



Mould biodiversity in homes II. Analysis of mattress dust

Hugues Beguin

Institute of Hygiene and Epidemiology, Section of Mycology, J. Wytsmanstreet 14, B-1050 Brussels, Belgium

Received 31 January 1994; accepted 23 September 1994

Abstract

Fungal species from 130 samples of mattress dust have been identified. The number of moulds varies from one mattress to another with extreme values ranging from less than 1000 to more than 70 000 000 CFU/g of dust (median value of 30 000 CFU/g). *Eurotium repens* is undoubtedly the most frequent species detected in mattress dust. *Aureobasidium pullulans*, *Alternaria alternata*, *Penicillium chrysogenum*, *Aspergillus penicilloides* and *Aspergillus restrictus*, which were frequently isolated and/or revealed important concentrations in dust samples, are the other main occurring species. Fungal flora in mattresses are more numerous in winter, the peak period being December–January. The most important contaminations by xerophilic species occurred during that peak period, whereas non-osmophilous species were constantly present during the year. The qualitative conditions of the habitat have an influence on the abundance of moulds in mattresses. Mattresses from damp houses could be a source for *Alternaria* throughout the year. No significant difference has been detected between the contamination level of men and women's mattresses ($P = 0.651$). Children's mattresses are less contaminated than adults ($P = 0.025$). The level of contamination could be affected by perspiration.

Keywords: Mould allergy; Fungi; Mattress; Dust; Dwelling; Home

1. Introduction

Moulds in homes are largely linked with the aetiology of asthma. Respiratory allergy to moulds could affect from 2 to 30% of the inhalation allergic population (Gravesen, 1979). The mycological analysis of the habitat is consequently important. To be complete, mattress dust must be included in this inquiry. Indeed, mattresses are known to host several types of moulds (van de Lustgraaf, 1977). In several studies, different types of mattresses or stuffing material have been compared in order to determine those which would be most receptive to moulds (Conant et al., 1936; van de Lustgraaf and Jorde, 1977).

Pyroglyphid mites and more especially their faeces are the primary source of antigen in mattress dust. The main antigen is a heat-labile glycoprotein (Der p1). Some moulds are not only potential antigens, but they can also stimulate the growth of these micro-organisms. For example, yeasts may be a source of vitamins for mites, and some microfungi may constitute a food supplement for them (Sinha et al., 1970; Chirilă et al., 1981; Andersen, 1985). They could also play a role in the food chain of these microarthropoda predigesting human dandruff (Bronswijk and Sinha, 1973; van de Lustgraaf, 1978).

Consequently mould suppression could provoke a decrease in mite population (Bronswijk and Koekkoek, 1971; de Saint Georges, 1981). As much information as possible should be given in order to eliminate moulds or to prevent their development.

The aim of the present study is to assess fungal contamination throughout the year according to the habitat and relate contamination to age or the sex of the mattress owner. The mattresses were selected on the basis of medical files of patients suffering from an allergy as described previously (Beguin and Nolard, 1994).

2. Materials and methods

2.1. Dust collection

Dust samples from 100 mattresses were collected in a wide range of houses and localities. Dust was sampled with a standard domestic vacuum cleaner (Miele type S 247i). The vacuum cleaner was fitted with a device containing a 5-cm diameter circular filter at the end of the hose in order to standardize sampling. The surface of either the right side or the left side of the mattress was vacuum cleaned for a minute at a suction rate of 1200 W. The filters were packed separately in clean plastic bags and kept at 5°C until dust analysis. Thirty-nine

children's mattresses and 61 adults' mattresses were sampled. Thirty double bed mattresses, however, were vacuum cleaned on both half-sides in order to make a comparison according to the patients' sex. One-hundred and thirty samples of dust were thus analyzed: 39 coming from children's mattresses, 39 samples from mattresses or sides belonging to a man and 52 dust samples coming from beds or sides belonging to a woman. Samples were taken from 17 August 1991 to 17 March 1993. The distribution, between spring and summer on the one hand (51 mattresses) and autumn and winter on the other hand (49 mattresses) with, respectively 67 and 63 dust samples for those two periods, is specified in Fig. 2 where the number of monthly mattresses is given.

