Acetic acid vapour as a resource: threshold differences among three *Drosophila* species

P. A. Parsons[1]

Department of Genetics and Human Variation, La Trobe University, Bundoora (Victoria 3083, Australia), 17 March 1980

Summary. Acetic acid vapour is utilized as an energy source up to a threshold where it becomes a stress in 3 *Drosophila* species. The threshold ranking is *D. melanogaster* ≫ *D. simulans* > *D. immigrans*, which qualitatively parallels that for ethanol. The capacity to use nutritive vapours appears to be very important in *Drosophila* ecology.

Gaseous ethanol is an energy source in *Drosophila* species attracted to fermented-fruit baits in nature [2–4]. This occurs to a threshold concentration where ethanol becomes a stress rather than a resource. Sympatric populations of 3 species from Melbourne, Victoria, gave threshold rankings *D. melanogaster* ≫ *D. simulans* > *D. immigrans*[5]. The sequence agrees with field data, since in a pile of grape residues immediately following vintage, only *D. melanogaster* larvae were found at high ethanol concentrations, while at low concentrations larvae of *D. melanogaster* and *D. simulans* coexisted, and *D. immigrans* larvae were not found[6]. The grape residues also contained acetic acid to concentrations approaching 5%; indeed in 1 zone 7% ethanol was associated with 3% acetic acid. Since the insect cuticle is a selective permeable membrane penetrated easily by ethanol and acetic acid[7], gaseous acetic acid could well be an additional energy source. Ethanol is in any case normally converted to acetic acid via acetaldehyde, and thence to products providing energy[8,9].

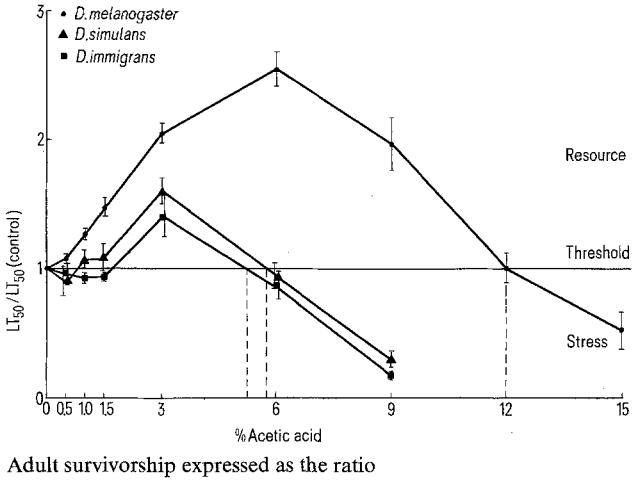
Adults of the above populations were exposed to gaseous acetic acid in a closed system containing a constant amount of acetic acid (water vapour in controls) in equilibrium with the liquid phase in a separate section of the apparatus; this is the same procedure as used for exposure to gaseous ethanol[4,10]. Adult tolerances were expressed as mean LT_{50}'s, being the mean number of hours at which 50% of flies had died. Since control LT_{50}'s varied among species,

$$\frac{LT_{50}}{LT_{50}\text{ control}}$$

values were calculated to investigate acetic acid effects (figure). The thresholds between acetic as a resource and a stress were *D. melanogaster* 12.0%, *D. simulans* 5.7% and *D. immigrans* 5.3%, compared with 12.0%, 3.4% and 1.6% respectively for ethanol[4].

Gaseous acetic acid is therefore utilized as an energy source in these 3 species in a parallel way to ethanol utilization. Because they are closely associated metabolically, the concentrations of the 2 metabolites would be expected to be correlated in nature, so that parallel utilization patterns would be predicted to occur through natural selection. Even so, *D. immigrans* utilizes a much higher concentration of acetic relative to *D. melanogaster* when compared with ethanol. This appears to confirm that resources apart from ethanol are much more important for *D. immigrans* than *D. melanogaster* as suggested elswhere[5].

Both laboratory and field results[6,11–13] have shown that ethanol is a very significant metabolite in *Drosophila* ecology, and the same appears true for acetic acid. Adults and larvae are attracted by ethanol, acetic acid, and other products of fermentation[14,15], some of which must presumably act as signals for feeding and oviposition sites. It is likely that in the small cavities of fermenting fruits and other *Drosophila* resources such as wineries[11] and the rot pockets of cacti[12], the concentration of ethanol, acetic acid and other 'metabolic' vapours could reach quite high levels. This means that the capacity of *Drosophila* adults to use nutritive vapours could be important in nature, and that additional such volatile compounds, for example other short chain alcohols[16], are likely to be found.



Adult survivorship expressed as the ratio

$$\frac{LT_{50}}{LT_{50}\text{ control}}$$

for 5 replicates of 20 flies (10 per sex) per acetic acid concentration tested for each species. The vertical bars indicate 95% confidence limits. (Repeat experiments at low concentrations show that no significance can be ascribed to the somewhat low *D. immigrans* responses on 1.0 and 1.5% acetic acid.) The intersection of the plots of each species with the horizontal straight line gives the threshold concentration between acetic acid as a resource and as a stress; these concentrations are indicated by vertical dotted lines. Mean LT_{50} control lifespans were *D. melanogaster* 56 h, *D. simulans* 41 h, and *D. immigrans* 83 h.

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