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INDOOR FUNGI, DISTRIBUTION AND ALLERGENICITY*

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SUMMARY

Modern houses in Western Europe contain a number of fungal biotopes in which mold allergens may develop: timber, food, feed, brick, plaster, wallpaper, paint, pets, window plants and dust, to name only a few. The allergens are present in spores as well as in mycelium, and are secreted in their environment. Current sampling results from the indoor air do not reflect total patient exposure.

Of the 250.000 mold species present on earth, allergological test results could be found of about 140 (0.06%). Of the 98 fungal taxa listed from the indoor environment, 38 (39%) were tested for their allergenic potency. Genera investigated in 3 or more groups of patients showed positive skin reactions in 10 to 32% of the cases. Hence, fungal allergies are a significant public health problem.

Unfortunately more than half a century of research on mold allergies has not led to an understanding of the exposure and sensitization of allergic patients in the indoor environment. Ecologically and clinically sound studies are urgently needed in the near future.

1. INTRODUCTION

Fungi in the home are a world-wide phenomenon. In the highlands of Papua New Guinea, for instance, growth of xerophilic species on the greasy surfaces of wooden cutlery is extensive (CASEY 1982).

Increased dampness of homes in Western Europe due to insulation, condensation and insufficient ventilation (LEUPEN 1982, ANONYMOUS 1985) has led to a renewed interest in indoor fungal growth. In severe cases this growth is noticed as a musty smell or as visible damage to construction or furnishing materials. In winter 500 fungal diaspores per m^3 indoor air are commonly present even when no signs of fungal decay are visible (BRAVERY 1985).

Allergic problems may arise at air-spora concentrations not associated with noticeable fungal damage. The inhalation of as little as 100 spores of *Alternaria tenuis* or 3000 of *Cladosporium herbarum* may elicit an allergic asthma or rhinitis episode (KREMPL-LAMPRECHT 1985). One fungal plant can produce 20 million air spora per minute (JORDE 1979).

From laboratory experiments (RIPE & PALMSTIERNA 1963) it became clear that mold allergen is present in both spores and mycelium, and that it is secreted into the fungal substrate. One discrimates between 'somatic' (structure of spores

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plus mycelium) and 'metabolic' (arising from food assimilation and excretion) fungal allergens (LOPEZ et al. 1976). Interestingly enough it was shown that fungi do not only produce allergens. Under exceptionally wet conditions they may also destroy them (MAUNSELL 1960).

STORM VAN LEEUWEN et al. (1925) were among the first to suspect airborne mold spores indoors as causative agents in allergy attacks. In the last half century fungal growth in the home has repeatedly provoked allergological concern (KREMER 1932, WERFF 1958, BRONSWIJK 1985). A recent compilation of "aeromycological" studies is given by AL-DOORY & DOMSON (1984).

Allergies are ecological diseases and many of their governing factors have changed during the last 50 years (JORDE & LINSKENS 1984). Building and furnishing materials were partly replaced by synthetic versions. The present indoor temperature, humidity and ventilation level are strongly at variance with those before World War II (BRONSWIJK 1981). At the same time, in the Netherlands at least, the available floor-space per person increased dramatically (CENTRAAL BUREAU STATISTIEK 1975). However, the fungal taxa commonly included in allergological testing have changed little. Compare, for instance, FEINBERG (1935) with CHAPMAN & WILLIAMS (1984).

In this paper we present a non-exhaustive inventarisation of some of the major indoor fungal biotopes and taxa, and their allergenicity. The resulting lists may serve as an aid to diagnosis and prevention of fungal allergies in temperate climates.

2. ASSESSMENT OF FUNGAL ALLERGENICITY

The allergenicity of a substance can be assessed by in vivo methods such as skin tests and provocation tests, and in vitro methods, such as the RAST (= RadioImmunoSorbent Test) (AL-DOORY & DOMSON 1984). Skin tests are known to give some clinically irrelevant false positive reactions, especially with fungal extracts (BOHLMANN 1978, COLLINS-WILLIAMS et al. 1972, KERSTEN & HOEK 1980, KURIMOTO 1975). The RAST, on the other hand, often gives false negative reactions to fungi (KERSTEN & HOEK 1980). The only really reliable method is the provocation test, which unfortunately is still not popular due to its supposedly high risk.

KERSTEN & HOEK (1980) studied the correlation between skin tests and provocation tests for fungal allergens in 290 asthmatic patients. Overall, a positive skin test was correlated with a positive provocation test in 30% of the cases. This percentage varied from 13.7 to 57.4% depending on the fungal species used. KURIMOTO (1975) found both tests to be in agreement in approximately 70% of the patients. Provocation tests were not performed when skin tests were negative.

Correlations between skin test, provocation test and RAST were studied by KERSTEN & HOEK (1980) in 237 patients with positive skin reactions to molds. In 112 cases (47.3%) the provocation test proved to be positive and for 97 patients (40.9%) a positive RAST-score was found. However, only 49% of the patients with positive reactions in provocation test, had also a positive RAST.

Thus a negative RAST does not mean that the patient is not allergic!

In this review only skin tests are evaluated, notwithstanding the false positive reactions, since RAST-data are less frequently gathered and data from provocation tests are relatively scarce.

