

Fungi in carpeting and furniture dust

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The qualitative and quantitative species composition of fungi in carpets and upholstered furniture dust found in the living-rooms of nine Dutch dwellings was examined in a pilot study. Numbers of spores of xerophilic fungi did not differ in dust removed from carpeting and upholstery. Spores of hydrophilic species were found to be more predominant on floors ($P < 0.05$), whereas meso-hygrophilic spores, largely dominated by allergologically relevant *Penicillium* species, were significantly more abundant in dust taken from regularly used furniture ($P < 0.05$). Our results indicate that growth conditions for fungi in the micro-habitats of furniture differ from those in carpeting. No statistically significant differences in number of viable spores have been found in samples taken from ground-floor level compared with those taken from 1st to 3rd floor level of dwellings. From this study, the need for a micro-topographic analysis of the fungal flora in the human environment has become apparent. Efficient allergological home sanitation in dwellings of allergic patients requires detailed data about the colonization of the various micro-habitats by allergenic fungi.

Key words: allergens; fungi; home sanitation; house dust; micro habitat.

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A variety of fungal species are known as sources of allergens (9). Ten to 32% of all asthmatics are sensitive to fungal allergens liable to be encountered both outdoors and in the home environment (3). Allergological home sanitation, as advocated, includes avoidance measures that aim at reducing the fungal flora by lowering the humidity inside dwellings or by chemical extermination (18). Xerophilic and meso-hygrophilic species of the genera *Aspergillus* and *Penicillium* are considered to constitute house dust inhabitants (2). These fungi are able to grow and to sporulate below relative humidities (RH) of 80% (xerophilic) or from 80% to 90% RH (meso-hygrophilic). In addition, diaspores of allochthonic fungi penetrate the home together with the fresh air. During frost-free periods, indoor levels of spores, especially of *Cladosporium* and *Alternaria*, constitute 25% of the numbers found in the

outside air (19). The majority of these fungi are unable to propagate under normally dry domestic conditions, but in damp buildings they colonize the more hygroscopic materials (6, 9) and contribute towards the allergenic load of the atopic patient. A pilot study was started to examine the qualitative and quantitative aspects of the species composition in carpeting and upholstered furniture dust taken from the living-rooms of nine Dutch dwellings.

MATERIAL AND METHODS

Experiments were conducted in nine living-rooms of dwellings in the city and the surroundings of Utrecht (The Netherlands) during late summer. Four living-rooms were situated on the ground-floor level of tenement houses, whereas the remaining rooms were located on the 1st to 3rd floor of tenements. All these dwellings were considered

Table 1

Fungal taxa found on carpeting and furniture in living-room floors in 9 dwellings

Taxa	Carpeting	Furniture
Xerophilic species		
<i>Aspergillus glaucus</i> group	+	+
<i>Aspergillus restrictus</i> group	+	+
<i>A. ochraceus</i> Wilhelm	+	-
<i>A. sydowii</i> Thom & Church	+	-
<i>A. versicolor</i> Tiraboschi	+	+
<i>Wallemia sebi</i> von Arx	+	+
Meso-hygrophilic species		
<i>A. flavipes</i> Thom & Church	-	+
<i>A. niger</i> Van Tieghem	+	-
<i>A. terreus</i> Thom	+	-
<i>Mucor</i> Micheli ex Fries	-	+
<i>Penicillium brevicompactum</i> Dierks	+	+
<i>P. chrysogenum</i> Thom	+	+
Hydrophilic species		
<i>Alternaria</i> Nees ex Wallroth	+	+
<i>Cladosporium</i> Link ex Fries	+	+
<i>Rhizopus stolonifer</i> Lindner	+	-
No. taxa	13	10

to constitute “dry” homes without any sign of dampness problems or mould damage.

