

## HUMIDITY AS A FACTOR REGULATING FEEDING AND WATER BALANCE OF THE HOUSE DUST MITES *DERMATOPHAGOIDES* *FARINAE* AND *D. PTERONYSSINUS* (ACARI: PYROGLYPHIDAE)<sup>1</sup>

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**Abstract:** Feeding rates of *Dermatophagoides farinae* and *D. pteronyssinus* are significantly higher at ambient water vapor activities ( $a_v$ 's) above the critical equilibrium activity (CEA) than below it. The quantity of water obtained with equilibrated food at  $a_v$ 's below the CEA is insignificant when compared to that exchanged by sorption and transpiration and is not sufficient for dust mites to maintain water balance. The CEA for feeding mites is identical to that for fasting mites. Considering all possible avenues of water gain by house dust mites for maintaining water balance, their primary source of water to sustain life is that gained by passive and active sorption from ambient water vapor.

The American house dust mite, *Dermatophagoides farinae*, Hughes, 1961, and the European house dust mite, *D. pteronyssinus* (Trouessart, 1897), are cosmopolitan in distribution and closely associated with man and his dwellings. Their level of occurrence in dust in specific habitats in the house has been related to a number of physical and climatic factors (Arlian 1976, Brandt & Arlian 1976, Mulla et al. 1975, Bronswijk & Sinha 1971, Mitchell et al. 1969). One significant factor is the availability of water in the habitat (Brandt & Arlian 1976, Arlian 1975a, b, 1976, Bronswijk & Sinha 1971, Larson 1969, 1971). These mites obtain their water by 3 mechanisms. Like other animals, house dust mites ingest water with their food, although the quantity of water obtained in this manner has not been reported. Second, but of less significance, house dust mites obtain metabolic water from the oxidation of carbohydrates and fats (Arlian 1975b, Wharton & Arlian 1972). Third, house dust mites can passively and actively absorb water from unsaturated air (Arlian 1975a, Arlian & Wharton 1974, Larson 1969). While obtaining water by all 3 mechanisms, mites also constantly and simultaneously lose water from the body surface by transpiration or through processes associated with feeding, reproduction, defecation and excretion.

When living under fasting conditions, most water gain or loss for both species is restricted to sorption from or transpiration to the ambient air (Arlian 1975a, Arlian & Wharton 1974). The quantity

of water absorbed at some water vapor activities ( $a_v$ 's)<sup>3</sup> is enough to offset that which is transpired at the same  $a_v$  and thus the mite can maintain water balance. The lowest ambient  $a_v$  at which this equilibrium can exist is known as the critical equilibrium activity (CEA) (Wharton & Devine 1968). The CEA's for *D. farinae* and *D. pteronyssinus* are 0.70 and 0.73  $a_v$ , respectively (Arlian 1975a, Larson 1969).

Under natural conditions where food is available, these mites have the opportunity to gain and lose water while feeding. The quantity of water obtained in this manner is proportional to the quantity of food consumed and its water content. The water content is proportional to the ambient  $a_v$  in which the food has equilibrated. In turn, the quantity of water in food and the ambient  $a_v$  at which it has equilibrated may influence the feeding rate and thus the quantity of water gained or lost during feeding (Wharton & Arlian 1972). Water content of food and the  $a_v$  of ambient air may, in turn, act as regulatory mechanisms of feeding rate and behavior. Thus, it is possible that gain or loss of water associated with feeding can increase or decrease the CEA value for the mite, depending on the magnitude of this gain or loss component, and thus influence survival.

Several studies have been published in which survival or breeding of mites at dehydrating conditions with the opportunity to feed were determined (Arlian 1975a, Brandt & Arlian 1976, Miyamoto et al. 1975). However, the degree and significance of feeding and its contribution to the maintenance of water balance were not monitored. For that reason, the following study using house dust mites was undertaken to determine (1) the significance of  $a_v$  on feeding rates, (2) the quantity of water ingested at these feeding rates, and (3) whether CEA values for these species change as compared to those for fasting animals because of water gain or loss associated with feeding. The ecological significance of these factors is discussed.

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<sup>3</sup>The activity of water vapor ( $a_v$ ) in ambient air is approximated by  $eH/100$  or  $P_{wv}/P_{sat}$  (observed partial pressure of water vapor/saturation partial pressure of water vapor).

