

THE IMPORTANCE OF STORAGE MITE ALLERGENS IN OCCUPATIONAL AND DOMESTIC ENVIRONMENTS

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Abstract - The prevalence and severity of allergic diseases such as asthma, rhinitis and eczema in the developed world are increasing, resulting in greater focus on the causative agents. The majority of cases involve sensitivity to allergens from arthropods. Storage mites are recognised as a source of allergens by inhalation in certain occupational environments and in the domestic environment. To minimise the initial sensitisation and subsequent development of these diseases, it is essential to reduce chronic exposure to these allergens. Recent research in the United Kingdom suggests that this may be increasingly difficult. In a study of grain stores it was found that two of the common storage mite species were unlikely to be controlled by the most frequently used grain protectant. Other work has shown for the first time that storage mites are regularly found on sheep and dairy cattle farms, suggesting an additional circumstance for occupational exposure. A study of cereal-based foodstuffs has found that over a third of samples contained storage mites. Ingestion represents another route contributing to the overall allergen load. The numbers of mites found were low but some were probably alive immediately before analysis and one of the most infested samples was an item of baby food. Since the risk of sensitisation is greater early in life, work is urgently needed to quantify the threat to health. This depends upon establishing not the number of storage mites but the amounts of their allergens. This in turn requires identification of which allergens poses the greatest health threat and the development of methods to quantify their presence. Thresholds of exposure to these allergens for clinical effects must be properly established and comparison of exposure levels in both domestic and occupational environments must be made.

Key words - Arthropod, asthma, cereal, contaminant, ingestion, threshold

INTRODUCTION

It is widely recognised that the prevalence and severity of allergic diseases such as asthma, rhinitis and eczema in the developed world are increasing and this is leading to a greater focus on the causative agents. The majority of cases involve sensitivity to allergens from arthropods (van Lynden-van Nes *et al.*, 1996). A wide range of arthropods can produce allergic reactions, whose characteristics depend on the route of exposure. Reactions can occur in the skin, when blood-feeding species inject saliva to facilitate feeding. House dust mite allergens can produce eczema when rubbed into the skin, or asthma and rhinitis when inhaled (Maunsell *et al.*, 1968). Respiratory allergies to many other arthropods are recognised, including to cockroaches, cat fleas and silverfish.

Storage mites are recognised as a source of allergens by inhalation in certain occupational environments and in the domestic environment. Storage mites, also known as flour mites, grain mites and forage mites in the families Acaridae and Glycyphagidae are usually predominant. They are worldwide in distribution and utilise a wide range of food including grain, fishmeal, hay and substances containing sugars, for example dried fruit and cereals. Certain species also live in human habitations where they thrive on dust in damp and humid conditions.

To minimise the initial sensitisation and development of these diseases, it is essential to reduce chronic exposure to allergens (Colloff *et al.*, 1992), but recent evidence with storage mites suggests that this may be increasingly difficult. Wickman *et al.* (1993) suggest that changes in building techniques over recent years, particularly those associated with energy conservation, have increased the risk of indoor exposure to house dust mites. It is likely that the same applies to exposure to storage mites.

The purpose of this paper is to review recent evidence for the exposure of humans to storage mites in both occupational and domestic environments, to outline progress being made towards better understanding of the clinical significance of such exposure, and thereby to derive a list of urgent needs for further investigation.

STORAGE MITES IN THE OCCUPATIONAL ENVIRONMENT

Literature on occupational allergy to storage mites

Early suspicions, dating from the 1920s, of the involvement of storage mites in causing asthma among farmers were reviewed by Wraith *et al.* (1979) but the first definitive evidence for clinical symptoms resulting from occupational exposure to storage mites, as opposed to pollen, cereal dust or mould antigens, was reported by Cuthbert *et al.* (1979). Using skin tests and Radio Allergo Sorbent Test (RAST) assays, they attributed asthma in 38 farm workers in the Orkneys to storage mites, which were found in abundance in the hay and dust from grain and mattresses, and gave the name barn allergy to this new syndrome. Wraith *et al.* (1979) found that 25 of 42 patients with asthma or rhinitis who were involved in farming, milling or baking, gave greater skin reactions to storage mites than house dust mite and concluded that allergy to storage mites was not only more widespread than previously appreciated but that it was an important occupational hazard in the farming community and to those handling infested materials. Support for this conclusion was obtained using similar methods together with IgE analyses in studies of 440 farmers in Gotland (van Hage-Hamsten *et al.*, 1985) and 133 grain store workers in England (Blainey *et al.*, 1989). The problem is clearly widespread: Fernandez-Caldas (1997) quotes examples of the risk of occupational exposure to storage mites from Iceland, Finland, Ireland, Denmark and Sweden.

