Insect and storage pests causing occupational allergy

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ALLERGIES IN THE WORKPLACE

WORK-RELATED RESPIRATORY ALLERGY ASSOCIATED WITH SENSITISATION TO STORAGE PESTS AND MITES AMONG GRAIN-MILL WORKERS

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ABSTRACT

Background: Exposure to grain dust is associated with a number of adverse allergic health outcomes including conjunctivitis, rhinitis, urticaria/dermatitis and asthma. These clinical manifestations are the result of a multitude of allergens and bioactive materials present in the grain dust. The aim of this study was to assess the patterns of sensitivity to various storage pests among grain mill workers and their relationship to work-related respiratory symptoms and asthma.

Methods: This is a sub-study of the cross-sectional study previously conducted on 111 workers employed in a grain mill in Cape Town. The study instruments included a questionnaire based on the American Thoracic Society (ATS) questionnaire, and specific IgE determinations on serum obtained from workers. Blood samples were analysed by ImmunoCAP using the UniCAP® System (Pharmacia Diagnostics AB, Uppsala, Sweden) for house-dust mites *(Dermatophagoides pteronyssinus, Dermatophagoides farinae)*, storage mites *(Blomia tropicalis, Lepidoglyphus destructor* and *Tyrophagus putrescentiae)*, cockroaches *(Blatella germanica, Periplaneta americana, Blatta orientalis),* beetles *(Tenebrio molitor, Sitophilus granarius)* and mould (mouldmix - *Penicillium notatum, Cladosporium herbarum, Aspergillus fumigatus, Alternaria alternata).* According to the ImmunoCAP scoring system, a positive score was any value greater than 0.35 kU/l.

Results: Among this group of 111 workers, the majority (89%) were men and 49% smokers. The prevalence of IgE reactivity to house-dust mite (41%) was very similar to reactivity to at least one grain-dust allergen (42%) viz. cereal grains, insects and mites. Reactivity patterns to storage mites were similar to wheat (26%), while the prevalence of reactivity to cockroach (*B. germanica*) similar to rye (22%). Storage mite, *B. tropicalis*, produced the strongest IgE response (mean IgE=7.85 ku/l). Beetles such as grain weevil (16%) and mealworm (13%) produced a lower proportion of sensitised individuals, with the latter producing a stronger immune response (mean IgE=2.32 ku/l). Among the cockroaches, *B. orientalis* appeared to generate the strongest immune response. Very high statistically significant linear correlations (Spearman r = 0.75-0.9) were found between dust mites and storage mites, and between cockroaches and beetles, indicating the existence of similar allergens. Among the group of grain-mill workers studied, the prevalence of work-related asthma symptoms such as wheeze and tight chest was 13% and 5% respectively, while 7% of workers were being treated for doctor-diagnosed asthma. IgE reactivity to mealworm (*T. molitor*) was significantly ($p<0.05$) associated with work-related asthma (wheeze) as were cockroach species *(B. orientalis)* in atopic workers (workers with elevated IgE reactivity to house-dust mite).

Conclusion: Allergens from storage pests (mealworm and cockroach) in grain-mill dust is a significant predictor of work-related asthma symptoms. This is a particularly evident in atopic workers who demonstrated increased IgE reactivity to mealworm *(Tenebrio molitor)* and cockraoch *(B. orientalis)* associated with work-related asthma symptoms.

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Grain dust can be defined as the dust present in the ambient air of work environments in which the significant part of working activities have to do with grains, pulses or oil seeds.[1] This definition includes dust produced in animal feed production facilities, grain elevators and grain mills. Exposure to grain dust is associated with a number of adverse allergic health outcomes including conjunctivitis, rhinitis, urticaria/dermatitis and asthma.[2] These clinical manifestations are the result of a multitude of allergens and bioactive materials present in the grain dust. These include the actual grain kernels and husk containing vegetable protein, microflora (*Aspergillus* spp., *Cladosporium* spp., *Thermophillic actinomycetes* spp.), toxins (mycotoxins, endotoxins), mites (*Glycophagus destructor, Tyroglyphus arinae*) and insects (grain weevil, mealworm).[3]