## METHODS AND MATERIALS

*D. farinae* and *D. pteronyssinus* were reared in 0.014-liter glass jars on a human hair and Fleischmann's® yeast medium at 25°C and 0.75 a<sub>v</sub> (Arlian 1975a, b). Adult females were randomly selected from the cultures and their feeding rates determined at 0.225, 0.650, 0.750, 0.800, 0.850 and 0.950 a<sub>v</sub> at 25°C.

*Feeding rate determination*

Granules of Fleischmann's® yeast were individually caged (Arlian & Wharton 1974) and equilibrated 8 days at 0.225, 0.650, 0.750, 0.800, 0.850 or 0.950 a<sub>v</sub>. Each yeast granule was then removed from its cage, weighed and returned to the cage along with 5 adult female mites; the caged food and mites were returned to the equilibration a<sub>v</sub>. Twenty to 40 cages, each containing 1 yeast granule and 5 mites, were tested at each a<sub>v</sub>. At 24-hr intervals for up to 11 days the yeast remaining in the cage with the mites was weighed and then returned to the cage. Weighing of food from any cage was discontinued prior to 11 days if any mite death or mold growth occurred. The average difference between initial weight and final weight of a yeast granule per 24-hr period per mite for the 11-day period was calculated and used as a relative measure of feeding rate.

All test cages containing mites and yeast were equilibrated and held in closed desiccators containing glycerol or saturated salt solution to maintain the desired experimental a<sub>v</sub> (Winston & Bates 1960, Solomon 1952). Desiccators were stored in Biochemical Oxygen Demand (BOD) incubators to maintain the temperature at 25°C.

At each 24-hr weighing, the mites' activities and

interest in the food were recorded. Mite activity was classified as follows: (—) no mites were observed feeding, walking on the food or in close proximity to it, and no fecal material was visible; (+) mites were occasionally seen feeding, walking on the food or in close proximity to it (less than 10% of observations), and some fecal material was visible; (++) mites were observed feeding, or walking on or around the food, and abundant fecal material was visible.

*Determination of yeast water content*

Twenty granules of Fleischmann's® yeast were equilibrated for 5 days in each of five 10-cm desiccators that contained either glycerol or saturated salt solution to maintain 0.225, 0.380, 0.525, 0.750, or 0.850 a<sub>v</sub>. Following equilibration, each granule was individually weighed, placed singly in a 4.5-ml (1-dram) vial, dried over Drierite® at 70°C for 15 days, and the weight again determined. The water content of each granule was determined by taking the difference between the equilibrated weight and dry weight. The mean water content for yeast equilibrated at each a<sub>v</sub> was calculated. Water content for yeast equilibrated at a<sub>v</sub>'s above 0.850 was not determined because the yeast became tacky and difficult to handle. Samples in which fungal growth occurred were discarded. Water content of yeast at a<sub>v</sub>'s not measured was extrapolated by regression analysis.

All weights for water content and feeding rate determination were made on a Cahn Electrobalance® to the nearest 0.1 µg.

## RESULTS

Ambient a<sub>v</sub> directly influenced the feeding rates

TABLE 1. Amount of water consumed by *D. farinae* and *D. pteronyssinus* as a function of feeding rate on yeast equilibrated at specific water vapor activities at 25°C. Yeast equilibrated with test a<sub>v</sub> prior to and during testing. Feeding monitored for 11 days unless otherwise indicated.

PARAMETERS	<i>D. farinae</i>						<i>D. pteronyssinus</i>				
	WATER VAPOR ACTIVITIES (a <sub>v</sub> 's)							WATER VAPOR ACTIVITIES (a <sub>v</sub> 's)			
	0.225*	0.650	0.750	0.800	0.850	0.950	0.225*	0.650	0.750	0.850	
Yeast consumed/day/mite (µg)	0.17 ±0.05	0.48 ±0.15	1.08 ±0.03	3.61 ±0.24	5.52 ±1.11	7.60 ±0.42	0.05 ±0.03	0.28 ±0.01	0.60 ±0.01	2.95 ±0.46	
Yeast consumed/day/mite (% of body wt.)	1.3	3.7	8.4	28.0	42.8	58.9	0.9	4.8	10.3	50.9	
Yeast water content (% by wt.)	6.0	12.4	14.6	15.9	17.3	20.4	6.0	12.4	14.6	17.3	
Water obtained from yeast/day/mite (µg)	0.01	0.06	0.16	0.57	0.95	1.55	0.003	0.035	0.088	0.510	
Yeast dry wt. (biomass) consumed/day/mite (µg)	0.16	0.42	0.92	3.04	4.57	6.05	0.049	0.247	0.512	2.440	
Mite interest in yeast**	—	+	++	++	++	++	—	+	++	++	
No. mites tested	200	200	100	100	100	100	100	100	100	100	

\*100% death occurred within 5 days.

