

The accumulation of dust mite allergens on mattresses made of different kinds of materials

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Summary

Background: Different mattress materials may affect the accumulation of allergens.

Objective: To compare the amount of group 1 dust mite allergens (Der p1 + Der f1) on mattresses made of different kinds of materials before and after use.

Methods: Sixty new mattresses made of kapok, synthetic fiber, coconut fiber and sponge-like polyurethane, were placed in the house officers' dormitory at Siriraj hospital, Thailand. The dust samples were collected before (0), 1, 2, 3, 6, 9 and 12 months after the mattresses were used. Group 1 dust mite allergens were analyzed using two-site monoclonal antibody ELISA.

Results: Der f1 made up 86.7 % of group 1 allergens found in the mattress dust. After the 2nd month, only the mean level in sponge-like polyurethane mattress was under 2 µg/g dust (sensitized level). At the 6th month, the mean levels were 13.1 in coconut, 21.7 in kapok and 17.3 µg/g dust in synthetic fiber, all of which were more than 10 µg/g dust (symptomatic level). At the 9th month, the level in sponge-like polyurethane mattress was increased to 11.2 µg/g. At 12th month the level in coconut fiber,

sponge-like polyurethane synthetic fiber and kapok mattresses were 20.2, 22.4, 28.9 and 32.2 µg/g dust respectively.

Conclusions: The accumulation rate in kapok and synthetic mattresses was significantly higher than coconut and sponge-like polyurethane mattresses. The mean level of group 1 mite allergens exceeded 10 µg/g dust after the 6th month of use in coconut fiber, kapok and synthetic fiber and at the 9th month in sponge-like polyurethane mattress. (*Asian Pac J Allergy Immunol* 2010;28:155-61)

Key words: mite allergen, mattress, Der p1, Der f1, group 1 allergens

Abbreviations: HDM = house dust mite

Introduction

The incidence of atopic diseases has been shown to be increasing all over the world. In Thailand, the incidence of asthma was 12.7% and allergic rhinitis was 38.7%.¹ Domestic mites were found to play a major role in the initiation and development of allergic diseases, mainly asthma and allergic rhinitis.² The two major dust mite species that associated with respiratory allergic diseases were *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*.^{2,3} House dust mite (HDM) and their allergens were found in mattresses, carpets, rugs, chairs, sofas, couches and clothing.^{4,5} Among multiple locations in the house, the highest concentration of group 1 mite allergens was found in mattresses.⁵ Beds have been suggested to be the most important source of HDM allergen exposure for young children, who spend more than half of their time in close contact with bedding.⁶ Airborne levels of mite allergens were low compared to the high concentrations found in mattresses and bedding.

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A previous study showed that the sensitizing level of group 1 antigens was $>2 \mu\text{g/g}$ dust and the level that induced allergic symptoms was $>10 \mu\text{g/g}$ dust.⁷ Mite-sensitive patients with allergic asthma, allergic rhinitis, and atopic dermatitis should receive advice on how to avoid mite allergens in their mattresses.⁷⁻⁹ Several attempts were made to reduce the amount of house dust mites in mattresses.^{3,10,11} Previous studies showed a significant reduction in house dust mite allergen levels in mattresses covered with polyurethane encasing.¹²⁻¹⁵ Vacuuming of mattresses had been proven to be ineffective or to give only short-term benefit.^{16,17} A combination of acaricide and tannic acid were not effective in creating a low-allergen environment and their long-term toxicity was uncertain.^{18,19} In an environment with a high content of house dust mite allergens, chemical treatment of carpets and mattresses²⁰ or chemical treatment of carpets and bedding encasements²¹ is insufficient to produce a sustained beneficial reduction in mite allergen levels. Mite-impermeable mattress encasings have a significant but modest effect on dust mite allergen levels of mattresses with low initial mite allergen levels.^{13,22}

In clinical practice, a combination of encasing of mattresses and washing sheets, pillowcases, blankets, and mattress pad at least weekly in hot water ($>55^\circ\text{C}$) are often recommended.^{10,11} Despite much researches aimed at developing mite allergen avoidance strategies, conflicting data about the mite allergen content of mattresses made of different kinds of materials still exists.¹¹ Surprisingly, only a few studies about choices of mattress materials have been adequately completed.^{23,24}

The most common kinds of mattress materials in Thailand and many countries in Asia are kapok, sponge-like polyurethane, synthetic fiber, and coconut fiber. Allergic patients are advised to replace their kapok mattresses with synthetic fiber mattresses, despite the lack of scientific evidence to support this. The aim of this study is to compare the accumulation rate of dust mite allergens on new mattresses made of different kinds of materials over a twelve-month period after use.