2.2. Culture methods

Dust samples collected on the filter were put in suspension and shaken for 20 min in a watery solution of Tween 80 at 0.02%. The volume of this solution was adjusted in order to obtain a concentration of 10^{-2} g of dust/cc. The resulting suspension was subsequently diluted in sterile water in steps of 1:10. Aliquots of 1 cc from initial concentration and dilutions were added to Petri dishes. Media were then poured and the plates were rotated to mix medium and dust. The result is that, depending on the initial suspension, species at concentrations lower than 10^2 CFU/g were not counted. Three culture media with chloramphenicol (0.05%) added were used in parallel: MEA, M40Y (used by Raper and Fennel for the description of the osmophilous species of the genus *Aspergillus*) and M40Y + 5% NaCl (pH = 7). Schober (1988) favours the selection of the medium MEA + 40% sucrose. This medium reflects the qualitative and quantitative content of dust better than the same medium with 64% sucrose. MEA + 64% sucrose should be used to isolate xerophilic species among mesophilic species. The main difference between the medium MEA + 40% sucrose and M40Y is that the latter contains yeast extract at 5%, without any effect on the osmotic potential. The inoculated Petri dishes were then incubated at 25°C for a period ranging from 7 to 14 days. Results are given in CFU (fungal colony forming units). The colonies counted at each dilution are only taken into account if the previous dilutions or the corresponding dilution made on another medium confirms the results.

2.3. Statistics

The comparison of mould counts between men and women in double beds was performed with the Wilcoxon's matched pairs test with two-tailed *P*-values. The possible differences between the three groups of mattresses belonging to children, women and men were checked with the Mann-Whitney *U*-test.

3. Results

3.1. Number of CFU

A wide range in quantities of moulds were isolated ranging from less than 1000 CFU/g to 70 000 000 CFU/g of dust. The median value was 30 000 CFU/g. Fig. 1 categorizes mattress dust in accordance with the level of fungal contamination. More than 70% of the analyzed dust samples revealed less than 100 000 CFU/g.

3.2. Fungal identification

Table 1 shows the frequency of the different isolated moulds. Moulds which did not reveal high concentrations were not always identified up to species level. *Eurotium repens*, *Aureobasidium pullulans*, *Alternaria alternata*, *Penicillium chrysogenum* (many colonies completely colourless), *Epicoccum purpurescens*, *Aspergillus*

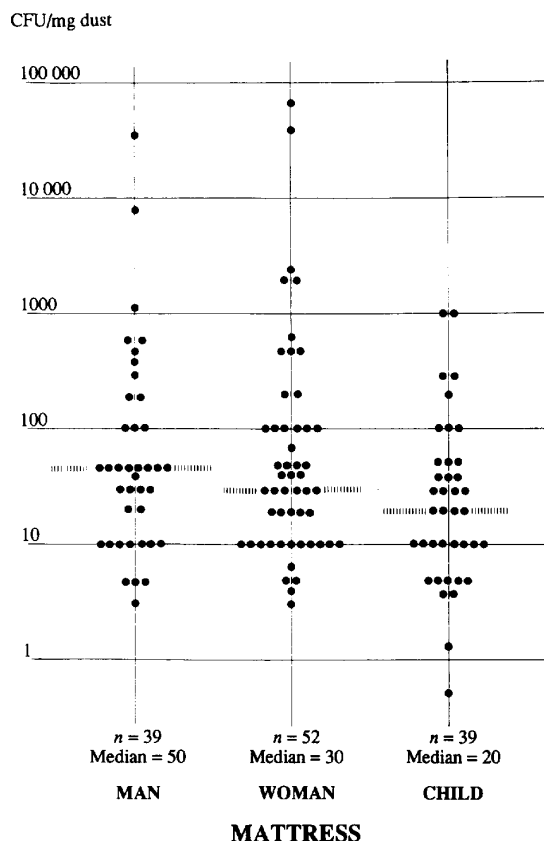


Fig. 1. Distribution of total fungal CFU in dust samples from men, women and children's mattresses. The horizontal lines indicate the medians. Range in moulds count: lowest, <1000 CFU/g; highest, 70 000 000 CFU/g. Median level of contamination by moulds from 130 samples: 30 000 CFU/g.

