

Eliminating *Dermatophagoides farinae* spp. (Acari: Pyroglyphidae) and Their Allergens Through High Temperature Treatment of Textiles

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ABSTRACT House dust mite allergens cause allergy and asthma in sensitized individuals. The allergens they produce are known to resist decay under natural household conditions and are thought to accumulate until removed. We sought to evaluate the effects of high temperature (96°C) generated by a hard surface cleaner on live mite populations of American house dust mites, *Dermatophagoides farinae* Hughes and their allergens in carpet and mattresses. Statistically significant ($P < 0.05$) mite mortality (100%) was observed in response to treatment in both textile surfaces. Similar effects were observed on *Der f1* fecal allergen. Allergen reductions in carpet with two or five pass treatment regimes were 61.4 and 100%, respectively. These results demonstrate the potential of employing a hard surface steam cleaner as a novel method to eliminate house dust mite populations and their allergens in a residential setting and appear particularly promising as an environmental control strategy.

KEY WORDS house dust mites, *Dermatophagoides farinae*, allergen avoidance, environmental control

HOUSE DUST MITE (HDM) allergens are recognized as a major risk factor for sensitization and the development of allergic asthma in all areas of the world in which the climate is conducive for mite population growth (Arlian and Platts-Mills 2001). As high as 85% of asthmatics show an IgE response to house dust mite allergen (Platts-Mills et al. 1997). HDM allergen exposure is linked to childhood allergic sensitization (Lau et al. 1989), with the risk of allergic sensitization doubling for every doubling of HDM allergen exposure level (Peat et al. 1996).

Exposure in the household environment often occurs after disturbance of an area. These reservoirs are often carpets, soft furnishings, and bedding. The predominant dust mite species in the United States are both the American (*Dermatophagoides farinae*) and European (*D. pteronyssinus*) house dust mites (Arlian and Platts-Mills 2001). Group 1 HDM allergens (*Der f1*, *Der p1*) associated with these species are heat-labile glycosylated proteins with cysteine protease activity produced during digestion and released into feces (Tovey et al. 1981, Stewart 1995). Group 2 allergens (*Der f2*, *Der p2*) are nonglycosylated proteins that are more resistant to changes in pH and temperature (Ledford 1994). Evidence suggests that group 2 allergens originate from the male mite reproductive tract (Thomas and Smith 1998). The stability of HDM allergen under simulated natural condition has been examined (Kort and Kneist 1994). Neither heating of *Der p1* allergen to 60°C nor the storage of allergen samples for 4 yr was shown to influence allergen de-

cay. An additional study examined HDM allergen decay after exposure to varying temperature (15°C, 20°C, and 25°C) and relative humidity (33, 55, and 75%) (de Boer et al. 1995). HDM mite group 1 allergens did not decay after being exposed to these conditions for 18 mo. The inability of HDM allergen to decay naturally shows that they are stable proteins in which the allergenicity of the initial protein remains constant over an extended period. Because HDM allergens decay slowly, if at all, naturally, they tend to accumulate within indoor settings until removed. The objective of this study was to determine the effectiveness of steam generated by the EcoVap hard surface cleaner (AmeriVap Systems, Atlanta, GA) on eliminating house dust mites and their allergens in carpet and mattresses.

Materials and Methods

Mortality Study

Mite mortality caused by steam generated by the EcoVap was assessed in vitro in carpet and specially constructed mini-mattresses. We examined two treatment regimes consisting of either two or five passes of the steam device over test surfaces. In carpet, three sections measuring 12 × 38 inches were cut from a new carpet roll. The sections were thoroughly vacuumed using a Filter Queen high efficiency particulate air (HEPA) vacuum cleaner to remove dirt and debris. A single-edge razor blade was used to carefully extract the 60 × 15-mm carpet sample from the larger carpet

Table 1. Mean mortality of American house dust mites, *Dermatophagoides farinae*, exposed to high temperature steam (97°C) treatment in medium cut pile nylon carpet and mini-mattresses

Treatment group	Carpet mortality ± SEM	Mattress mortality ± SEM
Two passes w/EcoVap	100 ± 0.0a	100 ± 0.0a
Five passes w/EcoVap	100 ± 0.0a	100 ± 0.0a
Untreated controls	10 ± 1.2b	9.79 ± 1.9b

