

Temperature dependent wingbeat frequency response in two weight groups of *Musca Domestica* L.

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Abstract

Musca domestica was evaluated for the effects of temperature on its wingbeat frequencies. The local flies were segregated into two weight groups with mean body mass of 26.05 ± 1.03 and 21.14 ± 0.08 mg respectively, with two contrasting distinct mean wingbeat frequencies, and were exposed to various constant temperatures ranging from 15 to 45°C. Wingbeat frequency, during experiment, ranged from 200 to 247, and 231 to 279 Hz for group A and B respectively. From the response curve, the wingbeat frequency was found to be highest at around 30-35°C and fell sharply towards the extremes of 15 and 45°C. This nearly coincides with the optima for other related functional responses. Significant asymmetry was present in both curves with skew towards the higher temperature. Thermal responses and characteristics, as could be predicted from the curves, were significantly similar for both groups. Highly significant correlation was observed between the temperature response curves of both the groups ($r=0.993$, $p < 0.01$). The mean frequencies of local *M. domestica* were significantly much higher than those reported from other places.

Keywords: *Musca domestica*, diptera, temperature, wingbeat frequency, ecotype

Introduction

Body temperature of insects, as in other ectothermic organisms, fluctuate with changes in the ambient temperature. Unlike in concealed and well protected habitats, in most habitats the seasonal and diurnal temperature variations are considerable. Metabolism is catalysed by enzymes, and these enzymes require an optimum set of conditions to function efficiently. Temperature is one such requirement which sets the pace of metabolism through its influence on enzymes. It strongly affects the capacities and rates of organisms and thus has been known for long as a key determinant of organismal performance and Darwinian fitness (Mathew, 2019) [10]. The acceleration in the metabolism with increasing temperature propagates through biological levels of organization in a bottom-up fashion to affect the pace of functions in cells, organs, systems, and finally whole-organism (Abram *et al*, 2017) [11]. This in turn affects the locomotion and flight kinematics of an insect.

During flight the oscillation of insect wings displaces air and produces a sound wave consisting of a fundamental first harmonic and a series of harmonics (Sueur *et al*; 2005) [15]. The fundamental frequency of the flight sound is in direct correlation with the observed frequency of the wingbeat (Mukundarajan *et al*, 2017; Pinto *et al*, 2022) [12, 13]. Wingbeat frequency is the main kinematic feature of wing motion and it depends on body mass, wing loading, and wing area (Byrne, 1988) [3]. House flies (*Musca domestica* L.) belong to the order Diptera, family Muscidae; and are cosmopolitan, ubiquitous, synanthropic insects that serve as mechanical or biological vectors for various microbes. They reproduce and develop in decomposing organic waste and therefore is constantly in contact with different species of microorganisms (West, 1951). Wingbeat frequency of *M. domestica* in tethered and free flight has been found to range from 130 to 180 Hz (Pinto *et al*, 2022) [13]. Several studies

have demonstrated that temperature affects wingbeat frequency (Sotavalta, 1952; Unwin & Corbet, 1984) [14, 16]. The current study compared the effect of temperature on wingbeat frequencies of two weight groups of local *M. domestica* flies.

Materials and Methods

The experiments will be performed using *M. domestica* from cultures maintained in the Centre for Environmental and Applied Entomology (CEAE) Lab, Department of Zoology, St. Andrew's College, Gorakhpur, India (26.758°N, 83.369°E). Flies were reared on prescribed medium at $27 \pm 2^\circ\text{C}$ in a 12:12 LD photoperiod at 60% relative humidity. Two mixed-sex weight groups of flies with a mean of 26.05 ± 1.03 and 21.14 ± 0.08 mg, respectively, were selected based on widely different wingbeat frequencies; however, it was similar within the groups and averaged around 243.21 ± 2.42 and 271.73 ± 3.02 Hz at 27°C. All experiments, for the effect of different constant temperatures, were conducted in BOD chamber after giving enough time for acclimatization. The constant temperatures used in the experiment ranged from 15 to 45°C with increments of 5°C.

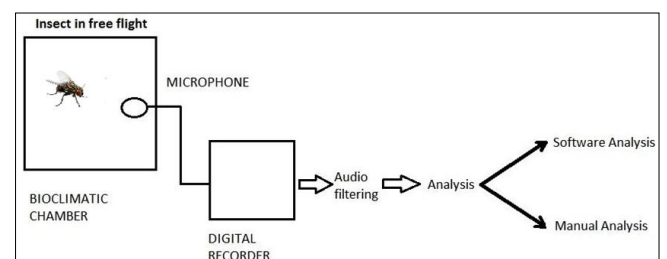


Fig 1: Schematic set-up for recording and analysis of flight sounds of the fly

The sound produced during the flight was recorded using a high-quality condenser microphone attached to a PC laptop through a high-end Behringer U-Phoria UMC404HD USB audio interface, with sampling rate of 44.1 kHz at 16-bit resolution. The condenser microphone was placed within the bioclimatic chamber and the flies were allowed, one at a time, to fly freely within (Fig 1.). Audio sample clips were taken of about 15 second duration. Ten flies of from each group were used for data acquisition. The filtered audio was analysed for the average frequencies using spectrogram analysis and reanalysed manually using online tone generator program (plasticity.szynalski.com/tone-generator.htm). This program was used to generate pure tone to match with the filtered audio of fly's wingbeat (Mathew *et al.*, 2016) [11].