After these early studies which served to draw attention to the link between observed symptoms of allergy and storage mites, efforts have continued to define the relationship more precisely, as exemplified by three recent studies of occupational exposure.

Demonstrated sensitivity after occupational exposure to storage mites does not conclusively prove that mite allergens are the cause of observed clinical effects. Vidal and Gonzalez-Quintela (1995) showed that a man who had serum-specific IgE to storage mites, house dust mites and cereal flours after exposure to feeding stuffs and flours, when given a bronchial challenge test with every allergen, showed a response only to barley flour.

The range of different allergens which might cause occupational asthma in 21 bakers, millers and farmers has been studied by Alvarez *et al.* (1996). Skin and challenge tests, specific IgE measurement and bronchial provocation tests showed that while cereals were the most common sensitisers, sensitisation was also found to the enzyme alpha-amylase, soyabean, storage mites and egg. It was suggested that differences in the degree of sensitisation between those in different jobs resulted from differences in exposure.

When sensitisation to cereal products themselves cannot be demonstrated, there is a greater emphasis on investigating various arthropods as causes of respiratory symptoms. Armentia *et al.* (1997) used RAST, prick and challenge tests to examine the sensitivity of 50 grain workers to various mite species and two species of insect. The six highest prevalences of sensitisation were to the Pyroglyphid dust mites *Dermatophagoides pteronyssinus* (Trouessart)(58%) and *Dermatophagoides farinae* (Hughes)(48%), to the mealworm, *Tenebrio molitor* (L.)(50%) and cockroach *Blatta orientalis* L. (36%) and to two of the storage mites, *Lepidoglyphus destructor* (Schrank) and *Tyrophagus putrescentiae* (Schrank)(both 38%). Remarkably, the study included over four thousand people living near cereal facilities. In this group, the prevalence of mite sensitisation was nearly 19%, but among these the sensitisation to storage mites was down to just under 12%. Also of interest was the finding that of the 50 grain workers, 11 who were sensitised to storage mites gave negative RAST results with the dust mites.

Prevalence of storage mites in farm/central/animal feed and oilseed stores

In the UK, a series of exercises has been undertaken to retrieve information on storage practice in various premises. The presence of pests, including mites, was investigated by a combination of visual inspection, sieving and the use of either bait bags or traps. The first two exercises investigated 742 farm grain stores during 1987, at a time when they were generally empty, and 283 central cereal stores with a capacity of over 1000 tonnes during 1989, when they contained harvested cereal. Mites were found

in 72% of farm stores, this figure being virtually independent of farm size, and in 81% of the central stores (Prickett, 1992). In the two most recent exercises, involving 178 animal feed mills in 1992 and 109 oilseed stores in 1995, one or more species of storage mites were found in 89% of both types of premises (Prickett, 1994, 1997). In all four exercises, the three most common mite genera found were *Acarus*, *Lepidoglyphus* and *Tyrophagus*, and within these genera the most frequently identified species were *Acarus siro* (L.), *L. destructor* and *Tyrophagus longior* (Gerv.) [*Tyrophagus palmarum* (Oudemans) in animal feed mills; *T. putrescentiae* in oilseed stores]. Although the general approach in all four exercises was similar, it cannot be deduced from the results that the frequency of mite infestation is increasing with time because of differences between the premises and commodities being stored, and advances in methodology, for example the introduction of the BT mite trap. It is clear that mite infestation in all these types of premises is widespread, perhaps more so than had previously been appreciated. The demonstrated frequency of mite occurrence in oilseed stores contrasts markedly with the view of managers of those store, who reported that in the year before the exercise, mite infestation in oilseed had occurred at only 14% of the 94 sites visited (Prickett, 1997).

