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EXPERIMENTAL ARTICLES

Groups and Sources of Yeasts in House Dust

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Abstract—House dust contains bacteria, mycelial fungi, microarthropods, and yeasts. House dust samples collected in 25 apartments in Moscow and the Moscow region were found to contain yeasts belonging to the genera *Candida, Cryptococcus, Debaryomyces, Rhodotorula, Sporobolomyces*, and *Trichosporon.* The most frequently encountered microorganisms were typical epiphytic yeasts, such as *Cryptococcus diffluens* and *Rhodotorula mucilaginosa*, which are capable of long-term preservation in an inactive state. The direct source of epiphytic yeasts occurring in the house dust might be indoor plants, which were contaminated with these yeasts, albeit to a lesser degree than outdoor plants. Along with the typical epiphytic yeasts, the house dust contained the opportunistic yeast pathogens *Candida catenulata, C. guillermondii, C. haemulonii, C. rugosa*, and *C. tropicalis*, which are known as the causal agents of candidiases. We failed to reveal any correlation between the abundance of particular yeast species in the house dust, residential characteristics, and the atopic dermatitis of the inhabitants.

Key words: yeasts, house dust, allergens.

Intense urbanization leads to the formation of specific anthropogenic habitats with a specific biota. Of particularly relevant interest are domestic interiors, where synanthropic organisms may produce allergens causing such diseases as bronchial asthma, atopic dermatitis, and allergic rhinit.

House dust is a very specific anthropogenic substrate, which contains both inorganic and organic components, such as soil particles, fabric fibers, food residues, shed human and animal epidermal cells, feathers, kapok, and pollen. House dust contains various microorganisms, including bacteria, fungal spores and mycelia, cyanobacteria, microarthropods, and mites of the families *Pyroglyphidae, Acaridae*, and *Glycyphagidae.* The house dust mites are well studied [1–3].

The interest of researchers in the mycobiota of domestic interiors is associated with the ability of mycogenic allergens to cause allergic diseases [4, 5]. At present, domestic mycelial fungi have been well studied [6–8], whereas little is known about domestic yeasts, although 84% of patients with atopic dermatitis show allergic reactions to the yeast *Malassezia furfur,* and 47% show allergic reactions to *Rhodotorula mucilaginosa* (= *Rh. rubra*) [9].

All this prompted us to study the abundance and the species structure of yeasts house dust and on indoor plants (as probable sources of the yeasts in the dust).

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MATERIALS AND METHODS

One hundred and forty-three dust samples were collected in 25 living apartments in Moscow and the Moscow region from beds, carpets, and upholstered furniture. The apartments were located in multistoried buildings with central heating systems. Each dust sample was collected for 1.5–2 min with a vacuum cleaner into fabric filters 0.5×0.5 m in size. The pore size of the filters did not exceed 0.1 mm.

Soil in flower pots and the green leaves and flowers of indoor plants were sampled throughout the year. All in all, 30 samples of leaves, 27 samples of flowers, and 41 samples of soil were analyzed. For a comparative analysis, we used our earlier data on the abundance and the species composition of yeasts found on the leaves of about 50 outdoor herbaceous plants grown in Moscow and the Moscow region [10]. The numbers of samples analyzed in the work cited and in this work were about the same.

Yeasts were enumerated by the standard method of plating appropriate sample dilutions on malt extract agar, which was acidified with lactic acid (4 ml/l) to suppress bacterial growth. The dust samples were diluted 1 : 1000, the samples of leaves and flowers were diluted 1 : 50, and the soil samples were diluted 1 : 20. The yeast colonies were counted after incubating the agar plates at room temperature for 7 days. The major colonial morphotypes were distinguished, and the colonies of each morphotype were counted by using a binocular magnifying glass. Several representatives of each colonial morphotype were isolated in pure culture.

The isolates were identified to the species level according to the morphological and physiological criteria presented in the manual [11].

All the samples were analyzed for the total population of yeasts in colony-forming units (CFU) per g sample and the relative abundances of particular yeast species. The results were subjected to statistical analysis with the aid of the Statistica 6 software package (StatSoft Inc., 2001).

RESULTS AND DISCUSSION

Sixty percent of the house dust samples were found to contain yeasts in amounts of 10^3 to 10^6 CFU/g, averaging 10^4 CFU/g. Most natural habitats, such as soil, plant debris, and the aboveground parts of plants, contain yeasts in about the same amount as calculated per g of the sample [10]. However, the concentration of yeasts in the house dust as calculated per unit volume is lower than in the natural habitats, since the specific gravity of the house dust is very low. The mean abundances of yeasts in the dust samples collected in various apartments were different, but the apartments with and without allergic inhabitants did not exhibit statistically significant differences in the mean yeast abundances (3.9 ± 0.1 and 4.0 ± 0.1 CFU/g, respectively).

