

Reduction of house-dust mite allergen concentrations in carpets by aluminium potassium sulfate dodecahydrate (alum)

Coskun Sevki, Ph.D.,* Aydin Levent, Ph.D.,* Gulegen Ender, Ph.D.,* and Mor Firdevs, Ph.D.# (Turkey)

ABSTRACT

Special tools and skilled labor are required to reduce house-dust mite allergens in carpets. The main house-dust mite allergen is Der p 1, a soluble protein found in high abundance in woolen carpets. Current chemical treatment options are either unsafe or ineffective in eradicating Der p 1. Here, we present an effective, safe, and easy application reagent to reduce the allergen levels in carpets. Sixty woolen carpets with Der p 1 concentrations $>2 \mu\text{g/g}$ in fine dust were divided into three homogeneous groups of 20 carpets each, according to their allergen load. We tested alum dissolved in 60 mL of water at doses of 3, 6, and 9 g/m² against Der p 1 in groups 1, 2, and 3, respectively. The test side of the carpets was sprayed with the reagent. The control side was treated with the 60 mL of tap water. Dust particles were collected from a 1-m² area on each carpet side 24 hours after treatment and were analyzed for Der p 1 content with a monoclonal ELISA. Alum reduced the Der p 1 concentrations by $48.6 \pm 6.2\%$, $78.8 \pm 7.2\%$, and $95.2 \pm 3.0\%$ at 3, 6, and 9 g/m² in the carpets, respectively. Moreover, there were no complaints registered by the residents against the alum applications. Alum, at 9 g/m² (in a solution at 15%) in water, can be used for decreasing existing Der p 1 concentrations in woolen carpets.

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Avoiding exposure to allergens is the first line of treatment for allergic asthma, rhinitis, and eczema.¹ House-dust mites are the main source of allergens in the domestic environment. More than 30 years of research to reduce mite allergen concentrations in carpets by a cheap and easy application method has not been produced. Tannic acid, a well-known protein denaturant, gives conflicting results ranging from 23.0 to 90.0% in carpets.^{2–8} Even in combination with acaricides, the degree of allergen reduction remains unsuccessful.^{3–8} Additionally, tannic acid discolors light-colored carpets. Some physical measurements, such as washing,⁹ active heat-steam treatments,^{10–12} and corona discharge applications¹³ can mitigate high house-dust mite allergen concentrations. However, none of these methods has gained wide acceptance as an application for carpets, because they all require

special tools, skilled labor, and high costs, reaching US\$800.00, for a three-room carpeted house.¹¹

Aluminum potassium sulfate dodecahydrate (alum) is a natural mineral salt that is easy to produce, cost effective, colorless, odorless, and soluble in water. Chemically, alum is a double salt of aluminum or potassium aluminum sulfate (Alum, $\text{KAl}[\text{SO}_4]_2 \cdot 12\text{H}_2\text{O}$). It has been used for a wide range of tasks since the time of the early Egyptians. The subject of alum-protein interactions is very complex.^{14–16} Proteins binding to alum can be released gradually or deactivated completely. For instance, alum is used in industry to tan leather because it is highly acidic and precipitates hide proteins irreversibly.¹⁷ Depending on its concentration, the alum efficacy is highly variable for medicinal purposes. It is used as an adjuvant in some vaccines,¹⁶ because the proteins absorbed by alum are carried to the target tissues and released gradually. Alum acts as an astringent at concentrations higher than 0.5% by precipitating proteins over a bleeding surface.^{18,19} Alum, in its pure form, is used as a styptic pencil for treating small shaving injuries. However, it inhibits platelet aggregation at concentrations of $<0.1\%$.²⁰ Based on its documented ability to bind and precipitate proteins, we performed this study to ascertain whether alum can effectively lower the concentra-

From the *Department of Parasitology, Faculty of Veterinary Medicine, Uludag University, Bursa, Turkey, and #Department of Pharmacology, Faculty of Veterinary Medicine, Akdeniz University, Burdur, Turkey

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Address correspondence and reprint requests to Sevki Coskun, Ph.D., University of Uludag, Faculty of Veterinary Medicine, Department of Parasitology, 16059 Bursa, Turkey

E-mail address: scoskun@uludag.edu.tr

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tion of the main house-dust mite allergen Der p 1 in woolen carpets.

MATERIALS AND METHODS

Selection of Carpets

The test sites comprised 64 homes in Bursa, Turkey, with woolen carpets in the living rooms and bedrooms. We sprayed an area of 1m² on one side of the carpets (control side) with 60 mL of tap water. Dust samples from the sprayed areas were vacuumed for 2 minutes after a drying period of 24 hours. We tested 60 carpets with measurable concentrations of Der p 1 >2 µg/g using a sandwich ELISA kit (Indoor Biotechnologies, Ltd., Cardiff, U.K.).