Table 1
Fungi isolated from 130 samples of mattress dust

Species	% of mattresses with $\geq 10^5$ CFU/g	% of dust samples	Upper range (CFU/g)
<i>Absidia corymbifera</i>	1	3.84	10^5
<i>Acremonium charticola</i>	1	1.53	10^5
<i>Acremonium strictum</i>		1.53	10^4
<i>Acremonium</i> spp.		6.92	10^4
<i>Acrodontium salmoneum</i>		0.76	10^4
<i>Alternaria alternata</i> gr.		50.76	10^4
<i>Aposphaeria</i> sp.		0.76	10^4
<i>Arthrinium phaeospermum</i>		1.53	10^4
<i>Ascochyta</i> sp.		0.76	10^4
<i>Aspergillus candidus</i>		1.53	10^2
<i>Aspergillus fumigatus</i>		12.30	10^3
<i>Aspergillus niger</i>		23.07	10^4
<i>Aspergillus ochraceus</i>		2.30	10^4
<i>Aspergillus penicilloides</i>	9	12.30	7×10^7
<i>Aspergillus restrictus</i>	4	15.38	4×10^7
<i>Aspergillus sydowi</i>		2.30	10^4
<i>Aspergillus tamarii</i>		6.15	10^4
<i>Aspergillus terreus</i>		0.76	10^2
<i>Aspergillus unguis</i>		2.30	10^4
<i>Aspergillus ustus</i>		0.76	10^2
<i>Aspergillus versicolor</i>	3	25.38	2×10^6
<i>Aureobasidium pullulans</i> var. pullulans	6	66.92	2×10^5
<i>Botryotrichum</i> sp.		2.30	10^3
<i>Botrytis cinerea</i>		13.07	10^2
<i>Candida parapsilosis</i>	2	5.38	4×10^5
<i>Chaetomium globosum</i>		2.30	10^4
<i>Chaetomium indicum</i>		0.76	10^3
<i>Chaetomium</i> spp.		6.92	10^2
<i>Cladosporium cladosporioides</i>		4.61	10^4
<i>Cladosporium herbarum</i>		10.76	10^4
<i>Cladosporium sphaerospermum</i>	1	23.84	10^5
<i>Cladosporium</i> spp.		7.69	10^3
<i>Coniothyrium fuckelii</i>		0.76	10^4
<i>Coniothyrium</i> sp.		0.76	10^4
<i>Cryptococcus albidus</i>		1.53	10^4
<i>Cryptococcus laurentii</i>		1.53	10^4
<i>Debaryomyces hansenei</i>	3	2.30	10^6
<i>Doratomyces</i> sp.		0.76	10^2
<i>Drechslera erythrospila</i>		0.76	10^4
<i>Drechslera</i> sp.		0.76	10^2
<i>Emericella nidulans</i>		0.76	10^2
<i>Epicoccum purpurescens</i>		26.92	10^4
<i>Eurotium chevalieri</i>		3.07	10^3
<i>Eurotium amstelodami</i>		2.30	10^3
<i>Eurotium repens</i>	4	71.53	2×10^5
<i>Eurotium ruber</i>		1.53	10^3
<i>Exophiala jeanselmei</i>		1.53	10^4
<i>Fusarium culmorum</i>		2.30	10^4
<i>Fusarium merismoides</i>		0.76	10^4
<i>Fusarium nivale</i>		0.76	10^4
<i>Fusarium solani</i>		0.76	10^3
<i>Fusarium verticillioides</i>		0.76	10^3
<i>Fusarium</i> spp.		4.61	10^3
<i>Geomyces pannorum</i>		0.76	10^4
<i>Gliocladium roseum</i>		0.76	10^3
<i>Gliomastix murorum</i>		0.76	10^2
<i>Gliomastix murorum</i> var. felina		0.76	10^2
<i>Khuyveromyces marxianus</i>		0.76	10^4
<i>Microdochium</i> sp.		0.76	10^3

Table 1 (Continued)

Species	% of mattresses with $\geq 10^5$ CFU/g	% of dust samples	Upper range (CFU/g)
<i>Monilia sitophila</i>		0.76	10^3
<i>Mucor circinelloides</i>		14.61	10^4
<i>Mucor hiemalis</i> f. <i>hiemalis</i>		2.30	10^3
<i>Mucor racemosus</i>		0.76	10^3
<i>Mucor</i> spp.		31.53	10^4
<i>Myrothecium roridum</i>	1	0.76	2×10^5
<i>Paecilomyces marquandii</i>		0.76	10^4
<i>Papularia arundinis</i>		0.76	10^4
<i>Penicillium aurantiogriseum</i>		7.69	10^4
<i>Penicillium brevicompactum</i>		6.15	10^4
<i>Penicillium chrysogenum</i>	6	33.84	2×10^5
<i>Penicillium corylophilum</i>		2.30	10^4
<i>Penicillium digitatum</i>		1.53	10^4
<i>Penicillium italicum</i>		0.76	10^3
<i>Penicillium rugulosum</i>		3.07	10^4
<i>Penicillium spinulosum</i>		2.30	10^4
<i>Penicillium waksmanii</i>		0.76	10^4
<i>Penicillium</i> spp.		60.00	10^4
<i>Phaeococcomyces exophialae</i>		0.76	10^4
<i>Phialophora radicola</i>	1	0.76	10^5
<i>Phoma herbarum</i>	2	7.69	6×10^5
<i>Phoma</i> spp.		20.00	10^4
<i>Pithomyces chartarum</i>		25.38	10^4
<i>Pleospora herbarum</i>		6.15	10^4
<i>Pyrenochaeta</i> sp.		0.76	10^4
<i>Ramularia</i> sp.		0.76	10^2
<i>Rhizopus oryzae</i>		0.76	10^2
<i>Rhizopus stolonifer</i>		24.61	10^4
<i>Rhodotorula graminis</i>		0.76	10^4
<i>Rhodotorula mucilaginosa</i>	2	1.53	10^6
<i>Rollandina hyalinospora</i>		0.76	10^3
<i>Saccharomyces cerevisiae</i>	1	0.76	10^5
<i>Scopulariopsis brevicaulis</i>	1	3.84	2×10^5
<i>Scopulariopsis candida</i>		0.76	10^4
<i>Scopulariopsis fusca</i>		1.53	10^3
<i>Scopulariopsis</i> spp.		8.46	10^4
<i>Sporothrix</i> sp.		1.53	10^2
<i>Stachybotrys atra</i>		1.53	10^2
<i>Syncephalastrum racemosum</i>		2.30	10^3
<i>Trichoderma harzianum</i>		2.30	10^4
<i>Trichoderma pseudokoningii</i>		0.76	10^3
<i>Trichoderma viride</i>		0.76	10^4
<i>Trichoderma</i> spp.		28.46	10^3
<i>Trichophyton mentagrophytes</i> var. <i>interdigitale</i>		1.53	10^4
<i>Trichosporon cutaneum</i>		1.53	10^4
<i>Trichothecium roseum</i>		2.30	10^3
<i>Tripaspermum myrtii</i>		0.76	10^4
<i>Ulocladium botrytis</i>	1	20.00	10^5
<i>Ustilaginales</i> anamorph of	1	0.76	5×10^5
<i>Verticillium dahliae</i>		2.30	10^4
<i>Wallemia sebi</i>	1	16.92	5×10^5