The house dust was found to contain 15 yeast species belonging to the genera *Candida, Cryptococcus, Debaryomyces, Rhodotorula, Sporobolomyces,* and *Trichosporon* (Table 1), the most frequently encountered yeast species being *Cryptococcus diffluens* and *Rhodotorula mucilaginosa*. These widely spread yeast species are typically found on plants, plant debris, and in soil.

Of interest is the high relative abundance of *Cr. diffluens* in the house dust. This eurybiont can live in high and low latitudes [10] but is most abundant in subtropical deserts [12]. In the soils of middle Russia, the occurrence rate of *Cr. diffluens* is below 1% [13]. The distribution pattern of *Cr. diffluens* agrees with the high adaptive capability of this species, which already forms chlamydospore-like cells with thickened cell walls in 3- to 5-day-old cultures and can withstand a long-term desiccation in this state [14]. This can well explain the predominance of *Cr. diffluens* in the dry house dust. As an aside, *Cr. diffluens* is presently considered to be the variety *Cr. albidus* var. *diffluens*, although DNA similarity between *Cr. albidus* var. *albidus* and *Cr. albidus* var. *diffluens* is low (41%) [11].

The other dominant yeast species *Rh. mucilaginosa* is a typical inhabitant of natural plant substrates. The occurrence rate of this species is about 5% on plant

Table 1. Yeast species found in house dust and on indoor plant (numerals indicate the number of samples in which a given species was detected)

Species	House dust	Indoor plants	Soil in pots
Candida catenulata Diddens et Lodder	2	0	0
Candida guilliermondii (Castellani) Berkhout	0	1	0
Candida haemulonii (van Uden et Kolipinski) Meyer et Yarrow	6	0	0
Candida maltosa Komagata *et al.*	1	5	14
Candida rugosa (Anderson) Diddens et Lodder	2	0	0
Candida tropicalis (Castellani) Berkhout	1	0	0
Candida sp. 1	1	0	0
Candida sp. 2	1	0	0
Cryptococcus albidus (Saito) Skinner	22	12	1
Cryptococcus diffluens (Ruinen) von Arx et Weijman	69	1	0
Cryptococcus terricola Pedersen	0	0	1
Debaryomyces hansenii (Zopf) Lodder et Kreger-van Rij	24	9	2
Hanseniaspora guilliermondii Pijper	0	1	0
Metschnikowia reukaufij Pitt et Miller	0	5	0
Pichia anomala (Hansen) Kurtzman	0	3	0
Pichia onychis Yarrow	4	0	0
Rhodotorula glutinis (Fresenius) Harrison	9	0	0
Rhodotorula mucilaginosa (Jorgensen) Harrison	68	13	0
Sporobolomyces roseus Kluyver et van Niel	30	1	1
Trichosporon pullulans (Lindner) Diddens et Lodder	2	3	4
Total	143	57	41

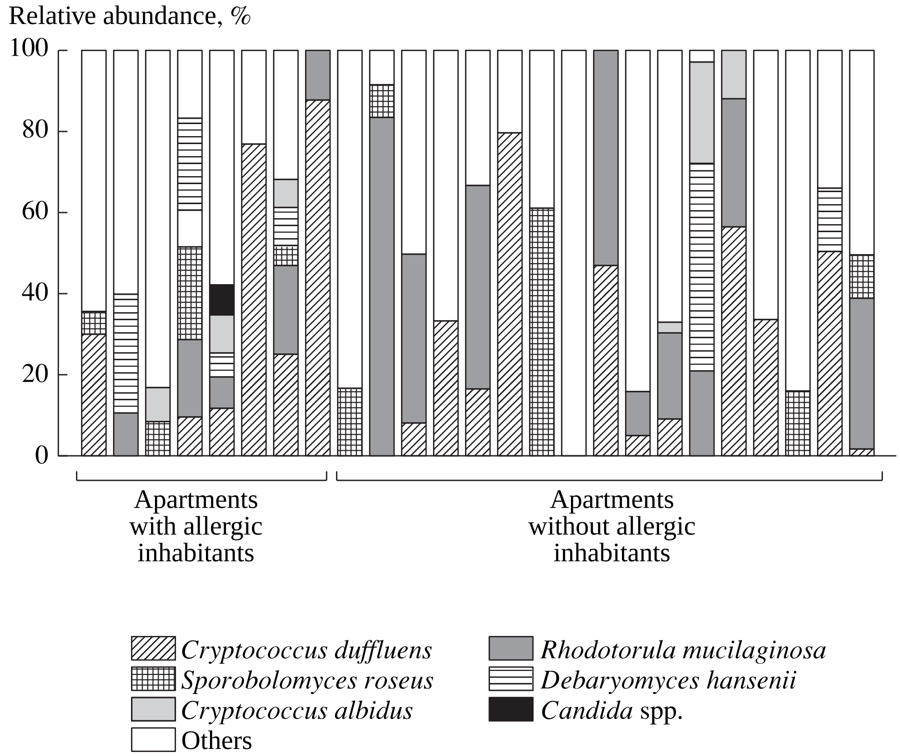

Fig. 1. The mean relative abundances of dominant yeasts in house dust.