Constitution of Study Groups and Application of Treatment

Sixty carpets were divided into three homogeneous groups of 20 carpets each, depending on their allergen loads. The allergen concentrations were averaged among samples and were reported as mean ± SD µg/g. We tested 3, 6, and 9 g of aluminum potassium sulfate dodecahydrate (Alum, KAl [SO₄]₂ + 12H₂O), respectively, as 5, 10, and 15% solutions in water, for each meter squared of the carpets. Each carpet served as test and control units; one side was sprayed with water (control), and a 1-m² area on the other side was treated with alum (3, 6, or 9 g) in 60 mL of water. To decrease the risk of contamination after treatment, the carpets were not used during the drying period of 24 hours.

Dust Sampling

Dust samples from an area of 1 m² were collected from the test and control sides of the carpets. The Mitest collector (Indoor Biotechnologies, Ltd.) was fitted into the wand of the vacuum cleaner (Arcelik model S6945, 1350 W; Arcelik Co., Istanbul, Turkey), and the sampling area was vacuumed for 2 minutes. The collected dust was stored for 3 days at 4°C until analysis. Dust sampling was repeated once to confirm the efficacy of the treatment in group 3, on the 15th day posttreatment.

Allergen Quantification

The Der p 1 levels contained in the dust collected from the test and control sides of each carpet were quantified using sandwich ELISA (Indoor Biotechnologies, Ltd.), as described previously.²¹ Briefly, 100 mg of fine dust was extracted 1:20 w/v overnight by shaking at 4°C with 1% BSA/PBS/0.5% Tween 20, pH 9.6. The extracts were centrifuged at 2500 × g for 20 minutes, and the supernatants were isolated and stored at -20°C until assayed. The amount of Der p 1 was ex-

pressed in micrograms of Der p 1 per gram of fine dust, as suggested by the allergen standard supplied with the kit.

Statistical Analysis

Student's *t*-tests, SPSS for windows 13.0, were used to check the association between control and treated dust samples in each group. For statistical significance determination, the value of *p* was set at 0.001 (*p* < 0.001).

RESULTS

After treatment with alum, the Der p 1 concentrations decreased from 9.6 ± 3.4 µg/g to 4.7 ± 1.8 µg/g (*p* < 0.001), from 9.5 ± 3.4 µg/g to 1.9 ± 0.6 µg/g (*p* < 0.001), and from 9.6 ± 3.6 µg/g to 0.5 ± 0.4 µg/g (*p* < .001) in groups 1, 2, and 3, respectively, as compared with the controls. These translated into reduction percentages of 48.6 ± 6.2%, 78.8 ± 7.2%, and 95.2 ± 3.0% for groups 1, 2, and 3, respectively. Details of these findings are provided in Table 1. The allergen load was completely eliminated in 5 of the 20 tested carpets treated with the highest dosage of alum. The allergen concentrations were 0.6 ± 0.3 µg/g in the carpets treated with 9 g of alum for each meter squared 15 days after treatment. None of the test site residents complained about the alum applications.

DISCUSSION

In this study, we treated woolen carpets with alum, a known protein chelator, and potential dust-mite allergen eliminator, with high success. A single alum treatment of 3, 6, or 9 g/m² to one carpet side achieved statistically significant reductions in the allergen loads, compared with the water-vehicle controls. The reduction rate in the group 3 (95.2 ± 3.0%) can be interpreted as being the most effective, because 5 of 20 carpets in this group were entirely allergen free. The residual Der p 1 concentration (0.5 ± 0.4 µg/g) was almost one-quarter of the risk level, which is produced by the group 1 allergen (Der p 1 + Der f 1 = 2 µg/g) for many individuals genetically predisposed.¹ The presence of small amounts of allergens in the dust samples collected from the treated sides may be related to an insufficient alum application or to the application quality.

Despite a slight increase, the allergen concentrations were still low (0.6 ± 0.3) in the carpets treated with 9 g/m² of alum 15 days after treatment. However, a long-term efficacy of the reagent was not expected, because almost all of the alum applied as reported here was vacuumed after the 24-hour drying period. Treatments should be repeated at intervals to keep the carpet safe for sensitive individuals. Detection of the exact intervals for subsequent alum applications should be determined in follow-up studies.

