Wingbeat frequency in small and large-sized Fruit fly, *Drosophila melanogaster*, in eastern Uttar Pradesh, India

Abstract

Drosophila melanogaster was evaluated for wingbeat frequencies based on its general body size. Apart from the critical role of flight in foraging, competing for a mate and evading predators, its flight tone is crucial in intraspecific auditory communication. The average wing beat frequencies during free flight of local *Drosophila melanogaster* were found to range from 215.63 ±5.26 to 261.20 ±6.53 Hz, from the smallest to large-sized flies respectively. The significant difference in wingbeat frequency between the two groups is due to the distinct differences in wing size and body weight. Variations seen within the group are a function of several factors like insect body weight, wing dimensions, age, metabolic status, locomotory requirements and ambient climatic conditions.

Keywords: *Drosophila melanogaster*, wingbeat frequency, flight tone, diptera

INTRODUCTION

"Dipteran flies are some of the most impressive flyers of class Insecta. In fact, their survival depends essentially on their ability to fly, as it impacts longevity and fitness, the ability to forage and hunt, compete for a mate and evade predators" (Mathew & Singh, 2017). "All insects produce sounds that are incidental to ordinary movements, such as flight tones and chewing sounds. In addition to these, there are several specialized methods of sound production by insects which have thoroughly been studied" (**Frings & Frings, 1958**). "Insects, depending on the body weight, may have distinctly distinguishable flight tones. Apart from the size and body weight of the insect, wingbeat frequency is also affected by factors such as age, wing structure, metabolic status or feeding, and climatic-environmental conditions" (**Parmezan et al., 2021; Yu et al., 2022**)

"Many Dipterans, like fruit fly, *Drosophila melanogaster*, have a well-defined auditory system consisting of a Johnston's hearing organ and antennal receptors. The antennal receptors can sense near-field sound, gravity, and wind" (**Boekhoff-Falk, 2005; Decker, 2020**). By fanning the wings fruit flies generate near-field sounds which can be picked up by their antennal velocity receivers. These near-field sound signals generated by the vibration of air particles decay much faster than far-field signals and are suitable for intimate communication. Courtship song have been reported to be generated by *D. melanogaster* (**Zanini et al. 2014**) using hums and pulse songs generated by regular wing strokes **(Arthur et al. 2014)**. Our study on wingbeat frequencies of local *D. melanogaster* is an effort to evaluate the wingbeat frequency during free flight as a function two distinct body sizes, in the eastern part of Uttar Pradesh in India.

MATERIALS AND METHOD

Insect collection

Overripe fruits kept in 500mL glass wide-mouthed jars, with mouth covered with netted cloth with gaps wide enough for the flies to pass, were used to attract flies in dim lighting conditions and were allowed to complete at least one life cycle before the actual experiment. The flies were raised in the months of March-April with nearly 11:13 light: dark cycle, at the lab (26.758°N 83.369°E), Gorakhpur, UP, India. The average temperature was around 27ºC and the relative humidity 40% during experiments. Adult flies were sorted based on their small or large size, while intermediate ones were not used.

Audio recording, measurement and analysis

The flight audio was recorded in a small 20mL vial used as bioclimatic chamber, following the methods used by Mathew & Singh (2017). The flight sound was recorded using a high-quality condenser microphone attached to a PC laptop through USB audio interface Behringer U-Phoria UMC404HD, with a sampling rate of 44.1 kHz at 16-bit resolution. The condenser microphone was attached to the side wall through a hole and the flies were allowed, one at a time, to fly freely within (Fig 1.). Audio sample clips each of 15 to 30 seconds duration were recorded. Thirty flies from each group were used for data acquisition. The audio files were recorded in wav. Format was equalised and filtered with a digital graphic equalizer to filter out unwanted frequencies at low and high range of audio spectrum. The filtered audio was analysed for the average frequencies using spectrogram analysis and manual method. For acoustical analysis RAVEN LITE version 1.0 for windows (Cornell Lab of Ornithology- Bioacoustical Research Program) was used for spectrogram analysis. Manual analysis was also performed using an online tone generator program (plasticity.szynalski.com/tone-generator.htm) (Mathew & Singh, 2017). Statistical analysis of data was done using SPSS Statistics version 20.0 (SPSS Inc., Chicago, IL, USA) statistical analysis software.

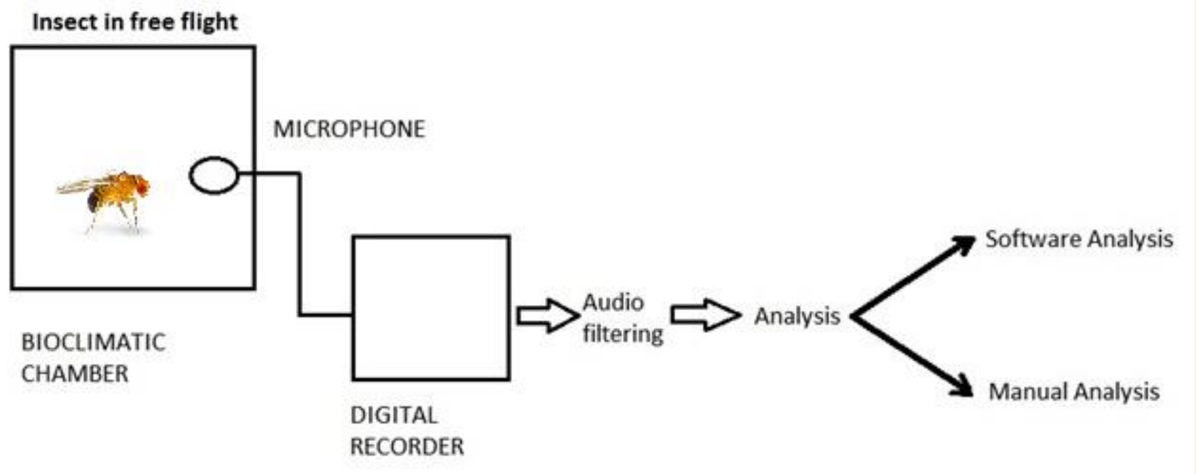

Fig 1. Schematic setup for recording and analysing wingbeat frequency of fly (*from*: Mathew & Singh, 2017)

