The body temperature of hornets (*Vespa crabro*) and wasps (*Vespula sp.*) during takeoff and landing at the nest entrance

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Abstract: Die Körpertemperatur von Hornissen (*Vespa crabro*) und anderer Faltenwespen (*Vespula sp.*) während des Abflugs und der Landung am Nesteingang.

Die Hornisse (*Vespa crabro*) ist die größte Faltenwespe in Mitteleuropa. Die thermoregulatorischen Fähigkeiten einiger Insektengruppen stehen in enger Beziehung mit der Körpermasse. Deshalb untersuchten wir die Körpertemperatur von Hornissen vergleichend mit zwei anderen, kleineren Wespen (*Vespula vulgaris, Vespula germanica*). Mit Hilfe der Infrarot-Thermographie wurde die Oberflächentemperatur von Thorax (T_{th}), Kopf (T_{hd}) und Abdomen (T_{ab}) vor dem Abflug und nach der Landung am Nesteingang gemessen. Die Messungen wurden über den gesamten Umgebungstemperaturbereich (T_a:~0-40 °C), bei dem die Tiere ausfliegen, durchgeführt.
Beim Abflug war die mittlere T_{th} der Wespen ziemlich konstant auf einem hohen Niveau (T_{th}=36,0–37,5°C). Die T_{th} der Hornissen jedoch variierte stärker beim Abfliegen. In der Kälte war sie hoch (T_{th}=38,5°C), sank um ~5°C bei mittlerer T_a ab und stieg wieder auf über 38,5 °C bei hoher T_a an. Bei der Ankunft am Nesteingang nach den Sammelflügen war die Temperatur von beiden, Wespen und Hornissen, ziemlich ähnlich. Sie war konstant bei niedriger T_a < 10°C (T_{th}=~30,0–31,5°C) und stieg dann ab einer T_a > 10°C nahezu linear mit der Umgebungstemperatur an (T_{th}=~30,0–40,0°C). Die T_{th} der Hornissen war immer~1°C höher als die der Wespen. Die Temperaturerhöhung des Thorax über die Umgebungstemperatur (T_{th}-T_a), als Maß für die endotherme Aktivität, verringerte sich bei beiden stark mit steigender T_a, sowohl beim Abflug als auch bei der Landung. Beim Abfliegen war die Temperaturerhöhung der Wespen ~2°C größer als die der Hornissen, aber bei der Landung ~1,5°C geringer. Die Abnahme der Temperaturerhöhung bei der Landung mit steigender T_a zeigt, dass beide, *Vespa* und *Vespula*, in der Lage sind, die Körpertemperatur während des Fluges zu regeln.
Trotz des großen Unterschiedes in der Körpermasse von *Vespa* (477,5±60,0 mg, n=50) und *Vespula* (82,7±18,3 mg, n=170) weisen sie erstaunliche Ähnlichkeiten im thermoregulatorischen Verhalten beim Abflug und bei der Landung am Nesteingang auf.

Key words: insect, hornet, wasp, thermoregulation, hive entrance, thermography

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Introduction

The vespine wasps are capable of endothermic heat production by means of their thoracic muscles. This improves their agility and allows a better exploitation of food resources (KOVAC & STABENTHEINER 1999). The hornet (*Vespa crabro*) is the largest species of vespine wasps in Middle Europe. The thermoregulatory capacity of some insect groups is related with their body mass. A positive relationship between thermoregulatory capability and body size (or mass) was observed, e.g. in moths (BARTHOLOMEW & HEINRICH 1973), beetles (BARTHOLOMEW & HEINRICH 1978), 18 species of Alaskan bees (BISHOP & ARMBRUSTER 1999), in wasps (HEINRICH 1984) and in solitary bees (*Anthophora plumipes*, STONE 1993). In general, small bees initiate flight at lower thoracic temperatures than larger ones (STONE 1993). In this study we investigated the body temperature of hornets in comparison with two other smaller vespine wasps (*Vespula vulgaris, Vespula germanica*) in order to verify whether the hornets have advantages in thermoregulation due to their larger body mass.