leaves and debris in middle Russia, 2–3% in soddy podzolic soils [13], and as high as 45% in the deep layers of bog peaty soils [15], where yeast cells probably occur in an inactive state (as in the house dust). *Rh. mucilaginosa* was also isolated from the skin of patients afflicted with atopic dermatitis [16].

The epiphytic species *Sporobolomyces roseus*, which was detected in about 30% of the samples, is a typical inhabitant of the plant phyllosphere and the air, since it produces ballistospores. About 10% of the samples contained the anamorphic species *Rhodotorula glutinis*, which was also isolated from the skin of patients with atopic dermatitis [16]. The pathogenicity of *Rh. glutinis* is considered to be low, although there is evidence that this species is able to cause systemic sepsis and meningitis in AIDS patients [17].

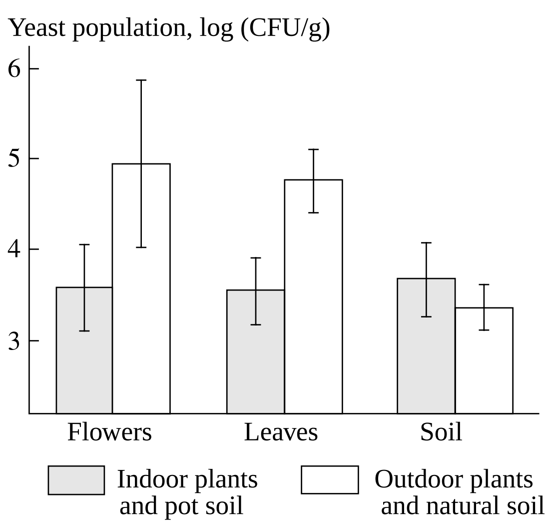

Fig. 2. The mean population of yeasts on domestic and natural substrates.

The ascomycetous yeasts of the house dust were dominated by the species *Debaryomyces hansenii*, the eurybiont that was frequently isolated from natural substrates, food, and the skin of patients with atopic dermatitis [16].

Along with the typical epiphytic yeasts, the house dust contained the opportunistic yeast pathogens *Candida catenulata*, *C. guillermondii*, *C. haemulonii*, *C. rugosa*, and *C. tropicalis*, which are known as the causal agents of candidiases [18].

The abundances of the dominant yeast species greatly varied with the apartment (Fig. 1), but we failed to reveal any correlation between the abundance of particular yeast species in the house dust, residential characteristics, and the atopic dermatitis of the inhabitants.

Thus, the yeasts found in the house dust are not diverse and are mainly represented by the typical epiphytic and eurybiotic basidiomycetous species, which are most frequently encountered on live and dead plants in natural habitats. Some of these yeasts are highly resistant to extreme environmental conditions, such as

Table 2. The mean fraction of most abundant yeast species in analogous domestic and natural substrates (% of the total yeast population)

Species	Domestic substrates			Natural substrates	
	dust	plants	soil	plants	soil
Candida spp.	5.8 ± 1.9	8.9 ± 3.7	34.1 ± 7.5	–	–
Cryptococcus albidus	6.4 ± 1.8	15.7 ± 4.6	2.4 ± 2.4	38.8 ± 6.5	2.8 ± 1.1
Cr. diffluens	32.9 ± 3.2	4.8 ± 1.8	–	–	0.5 ± 0.5
Cr. laurentii	–	–	–	15.3 ± 4.6	1.1 ± 0.8
Cr. podzolicus	–	–	–	–	1.5 ± 1
Cr. terricola	–	–	0.6 ± 0.2	–	66.0 ± 5.3
Cystofilobasidium capitatum	–	–	–	1.5 ± 0.5	2.6 ± 1.8
Debaryomyces hansenii	11.4 ± 2.4	11.9 ± 4.0	4.9 ± 3.4	3.1 ± 3.1	5.8 ± 2.7
Metschnikowia pulcherrima	–	–	–	5.1 ± 3.3	0.2 ± 0.2
M. reukaufii	–	4.8 ± 2.5	–	4.7 ± 3.1	–
Rhodotorula fujisanensis	–	–	–	3.9 ± 2.6	0.4 ± 0.3
Rh. glutinis	1.3 ± 1.2	0.5 ± 0.4	–	7.6 ± 2.3	1.6 ± 1.6
Rh. mucilaginosa	31.5 ± 3.1	19.1 ± 5.1	–	1.5 ± 0.5	1.2 ± 0.2
Sporobolomyces roseus	13.0 ± 2.6	1.2 ± 0.1	0.8 ± 0.8	12.0 ± 2.9	1.0 ± 0.9
Trichosporon pullulans	0.1 ± 0.1	–	–	–	13.9 ± 4.1
Trichosporon sp.	–	5.2 ± 2.9	7.4 ± 4.1	–	–