\*\*—Mites not seen feeding at 24-hr observations; +, occasionally seen feeding (less than 10% of observations); ++, seen feeding or on food at 24-hr observation (at least 90% of observations).

habitats and thus is not a factor in maintaining water balance. Water produced metabolically in these mites is insignificant relative to total water exchange (Arlian 1975b). Therefore, mites cannot and do not rely on food intake or production of metabolic  $H_2O$  as a source of water. Their primary source of water, then, is that which is passively and actively sorbed from the atmosphere.

It has been suggested that mites maintain water balance by extracting sufficient water from unsaturated air when the  $a_v$  is above the CEA to replace the net water loss by transpiration when the  $a_v$  around them falls below the CEA (Wharton 1976, Mitchell et al. 1969, Arlian 1972). This suggestion is supported by reports that the heaviest mite infestations appear to be in beds or other frequently used furniture where  $a_v$ 's can rise above their CEA's at least when these articles are occupied (Furumizo 1973, Sesay & Dobson 1972, Mitchell et al. 1969), even though the  $a_v$  in a home may be below the CEA (Brandt 1976), and the fact that mites can sorb water from the environment when the  $a_v$  is above the CEA at rates faster than it is transpired when the  $a_v$  is below the CEA (Arlian 1972). The results of this study indicate that this is, indeed, what must happen.

Mites do occur in homes where the ambient  $a_v$  does not rise above CEA for several months, yet they apparently breed since they are collected in significant numbers (Brandt 1976). In furniture and beds, the source of water to support this survival must be water that evaporates from the human body. Although difficult to measure, the water vapor activity at the surface of the human body is about 0.99 when it is in equilibrium with the body water. The ambient water vapor is usually less and thus favors the net diffusion loss from the body as per Fick's first law. As diffusion occurs, a water vapor activity gradient forms between the body and the ambient air which decreases in proportion to the distance from the body surface. Mites and fabric in contact with or in very close proximity to this body surface would be in an environment where the  $a_v$  is above the CEA of these mites. Under such conditions, mites could sorb sufficient water to tide them over periods when their habitat was not occupied. This environment of sufficient  $a_v$  can be provided when an article of furniture or bed is occupied. On the other hand, mites also occur in homes and are collected in significant numbers in habitats that are not directly occupied by animals (Brandt 1976). It is probable that these sites are not breeding sites and mites in these locations desiccate over a period of time. Their occurrence

in these locations is most likely the result of mites dispersing from breeding sites in beds and furniture by crawling or being transported there in air currents or on body surfaces and in clothing.

The feeding rate observed for both species in this study appears to be the result of the mites' activity response to ambient  $a_v$ . At higher  $a_v$ 's the feeding was more continuous as reflected by the quantity of food consumed, abundance of fecal pellets on or around the food, and the fact that mites were always in close proximity to the food. At lower  $a_v$ 's feeding was intermittent, mites were seldom seen on the food and few, if any, fecal pellets could be seen. It appeared that if water vapor conditions were satisfactory, the mites easily located the food and fed without hesitation. They displayed an obvious interest and attraction to the food material. At low  $a_v$ 's it appeared the mites lacked this interest and were not motivated to locate the food and feed. In general, mites held at low  $a_v$  were observed moving slowly about the surface of the cage or they clustered together in a groove at either end of the cage. This reduced feeding and activity may be the result of the mites' activity response to low and desiccating  $a_v$ , which may in natural situations result in their reducing water loss and maintaining water balance.

Insects and mites possess a variety of efficient behavioral, morphological and physiological mechanisms that facilitate water gain or minimize its loss and thus enable them to maintain water balance and survive otherwise desiccating terrestrial environments. Much has been published with respect to many of these adaptations, including factors that control feeding behavior, which is said to be motivated by hunger and nutritional requirements (Browne 1975). It is my opinion that in some cases feeding may not always be motivated by hunger or nutrient procurement needs, but rather by factors that relate to the water balance condition of the animal. For example, if sufficient water can be gained through feeding, an insect or mite may be motivated to feed primarily in order to maintain water balance and not because it is hungry or must procure nutrients. If sufficient water can not be gained through feeding, the animal probably will not feed and instead adapt behavior to minimize water loss in that environment or be motivated to locate a more favorable environment. Thus, in addition to meeting nutritional needs, feeding behavior may be motivated or inhibited by such components as potential water gain from food, potential water loss in the physical process of gaining food, metabolic processing of food