Past and recent evidence for storage mites on animal farms

Although storage mites are associated with stored cereals, the threat of occupational exposure to them is by no means restricted to premises involved primarily in the cereal trade. Inspection of 20 cheese stores in England between 1972 and 1974 revealed storage mites at all 20, both on cheeses and in the fabric of the store (Wilkin, 1979). Although no supporting figures were offered, infestation was heaviest on the oldest cheeses. Wilkin and Thind (1983) analysed feed samples taken from 114 dairy cattle farms in South West England during the dry hot summer of 1976 and found mites in the samples from over 96% of these farms. Use of a flotation method allowed them to estimate that the samples from 22% of these farms had more than 50,000 mites/kg. Cattle rejected feed containing this level of *A. siro*. They also reported finding mites in samples of pig feed taken from 92% of 70 farms in England and Wales during July 1980, with samples from 25% of the farms containing more than 25,000 mites/kg. Despite this evidence of high frequencies of mite infestation, there seems to have been little further investigation until recently, when the suggestion was made that mites might have a role in the transmission of scrapie (Rubenstein *et al.*, 1998). This led us to investigate the exposure of British sheep and cattle to mites and although the work is still underway, it is possible to present preliminary results here. At each of 30 sheep and 6 dairy cattle farms, samples of feedstuff, bedding and pasture were taken for laboratory analysis by flotation. The results are shown in Table 1. Mites were found on all 36 farms. Although the numbers of mites in each sample were generally low, at least one 20 g sample of feedstuff from 6 of the farms had over 1000 mites. If these small samples were representative of the bulk, this level would equate to an infestation level of 50,000 mites/kg. Additionally, up to 50 mite traps were used on each farm to catch live mites. Live mites were trapped on all 36 farms, the percentage of traps on each farm in which mites were found varying between 16 and 88%. The conclusion from all this evidence is that over the last 20 years there has been much opportunity for workers involved in various aspects of agriculture to suffer occupational exposure to storage mites.

Increasing difficulty of controlling mites

Not only is the occurrence of storage mites in various premises in the UK widespread, but their short developmental cycle under the conditions often found in such stores favours not only rapid population growth but also the development of pesticide resistance. The latter applies even to pirimiphos-methyl, the most commonly used insecticide in UK stores both for fabric treatments and admixture to grain (Prickett, 1997). While McCallum-Deighton and Pascoe (1976) demonstrated almost complete control of *Acarus*, *Tyrophagus* and *Glycyphagus* spp. in two field trials of wheat and barley treated with pirimiphos-methyl at 4 mg/kg, more recent evidence indicates a problem. Laboratory tests involving exposure to wheat treated with pirimiphos-methyl at 8 mg/kg, twice the recommended field dose, revealed resistance in 90% of the populations of *A. siro* collected during the study of UK animal feed mills in 1992 and 93% of

those from oilseed stores in 1995 (Prickett, 1997). Similarly, 77% of the populations of *T. palmarum* from animal feed mills in 1992 and 97% of those of *T. putrescentiae* from oilseed stores in 1995 were found to be resistant (Prickett, 1997). Mites surviving twice the recommended field dose of pesticide in laboratory tests are unlikely to be controlled in the field, which suggests that, in the absence of effective alternative control strategies, exposure to storage mites and their products will increase in cereal stores and may also do so along the food chain, perhaps even as far as the domestic environment.

STORAGE MITES IN THE DOMESTIC ENVIRONMENT

Evidence for storage mites in homes

Storage mites are known to have lived in human habitations for more than two millennia. Aristoteles (384–322 BC), described an animal found in honeybee combs which was small, white and seemingly headless. He called it “akari”, the Greek for “without head”. Interestingly, although this word applies to the singular animal, its similarity to a Latin plural has led to the misunderstanding that it applies to more than one, hence today “Acari” is used as the plural and the singular form is “Acarus”. The mite was probably *Glycyphagus domesticus* (De Geer), which is the predominant mite species found in beehive combs (Emmanuel, 1982). Despite this early report, the presence of storage mites in dwellings was not commonly recognised even relatively recently. Secord (1990) refers to an account from 1836 by Andrew Crosse who noticed living mites of the genus *Acarus* unexpectedly emerging from an electrical experiment in his laboratory in a Jacobean country house and deduced that he had created life.