Sterile mycelia have not been taken into consideration.

versicolor, *Pithomyces chartarum*, and *Cladosporium sphaerospermum* occurred most frequently. Several species of *Mucorales* and *Trichoderma* were also detected. *Aspergillus penicilloides* and *Aspergillus restrictus* were

the most important contaminants, with upper range, respectively 7×10^7 and 4×10^7 CFU/g. Some results were surprising. *A. alternata*, *E. purpureus*, and *P. chartarum* occurred quite frequently, often with

noticeable quantities. On the contrary, *Aspergillus fumigatus* was rather rare and detected in small quantities.

Dilution techniques mainly reveal the most numerous moulds in dust. The others will be selected according to the antagonists present in the samples. The competition and inhibition phenomena occur mainly in the initial concentration and in low dilutions and will cause absence in some counts. On the basis of the results, moulds isolated from the third dilution, corresponding to 10^5 CFU/g, are estimated more or less independent from these phenomena. This dilution was chosen arbitrarily in order to distinguish weakly or moderately contaminated mattresses from those abnormally or heavily contaminated.

Comparison of the total number of colonies, isolated by both high osmotic pressure media, showed that the salt medium revealed more colonies of *A. penicilloides* and *A. restrictus* than the M40Y medium: *A. penicilloides* c. 850×10^5 vs. c. 154×10^5 (5.5 times more), and for *A. restrictus* c. 807×10^5 vs. c. 177×10^5 (4.5 times more). Furthermore, among 15 dust samples collected on 12 mattresses, where *A. penicilloides* and/or *A. restrictus* had a concentration equal or superior to 100 000 CFU/g (Table 2), four did not reveal xerophilic moulds on M40Y medium.

3.3. Environmental conditions

Table 1 shows, in bold, the species found at concentrations equal to or higher than 10^5 CFU/g. The main species were *A. penicilloides*, *A. pullulans*, *A. restrictus* and *P. chrysogenum*, present at these concentrations, in, respectively eleven, eight, six and six samples. Very special local conditions may be at the origin of these species and their prevalence in mattresses. For instance two mattresses, contaminated by *A. penicilloides*, came from the same home. According to the cases analyzed, with the methodology described previously (Beguin and Nolard, 1994), the same moulds, as those found in the mattresses, were also detected in the air or surface sampling of the atopic patient's home (air and surface sampling were conducted before vacuum cleaning). For example, among the species found at $\geq 10^5$ CFU/g, in bold in Table 1, *Absidia corymbifera* was isolated in the bedroom air (75 CFU/m³ air); *Acremonium charticola* on a bedroom wall; *A. versicolor* in the bedroom air, on the furniture and even in other rooms of the home; *Phoma herbarum* was isolated with a swab on the bedroom window frame; *A. restrictus* was detected in the bedroom and bathroom air (175 CFU/m³ of air); *Debaryomyces hansenei* in the parents' mattress and in their child's bedroom, in the mattress and on the furniture; and finally, still in Table 1, the anamorph of *Ustilaginales* with a concentration level comparable, in mattress dust, from the woman's side and the man's side, and in the carpet dust of the staircase. (The tax-