OBSERVATION AND RESULTS

Two groups of 30 flies each, were analysed for wingbeat frequency. The mean wing beat frequencies ±SD during free flight of small and large-sized *D. melanogaster* were 215.63 ±5.26 and 261.20 ±6.53 Hz respectively. The mean frequencies of the two groups were significantly (p<0.05) different from each other. Smaller flies showed the highest wingbeat frequency owing to its smaller body and wing size followed by the larger ones, and the largest ones showed the highest frequencies (Fig. 2)

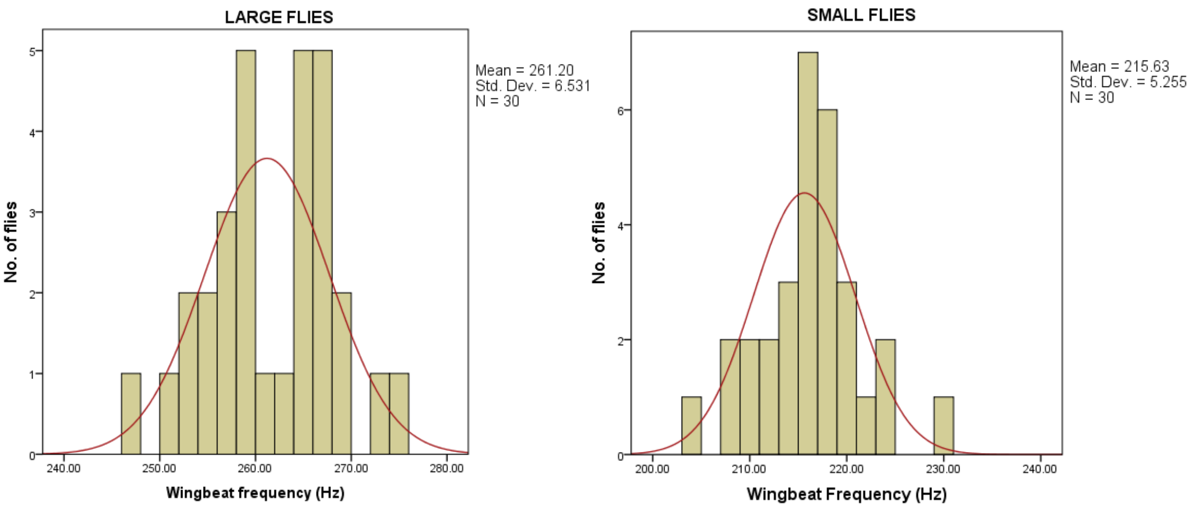

Fig. 2. Frequency distribution of (a) Small-sized, and (b) Large -sized, *D. melanogaster* against its wingbeat frequency

DISCUSSION

The two groups of *D. melanogaster* showed significant differences between their wingbeat frequencies. The small-sized flies showed the highest wingbeat frequency as expected from their smaller bodies and wing size, followed by the larger ones. Similarly, the largest ones with larger body sizes and area of wings produced the lowest frequencies. Although the mean frequency between the groups was significantly different, variations existed between flies within the groups. One reason for these slight differences can be attributed to the variations in the size of the flies themselves and of the wings as well. Usually, the larger the wings, the lower the frequency as it will take more time for longer wings to complete one full up-and-down motion, therefore beating fewer times per second. This is partly due to inertia and air resistance. However, the effect of weight on wing loading cannot be ignored as well. Therefore, wingbeat frequency of a fly may depend upon several factors like the insect's body weight, wing structure, age, metabolic status, locomotory requirements, ambient climatic factors, etc (Mathew & Singh, 2017).

Dipterans like *D. melanogaster*, have a specialised mechanosensory organ at the base of their antenna called Johnston's organ (**McIver, 1985; Westheide and Rieger, 1996**), which can receive acoustic signals. "By fanning the wings, fruit flies generate near-field sounds which are picked up by their antennal velocity receivers. This is suitable for intimate communication and in fact courtship song have been reported to be generated by *D. melanogaster"* (**Tauber & Eberl 2003; Zanini et al. 2014**). "This is composed of hums with a dominant frequency between 140 and 170 Hz produced by continuous fanning of the wings, and pulse songs generated by regular wing strokes with 35 ms interval that produce pulse trains with a carrier frequency of 150-200 Hz" **(Arthur et al. 2014)**.

Conclusion

Wingbeat frequency is a principal kinematic feature of wing motion (**Pinto et al., 2022**). There cannot be an absolute wingbeat frequency for any species that can be universally accepted. However, there exists a definite range for each species, and any departure from it can be indicative not only of the influence of the above-mentioned factors but also of noteworthy adaptive variation existing among populations. In a species like *D. melanogaster*, variations in wingbeat frequencies may have a larger bearing on populations as it seems to play an important role in their reproduction and survival. The wingbeat is also a strong indicator of its rate of metabolism, and physical structure, and is inversely related to the wing length and body mass.

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