviposition on all the fish substrates but subsequently there was reduction in numbers as the days progressed and insects got older (Ezenwaji and Obayi, 2004). Oviposition behaviour in insects is an important contributor to the fitness of insects because of the consequent effect on the number and quality of offspring (Honek, 1993; Stejskal and Kucerova, 1996). The study further showed that 75% of eggs were laid between the 13th and 17th day on all the fish substrates. The peak laying period agrees with the results of Ezenwaji and Obayi (2004) who indicated that full oviposition in *D. maculatus* is attained during the first 6-8 days, becoming fairly uniform in about 16 days, indicating reduction in rate of oviposition with time as sperm viability also declined with age (Kidd *et al*., 2001; Oakes *et al.*, 2003; Szczesnny *et al.*, 2003).

Eggs were laid in different batches, ranging from 2-6 batches with 28 eggs per batch as the highest and this contradicts the results of (Osuji, 1975) who recorded upto 38 eggs in a batch. Maximum number of eggs recorded on *O. niloticus* was 151 within 30 days confirming the findings by previous workers (Amusan and Okorie, 2001), but differs from the findings of (Seal and Tilton, 1985 and Ezenwaji and Obayi, 2004) who recorded 407 and 598 eggs respectively.

The maximum egg laying period of 30 days recorded contradicts those of Taylor (1964) and Osuji (1975) who found maximum egg laying period in *D. maculatus* to be 14 and 189 days, but similar to the works of Coombs (1978). These may be attributed to the differences in temperature, relative humidity, age of the insects and the amount and kind of food supplied.

4.2. Larval instars in D. maculatus reared on different fish substrates

Observations made during the study showed that the hairy creamy larva on emergence darkens to light grey within a few hours. Although there were no significant differences in the duration of development of the larvae in the various fish species, larval development was shorter on *C. gariepinus* than on the other fish substrates. Assuming that a short development time on a certain fish species is an indication of good host suitability then, *C. gariepinus* may be marginally more suitable for development of *D. maculatus* which suggests higher level of infestation on *C. gariepinus.* Five larval instars were recorded on *C. gariepinus* but six on each of the other substrates. These differences could be attributed to the nutritional composition of the fish species as reported by Samish *et al*. (1992) that *D. maculatus* larva prefers substrates with high protein content. The second instar was longer on *Synodontis sp.* and *B. capriscus*, while it was longer for the fifth instar on *C. gariepinus* and the mixed substrates. This conforms with the findings of Osuji (1975) and Rustin and Munro (1984), but different from Lale *et al* (2000) who observed no differences in the numbers of larval instars on different fish species.

Larval development in *D. maculatus* does not involve any visible morphological change but only an increase in size from the previous instars (Osuji, 1975). The total development period of 31 days observed on *C. gariepinus* to 42.75 days on mixed substrates greatly differed from 91 days by Scoggin and Tauber (1951) and 16 days by Kreyenberg (1928). No differences in total developmental period between males and females were observed as was reported by (Kreyenberg, 1928).

4.3. Pre-pupal periods

In each of the fish substrates a quiescent period was observed at the end of the last larval instar where it became almost C-shaped, thickened and reduced in length from 10.99 to 6.54 mm on *O. niloticus*, 12.50 to 9.38 mm on *Synodontis sp*., 12.95 to 8.42 mm on *C. gariepinus*, 11.38 to 8.34 mm on *B. capriscus* and 11.97 to 9.22 mm on mixed substrates. The observation of a non-motile nature of the pre-pupa agrees with those of Osuji (1975), Anonymous (1980) and Cloud and Collison (1986). However, the pre-pupal and pupal duration differed from those of Ezenwaji and Obayi (2004) and Rustin and Munro (1984). It was also observed that pupal duration was not sex dependent as reported by (Kreyenberg, 1928).

4.4. Adult emergence

Comparing developmental period from eggs to adult emergence of the four fish substrates indicated that *C.*

gariepinus proved to be the most suitable for *D. maculatus* development because this fish substrate recorded the shortest period, even though it did not differ statistically from the others. These differences recorded may be due to evolutionary trend, physical form of the fish or its nutritional composition as reported by (Zakka *et al*., 2009). It is not clear why *D. maculatus* females would prefer one fish substrate for oviposition and a different fish for feeding, since more eggs were laid on *O. niloticus*.

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