Methods

The study was approved by Ethics Committee and the written informed consent had to be signed before the study began. Sixty new mattresses

made of 4 kinds of materials; kapok, synthetic fiber, coconut fiber and sponge-like polyurethane (15 of each), were obtained for regular use by house officers living in the house officer's dormitory at Siriraj Hospital, Mahidol University, Bangkok, Thailand. These mattresses were used for a 12-month period without any being cleaned. Each mattress was partially covered with a cotton bed sheet that was cleaned by regular washing method every 1-2 weeks. The mattresses were used regularly at least 4 days per week. The floor of all of the rooms was made of cement without carpet. Air ventilation occurred via three windows and two doors. The room temperature and humidity levels on the upper surface of mattresses were recorded each time dust samples were collected. The house officers' dormitory was surrounded by a cluster of tall buildings and is approximately 500 meters far from the Chao Praya River. To control for the effect of different seasons on HDM and their allergens, the starting times of the study of each type of mattresses were randomly distributed throughout the year.

Collection of dust samples and allergen extraction

Dust samples from the mattresses were collected before use (0), and after 1, 2, 3, 6, 9, and 12 months of use. Each sample was collected from the upper surface of the mattress by two-minute vacuuming with the same vacuum cleaner (Kelvinator 1000 W) attached to a dust collector (ALK laboratory, Denmark) as described in the third international workshop of indoor allergens and asthma.²⁵ The samples were sealed in plastic bags and stored at 4°C until they were analysed. For allergen extraction, 0.1 g of fine dust samples was stored in 2 ml of phosphate buffered saline overnight at 4°C . Two-fold dilution of dust extracts from 1:20 to 1:80 in 1% bovine serum albumin-phosphate buffer saline-tween was conducted for measuring of group 1 allergens.

Allergen determination

Der p1 and Der f1 concentration in dust samples were determined using two-sided monoclonal antibody methods²⁶ using mAb 5H8 for Der p1, mAb 6A8 for Der f1 and the standards from Biotechnologies, UK. Flat-bottom ELISA plates (Nunc, Denmark) were coated with monoclonal antibodies for determination of specific group 1 allergens. One percent bovine serum albumin was used as diluents for blocking a



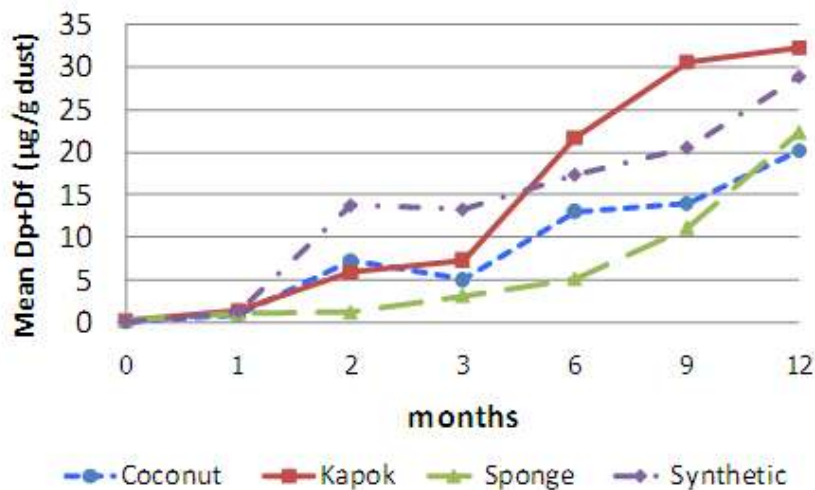


Figure 1. Group I mite allergens in different kinds of mattress over time

non-specific reaction and 0.05% PBS-tween was used as a washing solution throughout the experiment. The allergen concentration in the dust samples was expressed in micrograms of group 1 allergens (Der p1 + Der f1) per g of fine dust.

Statistical analysis:

In this study, dust samples were collected from each mattress at variable intervals: 0, 1, 2, 3, 6, 9, and 12 months. Group 1 mite allergens in different kinds of mattress material were compared over a 12-month-period by using ANOVA to calculate the p value.

A linear mixed model was used due to multiple measurements, irregular (unequal) time intervals and missing data.^{27,28} In our linear mixed model, the dependent variable was the log of dust mite allergen and the independent variable was time in months. Time was considered to be a fixed effect in the model whereas each mattress was deemed to be a random effect.