The allergenicity of a fungus is expressed as the mean percentage of positive reactions and its standard deviation (*tables 1–7*). The number of studies in which the fungus was tested is given in brackets. Older synonyms of fungal names are included since they can still be found in modern medical literature. The assessment of the allergenicity of the fungi mentioned could only be compiled from studies with varying extracts, test techniques and patient material, which accounts for the enormous variation found among the different studies (AL-DOORY & DOMSON 1984). Our measure of allergenicity should only be regarded

Table 1: The wood-rotting fungi of Western-Europe (according to COGGINGS 1980; GROSSER 1985) and their allergenicity as mean and standard deviation of the positive reactions found in different studies. Number of allergenic studies in brackets (**).

taxa	allergenicity*
Major wood-rotting fungi (together accounting for 95% of wood rot problems in Great-Britain).	
Coniophora puteana (Schum. ex Fr.) Karst	
= *C. cerebella* (Pers.) Duby	NOT TESTED
Fibroporia vaillanti (DC. ex Fr.) Parm	
= *Poria vaillantii* (DC. ex fr.) Cke	
= *Poria vaporaria* (Pers. ex Fr.) Cke	NOT TESTED
Serpula lacrymans (Wulf.) Bond.	
= *Merulius lacrymans* (Wulf.) Fr.	
= *M. silvester Falck*	10.3 ± 12.8[6]
Minor wood-rotting fungi (together accounting for 5% of wood rot problems in Great-Britain)	
Antrodia malicola (Berk. & Curt.) Donk	
= *Trametes malicola* Berk. & Curt	probably allergenic [2]
Antrodia serialis (Fr.) Donk	
= *Trametes serialis* Fr.	probably allergenic [1]
Antrodia xantha (Fr. ex Fr.) Ryv.	
= *Amyloporia xantha* (Fr. ex Fr.) Cooke	
= *Poria xantha* (Fr.) Cooke f.	NOT TESTED
Asterostroma ochroleucum	NOT TESTED
Ceratocystis Ellis & Halst.	
= *Ophiostoma* Syd.	NOT TESTED
Cladosporium Link ex Fr.	25.8 ± 22.2 [28]
Coriolus versicolor (L. ex Fr.) Quél	
= *Trametes versicolor* (L. ex Fr.) Pilát	
= *Polyporus versicolor* L. ex Fr.	
= *Polystictus versicolor* (L. ex Fr.) Fr.	allergenic [1]
C. hirsutus (Wulf ex Fr.) Quél	
= *Trametes hirsuta* (Wulf ex Fr.) Pil.	
= *Polyporus hirsutus* (Wulf ex Fr.) Fr.	probably allergenic [1]
Daedalia quercina L. ex Fr.	
= *Trametes quercina* (L. ex Fr.) Pilát	probably allergenic [1]
Daldinia concentrica (Bolt. ex Fr.) Ces. & de Not.	NOT TESTED

Table 1. Continued.

taxa	allergenicity*
Donkioporia expansa (Desm.) Kotl & Pouzar	
= *Phellinus megalosorus* (Pers.) Heim	
= *P. cryptarum* Karst	
= *Poria megalopora* (Pers.) Cke.	
= *P. expansa* (Desm.) Jahn	
= *Fomes expansus* (Desm.) Dom. & Orlicz	NOT TESTED
Ganoderma lucidum (Fr.) P. Karst	probably allergenic [2]
Gloeophyllum abietinum (Bull. ex Fr.) Karst	
= *Hirschiopurus abietinus* (Dicks. ex Fr.) Donk	
= *Trichoptum abietinum* (Dicks. ex Fr.) Ryv.	
= *Polyporus abietinus* Dicks. ex Fr.	
= *Coriolus abietinus* (Dicks. ex Fr.) Quél.	
= *Polystictus abietinus* (Dicks. ex Fr.) Fr.	
= *Lenzites abietina* (Bull. ex Fr.) Fr.	probably allergenic [1]
G. sepiarium (Wulf. ex Fr.) Karst	
= *Lenzites sepiaria* (Wulf. ex Fr.) Fr.	NOT TESTED
G. trabeum (Pers. ex Fr.) Murril	
= *Lenzites trabea* (Pers. ex Fr.) Fr.	NOT TESTED
Graphium Corda	NOT TESTED
Laetiporus sulphureus (Bull. ex Fr.) Murrill	NOT TESTED
Lentinus lepideus (Fr. ex Fr.) Fr.	NOT TESTED
Merulius hydnoides Henn.	probably allergenic [6]
M. sclerotiorum Falck	probably allergenic [6]
Paxillus panuoides (Fr. ex Fr.) Fr.	
= *P. acheruntius* (Humb.) Schroet.	NOT TESTED
Phellinus contiguus (Fr.) Pat.	
= *Poria contigua* Pers. ex Fr.	NOT TESTED
Phlebia gigantea (Fr. ex Fr.) Donk	
= *Peniophora gigantea* (Fries) Massee	NOT TESTED
Poria medulla-panis Pers.	NOT TESTED
Poria placenta Fr.	
P. monticola Murr.	NOT TESTED
Schizophyllum commune Fr.	NOT TESTED
Serpula pinastri (Fr.) Bond.	NOT TESTED
= *Merulius pinastri* (Fr.) Burt	probably allergenic [6]
Serpula tignicola (Harmsen) Christians	
= *S. minor* Falck	
= *Merculius tignicola* Harmsen	probably allergenic [6]