Within each column mean mortalities followed by different letters were significantly different ($P < 0.05$, t -test proportions, $n = 3$, 50 mites per replicate).

section. Next, 50 adult American house dust mites were inoculated into each carpet core using a fine (000) artist's brush. Once carpet cores were seeded with HDM, they were returned to the larger section of carpet and Vapormax steam treated with either two or five passes with the device. For controls, carpet cores were inoculated, and then returned to the larger section, removed promptly, and assessed. Mortality was determined by the heat escape method, as previously described (Bischoff et al. 1992). Mites were scored dead if in response to gentle brushing failed to move one body length.

In a similar manner, we assessed mortality in mini-mattresses constructed from top to bottom similar to a normal mattress: fabric ticking, foam padding, foam padding, and fabric ticking. Mites were inoculated into the center of a 15 × 100-mm circle on each mattress and then steamed with either two or five passes. Mattresses were disassembled and visually inspected under light microscopy. Experiments on mattresses and carpets were conducted in triplicate. A Student's t -test of proportions was performed on mean mortalities to determine statistical significance between treatment groups at 95% confidence levels (Stat View SE, 1993).

Allergen-Denaturing Study

The effect of steam generated by the EcoVap on HDM allergen, *Der f1*, was examined by treating carpet in the home of a volunteer. Reference dust consisting of dead mite culture was thoroughly mixed with fine dust collected from a vacuum cleaner bag. Reference dust (500 mg) was then evenly distributed into each carpet section and worked into carpet using a carpet rake. Next, 1-meter square sections of carpet were marked and treated with two or five passes of the EcoVap. Immediately after steaming treatment, allergen-containing dust was collected using a HEPA vacuum cleaner (Filter Queen) onto a specially designed allergen trap. Allergen was extracted from dust in phosphate-buffered saline with Tween 20 overnight at 2°C and centrifuged at 3000 RPM for 20 min, and the allergen-containing fraction was then stored at -20°C until analyzed. Allergen quantification was performed using a standard enzyme-linked immunoabsorbency assay, as previously described (Luczynska et al. 1989).

Table 2. Allergen reduction of *Der f1* allergen in medium cut pile nylon carpet compared with controls after high temperature (97°C) steam treatment

Treatment group	<i>Der f1</i> concentration (μg/g)	Allergen reduction (%)
Two passes w/EcoVap	0.21 ± 0.07*	61.04
Five passes w/EcoVap	0.00 ± 0.0*	100.00
Untreated controls	0.53 ± 0.1	N/A

Statistical significance is indicated by (*) from controls ($P < 0.05$, t -test of proportions, $n = 3$).

Results

Mortality of house dust mite exposed to either two or five passes of the EcoVap is listed in Table 1. Both two and five passes over carpet caused 100% mortality of house dust mites. Both treatments were statistically significant from untreated controls of 10% ($P < 0.05$). The EcoVap performed similarly on mattresses. Treatments with an EcoVap on mattresses caused 100% mortality of house dust mites compared with 9.79% for untreated controls. This result was statistically significant ($P < 0.05$). The dead mites observed in these experiments appeared turgid with their lateral dermal opisthonotal glands stained black. The results of high temperature steam treatment on HDM allergen in carpets are listed in Table 2. Two passes of the EcoVap reduced *Der f1* allergen in carpet dust by 61.04%. Five passes caused total elimination of HDM allergen ($P < 0.05$).

Discussion

House dust mite allergens are glycoproteins that are subject to breakdown at certain temperatures. A glycoprotein is simply a protein with a bound glucose or sugar molecule. Three approaches can be used to denature allergens: 1) high temperatures, 2) mildly acidic solutions, or 3) surfactants. The specific means to deliver steam heat in a cost-effective way has not been available. The EcoVap provides a new, relatively inexpensive means to eliminate allergens and house dust mites on textile surfaces and mattresses. This dual effective makes steam treatment of textiles a novel intervention in house dust mite management practices.