Materials and methods

The insects (*Vespa crabro, Vespula vulgaris, Vespula germanica;* Vespidae, Hymenoptera) were filmed during takeoff and landing at the nest entrance with an infrared camera (ThermaCam SC2000 NTS or i60, FLIR). The infrared cameras were calibrated periodically by slotting in a self-constructed peltier-driven reference source of known temperature and emissivity (for details of calibration see Stabentheiner & Schmaranzer 1987, Schmaranzer & Stabentheiner 1988). The ambient air temperature (T_a) was measured with thermocouples near the nest entrance. The solar radiation was measured with a miniature global radiation sensor (FLA613-GS mini spezial, AHLBORN) also in the vicinity of the nest. The temperature and radiation data were stored every second with ALMEMO data loggers (AHLBORN). The temperature of the three body parts was calculated from the infrared thermograms by means of the AGEMA Research software (FLIR) controlled by a self-written Excel VBA-macro (Microsoft Corporation). The surface temperatures of head (T_{hd}), thorax (T_{th}) and abdomen (T_{ab}) were calculated with an infrared emissivity of 0.97, determined for the honeybee cuticle (Stabentheiner & Schmaranzer 1987; Schmaranzer & Stabentheiner 1988). Because the infrared cameras work in the long-wave infrared range (7.5-13 µm) the reflected radiation from the wasps' cuticle produced only a small measurement error (0.2 °C for 1000 Wm^{-2}), which was compensated for. In this way we reached an accuracy of 0.7 °C for the body surface temperature of the insects at a sensitivity of <0.1°C. The entire range of ambient temperature (T_a: ~0 – 40°C) where the insects exhibited flights was investigated. Measurements were conducted on four hornet (*Vespa*) nests and six wasp (*Vespula*) nests. For determination of the body weight, insects leaving the nest were captured and weighed with a balance (AB104, METTLER-TOLEDO).

Results and discussion

At the departure the mean T_{th} of *Vespula* was rather constant at a high level (T_{th} = 36.0 – 37.5°C, Fig. 1). However, the T_{th} of the hornets showed a stronger variation. It was high in the cold (T_{th}=38.5°C), decreased by ~5°C at medium T_a, and increased again to above 38.5°C when it was warm. At the arrival at the nest entrance after foraging flights the temperature of both, wasps and hornets, was quite similar. It was constant at low T_a < 10°C (T_{th}~30.0 – 31.5°C) and increased nearly linearly with T_a at T_a > 10°C (T_{th}~ 30.0 – 40.0°C). The hornets' thorax temperature was mostly ~1°C higher than that of the wasps. The thorax temperature excess (T_{th}-T_a) as a measure of the endothermic activity decreased strongly with T_a during both departure and arrival. The excess temperature of *Vespula* (as determined by linear interpolation) was ~2°C higher than that of the hornets during takeoff, but ~1.5°C lower after landing. The decline of the landing temperature excess with increasing T_a reveals that both *Vespa* and *Vespula* are able to regulate the body temperature in flight. At high T_a it seems that the hornets had more problems to get rid of the surplus of heat, because the temperature of the hornets' head and especially of the abdomen increased stronger with T_a than in the wasps. This difference was not visible in the thorax (Fig 1C).

Despite the big difference in body weight of *Vespa* (477.5 ± 60.0 mg, n=50) and *Vespula* (82.7 ± 18.3 mg, n=170) they exhibited astounding similarities in their thermoregulative behavior during arrival and departure at the nest entrance. It remains to be investigated in detail whether or not the somewhat higher body surface temperature is beneficial for the hornets' flight performance, or is just a necessity to compensate disadvantages due to their about 5-6 times higher body mass.