* allergenic = positive in skin test, no further details known.
probably allergenic = a related or unknown species in the genus was positive in the skin test.
** after: ADAMS et al. 1968; BEAUMONT et al. 1984; BEAUMONT et al. 1985; BOHLMANN 1978; BRUCE 1963; CHAPMAN & WILLIAMS 1984; CHARPIN et al. 1965; COLLINS-WILLIAMS et al. 1972; CUTHBERT 1981; DEBELIC & VIRCHOV 1968; HARRIES et al. 1985; HASHAIN et al. 1981; HOPE & BANGHAM 1981; JONES & GERSON 1971; JORDE & RIJCKAERT 1979; KERSTEN & HOEK 1980; LIEBESKIND 1971; LOPEZ et al. 1976; NILSBY 1949; PRINCE & MORROW 1962, 1971; RIJCKAERT unpublished 1978, 1980; ROBY & SNELLER 1979; ROMANSKI et al. 1968; SHERMAN & MERKSAMER 1964; TARLO et al. 1979; WARREN & ROSE 1968; WILHEMSSON et al. 1984.

as a rough estimate of the relative importance of the various molds. Our survey

Table 2. Fungal taxa present on 27 salami and other raw sausages, percentages of occurence (after LEISTNER & AYRES 1967) and their allergenicity as mean and standard deviation of the positive reactions found in different studies. Number of allergenic studies in brackets**.

taxa	allergenicity
Penicillium Link ex Gray (89%)	23.5 ± 19.1 [18]
P. chrysogenum Serie Thom	4.6 ± 1.5 [3]
P. citrinum Serie Thom	NOT TESTED
P. commune Serie Thom	9.4 ± 5.9 [3]
P. expansum Serie Link ex Gray	34.6 ± 36.0 [2]
P. janthinellum Serie Biourge	NOT TESTED
P. roqueforti Serie Thom	8.0 [1]
P. urticae Serie Bainier	NOT TESTED
Scopulariopsis Bainier (41%)	NOT TESTED
S. albo-flavescens Zach.	NOT TESTED
S. brevicaulis (Sacc.) Bainier	NOT TESTED
Aspergillus Mich. ex Fr. (33%)	24.9 ± 21.7 [18]
A. amstelodami (Mangin) Thom & Church	11.9 ± 6.9 [2]
A. candidus Link	NOT TESTED
A. chevalieri (Mangin) Thom & Church	25.0 [1]
A. flavus Link ex Fr.	26.7 ± 37.5 [3]
A. niger van Tieghem	4.3 ± 3.3 [3]
A. repens de Bary	22.1 ± 9.7 [9]
A. ruber (Konig, Spieckermann & Bremer) Thom & Church	66.7 [1]
Rhizopus Ehrenb. ex Corba (11%)	18.9 ± 12.8 [11]
Mucor Mich. ex Fr. (4%)	19.8 ± 21.2 [21]
Mortierella Coemans (4%)	NOT TESTED

** after: BEAUMONT et al. 1984; BEAUMONT et al. 1985; BOHLMANN 1978; BRUCE 1963; CHAPMAN & WILLIAMS 1984; CHARPIN et al. 1965; COLLINS-WILLIAMS et al. 1972; DEBELIC & VIRCHOV 1968; FEINBERG 1935; GOLDFARB 1968; JONES & GERSON 1971; JORDE & RIJCKAERT 1979; KERSTEN & HOEK 1980; LIEBESKIND 1971; LOPEZ et al. 1976; NILSBY 1949; PRINCE & MORROW 1962; REYMANN & SCHWARTZ 1947; RIJCKAERT unpublished 1978, 1979, 1980; RIJCKAERT & JORDE 1981; RIJCKAERT & LUSTGRAAF 1980; RIJKAERT et al. 1981; ROBY & SNELLER 1979; ROMANSKI et al. 1968; SHERMAN & MERKSAMER 1964; TARLO et al. 1979; TOPPING et al. 1985; WARREN & ROSE 1968; WILHEMSSON et al. 1984.

of skin test studies included in total more then 140 different taxa.

3. INDOOR BIOTOPES AND ALLERGEN PRODUCTION

From an ecological point of view indoor fungi can be divided into three categories: (a) species that never propagate on indoor substrates but are introduced from the outdoor atmosphere (for example obligate tree pathogens), (b) species that occassionally propagate on indoor substrates, and (c) species that are able to propagate in almost any home (for example xerophilic house-dust inhabiting fungi). We have only dealt with the last two categories.

Many fungal substrates are found indoors: food, wood, paper, textiles, pets, window plants and man. Other surfaces that are not inhabitable themselves, such as mortar, brick and plaster, may be attacked if some organic material

Table 3. Fungi commonly active in the deterioration of grain and its products (after CHRISTENSEN & KAUFMANN 1965; PANASENKO 1967) and their allergenicity as mean and standard deviation of the positive reactions found in different studies. Number of allergenic studies in brackets**.