The impetus for detailed investigations of mite fauna in dwellings originated early this century, with mites implicated as producers of allergens in house dust (Dekker, 1928). Such studies led to the identification of mites species of the family Pyroglyphidae as the major source of house dust allergen (Voorhorst *et al.*, 1964 and 1969). Several surveys of mite fauna have since shown that in addition to the predominant Pyroglyphid species, there are other species, including storage mites, in dwellings (Spieksma and Spieksma-Boezeman, 1967; Oshima, 1967 and 1970; Cunnington, 1967; Maunsell *et al.*, 1968; Colloff, 1987). However, detailed knowledge of the presence of storage mites in dwellings is probably incomplete since most were aimed at detecting Pyroglyphid mites so concentrated on the main foci of those mites, while other habitats were ignored.

Factors which influence the distribution of mites within homes

It is apparent that various mites species infesting dwellings occupy particular niches (Hughes, 1976; Cunnington, 1980; Spieksma, 1997). The house mite, *G. domesticus* as its name implies is a common inhabitant of dwellings. It is associated with damp conditions and often found on damp wall paper and windowsills. Under such ideal conditions, this mite can rapidly develop into enormous numbers (Cunnington, 1980). Variation in the occurrence of mites, in particular storage mites of the genera *Acarus*, *Tyrophagus* and *Glycyphagus*, is due in part to environmental factors (temperature and humidity) as dealt with in some detail by Wraith *et al.* (1979). In Brunei, with a warm and humid climate, dust from sleeping areas showed that storage mites especially Glycyphagid species were predominant in house dust (Woodcock and Cunnington, 1980). More recently, Thind and Dunn (1999) used a new flotation method to analyse 200 samples, each of up to 2 g of dust, from domestic premises. Approximately equal numbers of samples were taken from the bedrooms and the living rooms. They found a wider range of mite species in dust from living rooms (over 21 species) than in that from bedrooms (7 species). Pyroglyphid mites were predominant and constituted 90.8% and 87.8% of the mite population in dust collected from the bedroom and the living room. These samples also contained storage mites belonging to the families Acaridae and Glycyphagidae but in low numbers which constituted 9.1% and 12.1% of mite population in the bedroom and living room samples. Typical species found included *A. siro* (L.), *G. domesticus*, *L. destructor* (Schrank) and *T. putrescentiae* (Schrank).

Few surveys on mites in dwellings include the kitchen, even though this is an area with potentially favourable environmental factors and plenty of food for storage mites to persist and multiply. Eaton

et al. (1985) found frequent occurrences of storage mites in dry food stores (cupboards or larders) in rural dwellings in the UK. In some cases they found over 100 mites in the dust collected from food stores. Turner and Bishop (1998) surveyed domestic kitchen cupboards for psocids. They reported that 13.48% ($n = 727$) of the household kitchens also contained mites, even though the trap they used (dry yeast based requiring 14 days exposure) was not ideal for mite detection. They detected five species of storage mites, of which *Tyrophagus putrescentiae* was the most abundant ($n = 46$). Interestingly, they reported that the presence of mites correlated with storage location. Significantly more than expected floor-standing cupboards had mites than the wall-mounted cupboards. Although they could not find any obvious explanation for this finding, it is not unreasonable to speculate that the former are subjected to relatively cold air with higher moisture while the latter enjoy relatively warmer air with less moisture.

Evidence for storage mites on food

Recent evidence has proved that storage mites are not only present in kitchens, but in the food itself. Thind and Clarke (1999) analysed cereal-based food products including baby food, biscuits, breakfast cereals and flour for the presence of mites. They detected mites, predominantly of the genera *Acarus*, *Lepidoglyphus* and *Tyrophagus*, in 37% of 20 g samples of 423 products, which had been purchased at food retail outlets in the UK and were examined after six weeks of storage in volunteers' homes. This frequency of infestation was significantly greater (sign test; 5% level) than that found in samples examined soon after purchase at retail outlets (21% of 567 samples). However, funding limitations rendered it impossible to establish whether any of the products became infested during domestic storage. Circumstantial evidence suggested that in some samples of every type of food examined, some of the mites were alive immediately before analysis. Since the kitchen environment provides ideal warmth and humidity for storage mite development, numbers of mites could increase rapidly. Most of the infested samples had fewer than five mites but 4% had over 20 mites, and one had as many as 375 mites. Thus domestic exposure to storage mites must include the route of ingestion. In this regard it is of particular interest to note that the most infested sample of baby food contained 317 mites. Sporik *et al.* (1990) reported that exposure in early childhood to house dust mite allergens is an important determinant of the subsequent development of asthma. If this is also true for storage mites, and the number of mites is sufficient to result in sensitisation, then mite infestation of baby food, however caused, could have serious consequences.

