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Survival of the House Dust Mite, *Dermatophagoides farinae*, at High Temperatures (40–80°C)

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Abstract Experiments were conducted to evaluate the survival time of randomly selected female *D. farinae* exposed to temperatures from 40 to 80°C and relative humidities (RHs) between 10 and 90%. Significant temperature effects were found on the length of time mites can survive under those conditions. The time needed to induce 100% mortality for female *D. farinae* held at 40°C varied between 39 and 84 h. At 70 and 80°C, all mites died within 5 minutes. At 50°C and above, RH had little influence and temperature alone was the determining factor for mite survival. The length of survival time decreased precipitously between 40 and 50°C, suggesting that a loss of physiological integrity of female *D. farinae* probably occurred in this range. The results of this study indicated that the technique of raising temperatures to above 40°C for a short duration can be used to reduce living house dust mite populations in homes significantly.

Key words Dust mites; *D. farinae*; Survival; Mortality; Temperature; Relative humidity.

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Introduction

House dust mite allergy is of great concern in the treatment of asthma, rhinitis, bronchitis, conjunctivitis, and atopic dermatitis, both in adults and children (Platts-Mills and de Weck, 1989; Pope et al., 1993). The mites, *Dermatophagoides farinae, D. pteronyssinus, Euroglyphus maynei*, and *Blomia tropicalis*, are the main sources of house dust allergens (Tovey et al., 1981; Arlian et al., 1992; Arlian, 1989; Fernandez-Caldas et al., 1990; Hurtado and Parini, 1987). These mites occur in human dwellings in humid climates and are most prevalent in high-use areas such as mattresses, pillows, carpets, and overstuffed furniture dust where skin scales accumulate and serve as food (Tovey et al., 1981; Arlian, 1989 and 1992).

Almost all of the previous laboratory research on the biology of house dust mites was conducted at temperatures <40°C. These laboratory studies and field surveys showed that adequately high ambient RH in the mites' microhabitat is a key for reproduction and survival of these mites (Spieksma and Spieksma-Boezeman, 1967; Bronswijk and Sinha, 1971; Lang and Mulla, 1977; Furumizo, 1978; Murray and Zuk, 1979; Korsgaard, 1983; Arlian et al., 1982 and 1983; Larson, 1969). It was determined that there is a critical equilibrium humidity (CEH) for *D. farinae* and the CEH was temperature-dependent (Arlian and Veselica, 1981a and b; Larson, 1969). Mites living at RHs higher than the CEH maintained water balance in their bodies. If the mites were exposed to RHs below the CEH for a sustained period of time (usually several weeks), they would gradually dehydrate and die (Brandt and Arlian, 1976; Arlian, 1975). Field studies have shown that the density of mites in homes located in humid and temperate geographical areas fluctuated sharply with seasonal variations of indoor and outdoor RHs (Furumizo, 1978; Lang and Mulla, 1978; Arlian et al., 1982 and 1983; de Andrade et al., 1995). High mite levels occurred during the humid summer months, and the mite level dropped significantly during the dry winter months. Few house dust mites have been found in dwellings located in dry climates (Moyer et al., 1985; de Andrade et al., 1995). Thus, maintaining a low indoor RH has been considered a measure to control the mite population in human dwellings to relieve the associated allergy problems (Korsgaard, 1983; Pope et al., 1993).

Fragmented data showed that high temperature killed mites or suppressed their reproduction. Tsutomu

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(1973) indicated that adult *D. farinae* and active immature stages remained alive for 24 h at 38°C, but all perished within 90 minutes of exposure to 47°C. Arlian and Veselica (1981b) reported that adult female *D. farinae* died within the first hour of exposure to 52°C and 75 or 95% RH. Kinnaird (1974) found that heating to approximately 50°C effectively killed cultivated house dust mites. Use of electric heating blankets reduced mites and their allergens in beds (Mosbech et al., 1988). Heat treatment at 45°C for 30 minutes suppressed growth of cultivated *D. farinae* but did not kill the population, while heating at 50°C for 30 minutes killed most of the mites in culture (Shibasaki and Takita, 1994).

Since the fragmented data indicated that house dust mites cannot survive for long at temperatures above 40°C and that they dehydrate and die when exposed to sustained low RHs, it may be possible to eliminate the whole mite population in homes by altering ambient RH and temperature for only a short period of time. Experiments were conducted to systematically investigate mite survival in a wide range of temperatures and RHs. The objectives of this paper are to report the experimental data at high temperatures (40–80°C) and to evaluate the effects of RH and temperature on mite survival.