taxa	allergenicity
Aspergillus Mich. ex Fr.	24.9 ± 21.7 [18]
A. amstelodami (Mangin) Thom & Church	11.9 ± 6.9 [2]
A. candidus Link ex Fr.	NOT TESTED
A. chevalieri (Mangin) Thom & Church	25.0 [1]
A. olavatus Desmazières	8.7 [1]
A. flavus Link ex Fr.	26.7 ± 37.5 [3]
A. fumigatus Fresenius	17.9 ± 12.9 [10]
A. niger van Tieghem	4.3 ± 3.3 [3]
A. ochraceus Wilhelm	NOT TESTED
A. repens de Bary	22.1 ± 9.7 [9]
A. restrictus Smith	25.0 [1]
A. ruber (Konig, Spiek. & Brem.) Thom & Church	66.7 [1]
A. tamarii Kita	NOT TESTED
A. terreus Thom	4.5 ± 2.1 [2]
A. versicolor (Vuill.) Tiraboschi	24.3 ± 19.9 [4]
A. wentii Wehmer	NOT TESTED
Fusarium Link ex Fr.	21.5 ± 17.8 [16]
Geotrichum Link ex Pers.	NOT TESTED
Mucor Mich. ex Fr.	19.8 ± 21.2 [21]
Penicillium Link ex gray	23.5 ± 19.1 [18]
P. chrysogenum Thom	4.6 ± 1.5 [3]
P. commune Thom	9.4 ± 5.9 [3]
P. expansum Link ex Gray	34.6 ± 36.0 [2]
P. notatum Westling	15.2 ± 11.8 [7]
P. oxalicum Currie & Thom	NOT TESTED
P. veridicatum Westling	16.6 ± 20.8 [2]
Rhizopus Ehrenb. ex Corda	18.9 ± 12.8 [11]
Trichothecium Link	22.3 ± 30.7 [2]

** after: BEAUMONT et al. 1984; BEAUMONT et al. 1985; BOHLMANN 1978; CHAPMAN & WILLIAMS 1984; CHARPIN et al. 1965; COLLINS-WILLIAMS et al. 1972; CUTHBERT 1981; DEBELIC & VIRCHOV 1968; FEINBERG 1935; GOLDFARB 1968; HARRIES et al. 1985; HOPE & BANGHAM 1981; JONES & GERSON 1971; JORDE & RIJCKAERT 1979; KERSTEN & HOEK 1980; LOPEZ et al. 1976; NILSBY 1949; MALO & PAQUIN 1979; PRINCE & MORROW 1962; REYMANN & SCHWARTZ 1947; RKJCKAERT unpublished 1978, 1979, 1980; RIJCKAERT & JORDE 1981; RIJCKAERT & LUSTGRAAF 1980; RIJCKAERT et al. 1981; ROBY & SNELLER 1979; ROMANSKI et al. 1968; SHERMAN & MERKSAMER 1964; TARLO et al. 1979; TOPPING et al. 1985; WARREN & ROSE 1968; WILHEMSSON et al. 1984.

(such as house dust or grease) has settled on it. Environmental circumstances such as temperature and relative humidity ranges, moisture content and surface texture determine nature and extent of the infestation and subsequent allergen production.

3.1. Wood rot

The problem of dry rot of timber on land increased to troublesome proportions in the first decades of the 20th century when the cheaper, quickly seasoned, softwood (of Gymnosperm origin) replaced more and more the well-seasoned

Table 4. Fungi thriving on brick, mortar, plaster and unglazed ceramics under wet domestic conditions in Western Europe (after COGGINGS 1980) and their allergenicity as mean and standard deviation of the positive reactions found in different studies. Number of allergenic studies in brackets**.

taxa	allergenicity*
Aspergillus Mich. ex Fries	24.9 ± 21.7 [18]
Aureobasidium Viala & Boyer = *Pullularia* Berkhout	20.1 ± 15.4 [15]
Coprinus domesticus Fries	probably allergenic [1]
Penicillium Link ex Fries	23.5 ± 19.1 [18]
Peziza L. ex St. Amans	NOT TESTED
Serpula Pers. ex. S. F. Gray = *Merulius* Haller	10.3 ± 12.8 [6]
Trichoderma Persoon ex Fries	12.6 ± 13.3 [5]

* probably allergenic = a related or unknown species in the genus was positive in the skin test.
** after: BEAUMONT et al. 1984; BEAUMONT et al. 1985; CHAPMAN & WILLIAMS 1984; CHARPIN et al. 1965; COLLINS-WILLIAMS et al. 1972; DEBELIC & VIRCHOV 1968; FEINBERG 1935; GOLDFARB 1968; JONES & GERSON 1971; JORDE & RIJCKAERT 1979; KERSTEN & HOEK 1980; LIEBESKIND 1971; LOPEZ et al. 1976; PRINCE & MORROW 1962; REYMANN & SCHWARTZ 1947; RIJCKAERT unpublished 1980; ROBY & SNELLER 1979; ROMANSKI et al. 1968; SHERMAN & MERKSAMER 1964; TARLO et al. 1979; WARREN & ROSE 1968; WILHELMSSON et al. 1981.

hardwood (of Angiosperm origin), such as oak (COGGINGS 1980). The allergenicity of most major and minor wood-rooting fungi is still unknown (*table 1*). We may presume an incessant exposition of atopic people to their products, if not spores, in damp homes.

Timber at or below a moisture content of 20% or a surface relative humidity of 70% is immune to attack by wood-rotting fungi. In a dry central-heated home timber contains 6–8%, occassionally 10% moisture. When stove heating is used in dry homes 8–10% water may be expected (GROSSER 1985). This makes only damp homes, or moist sections of dry homes, liable to attack by (allergen developing) wood inhabiting fungi.