Table 2
Distribution of mattresses according to season

Isolated species or group of species in each mattress at a level of contamination $\geq 100\ 000$ CFU/g dust	Number of mattresses	
	Autumn– winter	Spring– summer
<i>A. charticola</i>	1	—
<i>P. radicola</i>	1	—
<i>P. herbarum</i>	1	—
<i>P. herbarum</i> , <i>R. rubra</i>	1	—
<i>P. chrysogenum</i>	—	1
<i>P. chrysogenum</i> , <i>A. versicolor</i> , <i>S. brevicaulis</i>	—	1
<i>C. parapsilosis</i> , <i>C. sphaerospermum</i> , <i>S. cerevisiae</i>	—	1
<i>M. roridum</i>	—	1
<i>D. hansenei</i>	1	—
<i>A. pullulans</i>	—	4
<i>A. pullulans</i> , <i>C. parapsilosis</i>	—	1
<i>A. pullulans</i> , anamorph of <i>Ustilaginales</i> , <i>P. chrysogenum</i>	1	—
<i>A. repens</i> , <i>A. corymbifera</i>	1	—
<i>A. repens</i> , <i>D. hansenei</i>	—	1
<i>A. restrictus</i>	1	—
<i>A. restrictus</i> , <i>D. hansenei</i>	1	—
<i>A. restrictus</i> , <i>W. sebi</i> , <i>A. repens</i> , <i>A. versicolor</i>	1	—
<i>A. penicilloides</i>	4	—
<i>A. penicilloides</i> , <i>A. restrictus</i>	1	—
<i>A. penicilloides</i> , <i>P. chrysogenum</i>	2	—
<i>A. penicilloides</i> , <i>R. rubra</i>	1	—
<i>A. penicilloides</i> , <i>A. repens</i> , <i>A. versicolor</i> , <i>P. chrysogenum</i> , <i>U. botrytis</i>	1	—

onomy of anamorph species belonging to the group ustilaginoid yeasts is hampered by lack of sufficient specific characters) Contamination of human origin can also explain the presence of some species. *Candida parapsilosis* was detected in a home, at the same time in a sofa bed and in the double bed mattress. This species, agent of candidosis, is associated with mouth, vagina, external ear, skin or nail infections.

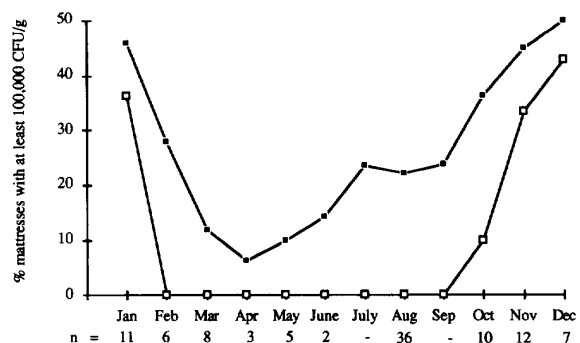


Fig. 2. Seasonal variations of fungi in mattresses. ■, simple moving average ratio of mattresses with a contamination by total all moulds; □, ratio of mattresses with a contamination by *A. penicilloides* and/or *A. restrictus*; n, number of monthly mattresses.

3.4. Seasonal distribution

Twenty-nine mattresses revealed an important contamination, equal to or higher than 100 000 CFU/g, by one or several species. At this concentration, a mattress can still be contaminated jointly by several species. The taxa are listed in Table 2. The mattresses are divided according to the period when dust samples were collected, in either autumn–winter or spring–summer. The seasonal distribution was uneven since 19 mattresses revealed a contamination $\geq 10^5$ CFU/g for the autumn–winter period and 10 for the spring–summer period. This means that 38.77% of the dust mattresses, analysed during the autumn–winter period, were contaminated at $\geq 10^5$ CFU/g vs. 19.60% in spring–summer period.

Well-known xerophilic species, *A. penicilloides* and *A. restrictus*, present at these concentrations, were always found during the autumn–winter period. Those two species are therefore responsible for the highest contaminations. The species *Aureobasidium pullulans* was mainly found in summer. Moulds were more numerous in December–January. Fig. 2 represents the seasonal fluctuations of moulds in mattresses. Important contaminations by xerophilic species were exclusively detected during the coldest months. It should be noted that the xerophilic moulds, that are not reported on the graph during spring and summer, actually occur in lower concentrations (see respective frequencies).

3.5. Comparison according to sex or age

Double beds are ideal to compare possible differences according to the sex of the person. Indeed, double mattresses can show a more important fungal contamination on one side than on the other. This difference could be attributed to the person sleeping in the bed since environmental factors are the same for both sides of the mattress. Twenty mattresses out of 30 revealed an asymmetric contamination level. The Wilcoxon's matched pairs test was used to show that there is no significant difference between the fungus contamination level on the women's sides and the men's sides ($T = 96$; $P > 0.05$). That was confirmed by looking at the results for all the mattresses analysed, independently from the stuffing components and various types of environments. After log-transformation, the data were checked with the Kolmogorov–Smirnov test and appeared not to have a normal distribution ($P = 0.001$). Therefore, the nonparametric Mann–Whitney U -test was used to test whether the contamination levels according to men, women and children's mattresses were similar. The concentrations of moulds did not differ significantly when mattresses from men and women were compared ($z = -0.452$; $P = 0.651$). On the other hand, contamination levels of the adults' mattresses were significantly higher than those of the children ($z = -2.232$; $P = 0.025$).