Materials and Methods

The experiments for this research were conducted in the laboratory of Dr. Larry G. Arlian at Wright State University. *D. farinae* used for experimentation were obtained from thriving pure cultures maintained at 21 to 22°C and 75% RH in Dr. Arlian's laboratory. Adult female mites were selected randomly from thriving cultures with the aid of a dissection microscope and confined in groups of approximately 10 in ventilated cages. The cages consisted of glass tubes (25 mm long and 4 mm in diameter) closed at each end with 400 mesh nylon cloth as previously described (Arlian et al., 1990; Arlian and Dippold, 1996). Five cages each containing approximately 10 females were placed in petri dishes to make up one sample set. Three to five sample sets were prepared for each temperature and RH combination to be tested. The sets of caged mites were held in culture chambers maintained at 75% RH and 21 to 22°C for 12 to 24 h then examined before being transferred to environmental exposure chambers to ensure that the mites were in good condition.

The environmental exposure chambers were held in calibrated incubators with temperatures controlled at 40, 45, 50, 60, 70, and 80°C. Each exposure chamber consisted of an airtight glass Pyrex® container (15×20 cm; 1.5 L capacity) filled approximately 12 mm (300 ml) from the bottom with appropriate concentrations of glycerol and water solutions to provide the desired RH in each chamber for the tests (Segur, 1953). The experimental RHs were 10, 15, 20, 25, 30, 40, 50 ,60, 70, 80, and 90% which were maintained by 95, 93.5, 92, 90.5, 89, 84, 79, 72, 64, 51, and 33% glycerol solutions, respectively.

After the environmental exposure chambers were equilibrated for 1 to 2 hours in the incubator controlled at a specific temperature, one set of caged mites contained in a petri dish was placed into each chamber. The petri dish was held by an 8 cm diameter glass bowl in the Pyrex® container to avoid any contact between mites and glycerol solution. Three to five sets were placed in their chambers for each temperature/RH combination at the start of each experiment. At specific times, the set of caged mites in one environmental exposure chamber was removed to determine survival with the aid of a microscope. Mites were classified as dead if they were inactive: that is, if they were immobile or if no movement was noted in response to prodding. For each set of caged mites, data were recorded on the basis of percent of mortality versus exposure time. In parallel, an appropriately caged control set of mites was held at 75% RH and 21–22°C to check the viability/survival of mites for each new batch of mites used.

Table 1 Time interval (minutes) in which 100% mortality occurred for female *D. farinae* held at specific temperatures and RHs

RH (%)	Temperature (°C)					
	40	45	50	60	70	80
10	2520–2700	90–105	27.5–30	5–10	2.5–5	2.5–5
20	2520–2580	90–105	32.5–35	5–10	2.5–5	2.5–5
30	2280–2340	90–105	<25	7.5–10	2.5–5	2.5–5
40	2380–2520	120–135	<30	7.5–10	2.5–5	2.5–5
50	2700–3630	120–135	25–27.5	7.5–10	2.5–5	2.5–5
60	4050–5040	90–105	ND[a]	7.5–10	2.5–5	<2.5
70	2700–3630	120–135	27.5–30	5–7.5	2.5–5	<1.5
80	2460–2520	180–210	30–40	<7.5	2.5–5	1.5–4
90	2460–2520	210–240	20–25	5–7.5	<2.5	<1.5