3.2. Moldy food and feed

Fungi play an important role in manufacture and decay of food and feed. Well known examples are beer, wine, Camembert cheese and rotten apples. All of them are sources of fungal allergens in the home. We will have a closer look at raw sausages and the fungal deterioration of grain products.

The flavor of salami improves with the inoculation and subsequent growth of certain *Penicillium* species. But not-inoculated taxa, such as the xerophilic *Aspergillus* species, are encountered too on raw sausages (*table 2*). Since the fungal growth is confined to the outer surface of the sausage, handling it will probably make mold products airborne. Patients tested with the taxa concerned gave positive skin reactions in 4.3 to 66.7% of the cases. Seven of the 19 taxa involved (37%) were never tested on patients!

Fungi cannot be missed in the processing of salami, but the same species are considered hazardous when active in the deterioration of grain products. Grain

fungi were found positive in 4.6 to 66.7% of the cases studied. Twenty of the 26 taxa (77%) were investigated allergologically (*table 3*).

3.3. Brick, plaster, wallpaper and paint

Molds on brick, mortar, plaster, stone and unglazed ceramics range from the microscopic *Aspergillus* species that can only be seen with the naked eye when larger surfaces are covered, to the clearly visible Ink-Cap mushrooms (*Coprinus*), Elf Cups (*Peziza*) and the Dry-Rot fungus (*Serpula*). None of these do structural damage to mineral-based materials, however, their presence is considered unsightly and positive reactions in skin tests by exposed allergic patients are not uncommon (*table 4*). Other niches connected with construction material are just as liable to fungal infestation under damp or wet conditions. A good example are window frames that are commonly inhabited by a combination of *Alternaria*, *Cladosporium* and *Aureobasidium* (GRAVESEN 1979), three proven allergenic genera.

Wallpaper and paint exhibit visible fungal growth in damp homes or damp niches of dry homes. At least 10 genera are common in Western Europe. Most of the taxa concerned have been tested on the skin of patients in two or more studies. Positive reactions ranged from 4.3 to 38.0% per study group (*table 5*).

3.4. House dust

On non-selective and so called "wet media" (water activity of 0.99 or more), the house-dust fungal flora appears to reflect the air-spora of the atmosphere (MALLEA 1974), except for a suppression of *Cladosporium* on malt agar in Britain (DAVIES 1960) and a higher incidence of Mucorales on fruit juice agar in Denmark (GRAVESEN 1978).

The number of fungal species flourishing in relatively dry, settled and packed house dust and in impacted grease in furniture, carpeting, (unused) clothing, floor crevices and bedding is limited (*table 6*). A vital requirement for these organisms is a relative humidity of 70 to 80%. In the summer season these values are common in modern buildings, even in dry homes (LUSTGRAAF et al. 1978).

Six of the 16 taxa of xerophilic house-dust fungi (38%) were not tested for their allergic potency. The others provoked positive reactions in 3.0 to 66.7% of the patients in the different groups studied (*table 6, fig. 1*).

House dust not only occurs on floor and furniture, it is also present in air-conditioning systems and hot-air central heating. Filters used as air cleaners accumulate fungal spores and sustain their survival (CHRISTENSEN 1950) and even development (ELIXMANN et al. 1986). With the "clean" air mold allergens of dust fungi are disseminated into the indoor environment.

3.5. Pets, window plants, and mushroom cultures

Dermatophytes, the keratinophilic fungi of human and animal skin, were sampled from the indoor air in southern Georgia, U.S.A. (WRAY & O'STEEN 1975) and Denmark (GRAVESEN 1972). *Microsporum canis* had become air-borne in one of 44 Danish homes investigated with open petri dishes with a fruit juice

Table 5. Common fungi on wallpaper and paint in the home (after GROSSER 1985 and PLEYSIER 1986) and their allergenicity as mean and standard deviation of the positive reactions found in different studies. Number of allergenic studies in brackets**.

taxa	allergenicity
Alternaria Nees ex Fr.	41.5 ± 33.7 [10]
Aspergillus Mich. ex Fr.	24.9 ± 21.7 [18]
A. glaucus group	6.0 ± 0.0 [2]
A. niger van Tieghem	4.3 ± 3.3 [3]
A. versicolor (Vuill.) Tiraboschi	24.3 ± 19.9 [4]
Aureobasidium Viala & Boyer = *Pullularia* Berkhout	20.1 ± 15.4 [15]
Cladosporium Link ex Fr.	25.8 ± 22.2 [28]
C. cladosporoides (Fr.) de Vries	38.0 [1]
C. herbarum Link ex Fries	11.1 ± 10.3 [8]
Fusarium Link ex Fr.	21.5 ± 17.8 [16]
Mucor Mich. ex Fr.	19.8 ± 21.2 [21]
Penicillium Link ex Fr.	23.5 ± 19.1 [18]
P. brevicompactum Series Dierckx	6.6 ± 5.1 [5]
P. chrysogenum Series Thom	4.6 ± 1.5 [3]
P. expansum Link ex Gray	36.4 ± 36.0 [2]
P. purpurogenum Stoll	NOT TESTED
Phoma Saccardo	32.0 ± 22.8 [12]
Sclerophoma pityophila	NOT TESTED
Stachybotrys Corda	NOT TESTED