4. Discussion

Independently from the medium, it should be emphasized that, for the same mattress, the isolated quantities of fungi will depend on the power of the vacuum cleaner and the characteristics of the filters used. Among the xerophilic species showing salt medium preference, *A. penicilloides* and *A. restrictus* could reach very high concentrations in mattresses whereas *Wallemia sebi*, which is a less ubiquitous fungus, only reached 5×10^5 CFU/g. Little attention has been given to the quantities of moulds found in mattresses. Values from 200 to more than 6000 CFU/g reported by Mallea (1974) cannot be compared since the samples were collected by sweeping methods. As for van de Lustgraaf (1978), he relates a maximum of 3.8×10^4 diaspores/g of dust.

The number of propagules in the air within homes may fluctuate sharply in the course of the day, apparently increasing when the amount of physical activity within the home increases (Sweably and Christensen, 1952). Also, environmental conditions may provoke spore occurrence in the air (Pasanen et al., 1991). The counting of species in dust samples is thus more independent from the time of sampling. Some species are found whose spores may remain inactive as a consequence of a previous sedimentation of airborne fungal spores, and others which actually develop there. The spores of the former known as 'inhibited survival' can immediately germinate in good conditions but they remain inhibited in the mattresses because their environment is inadequate. Some species are not detected in mattress dust, probably owing to the fact that the viability of cells, spores or conidies is rapidly lost in the hard mattress conditions. For Coleman et al. (1975), microbial antagonisms were suggested as factors in the limited host-free survival of *Candida albicans* in sewage. This mechanism probably explains why *C. albicans* was not detected in the cultures. *Cladosporium herbarum*, which is plentiful indoors when air exchanges with outdoors is favourable, is virtually not represented in this survey. Obviously, this species does not grow in beds. Indeed, it has never been isolated in somewhat high dilutions. Davies (1960) suggests that it would seem more probable that *Cladosporium* spores lose their ability to germinate in house dust. From Gravesen (1978), it is remarkable that *Cladosporium* which was recorded 100% in the air sampling only occurred in 53% of the dust samples.

van Reenen-Hoekstra et al. (1993) found that *Phoma* and *Scopulariopsis* occurred more frequently in dust from mattresses than from floors. According to Hyvärinen et al. (1993), *A. pullulans* would occur more frequently in dust than in the air. Looking at the concentrations and their predilection for a substrate, their growth in mattresses is certain. *A. alternata* is more frequently detected in mattresses than in the air within the

home. According to Wickman et al. (1992), *A. alternata* would be listed second immediately after *Penicillium*, and its growth would be more prevalent in dust samples from homes with, rather than in homes without, additional mineral-wool insulation. The growth of *A. alternata* in mattresses is certainly limited because of its need for water. However, in some cases, it is detected up to a 10^4 CFU/g concentration.

Seasonal fluctuations noted for fungi may suggest that weather conditions even inside the home may have an impact. As far as mesophilic moulds are concerned, Andersen (1985) analyzed dust samples coming from two beds every month for a year and detected that *Penicillium* occurred almost constantly during the year while *Cladosporium* and *Alternaria* showed significant seasonal variations. van de Lustgraaf (1978) reported that dust mites and xerophilic moulds showed seasonal variations with a peak (lower than 10^5 CFU/g) which extended from 17 June to 15 August; and, the number of xerophilic *Aspergillus* was minimal from October to the end of May. Furthermore, his survey was based on the analysis of five mattresses all coming from the same cottage. His results may thus depend very much on a distinct environment.

The correlation of mould colony counts with total mite content suggests that similar environmental conditions such as temperature and humidity may promote growth of each (Wood et al., 1988). Reiser et al. (1990) revealed the possible incidence of humidity in bedroom walls on mites in mattresses. Humidity in bedroom walls may influence the level of Der p1 antigen and is closely related to relative humidity and absolute humidity. Humidity in walls would decrease with central heating or single glazing. After a month interval, the level of Der p1 antigen is maximum when the humidity in the walls reaches the maximum level, that is to say between November and February. This period corresponds to the one observed for moulds in the present study where mattresses are coming from various environments. It corresponds to the coldest period of the year when in general people are reluctant to air their rooms, thus keeping humidity inside their homes.

