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Research Article
Effect of Pre-Exposure to Various Temperatures on the Development and Survival of *Musca domestica* (Diptera: Muscidae)

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Abstract

Background and Objective: The housefly species are found in human habitations and refuse dumpsites. The housefly is a notable pest in animal production facilities. The study evaluated the effect of temperature gradient on the survival and mortality of the developmental and adult stages of the housefly, *Musca domestica*. This is intended to determine the effect of temperature variations on the development of egg, larva, pupa and survival of the adult *M. domestica*. **Materials and Methods:** The immature stages produced by the adults of the flies were separately exposed to 15.6, 22.2, 28.8, 32.2 and 36.1°C, using SPX-II biochemical incubator. Twenty of each of the developmental stages was exposed to the different temperatures in four replicates. Adult males and females of ages 0, 5, 10, 15 and 20 days were divided into batches (n = 20) and incubated for 8 hrs and further monitored for 72 hrs in the laboratory. **Results:** Temperature has a significant effect on the development of the eggs, larvae and pupae, the development of the immature stages was highest at 28.8 and 32.2°C but lowest at 36.1°C. Adult emergence was highest under 28.8°C and lowest under 36.1°C. Temperature significantly ($p \leq 0.05$) affected the survival of adults, irrespective of their age. Adult survival was highest under 22.2°C and lowest under 36.1°C and females have higher survival than males under the same temperature. **Conclusion:** Based on the developmental and survival data obtained, temperature variation can be used as an effective means to control the population of both developmental and adult stages of *M. domestica*.

Key words: Housefly, *Musca domestica*, temperature-dependent development, thermal requirement

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The housefly, *Musca domestica* (Diptera: Muscidae) is a cosmopolitan fly species found in human habitations and refuse dumpsites. The housefly is a major pest in animal production facilities, especially poultry houses. Female *Musca* lays batches of about 150 eggs on decaying organic matter such as garbage, carrion or faeces. *Musca domestica* will produce five or six batches of eggs within a few days which hatch into larvae within 24 hrs and transform into pupae after 2-5 days[1]. Houseflies pass through four distinct stages: Egg, larva, pupa and adult. The life expectancy of a housefly is generally 4-6 weeks depending on temperature and availability of diet[2]. *Musca domestica* are found on uncleared refuse and dump sites and those maintained in the laboratories develop faster and live longer than those living in the wild. Adults feed on a variety of liquid or semi-liquid substances such as meat juice or decaying organic matter. They carry pathogens on their bodies and in their faeces and can contaminate food, thus contributing to the transfer of food-borne illness[3].

The metabolic rate of flies is known to be higher and lifespan shorter at elevated ambient temperatures[4]. Johnson *et al*.[5] reported that, heat also affects the reproduction and immature stages of olive fly (*Bactrocera oleae*). *Parasarcophaga ruficornis*, a flesh fly grew through normal developmental stages at 35°C, but at higher temperatures, there was mortality[6]. Grassberger[7] stated that the duration of development from oviposition to adult emergence in *Lucilia sericata* was inversely related to temperature. Mohamed *et al*.[8] demonstrated that the embryonic development of the peach fruit fly, *Bactrocera zonata* declined gradually as the temperature increased from 20-35°C and the highest percentage of egg hatch occurred at 30°C and lowest at 35°C. The developmental rate of larvae gradually increased with an increase in temperature and the same trend was observed for pupation rate with a declining rate as the temperature increased.

Danjuma *et al*.[9] reported a positive linear relationship between temperature and developmental rate of immature stages of *Bactrocera carambolae* and *Bactrocera papayae*. Bayoh and Lindsay[10] earlier demonstrated that the rate of development from one immature stage in *Anopheles gambiae* to the next increased at higher temperatures, peaking at around 28°C and then declining. The adult development rate was highest between 28 and 32°C with no adult emerging below 18°C or above 34°C. Harnden and Tomberlin[11] observed that *Hermetia illucens* larvae reared at 27.6 and 32.2°C required more hours to complete their development and had greater larval weight than larvae reared at 24.9°C. There was a reduction in mortality at a warmer temperature of the larvae of stable fly *Stomoxys calcitrans*[12].

Liu and Ye[13] reported that the developmental time of pre-imago stages of the fruit fly (*Bactrocera correcta*) decreases as temperature increases from 18-33°C and a physiological maximum at the higher temperature (36°C). Ali[14] observed a significant decrease in the developmental time of immature stages of *Bactrocera zonata* and *Dacus ciliatus* as temperature increases from 20-30 and 20-40°C, respectively. When *Drosophila suzukii* was mated at 31°C for 4 days, none of the eggs hatched, female oviposition and egg hatching rate were also reduced as temperature increased during the oviposition period[15].