Table 1 Efficacy of alum against Der p 1 in carpets

Groups (Sample Numbers)	1 (3 g/m ²)		2 (6 g/m ²)		3 (9 g/m ²)	
	Control	Treatment	Control	Treatment	Control	Treatment
Concentrations of Der p 1						
1	13.6	8.3	13.8	2.6	13.7	0.9
2	10.4	5.6	10.7	2.4	10.6	0.8
3	9.0	4.2	9.2	1.8	9.1	0.4
4	4.3	1.4	4.1	2.6	4.3	0.2
5	6.4	3.0	6.2	2.0	6.2	0.0
6	8.8	4.4	8.6	2.1	8.2	0.5
7	11.7	4.6	11.2	2.4	11.0	0.6
8	11.8	4.8	11.9	2.3	12.1	0.0
9	10.5	5.2	10.4	1.9	10.6	0.8
10	10.9	5.2	11.0	2.1	10.8	0.0
11	3.2	1.8	3.2	0.8	3.3	0.2
12	8.4	4.0	8.2	1.0	8.4	0.7
13	9.2	4.1	9.0	1.1	9.2	0.0
14	14.9	7.2	15.0	1.5	15.6	0.8
15	16.0	8.0	15.8	1.5	16.7	1.0
16	3.4	1.8	3.5	0.8	3.1	0.0
17	9.5	4.8	9.5	2.1	9.6	0.7
18	9.5	5.0	9.6	2.6	9.4	0.5
19	10.4	5.6	10.5	2.6	10.7	0.8
20	10.1	4.8	8.6	2.0	9.5	0.7
Mean $\pm$ SD	9.6 $\pm$ 3.4	4.7 $\pm$ 2.8	9.5 $\pm$ 3.4	1.9 $\pm$ 0.6	9.5 $\pm$ 3.6	0.5 $\pm$ 0.4
Rate of reduction (%)	48.6 $\pm$ 6.2		78.8 $\pm$ 7.2		95.2 $\pm$ 3.0	

The allergen load was completely eliminated in 5 of the 20 tested carpets treated with the highest dosage of alum. The allergen concentrations were $0.6 \pm 0.3 \mu\text{g/g}$ in the carpets treated with 9 g of alum for each meter squared 15 days after treatment. None of the test site residents complained about the alum applications.

In healthy organisms, alum is well tolerated¹⁴ and is used routinely to treat massive bladder hemorrhages without inducing severe side effects.^{18,19} Also, it is used to stop bleeding and for refreshing the skin after shaving (Alum Block, www.sephora.com/browse/product.jhtml?id=P0916). However, acute alum intoxication cases have been reported after intravesical alum instillation in patients with renal failure.²²

Chronic or acute intake of this dietary salt may cause accumulation of aluminum in the bones,^{14,23} brain,¹⁴ and other tissues,²⁴ resulting potentially in osteomalacia, neurodegenerative, or metabolic diseases. Thus, the quality of alum application is crucial for obtaining a better reduction rate and for minimizing the potential risk of intoxication. In this study, we observed no complaint regarding alum applications by the residents, and there was no harmful effect detected on the carpets.

The cost of alum, in amounts sufficient to treat a 100-m² carpet, is roughly 5% of reagents containing tannic acid alone or with an acaricide. Thus, alum is a

cost-effective way to reduce water-soluble household allergens.

However, the mode of alum efficacy is not clear. Interactions between alum and proteins are closely related to the electrical charge and load of the target protein. Additional studies are required to determine the exact interaction between alum and the allergen. Presumably, Der p 1, a water-soluble protein,²⁵ was precipitated and absorbed by alum. The dust consisting of the alum-allergen complex was vacuumed easily after the drying period.

In previous studies,³⁻⁸ tannic acid or its combinations with some acaricides showed variable results ranging from 23.0 to 90.0% reduction of Der p 1 concentration in carpets. Additionally, the efficacy of tannic acid has been reported as questionable, because of its interference with many immunoassays, causing an apparent reduction in allergen levels.³

Physical interventions, such as heat-steam applications, can mitigate house-dust mite allergen concentrations at rates varying from 61.4 to 100% in carpets.¹⁰⁻¹²

However, this method carries a risk of injury by burning (110°C) during the application process. Also, this method requires repeated bimonthly applications, costly special tools, and skilled labor amounting to roughly US\$800.00 for a home with three carpeted rooms.¹¹ Corona discharge, an electrostatic way of destroying Der p 1, also lowers allergen concentrations to some extent,¹³ but this technique requires continuous application for 3 weeks. Thus, none of the aforementioned physical methods have gained wide acceptance for allergen eradication in carpets. A single spraying of 9 g/m² of alum dissolved in 60 mL of water reduces Der p 1 concentrations by $95.2 \pm 3.0\%$. This reagent appears to be highly useful for removing dust-mite allergen and thus is recommended for wide-use applications for carpet treatment.

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