Allergen avoidance programs should combine strategies for mite extermination with allergen removal. Novel ways to physically remove or prohibit exposure to HDM allergens have had varying degrees of success. Prior allergen avoidance strategies have emphasized physical barriers on the bedding, hot water extraction, and HEPA filters to minimize exposure. The effectiveness of HDM physical control measures such as encasing mattresses with hypoallergenic barrier material and hot water extraction of carpet shows promise. Encasing mattresses reduced *Der f1* and *Der p1* by a median of 99% and improved bronchial responsiveness in mite-sensitive asthmatic children when combined with immunotherapy (Paul et al. 1998). Domes-

tic hot water extraction or steam cleaning was shown to reduce *Der p1* by as much as 86.7% in carpet (Colloff et al. 1995). It is important to note that steam cleaning is a misnomer, as temperatures employed during conventional steam cleaning are closer to warm tap water (50°C) at the carpet surface, not 100°C. Recently, a clinical study examined the effectiveness of commercial steam cleaning and hot air (110°C) treatment of household textiles (Htut et al. 2001). The study reported a 4-fold improvement in bronchial hyperresponsiveness. However, HDM group 1 allergens were above known sensitization thresholds at the end of the study.

Results from laboratory experiments on carpet and mattresses show the potential for EcoVap treatment of household surfaces as a novel method to eliminate house dust mite populations in a residential setting. The thermal death point for dust mites is at or above 50°C (Kinnaird 1974). Steam produced by the EcoVap (96°C) eradicated dust mites upon contact in laboratory tests. However, the two treatment regimes tested provided different effects on dust mite allergens. Two passes eliminated 61% of the allergen, whereas five passes eliminated 100% of the heat-labile *Der f1* allergen. Heat generated with the two passes was not sufficient to completely denature the allergen. The recommended treatment should be five passes with the EcoVap over carpeted flooring. These results are applicable to house dust mite allergens present in mattresses as well.

Steam generated by an EcoVap has many advantages over conventional hot water extraction, mattress encasements, and chemicals. Hot water extraction is effective in removing surface allergens and killing mites in carpet if temperatures are sufficiently high (Colloff et al. 1995). However, hot water extraction typically does not penetrate deeply enough into carpet or furniture fiber where large mite populations may exist, and thus a significant portion of mites will survive. Furthermore, residual moisture after hot water extraction may in fact promote mite and mold growth, producing the opposite desired effect (Arlian and Platts-Mills 2001). In this experiment, treated textiles had minimal residual water and were completely dry after 3 h posttreatment. Because all mites were killed on contact with steam treatment, concerns surrounding the brief increase in humidity are eliminated. Hot water extraction does not kill nor remove all of the mites, and populations can rebound within 1–3 mo after carpet cleaning (de Boer et al. 1996). Evidence suggests that reinfestation occurs by passive dispersal of mites on infested clothing and scalp hair (Mollet and Robinson 1994, Tovey et al. 1995). Therefore, professional hot water extraction of the entire home has to be performed four to six times per year, making this approach costly to the allergic individual. Steam-treating carpets could be performed on a similar interval, but at a fraction of the cost. The recommended strategy for reducing allergen exposure in mattresses is to encase bedding in hypoallergenic barrier material. Because HDM allergens accumulate to harmful levels on mattress covers over time (Jooma et

al. 1995), covers should be washed frequently to eliminate buildup.

Furthermore, there are few risks associated with employing steam treatment. This is an important advantage over using acaricides, as many HDM-allergic individuals have chemical sensitivities as well. One risk associated with the equipment is mishandling or carelessness during operation, which could result in burns. However, when directions are followed, the machine can be used easily and safely. Another concern may be the removal of stain blockers during carpet treatment, and therefore it may be advisable to reapply stain blockers after treatment. The availability of the EcoVap may be an issue.

Ultimately, the success or failure of HDM environmental control strategies rests on patient compliance. Education on the benefits/risks of each control strategy may improve compliance, and tailoring an individualized strategy that works best for each patient may improve adherence. In conclusion, the results from these experiments show that the EcoVap provided 100% eradication of house dust mites in mattresses and carpeted flooring. Compared with other environmental control methods, steam heat provides a user-friendly, safe, and inexpensive means to control house dust mites, eliminate allergens, and possibly lower allergen exposure in the home.

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