A previous review described the insect and storage pests causing occupational allergy among workers in a diverse range of occupations (Fig. 1).[4] The insects of interest in relation to grain dust are cockroaches, locusts, moths and beetles, as well as storage mites, which also belong to the phylum Arthropoda. Together, they comprise a large proportion of storage pest matter found in grain dust, all capable of causing allergic reactions in sensitised workers. A Spanish study of 50 grain-mill workers showed that 36% of the workers had specific IgE to the cockroach *Blatta orientalis*, 38% to storage mites *Lepidoglyphus destructor* and *Tyrophagus putrescentiae*, and 50% to the mealworm *Tenebrio molitor* (Fig. 2).[5] In this study over 20% had monosensitivity to various storage mites, but not to house-dust mite (HDM). These data indicate that occupational asthma due to storage mites contaminating foods is an important consideration of food safety and public interest.[6,7]

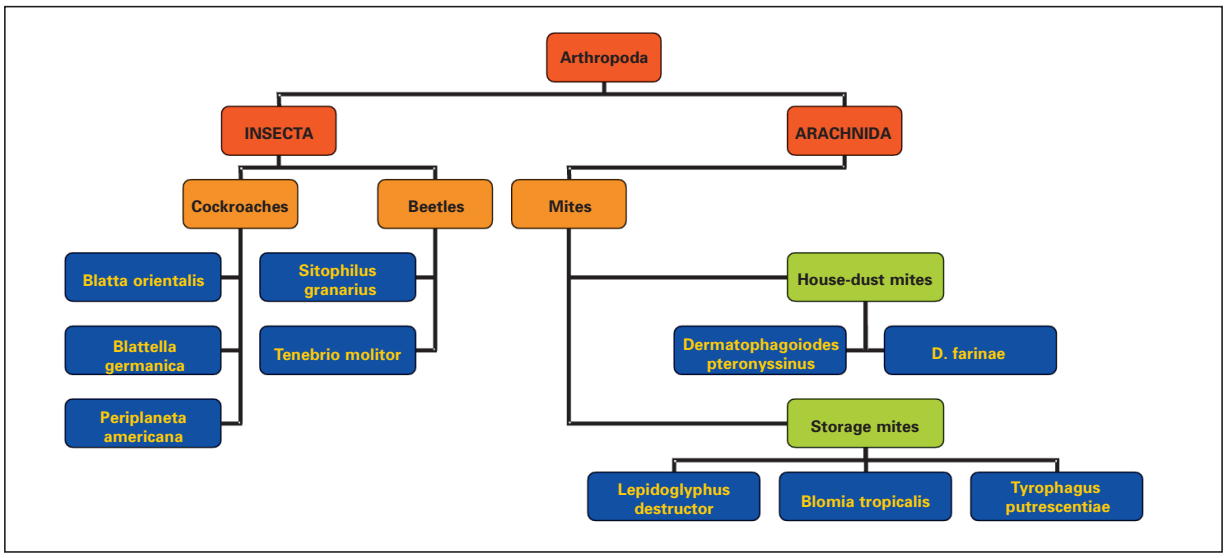

Fig. 1. Main classes of insects and mites in the phylum Arthropoda that cause occupational allergies.

Studies of grain-mill workers in the late 1980s first highlighted the burden of respiratory disease associated with exposure to grain dust in Cape Town.[8,9] The allergens responsible for the respiratory symptoms were reported in a subsequent study on a sub-group of these workers in which a high prevalence (17%) of occupational allergic asthma due to grain dust constituents was found.[10] In this study, the prevalence of sensitisation to storage mite allergens such as *T. putrescentiae* (23%), was very similar to that of the cereal allergens, wheat (26%) and rye (22%), suggesting that the role of storage pests needed further investigation. The aim of this study was to assess the patterns of sensitivity to various storage pests in this group of grain-dust-exposed workers and their relationship to work-related respiratory symptoms and asthma.

Study design and methodology

This is a sub-study of the cross-sectional study conducted on 111 workers employed in a grain mill in Cape Town. The mill obtained and processed wheat (and rye in the past) from grain farms in the Western Cape. The study instruments included a questionnaire based on the American Thoracic Society (ATS) questionnaire, slightly modified for local conditions, and specific IgE determinations on serum obtained from workers. Of the group, 106 workers consented to blood samples being analysed for sensitivity to grain-dust allergens. Blood samples were analysed by ImmunoCAP using the UniCAP System (Pharmacia Diagnostics AB, Uppsala, Sweden) for house-dust mites (*Dermatophagoides pteronyssinus, Dermatophagoides farinae*), storage mites (*Blomia tropicalis* (d201), *Lepidoglyphus destructor* (d71) and *Tyrophagus putrescentiae* (d72), cockroaches (*Blatella germanica, Periplaneta americana, Blatta orientalis*), beetles (*Tenebrio molitor* (Ro212), *Sitophilus granarius* (Ri202)) and mould (mouldmix1 containing *Penicillium notatum, Cladosporium herbarum, Aspergillus fumigatus, Alternaria alternata*). According to the ImmunoCAP scoring system, a positive score was any value greater than 0.35 kU/l. Stata Computer software was used for data analysis.