The risk of ingestion of mites is not restricted to the UK, neither is it restricted to the domestic environment. Li and Li (1990) reported finding 10 species of storage and dust mites in the sputum of 49 sufferers of pulmonary acariasis working in either grain or herb storage in China. In Mexico, Quintero and Acevedo (1991) found *Carpoglyphus lactis* (L.), a mite associated with carbohydrate foods and dried fruits in 28 out of 84 samples of a fermented drink, and *T. putrescentiae* in 6 out of 10 samples of vinegar. More seriously, Matsumoto *et al.* (1996) report two cases of systemic anaphylaxis in children resulting from the ingestion of food contaminated with large numbers of the storage mite *T. putrescentiae* in Japan.

STORAGE MITE ALLERGENS AND THEIR CLINICAL SIGNIFICANCE

Differences in importance of allergens

Identification of the allergens responsible for illness is required before they can be measured to assess risk. Individual species of mite produce several hundreds of macromolecules capable of inducing allergic responses. Some are components of mite bodies. Others are secretory products. These vary in their allergenic potency and clinical importance. Some induce IgE-class antibody production in only a minority of individuals. Major allergens are defined as those inducing IgE responses in over 75% of sufferers (King *et al.*, 1994). Even then, there may be significant differences in their clinical significance. So for example, the first major house dust mite allergen described (and which is still assumed

by many to be its most important allergen), *Der p 1*, is now known to be clinically less important than *Der p 2*.

Western blotting has been used in recent years to identify and compare antibody responses to different mite constituents. In this procedure, the components of mite extracts are first separated according to molecular size by polyacrylamide gel electrophoresis. The separated components are then transferred to the surface of a nitrocellulose membrane, which immobilises them. When incubated with a patient's serum, antibodies specific to a particular protein will bind and can then be visualised using a labeled second antibody directed against human immunoglobulin.

Western blotting experiments by a number of groups (including ourselves) are in agreement, that the most important allergens of all the mite species studied are in the 13 to 18 kDa size range. The most important allergens of *Lepidoglyphus destructor*, *G. domesticus* and *T. putrescentiae* have significant sequence homology with *Der p 2* of house dust mites. Despite this, there is no antigenic cross-reactivity between the storage and dust mite allergens (van Hage-Hamsten *et al.*, 1987; Griffin *et al.*, 1989). There is cross-reactivity between the closely related species of *L. destructor* and *G. domesticus*, which do not cross-react with *T. putrescentiae* or *A. siro*. In contrast, the major 15 kDa allergen of *A. siro* has no homology with *Der p 2*, but it does show considerable homology with a 14.8 kDa major allergen of the tropical house mite *Blomia tropicalis* (van Bronswijk, de Cock, Oshima)(Eriksson, T. personal communication).

Differences in response to allergens

Approximately one third of all racial groups are atopic. That is, that they inherit the predisposition to produce antibodies of IgE class against common environmental allergens and thus develop the conditions of asthma, eczema and hay fever. A number of environmental factors influence the development of overt disease in this predisposed group.

We have screened 200 non-occupationally exposed suffers of allergic symptoms, attending at a UK allergy clinic and have found IgE antibody directed against one or more of four common storage mites in over 30%. It is important to emphasise that the clinical significance of this observation is uncertain at the present time. We do not know whether sensitisation is due to exposure by inhalation or ingestion, or whether it is causally related to any disease. While we know that ingestion of small amounts of storage mite products is probably common (Thind and Clarke, 1999), the vast majority of our subjects gave no history of food-related allergic manifestations.

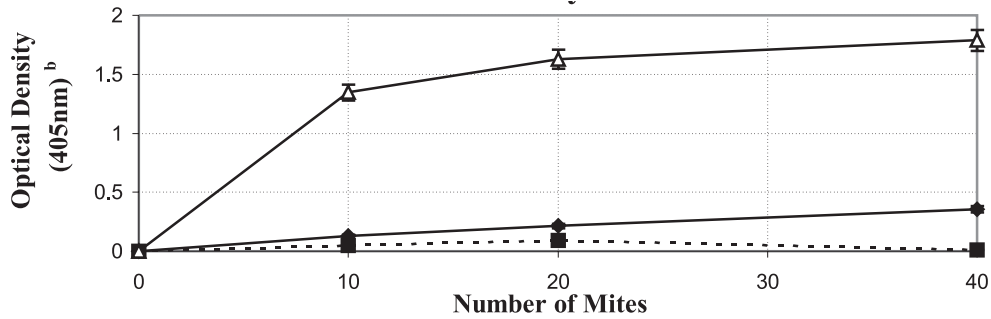
MEASUREMENT OF STORAGE MITE ALLERGEN LEVELS