Statistical Analysis

Wingbeat frequency and temperature data were subjected to appropriate statistical analysis using SPSS Statistics version 20.0 (SPSS Inc., Chicago, IL, USA) statistical analysis software. Wingbeat frequencies of both groups were analysed for correlation.

Observation and Results

Wingbeat frequency of houseflies under study mostly ranged from 200 to 247, and 231 to 279 Hz for first and second group, respectively, through the whole experiment (Fig 2.). As expected, the frequency was highest around 30-35°C and fell sharply towards the extremes. The sharpest falls were seen at 15 and 45°C. However, there was significant asymmetry with skew towards the higher temperature in both curves. Thermal characteristics like upper and lower temperature thresholds, optimal temperature and thermal requirements, as could be predicted from the curves, were similar for both groups. There was clearly evident from the highly significant correlation between the temperature response curves of both the groups ($r=.993$, $p < .01$).

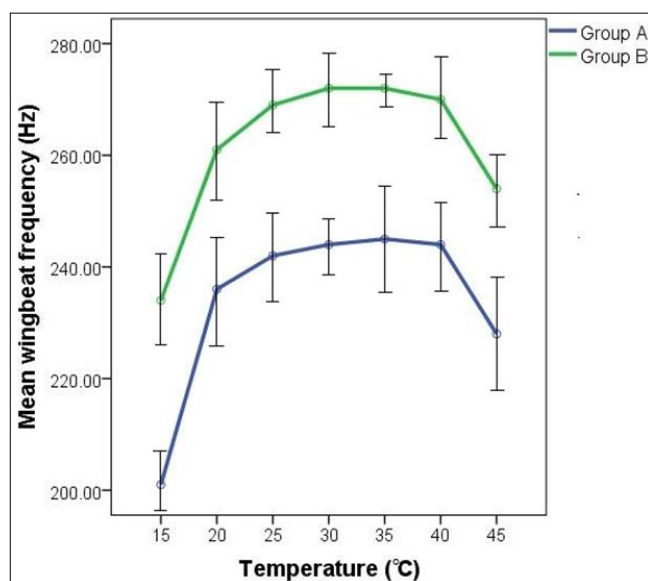


Fig 2: Mean wingbeat frequency response of two groups of *Musca domestica* at different constant temperatures

Discussion

The two groups of *M. domestica* shows the typical effect of temperature on their wingbeat. Thermal characteristics and

responses like upper and lower temperature thresholds, optimal temperature and thermal requirements, were independent of wingbeat frequencies, and thus were similar for both groups. This is directly linked to its metabolism. The rates of life activities are largely consequences of biological metabolism (Brown *et al.*, 2004) [2]. which can be visualized as a complex network of biochemical reactions that are catalyzed by enzymes, where the rates of reactions are always regulated. These enzymes require an optimum set of conditions to function efficiently. Temperature is one such requirement which sets the pace of metabolism through its influence on enzymes. It strongly affects the capacities and rates of organisms and thus has been known for long as a key determinant of organismal performance (Huey & Kingsolver, 2011) [7]. All physiological functions have optimal thermal ranges within which functions are optimal, and when temperatures depart from an organism's optimal range, negative effects are seen (Chown & Terblanche, 2007) [4].

There are present so many complexities regarding the flight of flies like mobilization of fuel and oxygen delivery to the insect during flight (Mathew & Singh, 2017) [9]. Low temperatures effect the physiological, mechanical and behavioral of the various insects adversely (Khaliq *et al.*, 2014) [8]. Higher temperature hikes kinetic energy causing increases in the rate of enzyme activity, as well as the proportion of reactants that reach the activation energy (Hochachka & Somero, 2002) [6]. Higher temperature also increases the fluidity of cell membranes, affecting permeability and transport of materials in and out of cells (Hazel, 1995) [5], mostly speeding up. The acceleration in the metabolism propagates through biological levels of organization in a bottom-up fashion to finally affecting the wingbeat frequency (Abram *et al.*, 2017) [1]. The opposite occurs at lower temperatures, debilitating functional responses, like flight of the fly. At very high temperatures exceeding an organism's thermal tolerances, and with not enough time for an adaptive response; the enzyme function deteriorates and lead to the accumulation of physiological damage. This leads to a drastic fall in functions and disruption of homeostasis.

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