Structural regulation of infrared radiation in butterfly wing scales

Chufei Tang

tcf0816@126.com

Institute of Leisure Agriculture, Jiangsu Academy of Agricultural Sciences, Nanjing 210014, China

The diversification of the periodic ultrastructure of wing scales plays a crucial role in regulating the functional properties of butterfly wings, contributing to their ecological adaptation. This study addresses the structural regulation of mid-infrared radiation (MIR) in wing scales, a property associated with cooling in thermoregulation and pheromone release during courtship. Using Danainae (Papilionoidea: Nymphalidae) as the model group, the study confirms the high morphological diversity of butterfly wing scales in a single individual with quantitative observations under scanning and transmission electron microscopy. It was found that this diversity shapes the heterogeneity of the wing emissivity through heating experiments, virtual simulations, and correlation tests. Summarizing the effects of each component on emissivity, it was demonstrated that the increase in scale emissivity is due to the increase in its internal surface area and thickness. Additionally, it was demonstrated that as the structural parameter positively correlates with emissivity increases, the area of scent patches, a high emissivity region where males emit pheromones, decreases significantly, whereas the size of scales on the scent patch increases significantly. A further study of 99 butterfly species from several families shows that as the range of butterfly species moves from low to high latitudes, which generally corresponds to a decrease in habitat temperature, the efficiency of infrared radiation in the wing scales decreases, i.e. the wing radiates less efficiently for cooling and less heat is dissipated. This phenomenon is also shaped by variations in the overall structure of the scales. The study provides a reference for understanding functional adaptation in butterflies.