** after: BEAUMONT et al. 1984; BEAUMONT et al. 1985; BOHLMANN 1978; BRUCE 1963; CHAPMAN & WILLIAMS 1984; CHARPIN et al. 1965; COLLINS-WILLIAMS et al. 1972; CUTHBERT 1981; DEBELIC & VIRCHOV 1968; FEINBERG 1935; GOLDFARB 1968; HARRIES et al. 1985; HOPE & BANGHAM 1981; JONES & GERSON 1971; JORDE & RIJCKAERT 1979; KERSTEN & HOEK 1980; LIEBESKIND 1971; LOPEZ et al. 1976; NILSBY 1949; PRINCE & MORROW 1962; PRINCE & MORROW 1971; REYMANN & SCHWARTZ 1947; RIJCKAERT unpublished 1978, 1979, 1980; ROBY & SNELLER 1979; ROMANSKI et al. 1968; SHERMAN & MERKSAMER 1964; TARLO et al. 1979; WARREN & ROSE 1968; WILHELMSSON et al. 1981.

agar.

In The Netherlands, about one out of every 83 households owns a pet with a dermatophyte infection (KORT 1985 unpublished). House mice (*Mus musculus*), a common pest in buildings, are also a source of determatophytes (CHMEL et al. 1976). Exposure to inhalation allergens of dermatophytes is apparently not uncommon. Skin tests with these fungi (genera *Epidermophyton, Microsporum, Trichophyton*) were performed in 8 studies. The species *Microsporum canis* showed positive skin tests in 16.1 ± 3.9 cases of a study group (2 studies: JORDE & RIJCKAERT 1979; RIJCKAERT unpublished 1978). The corresponding figures for the genus *Trichophyton* are 9.6 ± 12.9% (6 study groups: PRINCE & MORROW 1962, LIEBESKIND 1971, GOLDFARB 1968, FEINBERG 1935, NUEVONEN et al. 1985).

Not only pets, but also window plants are sources of fungal products. Rust (Uredinales), smut (Ustilaginales) and mildew (Erysiphales), but also the well known allergenic genera, such as *Aspergillus, Alternaria* and *Cladosporium*, are house plant pathogens (MANDERSLOOT 1981). It is reassuring that at least in one study (BURGE et al. 1982) homes with a moderate quantity of undisturbed

Table 6. Xerophilic house-dust fungi (mainly after BRONSWIJK 1981) and their allergenicity as mean and standard deviation of the positive reactions found in different studies. Number of allergenic studies in brackets**.

taxa	allergenicity
Aspergillus Mich. ex Fr.	24.9 ± 21.7 [18]
A. amstelodami (Mangin) Thom & Church	11.9 ± 6.9 [2]
A. candidus Link ex Fr.	NOT TESTED
A. chevalieri (Mangin) Thom & Church	25.0 [1]
A. flavipes (Bainier & Sartory) Thom & Church	NOT TESTED
A. gracilis Bainier	NOT TESTED
A. halophilicus Christensen, Papavirens & Benjamin	NOT TESTED
A. ochraceus Wilhelm	NOT TESTED
A. penicilloides Spegazzini	24.9 ± 9.4 [4]
A. repens de Bary	22.1 ± 9.7 [9]
A. restrictus G. Smith	25.0 [1]
A. ruber (Konig, Spiek. & Brem.) Thom & Church	66.7 [1]
A. sydowii (Bainier & Sartory) Thom & Church	3.0 [1]
A. versicolor (Vuillemin) Tiraboschi	24.3 ± 19.9 [4]
Chrysosporium Corda in Sturm	NOT TESTED
Wallemia Johan-Olsen	23.4 ± 5.70 [4]
Xeromyces Ces.	NOT TESTED

** after: BEAUMONT et al. 1984; BEAUMONT et al. 1985; BRUCE 1962; CHAPMAN & WILLIAMS 1984; CHARPIN et al. 1965; COLLINS-WILLIAMS et al. 1972; DEBELIC & VIRCHOV 1968; FEINBERG 1935; JONES & GERSON 1971; JORDE & RIJCKAERT 1979; KERSTEN & HOEK 1980; LOPEZ et al. 1976; PRINCE & MORROW 1962; REYMANN & SCHWARTZ 1947; RIJCKAERT unpublished 1978, 1979, 1980; RIJCKAERT & JORDE 1981; RIJCKAERT & LUSTGRAAF 1980; RIJCKAERT et al. 1981; ROBY & SNELLER 1979; ROMANSKI et al. 1968; SHERMAN & MERKSAMER 1964; TARLO et al. 1979; TOPPING et al. 1985; WARREN & ROSE 1968; WILHELMSSON et al. 1984.

house plants did not show significantly elevated airspora levels.

Usually forgotten source of indoor fungal allergens are the toadstools grown indoors as a hobby and food source. Most of the common species are apparently not studied from an allergological point of view (*table 7*). Mushroom culture inside the home cannot be recommended for the allergic patient as long as the potential allergological harm of this hobby is so poorly understood.

4. AEROBIOLOGY AND EXPOSURE

Fungal allergens from whatever biotope, are inhaled as particulate matter. Clean indoor air at breathing level (1.5 m above the ground) contains 20–40 mu g/m^3 of dust as small particles (MEYER 1983). Part of it will be fungal material or products.