The need for measurement of allergen levels

The ability to establish threshold levels of allergens for sensitisation and clinical effects is essential to be able to warn atopic patients about high-risk areas and to determine the need for, and effectiveness of, strategies to reduce the loading of allergen to safe levels. The dose-response relationship between allergen exposure and sensitization to house dust mites has been established (Chapman *et al.*, 1987; Luczynska *et al.*, 1989). From this, Platts-Mills *et al.* (1992) deduced theoretical thresholds, for example exposure to more than 2 mg *Der p 1*/g dust was presumed likely to result in sensitization. However, there are no data yet on the threshold levels of storage mite allergens. Given the increasing importance of occupational exposure to storage mites and, in particular, the increasing awareness of storage mite contamination of foodstuffs, establishing a method for the measurement of storage mite allergens, so that threshold levels for sensitisation could be determined, is now a priority.

Previous work on storage mite allergen measurement

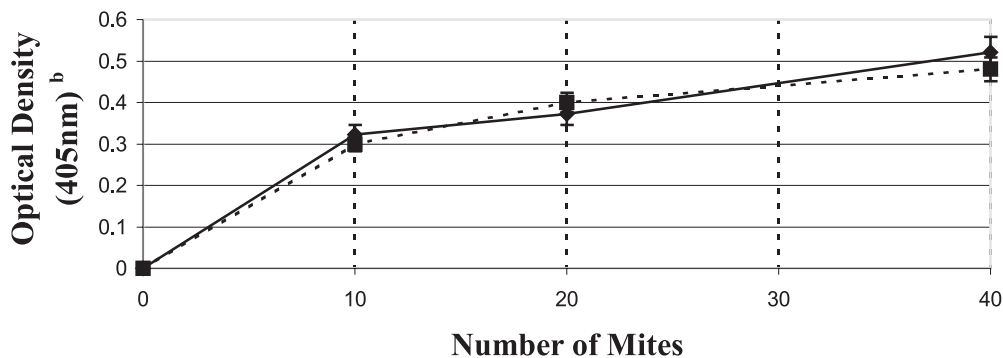
Direct measurement of allergens using specific antibodies by immunochemical methods such as radio-immunoassay (RIA) and enzyme-linked immunosorbent assay (ELISA) offers a technique which is sensitive, relatively cheap, easy to use and can be made available for on site use in kit form. This approach is the focus of current attention.



- △— Triple Antibody Sandwich ELISA
- ◆— Double Antibody Sandwich ELISA
- Indirect ELISA

^b(n=3), mean with standard error bars

Figure 1. Sensitivity of mAb 42B6 to two species of Glycyphagid mite ^a.



- ◆— *L. destructor*
- *G. domesticus*

^b(n=5), mean with standard error bars

Figure 2. Comparison of three different types of ELISA assays with known number of *L. destructor* mites in barley ^a.

Harfast *et al.* (1992) reported the use of an inhibition-ELISA assay to detect Glycyphagid and Acarid mites using a monoclonal antibody (mAb 42B6) which reacts with the carbohydrate part of 39 kDa glycoproteins. The same group (Harfast *et al.*, 1996) successfully used this antibody to determine levels of allergens from *L. destructor* in barn dust. Elsewhere, Stengard Hansen *et al.* (1996) obtained good correlation between the numbers of *L. destructor* in laboratory samples of grain and flour and the levels of the allergen *Lep d 1* determined by ELISA.

Recent progress in measurement of storage mite allergens

We have investigated the sensitivity of the monoclonal antibody raised by Harfast *et al.* (1992) and its selectivity to different species of arthropods at CSL by indirect ELISA (Harlow and Lane, 1988). The small size of the standard errors in Figure 1 shows that the sensitivity to the Glycyphagids *L. destructor* and *G. domesticus* is similar and far fewer than 10 mites. The allergen appeared to be present in Glycyphagid mites which had been dead for at least 10 days and in faecal pellets as well as in freshly killed

mites. This has previously been reported with Pyroglyphid mites (Tovey *et al.*, 1981). The allergen must be relatively stable and its presence in faeces suggests that it is involved with digestion, which supports the finding of van Hage-Hamsten *et al.* (1992). The ability to detect live mites, excretory products and dead mites could be an advantage because even in the absence of live mites, materials contaminated with dead mites or faecal pellets might still be hazardous to health.