Fig. 2. Tenebrio molitor, the common mealworm: adult beetle and larvae.

Results

Among this group of 111 workers, the majority (89%) were men and almost half of the workforce were smokers. Detailed IgE patterns of reactivity to common inhalants and the various storage pests are presented in Table I. The prevalence of IgE reactivity to HDM (41%) was very similar to the prevalence of IgE reactivity to at least one grain-dust allergen (42%). The prevalence of IgE reactivity to individual grain cereal allergens was 26% for wheat and 22% for rye (Fig. 3). Reactivity patterns to storage mites were similar to those for wheat, while the prevalence of reactivity to cockroach (*B. germanica*) was similar to reactivity to rye. Storage mite *B. tropicalis* produced the strongest IgE response (as evident from the mean IgE response and a larger proportion of the ImmunoCAP responses in the upper classes) among the storage mites, but this response was much lower than response to the common HDMs (Tables I and II). Beetles such as grain weevil (16%) and mealworm (13%) produced a lower proportion of sensitised individuals, with the latter producing a stronger immune response. Among the cockroaches, *B. orientalis* appeared to generate the strongest immune response.

The correlation matrix of IgE reactivity between the various species tested is presented in Table III. Very high statistically significant linear correlations (Spearman r = 0.8-0.9) were found between species of the same family of HDMs, storage mites, cockroaches and beetles. Furthermore, high correlations were also found between HDMs and storage mites, and between cockroaches and beetles. These high correlations were however not observed between mites and insects, which commonly had correlation coefficients Spearman r <0.65.

Among this group of 111 grain mill workers, 7% admitted to being treated for doctor-diagnosed asthma and 10% for hay fever at the time of the study. The prevalence of non-specific asthma-related chest symptoms

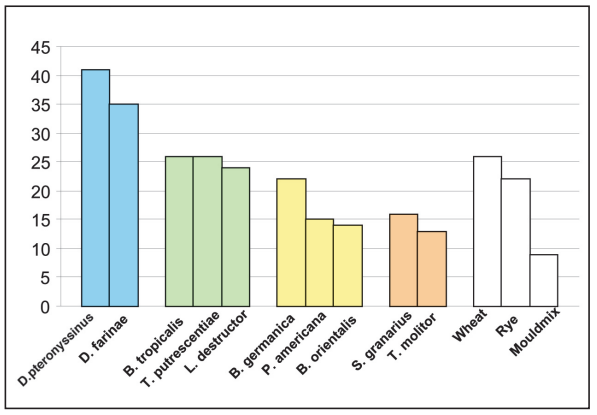

Fig. 3. Species-specific IgE reactivity as determined by positive ImmunoCAP results to house-dust mites, storage mites, insects (cockroaches and beetles), cereal grains (wheat and rye) and moulds among grain-mill workers (n=106).

such as tight chest and wheeze was 18% and 24% respectively. However, the prevalence of work-related asthma symptoms such as wheeze and tight chest was 13% and 5% respectively. IgE reactivity to cockroach (*B. orientalis*) and HDM (both species) was significantly associated ($p<0.05$) with hay fever (ocular-nasal symptoms) as were storage mites (*B. tropicalis* and *T. putrescentiae*) (Table IV). IgE reactivity to mealworm (*T. molitor*) was significantly ($p<0.05$) associated with work-related asthma (wheeze) as were cockroach species (*B. orientalis*) in atopic workers (workers with elevated IgE reactivity to HDM).