The sampling method has a significant effect on the estimated exposure of the patient, as is shown in *table 6*, which gives the aerial and dust distribution of xerophilic house-dust fungi. In an ecological approach LUSTGRAAF (1978) determined the quantity of diaspores in mattress dust as well as in bedroom air of a children's institution.

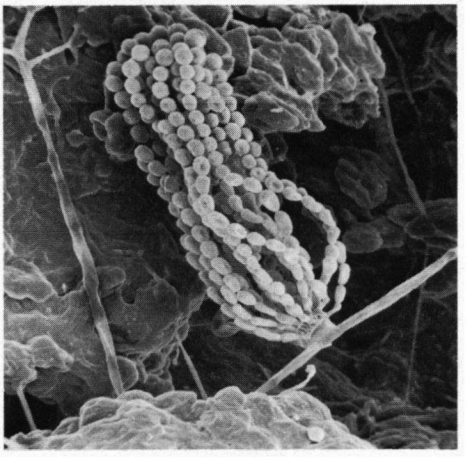

Fig. 1. *Aspergillus repens* de Bary, grown on skin material for 10 weeks at 25 degrees C and 75% relative humidity (from LUSTGRAAF et al. 1978).

According to LUSTGRAAF (1978) taxa found in bedroom air and mattress dust did not differ in any significant degree. They were mainly xerophilic species due to the low water activity of the agar medium used. Highest numbers of fungal diaspores in the air were found in November and December; in dust peak-densities occurred in July (*fig. 2*). This discrepancy may be explained by differences in human behaviour.

In winter, when the central heating was activated strong air currents brought much dust and fungal diaspores into the air, whilst growth of fungi in the mattresses was hampered by dryness.

In summer the indoor relative humidity rose to the same level as the outdoor value (70–80%). This resulted in a stimulation of fungal growth in the mattresses. Since the institution was closed during the school holidays, not much dust (carrying fungi) became air-borne.

In the building investigated by LUSTGRAAF (1978), the inhabitants apparently inhaled most fungal spores in July when sleeping and in November–December when awake. Only by using a combination of detection methods could this become clear. We fully agree with KOZAK et al. (1980), who state that even extensive air-sampling may need a supplementary search for fungal sources (with Scotch-tape imprints or otherwise).

5. DRY AND DAMP HOMES

The dry home, with relative humidities below 60% in winter and summer values not exceeding 80% (BRONSWIJK 1985), without pets or mushroom cultures, is inhabited by molds. Fungi are imported with food, feed and house plants; but more important, the omnipresent dust sustains a seasonal growth of xerophilic

Table 7. Mushrooms grown indoor in the Benelux-countries (in basement, barn, forcing-house or living room) as a food source (after VERFAILLE 1983) and their allergenicity as mean and standard deviation of the positive reactions found in different studies. Number of allergenic studies in brackets**.

taxa	allergenicity*
Agaricus L. ex Fr.	NOT TESTED
A. bisporus (Lge) Sing	allergenic [1]
A. hortensis Pers.	NOT TESTED
A. bitorguis (Quel.) Sacc.	
= *A. edulis* Bull	NOT TESTED
A. arvensis Schaeff. ex Fr.	NOT TESTED
A. silvicolus (Vitt.) Sacc.	NOT TESTED
Coprinus (Pers. ex Fr.) S. F. Gray	
C. comatus (Flora dan.)	40.0 [1]
Flammulina velutipes (Curt. ex Fr.) Sing.	
= *Collybia velutipes* (Fr.) Quel.	NOT TESTED
Keuhneromyces mutabilis (Schaeff. ex Fr.) Sing. & Smith	
= *Pholiota mutabilis*	
= *Agaricus mutabilis* Schaeff. ex Fr.	NOT TESTED
Lentinus edodes (Berk. non Schröt.) Sing.	NOT TESTED
Lepiota leucothites (Vitt.) Orton	
= *L. naucina* Fr. non auct.	NOT TESTED
Lepista nuda (Bull. ex Fr.) Cke	
= *Rhodopaxillus nudus* (Sing. ut *Rhodop.*)	
= *Tricholoma nuda*	NOT TESTED
Pleurotus (Fr.) Quel.	
P. ostreatus (Jacq. ex Fr.) Quel.	44.0 [1]
P. floridanus Sing.	NOT TESTED
P. canadensis	
= *P. quebeca*	NOT TESTED
Stropharia rugoso-annulata Farlow	NOT TESTED

* allergenic = positive in skin test, no further details known.
** after: ADAMS et al. 1968; LOPEZ et al. 1976.

fungi. The allergenicity of most taxa appearing under dry domestic conditions is documented. Only 13 of the 30 taxa listed by us in *tables 2* and *6* have not been tried in the allergological skin test.

In the damp home molds really flourish. In addition to the mycoflora of feed, food and house dust, mold growth is supported by construction materials, furnishings and furniture. The majority of the species flourishing in damp homes especially (38 of the 63 taxa mentioned in *tables 1, 3* and *6*) were never investigated for their allergological potency! After more than half a century of allergological studies on molds, we are still not informed to any degree on the allergenic species the patient is exposed to in damp premises.

In a temperate climate a healthy home is apparently a dry home since a smaller number of fungal habitats is present. In winter about 500 fungal spores are present per m^3 air in dry homes against 3.000–7.000/m^3 in damp houses (BRAVERY 1985).