Information on the selectivity of the antibody to various grain store pests and to house dust mite is presented in Table 2. This shows strong cross reactivity to the non-Glycyphagid mite *Aleuroglyphus ovatus* (Troupeau) and to a lesser extent to *Tyrophagus putrescentiae* and *A. siro*. There was very little reaction to the Pyroglyphid mite *D. pteronyssinus* or to the stored product insect, *Oryzaephilus surinamensis* (L.).

Table 1. Percentages of 36 farms (30 sheep and 6 dairy cattle) with the different numbers of mites found in the feedstuff, bedding and pasture samples.

Number of mites	Feedstuff samples (2 x 20g)	Bedding samples (2 x 20g)	Pasture samples (1 x 20g)
0	17	0	8
1-10	25	6	56
11-100	17	60	33
101-500	17	28	3
Over 500	24	6	0

Table 2. Reactivity of monoclonal antibody mAb 42B6 (Harfast *et al.*, 1992) to grain store pests and to house dust mite by indirect ELISA.

Species	Optical Density Value at 405 nm
<i>Lepidoglyphus destructor</i>	1.082
<i>Glycyphagus domesticus</i>	0.986
<i>Aleuroglyphus ovatus</i>	0.887
<i>Tyrophagus putrescentiae</i>	0.312
<i>Acarus siro</i>	0.246
<i>Dermatophagoides pteronyssinus</i>	0.007
<i>Oryzaephilus surinamensis</i>	0.025

The monoclonal antibody alone was unable to detect mites in grain using either indirect or double-antibody-sandwich ELISA methods. This was possibly due to non-specific binding to carbohydrates in the grain. However, when used in conjunction with a polyclonal antibody in a triple-antibody-sandwich ELISA (Harlow and Lane, 1988), quantification of *L. destructor* infested samples was achieved (Fig. 2).

A commercial assay is now available to quantitate an antigen in some foodstuffs specific to *L. destructor* and *G. domesticus* (Anonymous, 1999). Assays for allergens of at least two more species are expected to become available in the near future.

CONCLUSIONS AND FUTURE NEEDS

The recent evidence from the UK reported here demonstrates that storage mites are presently found in abundance in cereal stores and on farms rearing animals. The presence of these mites is not consistent with increasing demands from customers for food of high quality, free from contamination. The increasing difficulty of controlling these mites with conventional pesticides has reached the stage at which effective alternative approaches are needed urgently.

Although there have long been reports of storage mites in domestic premises, it is only relatively recently that firm evidence has been obtained for their presence in food. Even without knowing the proportion of occasions on which the ingestion of storage mites and their faeces affects human health, it can be argued that steps should be taken to avoid their presence. The first action must be to identify how they get into food. This information could then guide avoiding action which, given the proximity to consumption, is more likely to involve increased awareness, better hygiene and different storage practices in the home rather than chemical control.

Recent progress with immunoassay methods suggests that it should soon be possible to quantify the presence of those storage mite allergens which are likely to be most closely involved in causing clinical effects. Such methods will however require validation for allergen presence on various substrates including cereals and their rigour and selectivity will need to be understood to ensure that results obtained with them are properly interpreted.

We are currently performing graded oral provocation tests with storage mite extracts. These should allow us to establish the risk of reactions to ingestion and the oral allergen doses which trigger reactions. This information will at last establish the significance and relevance of both occupational and domestic exposures to storage mites. While establishing threshold levels for exposure to storage mite allergens will be a useful first step in defining and avoiding the medical risk of exposure, they are unlikely to be universally applicable because various factors are likely to influence the levels. Route of exposure, i.e. whether by inhalation or ingestion is one, while work by Munir *et al.* (1997) with house dust mites suggests that others are likely to be family history of allergy and even climate. It will therefore be essential to establish which factors influence threshold levels for exposure. Once this has been done, it will at last be possible to quantify the importance of storage mite allergens and take, where necessary, appropriate avoiding action.

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