Despite the ubiquity of house fly in the Nigerian environment, there is virtually no study on the effects of temperature on the housefly *Musca domestica.* The present study examined the effects of temperature variations on the developmental stages and survival of adult *Musca domestica* in the laboratory.

MATERIALS AND METHODS

Study area: The experiment was conducted at the Insect Physiology Laboratory of the Department of Zoology, Obafemi Awolowo University, Ile-Ife between March and December, 2019.

Rearing of *Musca domestica*: Adults of *M. domestica* were collected from Obafemi Awolowo University refuse dump, Ile-Ife, Nigeria and were used for developing a self-sustaining laboratory stock. Several generations of the fly species were raised in a rearing cage ($40\times30\times30$ cm^3) covered with mesh. Five grams of ground rice was mixed with 5 g of ground dry fish and water in the ratio of 1:1:1.5 v/w to form a paste and served as food for the flies. The food serves not only as a breeding medium for the flies but also as a source of protein-rich diet for the larvae. After the eggs were laid on the food medium, they were removed from the cage and transferred into another cage where the eggs eventually hatched. The eggs hatched into larvae which fed voraciously to pass through the three larval instars. At the third instar, the larva migrated from the Petri dishes containing the diet and settled into the bedding sawdust in the cage where they eventually pupated. The effects of various temperatures were subsequently observed in four replicates on the development of egg, larva and pupa, adult emergence and their survival under controlled temperatures using SPX-II Biochemical Incubator in the laboratory.

Development of egg, larva and pupa at various temperatures: Twenty eggs, larvae (1st, 2nd and 3rd instars) and pupae were separately exposed to 15.5, 22.2, 28.8, 32.2 and 36.1°C in the incubator for 8 hrs and were thereafter returned to the insectary (24±2°C and 60±5% rel. humidity) for further development on a mixture of ground rice and fish diet made into a paste. Adults that emerged from each of the growth stages were counted and recorded accordingly.

Adult survival Twenty adult males and females at ages 0, 5, 10, 15 and 20 days were exposed to 15.5, 22.2, 28.8, 32.2 and 36.1°C in the incubator. After 8 hrs of exposure, the number of dead flies was recorded and removed. The survivors were further monitored for survival for 72 hrs in the insectary.

Statistical analysis: Data obtained were analysed by applying one way ANOVA in IBM SPSS® version 23 statistical package. Tukey's HSD Post Hoc test was used to resolve differences among means. A value of $p<0.05$ was used to indicate significant differences among groups.

RESULTS

The mean survival of each of the developmental stages of *M. domestica*, exposed to different temperatures is shown in Table 1. Survival was adversely affected by the extreme pre-exposed temperatures. 36.1°C was the most deleterious temperature to the development of the eggs. 15.6 and 22.2°C also proved unfavourable to the development of housefly eggs. 32.2°C sustained egg development slightly above average. However, 28.8°C supported optimum egg development.

The trend of survival was similar among the three instar larval stages. 36.1°C was severe. 15.6 and 22.2°C also did not sustain an average survival of the larval instars. The larval instars fared better at temperatures between 28.8 and 32.2°C. The pattern of survival and development of housefly pupa was not different from observed survival in egg and larva stages. 36.1 and 15.6°C did not support the optimum development and survival of the pupae. The 22.2 and 32.2°C merely supported above-average pupae survival however, 28.8°C supported optimum survival of the pupae.

There was a significant difference ($p<0.05$) in the mean survival of the different developmental stages with changes in temperature from 15.6-36.1°C. In all the developmental stages, mean survival was highest at 28.8°C and lowest at 36.1°C.

The emergence of adults from different developmental stages at various temperatures is shown in Table 2. The emergence of adults from various stages followed a similar trend from egg to pupal stage and at different pre-exposed temperatures. Optimum adult emergence was recorded at 28.8°C (17.00±0.7071) while 36.1°C recorded the lowest adult emergence (0.25±0.2500). At each stage, there was a significant difference in the number of adults that emerged with temperature variation. The number of adults that emerged from each of the stages are quite similar. The effect of different pre-exposed temperatures on each of the stages affected the number of adults that emerged.

Table 3 shows the survivorship data of adult male and female *M. domestica* at different ages exposed to different temperatures. There was no survival of adults at 36.1°C and survival at 15.6°C was the lowest/minimum. Adult survival was highest at 22.2°C and survival of adults was higher at 28.8

Table 1: Effect of pre-exposure temperatures on survival of each of the developmental stages (N = 20)