Each type of mattress (kapok, synthetic fiber, coconut fiber and sponge-like polyurethane) had its own population linear regression line. The slope of the linear equation showed rate of accumulation of log of mite allergens (per month). Since the regression equation was linear, the slope was constant over time. That is, one type of mattress will have one constant rate of accumulation of log of mite allergens. As it is similar to an ordinary simple linear equation, it can be used to predict the mean value of the log of the dust mite allergens after any period of use.

The population linear regression was calculated by the equation: $\text{pop} = \text{intercept} + \text{slope} \times \text{time}$.

All statistical analyses were performed using SAS 11.0. A 2-sided significant level of 0.05 was employed.

Results

The vast majority of group 1 allergens from this study were Der f1 (86.7% of total group 1 mite allergens). The average humidity was 60.6 % and average ambient temperature was 29°C. There was no significant difference in humidity and ambient temperature between the rooms that contained different mattress materials.

Group 1 mite allergens gradually increased overtime as shown in Figure 1. The levels of group 1 allergens in all kinds of mattress materials showed no significant difference at the end of the 1st month. By the 2nd month, mean group 1 allergen levels were 13.7 in synthetic fiber, 7.4 in coconut fiber and 5.9 µg/g dust in kapok mattresses. Only the mean level in sponge-like polyurethane mattress was 1.1 µg/g which was under the allergy sensitized level (2 µg/g dust).⁷ The level in sponge-like polyurethane increased to 3.2 µg/g at the 3rd month and 5.2 µg/g at the 6th month. At the 6th month, the mean levels were 13.1 in coconut fiber, 21.7 in kapok and 17.3 µg/g in synthetic fiber mattresses which were more than the level that induce allergic symptoms (>10 µg/g dust).⁷ The mean level in sponge-like polyurethane mattress was increased to 11.2 µg/g by the 9th month. At the end of the study (12th month), the levels in all kinds of mattress

Table 1. Mean, median and interquartile range of group 1 mite allergens in different kinds of mattress at different time points

mattress	month	Dust mite allergens Der p1 + Der f1 (microgram/gram dust)						
		0	1	2	3	6	9	12
Coconut	Mean	0.1513	0.9707	7.3693	5.0893	13.1120	14.0640	20.2333
	Median	0.14	0.96	1.36	1.05	4.61	13.30	16.60
	Inter quartile range	0.05-0.22	0.39-1.45	0.64-12.83	0.75-1.92	0-23.2	0-27.4	0-33.7
Kapok	Mean	0.2727	1.4180	5.9807	7.3747	21.7533	30.5667	32.2400
	Median	0.25	1.44	2.24	1.47	25.40	28.10	31.30
	Inter quartile range	0.21-0.35	1.06-1.83	0.57-6.00	0.53-2.44	0.00-31.7	26.10-43.50	17.40-42.80
Sponge	Mean	0.3060	1.1060	1.2723	3.2080	5.1867	11.1840	22.3667
	Median	0.10	0.96	1.04	1.18	.00	8.60	12.90
	Inter quartile range	0.05-0.58	0.23-1.75	0.15-2.02	0.13-4.78	0.00-11.40	0.20-15.4	1.00-17.90
Synthetic	Mean	0.0307	1.2667	13.7393	13.2880	17.3680	20.5733	28.9667
	Median	0.00	1.30	13.73	3.41	3.10	10.70	25.30
	Inter quartile range	0.00-0.04	0.80-1.89	1.46-22.40	1.63-21.90	0.00-29.29	0.80-43.80	12.10-32.50

materials were more than 20 µg/g dust. The level in coconut fiber, sponge-like polyurethane and synthetic fiber were 20.2, 22.4 and 28.9 µg/g dust respectively. The level in kapok mattresses was 32.2 µg/g dust which was the highest level of all. Mean, median and interquartile range of group 1 mite allergens in different kinds of mattress at different time points were shown in Table 1. Comparison of Group 1 mite allergens in different kinds of mattress materials over a 12-month-period by using independent sample t-test to calculate the p value showed significant difference ($p < 0.05$) between synthetic vs sponge-like polyurethane from the 2nd to the 3rd month, kapok vs sponge-like polyurethane at the 6th to 9th months and kapok vs coconut at the 9th as shown in Table 2.

The predicted mean values (population regression line; $\text{pop} = \text{intercepts} + \text{slope} \times \text{time}$) of natural log of mite allergens during the whole study period for each type of mattress are presented in Figure 2. The linear mixed models showed that four types of mattress could be classified into two groups according to the rate of accumulation of log of mite allergen levels. Mattresses produced from kapok and synthetic fibers were classified in the same group while the mattresses produced from sponge-like polyurethane and coconut fibers were in the other group. There were statistically significant differences in allergen accumulation rate between kapok vs. coconut, kapok vs. sponge-like polyurethane, synthetic vs. coconut, and synthetic vs. sponge-like polyurethane mattresses ($p < 0.05$).