Discussion

The patterns of sensitisation in this group of grain-mill workers demonstrate that storage mites (26%) and cockroaches (22%) cause IgE reactivity as frequently as cereal grains, wheat and rye. Other insects such as beetles, grain weevil (16%) and mealworm (13%), are less important but feature more prominently than moulds (9%) in causing allergic sensitisation. The pat-

Table I. Summary data for IgE allergic sensitivity to various storage pests and mites among grain-mill workers in Cape Town

Biological group	Insect species	Mean ± SD in kU/l n=106	No. of positive ImmunoCAP (%) n=106	Mean ± SD of positive ImmunoCAP in kU/l n=106
Cockroaches	*Blatella germanica*	0.53 ± 1.68	23 (21.7)	2.44 ± 2.94
	Periplaneta americana	0.32 ± 1.04	16 (15.1)	2.18 ± 1.82
	Blatta orientalis	0.33 ± 1.04	15 (14.2)	2.31 ± 1.79
Beetles	*Sitophilus granarius*	0.24 ± 0.79	17 (16.0)	1.51 ± 1.46
	Tenebrio molitor	0.31 ± 1.27	14 (13.2)	2.32 ± 2.85
Storage mites	*Blomia tropicalis*	2.07 ± 8.18	28 (26.4)	7.85 ± 14.60
	Tyrophagus putrescentiae	1.51 ± 7.11	28 (26.4)	5.73 ± 13.10
	Lepidoglyphus destructor	1.04 ± 6.08	25 (23.6)	4.41 ± 12.09
Mould	Mouldmix	0.11 ± 0.49	9 (8.5)	1.26 ± 1.27
House-dust mites	*Dermatophagoides pteronyssinus*	4.90 ± 17.49	43 (40.6)	12.09 ± 25.99
	D. farinae	4.29 ±14.01	37 (34.9)	12.29 ± 21.71

Note: Mono-sensitisation: *B. germanica* (1%); *T. molitor* (1%); Mouldmix (2%); *D. pteronyssinus* (6%); *D. farinae* (1%).

Table II. Allergic sensitivity to various storage pest and mite allergens according to ImmunoCAP categories among grain-mill workers in Cape Town

Species	Positive ImmunoCAP n (%)	Class 1 (%)	Class 2 (%)	Class 3 (%)	Class 4 (%)	Class 5 (%)	Class 6 (%)
Blatella germanica	23(21.7)	47.8	30.4	21.7	-	-	-
Periplaneta americana	16(15.1)	31.3	37.5	31.3	-	-	-
Blatta orientalis	15(14.2)	26.7	46.7	26.7	-	-	-
Sitophilus granarius	17(16.0)	47.1	35.3	17.7	-	-	-
Tenebrio molitor	14(13.2)	21.4	64.3	14.3	-	-	-
Blomia tropicalis	28(26.4)	14.3	53.6	21.4	7.1	3.6	
Tyrophagus putrescentiae	28(26.4)	21.4	53.6	17.9	3.6	3.6	
Lepidoglyphus destructor	25(23.6)	20.0	60.0	16.0	-	4.0	
Mouldmix	9(8.5)	55.6	33.3	11.1	-	-	
Dermatophagoides pteronyssinus	43(40.6)	34.9	25.6	23.3	9.3	-	7.0
D. farinae	37(34.9)	16.2	40.5	21.6	13.5	5.4	2.7

Categories of ImmunoCAP:

1 = > 0.35 - <0.7; **2** = 0.7 - <3.5; **3** = 3.5 - <17.5; **4** = 17.5 - <50; **5** = 50 - <100; **6** = ≥100

Table III. Spearman correlation coefficients for ImmunoCAP results for different storage pest and mite allergens among grain mill workers in Cape Town.

	B. germanica	*P. americana*	*B. orientalis*	*S. granarius*	*T. molitor*	*B. tropicalis*	*T. putrecentiae*	*L. destructor*	*D. pteronyssinus*	*D. farinae*
P. americana	0.80*									
B. orientalis	0.72*	0.92*								
S. granarius	0.88*	0.91*	0.81*							
T. molitor	0.74*	0.80*	0.74*	0.84*						
B. tropicalis	0.59*	0.61*	0.62*	0.54*	0.50*					
T. putrecentiae	0.60*	0.62*	0.62*	0.55*	0.50*	0.94*				
L. destructor	0.64*	0.66*	0.63*	0.59*	0.53*	0.90*	0.90*			
D. pteronyssinus	0.48*	0.51*	0.49*	0.43*	0.37*	0.77*	0.75*	0.68*		
D. farinae	0.46*	0.49*	0.50*	0.42*	0.40*	0.86*	0.87*	0.77*	0.86*	
Mould	0.36*	0.36*	0.37*	0.34*	0.37*	0.25†	0.26†	0.21‡	0.24‡	0.20‡