[a]not done

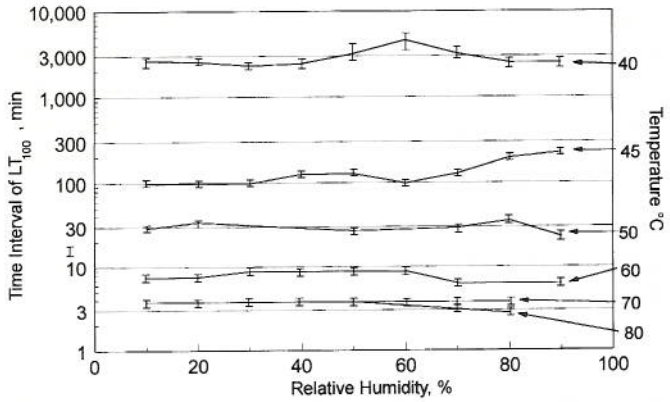

Fig. 1 Temperature and RH effects on longevity of female adult *D. farinae*

Results and Discussion

The time intervals in which 100% mortality of randomly selected female *D. farinae* occurred at various combinations of temperature and RH are given in Table 1. For each time interval listed, the higher number represents the time when the sample taken showed 100% mortality. The lower number indicates the last sample time before 100% mortality was obtained. When there is only one number with a less than (<) sign, 100% mortality was reached in the initial sample taken at the time represented by the number. Therefore, the LT_{100} (time required for 100% of a test population to die) at a particular set of conditions should be between the two sampling times (or less than the single sampling time) listed.

Effects of RH on Survival

Literature data taken at temperatures 34°C or below showed that there is an optimum RH range for mite survival. Tsutomu (1973) found that in the temperature range of 21.1 to 32.2°C the optimum RH range for the growth and development of *D. farinae* was between 70 and 80%. At RHs outside the optimum range, the mite development and survival was adversely affected. For example, at 75% RH and 28°C, the mean LT_{100} of mated and unmated female *D. farinae* was 24.2 and 32.6 days, respectively. However, when the RHs were 40 and 50%, the LT_{100} for randomly selected female *D. farinae* was only 8 days (Brandt and Arlian, 1976).

Current data (Figure 1 and Table 1) indicate that, for adult female *D. farinae*, the optimum RH range existed up to about 50°C and varied with temperature. For example, at 40°C, the optimum RH range was approximately 50 to 70% as shown in Figure 1. At 50°C, the optimum RH range appeared to be 70–90%. The existence of this optimum RH range can also be illustrated by mortality profile (mortality % as a function of time) data at 40°C as shown in Figure 2. All mites perished (LT_{100}) between 38–39 and 41–42 h at 30 and 90% RHs, respectively. The LT_{100}'s at 30 and 90% RHs were not significantly different. However, when the RH (60%) was within the optimum range, the test population stayed alive for a much longer period and the LT_{100} was prolonged to between 67.5 and 84 h.

On the other hand, when the temperature was higher than 50°C, it was not possible to identify any optimum RH range for mite survival. First, the mites died so quickly (LT_{100} less than 10 minutes) that, experimentally, it became very difficult to differentiate the relative survivability at various RHs. Second, the data scattered in a very narrow range (mostly within 2.5 minutes) which tends to make any difference insignificant. Figure 1 shows that, if there is any trend at temperatures greater than 50°C, high RHs (e.g., RHs greater than 70%) tend to accelerate the death of the mites, although the difference was all within 3.5 minutes. Therefore, practically speaking, RHs between 10 and 90% had little influence on the length of time mites survived at temperatures above 50°C and RH was not an important factor in determining the mite lethal time.

Effects of Temperature on Survival

Both Figure 1 and Table 1 show that temperature had a significant effect on the survivability of the randomly selected female *D. farinae*. The times to reach 100% mortality were inversely related to temperature over the 40–80°C range tested. At 40°C, it took more than 20 h to reach 100% mortality. At 50°C, less than 40 minutes was needed for all the mites to die. At 70 and 80°C, the time to reach 100% mortality was reduced to less than 5 minutes.

Figure 3 shows the temperature effects on female *D. farinae* survival time by comparing literature data (Brandt and Arlian, 1976) and current results at 40 and

