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Landing responses of *Anopheles gambiae* elicited by oxocarboxylic acids

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Abstract. A wind tunnel bioassay and video system were used to observe *Anopheles gambiae* Giles *sensu stricto* (Diptera: Culicidae) landing on glass cylinders, heated to human skin temperature (34°C) and treated with aqueous solutions of oxocarboxylic acids. Six of nine compounds tested: 2-oxobutanoic, 2-oxo-3-methylbutanoic, 2-oxopentanoic, 2-oxo-3-methylpentanoic, 2-oxo-4-methylpentanoic and 2-oxohexanoic elicited significant landing responses in comparison to a water control. Landing responses appeared to be restricted to C4–C6, 2-oxocarboxylic acids. A solution of 1 μg/μL of 2-oxopentanoic acid elicited the highest level of response that was temperature dependent: significant numbers of landings occurred only within ±2°C of human skin temperature. Chemical analysis by linked gas-liquid chromatography/mass spectrometry of methyl-oxime, trimethylsilyl derivatized samples of human sweat extracts revealed the presence of 2-oxopropanoic (pyruvic) acid and three behaviourally active, branched chain acids: 2-oxo-3-methylbutanoic, 2-oxo-3-methylpentanoic and 2-oxo-4-methylpentanoic.

Key words. *Anopheles gambiae*, attractants, host-seeking, human sweat, landing behaviour, mosquitoes, oxocarboxylic acids, 2-oxopentanoic acid, wind tunnel.

Introduction

Anopheles gambiae s.s. is considered highly anthropophilic (White, 1974), a factor that directly increases the vectorial capacity of the species. This apparent preference for humans has led to the hypothesis that *An. gambiae s.s.* females respond to human specific olfactory cues during host location. Studies with a wind tunnel trapping bioassay have reported that *An. gambiae s.s.* females are attracted to a mixture of carboxylic acids (Knols *et al.*, 1997) and to ammonia (Braks *et al.*, 2001). The human-specific carboxylic acids, 7-octenoic and (*E*)- and (*Z*)-3-methyl-2-hexenoic acid, have been shown to affect the behaviour of *An. gambiae s.l.* mosquitoes in field trials with odour-baited entry traps (Costantini *et al.*, 2001).

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Using a wind tunnel bioassay to record landing responses of female *An. gambiae s.s.*, we observed that human sweat and a solvent extract of human sweat elicited significant levels of landings (Healy & Copland, 2000). Lactic acid, a known attractant for *Aedes aegypti* (L.) females (Acree *et al.*, 1968), and a range of carboxylic acids identified in human sweat did not elicit the landing response. An oxocarboxylic acid, 2-oxopentanoic, did elicit highly significant levels of landings.

Recent chemical analyses of human sweat, using gas-liquid chromatography/mass spectrometry (GC/MS), revealed human sweat to be a complex mixture containing many carboxylic acids (Bernier *et al.*, 1999a,b; Cork & Park, 1996). These studies did not detect any oxocarboxylic acids, and only 2-oxopropanoic acid (pyruvic) has been previously reported as a volatile compound originating from humans (Ellin *et al.*, 1974).

Oxocarboxylic acids are highly polar compounds and are not ideally suited to analysis by GC, due to adsorption in the injector or on the column. To achieve reproducible