Sampling of carpeting and furniture dust was performed using heat sterilized bags and a vacuum-cleaner (Hoover 2907 A) for at least 10 min ($> 1 \text{ min/m}^2$ surface area). Fungal analysis was performed in duplicate with a dilution plate method (2, 12). By adding 40% sucrose to malt agar media, the plates were adjusted to a water-activity (aw) of 0.94 (17). Fine dust (0.02 g) was suspended in 1 ml distilled water. In addition to this stock solution, dilutions of 1:8 and 1:64 were plated. Fungi were identified using different literature sources (13, 14, 15). Results were expressed as numbers of dispores/g dust and /m² surface area. For statistical analysis, the non-parametric Wilcoxon rank sum test was applied (4) at a 5% confidence level.

RESULTS

The number of fungal species in carpet dust was found to be higher than that from upholstered furniture (Table 1).

Pronounced differences existed in the fungal flora of the dwellings studied. *Aspergillus versicolor* and one or more species of the *A. restrictus*- and *A. glaucus* groups were present on all

Table 2

Median and range of fungi/g dust analysed from carpeting and upholstered furniture in living-rooms on ground-floor level ($n = 4$), 1st to 3rd floor living-rooms ($n = 5$) and in all living-rooms ($n = 9$)

Fungal species:	Carpeting Numbers/g dust					
	Ground-floor		1-3rd floor		All rooms	
	median	range	median	range	median	range
xerophilic	24.1	(2.8-285.9)	4.0	(2.0-12.8)	11.4	(2.0-285.9)
meso-hygrophilic	0.6	(0-5.4)	0	(0-3.2)	0.3	(0-5.4)
hydrophilic	51.1	(7.9-244.8)	8.4	(3.0-98.8)	22.3	(3.0-244.8)
mycelia sterila	34.3	(1.2-142.6)	3.0	(1.2-116.9)	29.8	(1.2-116.9)
Fungal species:	Furniture Numbers/g dust					
	Ground-floor		1-3rd floor		All rooms	
	median	range	median	range	median	range
xerophilic	59.1	(13.0- 99.6)	7.4	(0.3-25.0)	16.6	(0.3- 99.6)
meso-hygrophilic	22.0	(1.0-155.0)	17.0	(0-53.4)	17.0	(0-155.0)
hydrophilic	2.6	(1.2- 21.6)	5.3	(2.0-14.6)	4.0	(1.2- 21.6)
mycelia sterila	6.9	(0.6- 12.0)	6.8	(0.3-10.8)	6.8	(0.3- 12.0)

floors and most furniture. *Penicillium brevicompactum* series was identified on furniture in all homes, but only in two floor dust samples. *Cladosporium* spp. appeared on all floors and furniture. *Alternaria* spp. appeared in all homes but one.

The number of spores of xerophilic, meso-hygrophilic and hydrophilic species in dust from carpeting or from upholstered furniture did not significantly differ statistically when comparing samples of ground-floor dust with that of 1st to 3rd floor rooms (Tables 1 and 2). However, when comparing the dust found in all nine living-rooms in carpeting and in upholstered furniture, the numbers of spores of hydrophilic genera/g dust were significantly more prominent on floors ($P < 0.05$), whereas meso-hygrophilic spores were significantly more abundant in furniture dust ($P < 0.05$) (Table 2). By comparing the estimated numbers of diaspores/m² (Table 3), a pronounced difference was observed for the meso-hygrophilic species: in furniture dust the number of viable spores was significantly higher than the number of spores found in dust from carpeting ($P < 0.05$). The majority of these meso-hygrophilic spores (>95%) belonged to the *Pen-*

icillium series, whereas other meso-hygrophilic species had only a low occurrence rate.

DISCUSSION

The general occurrence of xerophilic species of the *A. glaucus* and *A. restrictus* groups in all homes confirms the earlier findings of studies made with floor, bed and furniture dust (5, 12, 16).