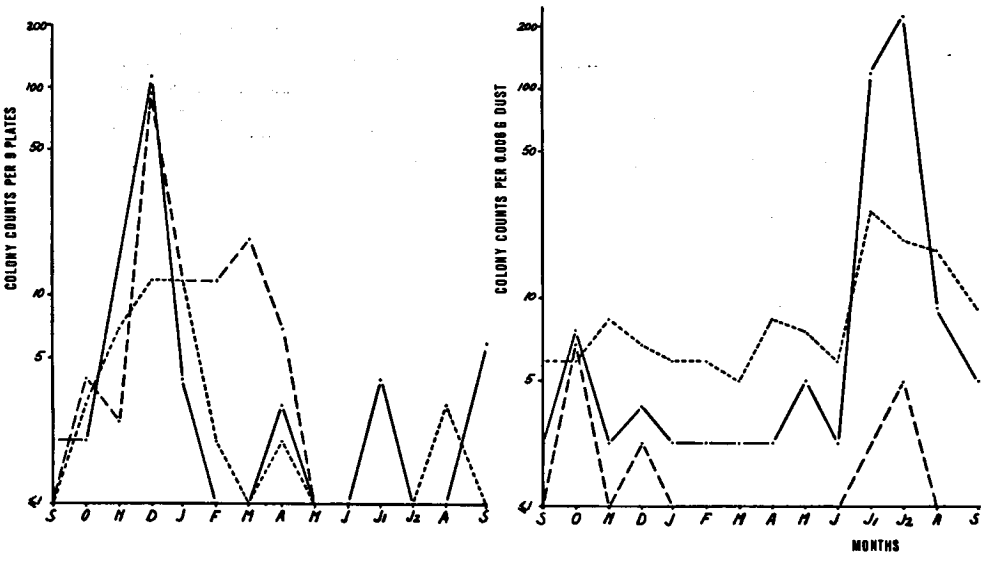

Fig. 2. Seasonality of the xerophilic fungi *Aspergillus glaucus* (-----), *A. restrictus* (—) and *Wallemia sebi* (– – –) in bedroom air and mattress dust in a children's home in The Netherlands. Samples were taken every four weeks from September 24, 1976 to September 30, 1977. The amount of fungi fragments in the air is expressed as the number of thalli on 9 malt agar + 64% sucrose plates, exposed for 20 minutes each; the figures in mattress dust are presented as the number of thalli grown from 0.006 g dust on the same agar medium.

6. FUNGI AND DWELLING HYGIENE

Fungal allergies constitute 10–30% of all allergies present in human populations (KERSTEN & HOEK 1980, ROMANSKI et al. 1968, PRINCE & MORROW 1971, NILSBY 1949). This agrees well with our figures as shown in the *tables 1–7*, with percentages of patients with positive skin reactions ranging from 10.3 ± 12.8 for *Serpula* to 32.0 ± 22.8 for *Phoma*. Taking in account that only 14–70% of these positive reactions reflect real allergies (see above), sensitivity to one or more mold species may range from 1.4 to 22.4% of the total number of allergic patients. Together with the common occurrence of fungi in the home, this considerable incidence makes them a hygienic problem in the indoor environment.

Bad hygienic conditions, house cleaning and repair work increase the spore load of the air (RIPE 1962; NILSBY 1949; MAUNSELL 1952). A good reverse correlation was reported between degree of dust control compliance and number of indoor mold isolates (KOZAK et al. 1979). House keeping plays an important role in exposure reduction.

Unfortunately the correlations found between fungal exposure and skin tests are generally low: 30% for *Cladosporium*, 20% for *Penicillium*, 18% for *Alternaria* and 8% for *Aspergillus* (ROBY & SNELLER 1979). But only about 100 of the 250,000 species of fungi are available for testing on allergic patients (JORDE 1979), and most routine test series contain less than 10 taxa. So it may be that

the relevant taxa are commonly not tested. To state that most fungi have no allergenic properties (KREMPL-LAMPRECHT 1985), seems to us a surprising but very probably erroneous conclusion.

7. MANAGEMENT PREREQUISITES

Aerobiological sampling techniques in allergological research are based on diaspore detection ((BEAUMONT 1985), but can never give a complete picture of the fungal species and products to which the atopic patient is exposed. A promising new method of assessing the total fungal allergen concentration of the indoor air is in development. It consists of a combination of an air sampler, a water soluble filter or glass fiber sheet (RICHARDS 1955, REED 1982) and the API-ZYM system to detect beta-glucosidase, alpha-galactosidase and 4 different proteases semi-quantitatively. These enzymes proved to be indicative for fungal activity in house dust extracts (BOUSQUET et al. 1980).

To assess the clinical relevance of fungi in the home of an allergic person, we need to know the total prevalence of mold products in the indoor air, the fungal species present, as well as the actual sensitization of the patient concerned. However, the usual way of sampling and patient testing will invariably lead to the well known list of *Alternaria, Cladosporium, Aspergillus* and *Penicillium,* while the more specialized taxa such as wood-rot fungi, house dust molds and pet dermatophytes are ignored. The conclusion that fungi in the home are of minor allergological concern (BEAUMONT 1985) results from the inadequate methods used.

More clinical and ecological research is needed to ascertain which fungal taxa really matter in the indoor environment. Designing a model environment to isolate atopics from the cause of their fungal allergies will be the next challenge for allergists and mycologists.

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