The statistical comparison of predicted means of log of mite allergens between each type of mattress at each time point is shown in Table 3. There were statistically significant differences of log of group 1 allergens between kapok vs. coconut, synthetic vs. coconut, and synthetic vs. polyurethane mattresses at and after six-month period and those between kapok vs. polyurethane mattresses at and after three-month period ($p < 0.05$).

Table 2. Comparison of (Der p1 + Der f1) on time

Mattress	Month : p-value					
	1	2	3	6	9	12
Kapok vs. Synthetic	0.506	0.065	0.299	0.589	0.162	0.73
Kapok vs. Coconut	0.59	0.701	0.591	0.225	0.005*	0.118
Kapok vs. Sponge	0.247	0.079	0.259	0.009*	0.001*	0.396
Synthetic vs. Coconut	0.25	0.13	0.125	0.581	0.336	0.35
Synthetic vs. Sponge	0.575	0.002*	0.045*	0.075	0.166	0.604
Coconut vs. Sponge	0.64	0.35	0.52	0.13	0.56	0.85

* $p < 0.05$

Discussion

The distribution of group 1 allergens in this study showed that Der f1 was the major species of dust mites in this dormitory which was near the Chao Praya River. A previous study carried out in Thailand showed that Der p1 was the major house dust mite allergen in the houses.²⁹ The difference in the distribution of group 1 allergens

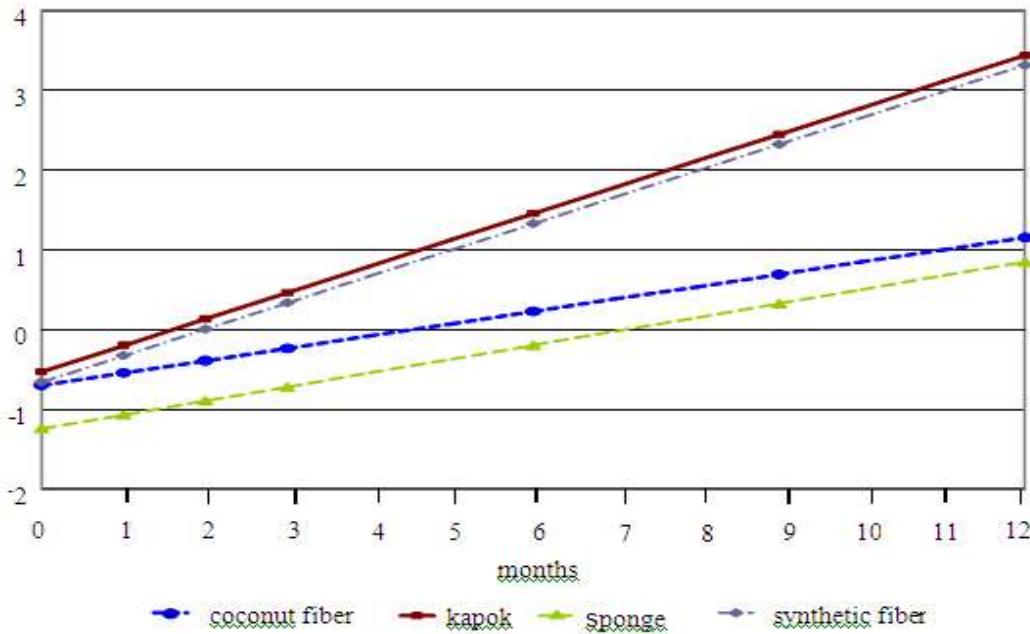


Figure 2. Population regression line of log of mite allergens Der p1 + Der f1 (pop = intercepts + slope × time)

in Thailand might be due to the different humidity in different locations.³⁰⁻³² At the 2nd month of use, mean group 1 allergen level in synthetic fiber mattress was 13.7 µg/g, which is already more than the level that induce allergic symptoms while the mean levels in coconut fiber and kapok mattresses were 7.4 and 5.9 µg/g. Only the mean level in sponge-like polyurethane mattress was 1.1 µg/g which is lower than the allergic sensitization level.