Degree of significance: *p<0.001, †p<0.01, ‡ p<0.05

Table IV. Predictors of respiratory symptoms and asthma among grain-mill workers

	Predictor	Chi-square (Fisher's exact test)	p-value
Work-related wheezing	**Cockroach**		
	- *Blatta orientalis**	4.550	0.070
	Beetle		
	- *Tenebrio molitor**	6.240	0.035†
	House-dust mite		
	- *Dermatophagoides pteronyssinus*	6.312	0.021†
Hay fever	**Cockroach**		
	- *Blatta orientalis*	4.891	0.049†
	Storage mite		
	- *Blomia tropicalis*	4.884	0.064
	- *Tyrophagus putrescentiae*	4.884	0.064
	House-dust mite		
	- *Dermatophagoides farinae*	4.342	0.049†
	- *Dermatophagoides pteronyssinus*	5.130	0.047†
Doctor-diagnosed asthma	**Beetle**		
	- *Tenebrio molitor*	4.055	0.088

Note: *Only for workers with IgE reactivity to house-dust mite

†Degree of significance: p<0.05

terns of reactivity in this group of workers suggest less exposure to storage pest contamination of grain dust than that observed among Spanish grain-mill workers. The latter group showed a high prevalence of IgE reactivity to mealworm (50%), storage mites (38%) and cockroaches 36%.[5] In the South African study, *B. tropicalis* storage mite, *B. germanica* cockroach, and the beetle *T. molitor*, appeared to be the most common sensitising agents in their respective taxonomical group. This has important implications for the choice of allergen test battery to be used for evaluating IgE reactivity among grain-mill workers in this province.

While the prevalence of respiratory symptoms in this group was as high as 24%, the prevalence of work-related asthma symptoms (wheeze) was 13%. The prevalence of work-related chest symptoms in the South African group was however lower than the 33% reported among workers in a United Kingdom study.[11] While the prevalence of sensitisation to HDM was much higher in this current study group (41%) compared with the Blainey *et al.*[11] study (30%), the prevalence of sensitisation to storage mite in both groups was very similar (25%), suggesting storage mite is less important relative to HDM in contributing to work-related asthma symptoms in the South African group, as the former was significantly associated with symptoms (Table IV). This is confirmed by the lack of association between IgE reactivity to storage mite and work-related asthma symptoms. However, IgE reactivity to cockroaches and storage mites was independently associated with ocular-nasal (hay fever) symptoms.

Correlational studies demonstrated strong associations between HDMs and storage mites. This suggests allergenic cross-reactivity between species within similar taxonomic groups. Early studies of the allergenic relationship between storage mites and HDMs, demonstrated limited allergenic cross-reactivity between the two species and suggested that both species had their own unique allergens.[12] Later studies demonstrated that in HDM-allergic patients the sensitisation to storage mite is in the range of 60-88%.[13] Most reports confirm that HDM extracts inhibit storage-mite-specific IgE-binding and vice versa. HDM seem to cross-react more strongly to *A. siro* and *T. putrescentiae* than to *L. destructor*. Results from CIE/CRIE (crossed immunoelectrophoresis) indicate that HDM and *T. putrescentiae* have 2 similar allergens and HDM and *B. tropicalis* have 2-4 similar allergens. The fact that high correlations were not observed between mites and insects supports the view that the evidence for cross-reactivity between sensitisation to cockroach and HDM is less convincing or doubtful.[13]

Instead, the independent associations observed may be due to co-reactivity since both insect and mite allergens can co-exist in stored debris.

The findings of this study have demonstrated that the presence of allergens from insect debris (cockroach and mealworm) in grain-mill dust is significantly associated with the presence of work-related asthma symptoms. This was particularly evident in atopic workers (IgE reactivity to HDM) who demonstrated increased IgE reactivity to mealworm (*T. molitor*) and cockroach species *B. orientalis*. Both these allergens also demonstrated a much stronger immune response (much higher IgE levels) in sensitised individuals. In the absence of possible cross-reactivity between insects and mites, this suggests that atopic workers exposed to these high-molecular-weight insect allergens are at higher risk of developing allergic asthma symptoms. The findings of this study are consistent with previous studies reporting occupational asthma to mealworm indicating that storage pests are an important consideration in symptomatic grain-mill workers who may fail to demonstrate IgE reactivity to cereal grains and storage mites on initial testing.[14]

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