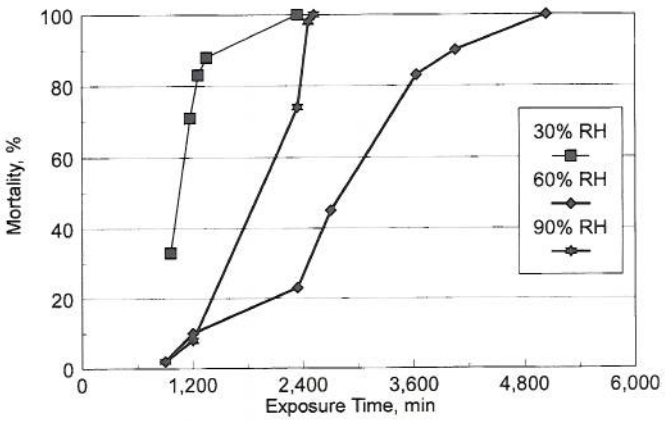

Fig. 2 Mortality % obtained vs. exposure time at 40°C and 30, 60, or 90% RH

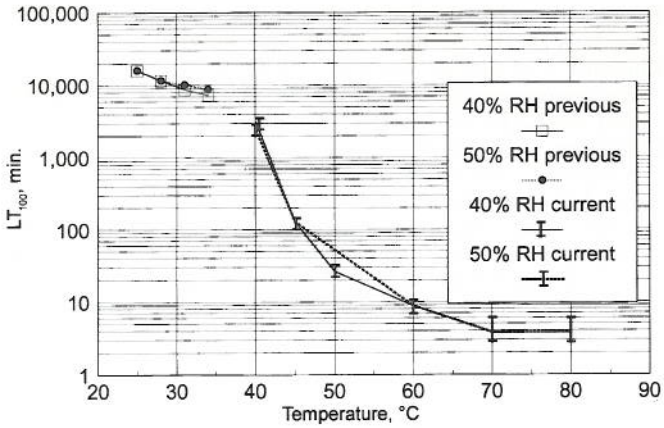

Fig. 3 Comparison of previous (Brandt & Arlian, 1976) and current LT_{100} data of female *D. farinae* at 40 and 50% RHs

50% RHs. At temperatures between 25 and 34°C, the LT_{100} was between 11 and 5 days when they were exposed to those unfavorable RHs (outside the optimum RH range of 70 to 80%). However, the LT_{100} was reduced to less than 10 minutes by a temperature increase of less than 40°C.

Figure 3 also shows that, although the times to reach 100% mortality were inversely related to temperature over the entire temperature range, the adverse effects of higher temperature on LT_{100} were not evenly distributed from 25 to 80°C. The most profound effects occurred between 40 and 50°C in which a 2 order-of-magnitude decrease of LT_{100} occurred. This decrease was considerably greater than that which occurred in any other 10°C increments.

It appears that the cause of the female *D. farinae's* deaths at temperatures below 40°C was different from that above 50°C. Brandt and Arlian (1976) reported that dehydration was the main cause of mortality at 40 and 50% RHs between 25 and 34°C. Since those RHs are below the CEH (70%) of female *D. farinae* (Larson, 1969), more water was transpired than absorbed from the atmosphere and the mites were not able to maintain a water balance in their bodies (Arlian, 1977). The effects of dehydration were also reflected by the dry and shriveled appearance of the dead mites. It was also found that high RH relieved the dehydration effects and greatly prolonged the mites' life spans. For example, while none survived for more than 5 days at 40% RH and 34°C, 97% of the female *D. farinae* survived for more than 7 days when the RH was raised to 75% at the same temperature.

On the other hand, we observed that the moribund and dead mites at temperatures above 50°C were plump and fresh. The RH was not a factor in determining the mite survival. Therefore, dehydration was not the cause of death at high temperatures. The fast deaths of female *D. farinae* were probably due to a loss of physiological integrity resulting from the environmental stress of high temperature (thermal death point) which started to manifest itself in the temperature range of 40 to 50°C (MacDonald and Tovey, 1992). Current experiments were not designed to investigate the exact cause of death. More experimental data are needed to evaluate the impact of high temperatures on mite biology.

Conclusions

Temperature has significant effects on the survival of a house dust mite, *D. farinae*. Experimental data indicate that, while subject to temperatures above 50°C, female *D. farinae* survived for less than 40 minutes. At 60, 70, and 80°C, 100% mortality occurred in less than 10 minutes. There was no pattern to indicate that either high or low RH helps or hinders mite survival at these high temperatures. It seems that RH did not play a key role, and temperature was the determining factor in mite survival when the temperature was higher than 50°C.

Data comparison indicates that the LT_{100} of female *D. farinae* was reduced by more than 4 orders-of-magnitude by raising the ambient temperature from 25 to 80°C. The reduction of LT_{100} was especially sharp in the temperature range of 40 to 50°C. The high temperature may have adversely affected physiological functions of the house dust mites which resulted in the extremely short lifetime. More experimental data are needed to evaluate the impact of high temperatures on mite biology, physiology, and ecology.

The inability of house dust mites to survive for long at high temperatures is important in developing guidelines and making recommendations for reducing mite and mite allergen levels in homes and therefore reducing human exposure. Engineering measures that expose the house dust mites to high temperatures can also be developed to eliminate mite population in infested homes in a fast and effective fashion.

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