The study showed that the mattresses produced from sponge-like polyurethane had the lowest rate of mite allergen accumulation. Synthetic fibers and kapok mattresses had the highest accumulation rate. The accumulation rate of coconut-fiber mattresses was slightly higher than those from sponge-like polyurethane materials. Over time, the mite allergen accumulation could occur on sponge-like polyurethane mattresses, but at a lower rate than for synthetic and kapok

Table 3. Results of linear mixed model of log (Der p1 +Der f1) on time:Comparison of predicted log (Der p1 +Der f1)

Mattress	Month : p-value						
	1	2	3	6	9	12	
Kapok vs. Synthetic	0.8355	0.8285	0.8233	0.8237	0.8452	0.8721	
Kapok vs. Coconut	0.5707	0.3697	0.2144	0.0276*	0.0052*	0.0025*	
Kapok vs. Sponge	0.1517	0.0772	0.0355*	0.0032*	0.0008*	0.0007*	
Synthetic vs. Coconut	0.7209	0.4984	0.3106	0.0489*	0.0100*	0.0046*	
Synthetic vs. Sponge	0.2226	0.1227	0.0612	0.0067*	0.0018*	0.0013*	
Coconut vs. Sponge	0.3875	0.3845	0.3877	0.4446	0.5605	0.6860	

* p < 0.05

mattresses. Statistically significant difference in mite allergen accumulation existed when compare sponge-like polyurethane or coconut-fiber mattresses with kapok and synthetic mattresses.

The structure of sponge-like polyurethane mattresses was spongy with numerous pores inside while coconut mattresses had relatively large natural fibers. The lower accumulation rate is probably related to the structure and properties of the mattress materials and the biology of house dust mites. Further study in this area is needed to explain the difference between mattress materials.

Although the rate of accumulation was lower in sponge-like polyurethane, the level was more than 2 and 10 $\mu\text{g/g}$ dust at the 3rd and 9th month, respectively. The antigen levels were higher than 10 $\mu\text{g/g}$ dust after the 2nd month in synthetic fiber, the 4th month in kapok, the 5th month in coconut fiber and the 9th month in sponge-like polyurethane mattresses. If we accept that the allergy sensitizing level for group 1 antigen is >2 $\mu\text{g/g}$ dust and the level that induces allergic symptoms is >10 $\mu\text{g/g}$ dust,⁷ the residents in this dormitory were exposed to very high levels of mite antigen. The group 1 antigen levels in all kinds of mattresses at the 12th month of use were much higher than the levels that induce allergic symptoms. High HDM antigen levels were also found in houses in UK and USA.^{30,31} In Manchester, UK, Two-thirds of homes contained Der p1 levels > 2 $\mu\text{g/g}$ dust and 40.3% contained Der p1 greater than 10 $\mu\text{g/g}$ dust.³⁰ House dust mite allergen concentrations in US beds were 46.2 and 24.2% at or greater than 2.0 and 10.0 $\mu\text{g/g}$ dust respectively.³¹ One of the explanation for this is that mite allergens persisted in the households for a long period of time. The median half life of Der f1 in mattresses dust samples was 10 years in exposed homes, 18 years in store rooms and 1 year in green houses.³³ The natural decay of Der f1 was about 10 years in houses.³³

The results from the linear mixed model are in line with the independent sample t-test. The population linear regression line for each kind of mattress material showed that the accumulation of group I mite allergens in kapok and synthetic fiber were significant higher than in coconut and sponge-like polyurethane.

Our study has showed that group 1 allergen accumulation in all kinds of mattresses increased significantly at three months after use (P value $<$

0.05). This is supported by the results of a previous study which showed that Der p 1 increased significantly at four months as compared with baseline level.³⁴ This means that new mattresses could become a significant source of exposure to mite allergens after a short period of time (3-4 months after use) so there appears to be little justification for advising mite sensitive patients to replace their mattresses as a part of avoidance regime.³⁴ Although the accumulation increased with time, to start with the new mattress which was produced from the materials that has the least group 1 mite allergen accumulation rate, ie spongy-like polyurethane or coconut mattresses, should be better. Regarding a mite allergen avoidance strategy, a combination of washing in hot water and the use of mattress covers would be preferable. A combination of the following: choosing new sponge-like polyurethane or coconut fiber mattresses with mite-impermeable covers and washing sheets, pillowcases, blankets, and mattresses pad at least weekly in hot water should be the best method of prevention in HDM allergen sensitive allergic patients.

In conclusion, this study showed that the accumulation of mite allergen on mattresses made of different kinds of materials was different. The accumulation rate in kapok and synthetic mattresses was significantly higher than for coconut and sponge-like polyurethane mattresses at and after the first 6 months of use. The mean level of group I mite allergens exceeded the level that induced allergic symptoms (10 $\mu\text{g/g}$ dust) at the 6th month in coconut fiber, kapok and synthetic fiber and at the 9th month in sponge-like polyurethane mattress.

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