Temperature (°C)	Eggs	1st instar larvae	2nd instar larvae	3rd instar larvae	Pupae
15.6	5.25±0.4787^{b}	5.75±0.4787^{b}	4.50±0.2886^{a}	5.75±0.8539^{ab}	8.25±0.4787^{a}
22.2	8.00±0.4083^{c}	9.00±0.4083^{c}	8.25±0.4787^{b}	8.50±0.6455^{b}	11.50±0.6455^{b}
28.8	18.75±0.4787^{c}	18.75±0.2500^{c}	18.00±0.4083^{d}	18.75±0.4787^{d}	19.25±0.4787^{d}
32.2	13.50±0.6455^{d}	14.50±0.6455^{d}	13.50±0.6455^{c}	15.00±0.7071^{c}	15.00±0.6455^{c}
36.1	0.75±0.4787^{a}	2.00±0.4083^{a}	2.25±0.8340^{a}	3.75±0.4787^{a}	5.75±0.8540^{a}

Means±SE with the same alphabet along the column are not significantly different at $p\leq0.05$ by Tukey HSD

Table 2: Adult emergence of *M. domestica* from various developmental stages pre-exposed to various temperatures (N = 20)

	Adult emergence				
Temperature (°C)	Eggs	1st instar larvae	2nd instar larvae	3rd instar larvae	Pupae
15.6	3.50±0.6455^{b}	4.00±0.9129^{a}	3.50±0.5000^{ab}	4.50±0.8660^{ab}	7.50±0.8660^{b}
22.2	6.75±0.4787^{c}	7.25±0.6292^{b}	6.50±0.6455^{b}	7.00±0.4083^{b}	10.00±0.4083^{b}
28.8	17.00±0.7071^{e}	16.50±0.2887^{d}	16.50±0.6455^{d}	16.00±0.4083^{c}	17.25±0.4787^{d}
32.2	10.25±0.6292^{d}	11.50±1.0408^{c}	11.25±1.1087^{c}	13.75±0.7500^{c}	14.00±0.5774^{c}
36.1	0.25±0.4787^{a}	1.00±0.4083^{a}	1.75±0.6292^{a}	2.25±0.4787^{a}	4.25±0.6292^{a}

Means±SE with the same alphabet along the column is not significantly different at $p\leq0.05$ by Tukey HSD

Table 3: Survival of adult *M. domestica* exposed to different temperatures (N = 20)

	Adult age (days)				
Temperature (°C)	0	5	10	15	20
Male					
15.6	11.00±0.9129[b]	13.00±0.9129[b]	13.00±1.0801[b]	14.00±0.4083[bc]	13.50±1.1902[b]
22.2	17.75±0.4787[d]	19.50±0.2887[c]	19.50±0.2887[c]	18.25±0.4787[d]	19.75±0.2500[c]
28.8	14.75±0.4787[c]	13.25±0.8539[b]	14.00±0.8165[b]	14.50±0.6455[c]	14.00±0.7071[b]
32.2	12.25±0.8539[b]	12.50±1.0408[b]	12.25±0.4787[b]	12.25±0.4787[b]	11.25±0.4787[b]
36.1	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]
Female					
15.6	11.75±0.6292[b]	15.00±0.4083[c]	15.25±0.4787[c]	15.00±0.4083[b]	14.50±0.6455[c]
22.2	18.50±0.2887[c]	19.50±0.2887[d]	19.25±0.4787[d]	19.25±0.4787[c]	19.75±0.2500[d]
28.8	14.00±1.0801[b]	15.00±0.4083[c]	14.50±0.6455[bc]	15.25±0.4787[b]	15.25±0.4787[c]
32.2	12.75±0.7500[b]	13.00±0.4083[b]	12.75±0.4787[b]	13.25±0.7500[b]	11.75±0.7500[b]
36.1	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]

Means±SE with the same alphabet along the column is not significantly different at p≤0.05 by Tukey HSD

Table 4: Survival of adult *M. domestica* after 72 hrs of exposure in the laboratory

	Adult age (days)				
Temperature (°C)	0	5	10	15	20
Male					
15.6	9.75±1.0308[b]	11.75±0.8539[b]	11.50±0.9574[b]	12.50±1.0408[b]	12.25±1.3769[b]
22.2	17.50±0.5000[c]	19.00±0.4083[c]	18.75±0.6292[c]	18.00±0.4083[c]	19.00±0.4083[c]
28.8	13.75±0.6292[c]	11.25±0.6292[b]	12.00±0.7071[b]	12.50±0.6455[b]	12.00±0.4083[b]
32.2	11.00±0.4083[b]	10.50±1.1902[b]	10.75±0.4787[b]	10.75±0.4787[b]	12.50±1.9365[b]
36.1	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]
Female					
15.6	10.50±0.8660[b]	14.00±0.4083[c]	13.50±0.6455[b]	13.50±0.6455[b]	12.75±1.0308[c]
22.2	18.25±0.4787[c]	18.25±0.4787[d]	18.75±0.6292[c]	17.75±0.4787[c]	18.50±0.2887[d]
28.8	11.75±1.4361[b]	13.00±0.4083[bc]	12.50±0.6455[b]	13.25±0.8539[b]	14.00±0.7071[c]
32.2	11.00±0.4083[b]	11.50±0.2887[b]	11.50±0.6455[b]	11.50±0.6455[b]	9.75±0.6292[b]
36.1	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]

Means±SE with the same alphabet along the column is not significantly different at p≤0.05 by Tukey HSD

than at 32.2°C. Survival generally decreased with temperature from 15.6-36.1°C except at 22.2°C. There was a significant difference in the mean survival of adult male flies concerning temperature. There was no survival of female adults at 36.1°C and survival at 15.6 and 32.2°C were the lowest/minimum. Adult survival was higher at 22.2°C than at 28.8°C. Survival was statistically significant ($p<0.05$) across all the temperatures of exposure.