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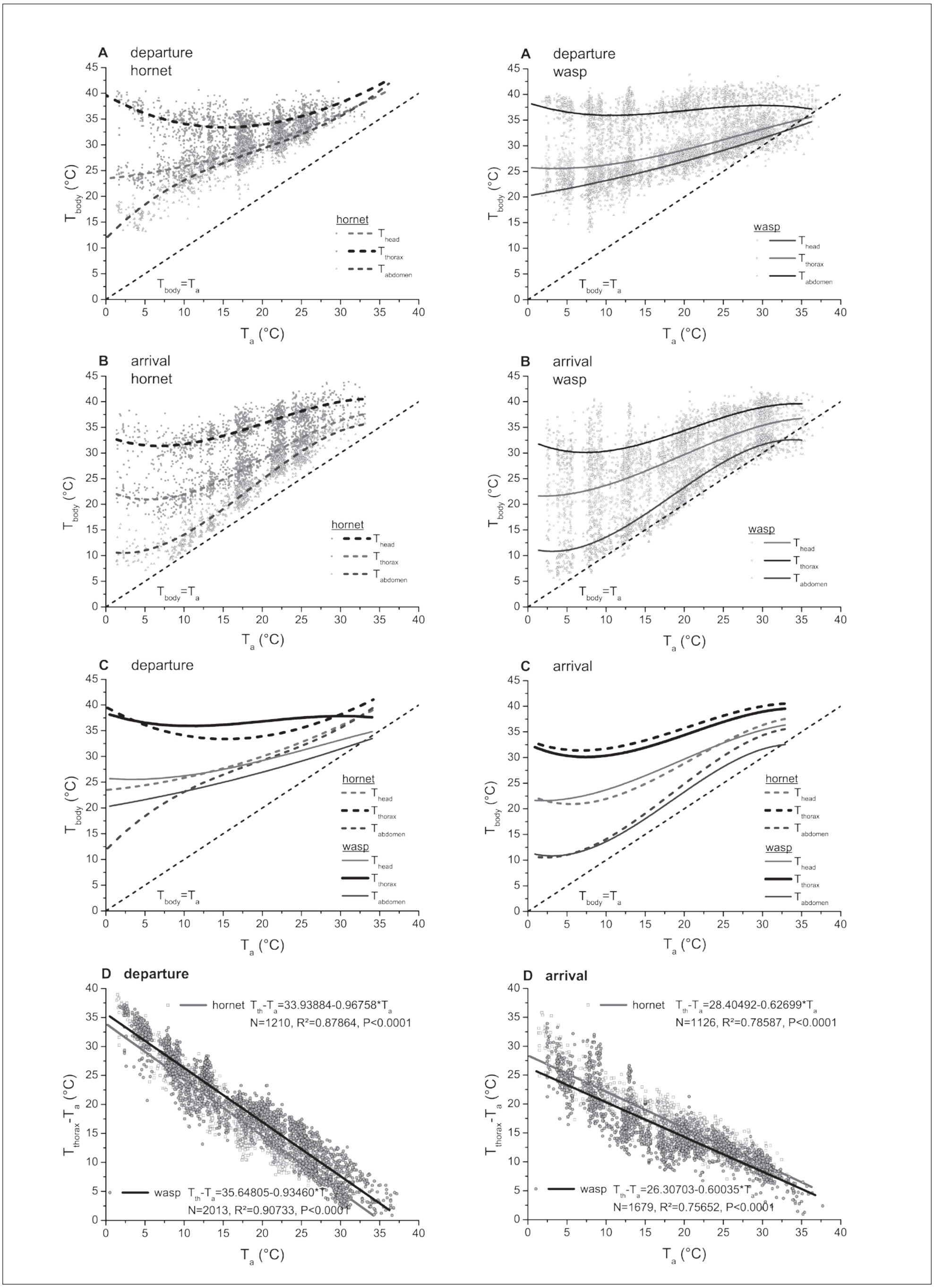

Fig. 1: The temperature of thorax (T_{thorax}), head (T_{head}) and abdomen ($T_{abdomen}$) of hornets and wasps at departure (A) and arrival (B) at the nest entrance in dependence on ambient temperature (T_a). (C) Comparison of the regression lines from (A) and (B); (D) thorax temperature excess (T_{th}-T_a) at departure and arrival in dependence on ambient temperature.

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