Apart from inter- or intra-specific competition, the physico-chemical factors of a particular niche may determine the species that colonize it. The material used to make the mattresses, temperature and the humidity of the nearby environment are the main factors responsible for the differences observed in species. The interaction of various factors such as the relative humidity (RH) of the outdoor air, the water excretion of the skin and lungs and also more local conditions (north-facing aspect of the house, ventilation, central heating, etc.) may influence the RH of mattresses and consequently the importance of the fungal contamination. The RH of the air may vary according to the region and also to the

period in the year. In Belgium, on the basis of a 7-year survey, the maximum RH would be reached in November–January depending on the region, whereas the minimum would be in April, May, July and August (Debontridder, 1992).

In dust, humidity, more particularly, affects not only the fungal growth and the sporulation, but also determines the prevalence of species. Davies (1960) reported that, at 85% RH and below, *E. repens* was the dominant species, but above 85%, more species developed and an ecological succession occurred. Table 2 shows that species responsible for large contaminations may vary according to the period related to the RH of the mattresses. Indeed, two types of contamination can be observed: the mesophilic species occurring throughout the year, and species limited to autumn and winter. The latter are xerophilic species which could be associated with species not requiring high RH from the substrate. One can thus imagine the following scenario. During the year, except during the coldest months when homes are heated, the RH of the rooms mainly depends on the outdoor air, and would be too important for xerophilic species to compete with mesophilic species. In summer the RH of the outdoor air decreases, thus allowing xerophilic species to grow. Concentrations of xerophilic species detected at that period (as in van de Lustgraaf's study, 1978) are lower than 10^5 CFU/g and are thus not yet optimal. The lack of sampling in July should be without effect on the period of the highest contaminations. During the colder months, the RH increases since humidity caused by people and their activity is not always evacuated. Either the homes are heated and ventilated and the RH of the mattresses can reach the extreme values of RH, thus allowing xerophilic species to grow in high concentrations (antagonists would be less severe and less numerous); or the homes are damp (no heating or insufficient heating, ill-conceived insulation, double glazing associated with poor ventilation, etc.), and the RH of the mattresses is high enough to maintain the growth of mesophilic species.

Humidity in homes may thus reduce or annihilate the seasonal variations of some mesophilic species. More moulds can be observed and under these conditions mesophilic species may develop in mattresses all year round. It is suggested that the genus *Alternaria* may develop in mattresses considering its high frequency in mattress dust and its concentration (Andersen, 1985; van Reenen-Hoekstra et al., 1993). Seasonal fluctuations may be reduced or eliminated according to the type of dwelling, and *Alternaria* could then be found all year round. This possibility should be investigated further since *Alternaria* is known to be one of the main genera implicated in respiratory allergy. To sum up, the peak of xerophilic species can be either in summer related to the RH of the outdoor air, or in the cold period

depending then on the local conditions found in the home. The most important contaminations are generated by the second situation.

5. Conclusions

There is a wide variety of mattress moulds. Some may develop in high concentrations. The absence or the presence of humidity associated with heating are the main factors of fungal growth in mattresses. The humidity of the bedroom may influence the contamination level of mattresses by microorganisms. In order to reduce dust allergens in mattresses, some people recommend regular vacuum cleaning. With this objective mind, Rao et al. (1975) have suggested frequent changing and washing of bed linen and brushing and cleaning of mattresses to prevent mite infestation. Chemical extermination products are largely used nowadays but the efficiency of fungicides and acaricidal products as well as their fungistatic activity depends on the recommendations and measures mentioned above. It should be noted that several cases of asthma have already been reported following the use of these products (Wolf, 1992; Shelton et al., 1992). Finally, the development of sensible and comfortable covers, impermeable to all particulate matter but permeable to water vapour (Owen, 1990), should be considered as a means to fight microorganisms in mattresses.