Xerophilic fungi, e.g. *Aspergillus*, have been reported to appear on a constant level in dwellings throughout the year (8), whereas the presence of allochthonic moulds (meso-hygrophilic and hydrophilic species) inside dwellings depends strongly on seasonal influences. However, some meso-hygrophilic *Penicillium* species are also commonly detectable in dwellings throughout the year (7, 8). The results of our studies demonstrate that in regularly used furniture, primarily *Aspergillus* and *Penicillium* species are commonly encountered as suspected earlier (21). The results show that furniture should be regarded as a major source of meso-hygrophilic *Penicillium* spores, i.e. spores of *Penicillium brevicompactum*. These fungi are known to contain allergenic properties (3).

Table 3

Median and range of fungi/m² analysed from carpeting and furniture in living-room floors on ground-floor ($n = 4$), 1st to 3rd floor living-rooms ($n = 5$) and in all living-rooms ($n = 9$)

Fungal species:	Carpeting Numbers/m ²					
	Ground-floor		1-3rd floor		All rooms	
	median	range	median	range	median	range
xerophilic	24.7	(16.9-659.5)	6.2	(0.3-16.0)	16.0	(0.3-659.5)
meso-hygrophilic	0.5	(0- 12.5)	0	(0- 1.5)	0.4	(0- 12.5)
hydrophilic	58.5	(51.4-226.2)	12.0	(1.1-93.2)	51.5	(1.1-226.2)
mycelia sterila	27.6	(9.9-328.9)	12.0	(0.2-56.5)	17.6	(0.2-328.9)

Fungal species:	Furniture Numbers/m ²					
	Ground floor		1-3rd floor		All rooms	
	median	range	median	range	median	range
xerophilic	39.6	(18.5-143.3)	11.2	(0.3-118.5)	18.5	(0.3-143.3)
meso-hygrophilic	48.6	(0.6-129.1)	52.4	(0-80.6)	52.4	(0-129.1)
hydrophilic	1.8	(1.0-238.0)	9.1	(3.0-48.3)	3.0	(1.0-238.0)
mycelia sterila	5.8	(0.5-103.6)	10.3	(0.3-32.2)	6.7	(0.3-103.6)

Results indicate that the growth conditions of fungi in the micro-habitats in furniture differ from those in carpeting.

The development of fungi is known to depend primarily upon the availability of water. However, a strong correlation between relative humidity and prevalence of fungi in bedrooms has also been reported (20), indicating the importance of "damp" living conditions for rapid fungal growth.

However, the different distribution of hydrophilic and meso-hygrophilic fungi in dust from carpeting and furniture in this study of "dry" homes can be considered to be the result of a difference in moisture availability of the sites.

Compared with the climate existing in carpeting on floors, the climate in upholstered furniture is known to be dryer and closer related to the room climate (2). However, regular use of furniture increases the moisture level in the upholstery as a result of the additional moisture produced by the user. Presumably, upholstered furniture is a specific biotope, with fluctuating temperature and humidity conditions which reduce hydrophilic species. Further research on the temperature and humidity relationships in biotopes should follow.

Ground-floor level rooms are usually more humid than those situated at higher levels. Beneficial effects of this additional humidity on the population development of allergen-producing house dust mites have been reported (1). Beneficial effects on fungi might also be expected (11). For that reason, the numbers of fungal spores of xerophilic, meso-hygrophilic and hydrophilic, as well as the total numbers of spores on ground-floor levels have been compared with those found on higher floor levels. However, no statistically significant differences in numbers could be found, even though in many cases medians of numbers of spores sampled on the ground-floor level were obviously higher.

From this study, the need for a micro-topographic analysis of the fungal flora in the human environment has become apparent. As many isolated fungi belong to taxa known to be allergen producers (2, 3), efficient sanita-

tion in dwellings of allergic patients requires detailed information on the colonization of the various micro-habitats by allergenic fungi. Dust sampling by using a vacuum-cleaner seems necessary to sample fungi actually present in dwellings. It seems important to distinguish between xerophilic, meso-hygrophilic and hydrophilic species, which have different ecological requirements. Allergological important fungal taxa can be overlooked, if only a routine survey is performed (by way of sedimentation agar or volumetric air sampling).

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