The mean survival of adult *M. domestica* exposed to various temperatures and then monitored for 72 hrs in the laboratory is shown in Table 4. In all the temperatures of exposure, survival was statistically significant ($p<0.05$). The pattern of survival after 72 hrs was similar across the board when compared with Table 3. With respect to the ages of the female flies, there was a significant difference in the mean survival of the flies at various temperatures. The highest survival was recorded at 22.2°C and the lowest survival was recorded at 32.2°C. There was no survival of adults at 36.1°C.

DISCUSSION

The current study demonstrates that the development and survival of *M. domestica* are affected by changes in temperature, it also affects the rate of development of the immature stages of the fly. Johnson *et al.*[5] reported that heat affects the survival and reproduction of immature stages of *Bactrocera oleae*. The metabolic rate of flies is known to be higher and lifespan shorter at elevated ambient temperature[4]. The temperature dependence of houseflies has probably made them diurnal insects, they are active during the day when the ambient temperature is optimum and rest at night. Temperature strongly influences the locomotors activity of *M. domestica*. Locomotor activity in houseflies increases with temperature from 10-30°C and decreases when the temperature exceeds 35°C[16]. Increased temperature may result in increased dispersal and transmission of pathogens.

Mild winter temperatures may be harmful to some overwintering insects especially, species that do not feed after winter diapauses (detrimental). However, low temperature allows conservation of energy reserves to maintain high survival and potential fecundity (beneficial)[17]. Zahn and Gerry[18] stated that under extreme temperature conditions such as lower than 10°C or higher than 40°C, *M. domestica* completely failed to show usual behaviour and activity patterns. *M. domestica* was reported more active at room temperature (25°C) than cold (16°C). Adult longevity, pre-oviposition period and laying phase were longer at 25°C than at 32°C in *M. domestica*. Lifetime egg production was lower at a higher temperature, but the number of egg clutches laid per female was unaffected by temperature[19]. Achiano and Giliomee[20] reported that the longevity of *M. domestica* decreased with increasing temperatures.

Temperature variations have a significant effect on the development of immature stages as well as the survival of adult *M. domestica*. The optimum temperature for the survival of the immature stages of *M. domestica* was between 28.8 and 32.2°C, while 22.2 and 28.28°C were the optimum temperatures recorded for the survival of the adult *M. domestica*. Survival was low at 15.6 and 36.1°C being the most lethal temperature against the immature stages and adults of *M. domestica*, meaning that temperature variation affects the rate of metabolism and physiology of *M. domestica*. This also suggests that certain temperature ranges such as those as high as 36.1°C and those as low as 15.6°C can be used as an effective tool for the control of *M. domestica* in places where high population density is a nuisance to human life. The pupal stage has some level of resistance to the effect of temperature variation probably due to the shielding effect of the pupa case.

Female *M. domestica* survived better than their male counterparts at a lower temperature. This may be related to the underlying differences in physical activity and metabolic rate between male and female houseflies. The males exhibit greater physical activity than females. Males tend to expend more energy in search of potential mating partners while females most often only mate once and they do not search for mating partners once they have mated. Schou *et al.*[16] reported an inverse relationship between the level of physical activity and life span in the *M. domestica*.

The lifespan of a housefly is noticeably shortened at higher temperatures. The rearing temperature influences some characteristics of the adult which in turn may affect species fitness[21]. Geden *et al.*[22] also reported that the mean longevities of males and females decreased with increasing temperature, with male longevities less than those of females.

CONCLUSION

Temperature plays a significant role in the development of immature stages and survival of adults of *M. domestica* and the temperature effect was not dependent on the age of the fly but has a slightly higher lethal effect on the males than the females. Hence, temperature variation can be used as an effective means of controlling the populations of both developmental and adult stages of *M. domestica*.

SIGNIFICANCE STATEMENT

This study revealed that the knowledge of the effect of temperature on the development and adult survival of *Musca domestica* is essential to understanding the biology and ecology of the species. This can be beneficial in the determination of post-mortem interval and forensic studies. Temperature variation along with other measures can be used as an effective means of controlling the populations of *Musca domestica.*

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