References

- Andersen, A. (1985) Microfungi in beds and their relation to house-dust mites. *Grana* 24, 55–59.
- Beguin, H. and Noland, N. (1994) Mould biodiversity in homes I. Air and surface analysis of 130 dwellings. *Aerobiologia* 10, 157–166.
- Bronswijk, J.E.M.H. van and Koekkoek, H.H. (1971) Nipagin (*p*-methyl hydroxy benzoate) as a pesticide against a house dust mite *Dermatophagoides pteronyssinus*. *J. Med. Entomol.* 8, 748.
- Bronswijk, J.E.M.H. van and Sinha, R.N. (1973) Role of fungi in the survival of *Dermatophagoides* (Acarina: Pyroglyphidae) in house-dust environment. *Environ. Entomol.* 2(1), 142–145.
- Chirilă, M., Capetti, E. and Bănescu, O. (1981) The relationship between air-borne fungal spores and *Dermatophagoides pteronyssinus* in the house dust. *Rev. Roum. Med-Med. Intern.* 19, 73–77.
- Coleman, A., Cook, W.L. and Ahearn, D.G. (1975) Abstracts of Annual Meeting of the American Society of Microbiology, N20, 187.
- Conant, N.F., Wagner, H.C. and Rackemann, F.M. (1936) Fungi found in pillows, mattresses, and furniture. *J. Allergy* 7, 234–237.
- Davies, R.R. (1960) Viable moulds in house dust. *Trans. Br. Mycol. Soc.* 43(4), 617–630.
- Debontridder, L. (1992) L'humidité relative de l'air en Belgique. Période de référence 1985–1991 = 7 ans. Institut Royal Météorologique de Belgique-Climatologie.
- Gravesen, S. (1978) Identification and prevalence of culturable mesophilic microfungi in house dust from 100 Danish homes. Comparison between airborne and dust-bound fungi. *Allergy* 33, 268–272.
- Gravesen, S. (1979) Fungi as a cause of allergic disease. *Allergy* 34, 135–154.
- Hyvärinen, A., Reponen, T., Husman, T., Ruuskanen, J. and Nevalainen, A. (1993) Composition of fungal flora in mold problem houses determined with four different methods. *Indoor Air '93, Proceedings of the International Conference on Indoor Air Quality and Climate, Helsinki, Vol. 4*, pp. 273–278.
- Lustgraaf, B. van de (1977) Xerophilic fungi in mattress dust. *Mykosen* 20(3), 101–106.
- Lustgraaf, B. van de (1978) Seasonal abundance of Xerophilic fungi and house-dust mites (Acarida: Pyroglyphidae) in mattress dust. *Oecologia (Berl.)* 36, 81–91.
- Lustgraaf, B. van de and Jorde, W. (1977) Pyroglyphid mites, xerophilic fungi and allergenic activity in dust from hospital mattresses. *Acta Allergol.* 32, 406–412.
- Mallea, M. (1974) Etude des moisissures contenues dans les poussières de matelas. Comparaison avec les moisissures des habitations. *Rev. Franç. Allergol.* 14(1), 31–36.
- Owen, S. (1990) Control of house dust mite antigen in bedding. *Lancet* 335, 396–397.
- Pasanen, A.-L., Pasanen, P., Jantunen, M.J. and Kalliokoski, P. (1991) Significance of air humidity and air velocity for fungal spore release into the air. *Atmos. Environ.* 25A(2), 459–462.
- Rao, V.R.M., Dean, B.V., Seaton, A. and Williams, D.A. (1975) A comparison of mite populations in mattress dust from hospital and from private houses in Cardiff, Wales. *Clin. Allergy* 5, 209–215.
- Reenen-Hoekstra, E.S. van, Samson, R.A. and Verhoeff, A.P. (1993) Comparison of the media DG18 and V8-juice agar for the detection and isolation of fungi in house dust. *Indoor Air '93, Proceedings of the International Conference on Indoor Air Quality and Climate, Helsinki, Vol. 4*, pp. 285–289.
- Reiser, J., Ingram, D., Mitchell, E.B. and Warner, J.O. (1990) House dust mite allergen levels and anti-mite mattress spray (natamycin) in the treatment of childhood asthma. *Clin. Allergy* 20, 561–567.
- Saint-Georges-Grédelet, D. de (1981) Mise au point d'une stratégie de contrôle de l'acarien des poussières (*Dermatophagoides pteronyssinus*) par l'utilisation d'un fongicide. *Acta Oecol. Appl.* 2(2), 117–126.
- Schober, G. (1988) Der Einfluss der Wasseraktivität des Nährmediums auf die Ausbeute von Schimmelpilzen in Staubproben. *Mycoses* 31(5), 255–258.
- Shelton, D., Urch, B. and Tarlo, S.M. (1992) Occupational asthma induced by a carpet fungicide-tributyl tin oxide. *J. Allergy Clin. Immunol.* 90(2), 274–275.
- Sinha, R.N., Bronswijk, J.E.M.H. van and Wallace, H.A.H. (1970) House dust allergy, mites and their fungal associations. *Can. Med. Assoc. J.* 103, 300–301.
- Swaeby, M.A. and Christensen, C.M. (1952) Molds in house dust, furniture stuffing and in the air within homes. *J. Allergy* 23, 370–374.
- Wickman, M., Gravesen, S., Nordvall, S.L., Pershagen, G. and Sundell, J. (1992) Indoor viable dust-bound microfungi in relation to residential characteristics, living habits, and symptoms in atopic and control children. *J. Allergy Clin. Immunol.* 89(3), 752–759.
- Wolf, S.I. (1992) Suffocating odor and asthma after Acarosol-powder carpet treatment. *J. Allergy Clin. Immunol.* 89(1), 637–638.
- Wood, R.A., Eggleston, P.A., Lind, P., Ingemann, L., Schwartz, B., Gravesen, S., Terry, D., Wheeler, B. and Adkinson, N.F. (1988) Antigenic analysis of household dust samples. *Am. Rev. Respir. Dis.* 137, 358–363.