low moisture content and a shortage of easily metabolizable nutrients. This resistance is likely to be due to their capability for long-term existence in an inactive state, as is evident from the predominance of these yeasts in natural habitats with conditions that are unfavorable for the development of saccharolytic yeasts.

The predominance of epiphytic yeasts in the house dust allowed the suggestion to be made that the direct source of yeasts occurring in the dust was indoor plants, which were present in most of the domestic interiors under study. In nature, plant leaves are colonized by yeasts to a density of 10^4 to 10^6 CFU/g. The most typical inhabitants of the plant phyllosphere in middle Russia are the yeast species *Cr. albidus*, *S. roseus*, *Cryptococcus laurentii*, *Rh. glutinis*, *Rhodotorula fujisanensis*, *Rh. mucilaginosa*, and *Metschnikowia pulcherrima*, whose occurrence rate in the phyllosphere is 10% and higher [10, 13]. Yeasts, dominated by the pedobionts *Cryptococcus terricola* and *Cr. podzolicus*, are always present in plant debris and in the upper horizons of forest soils. Indoor plants grow under specific microclimatic conditions, which are characterized by closed space and only sporadic contacts with pollinating insects and other invertebrates, commonly playing an important role in the formation of epiphytic microbial communities. This prompted us to perform a comparative analysis of the epiphytic yeast communities formed on the indoor and outdoor plants.

The mean abundances of yeasts on the indoor plants were considerably lower than those on the outdoor plants tested. Yeasts were detected in only 30% of the indoor plant samples, while yeasts are usually isolated from any sample of the leaves and flowers of outdoor plants. The mean abundance of yeasts in the soil of the flower pots that were found to contain yeasts was about the same as that in the upper horizons of soddy podzolic soils (Fig. 2).

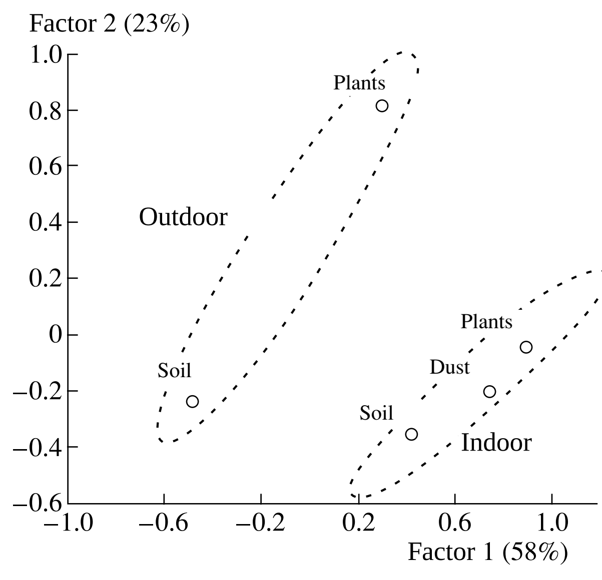

Fig. 3. Coordination of different habitats according to the mean relative abundance of yeasts by the method of major components (parenthesized is the percent of the total variance).

The taxonomic composition of the epiphytic yeast communities of the indoor plants and soil in the flower pots differed considerably from the taxonomic composition of yeasts in similar natural habitats (Table 2). First, none of the indoor plant samples contained such typical epiphytic species as *Cr. laurentii, Rh. fujisanensis*, and *M. pulcherrima*. Nor was the typical pedobiont *Cr. podzolicus* revealed in the flower pot soil. Another typical pedobiont of forest soils, *Cr. terricola*, was isolated from only one of the pot soil samples tested, while this species comprises more than half of the yeast population of soils in nature [10]. At the same time, the group of the opportunistic pathogens of the genus *Candida* capable of growing at 37°C amounted up to 9% of the population of epiphytic yeasts found on the leaves of indoor plants, 30% of the yeast population of soil in the flower pots, and about 6% of the yeast population detected in the house dust (see above), while the yeasts of this group are very rare on outdoor plants and in natural soils.

The red-pigmented yeast species *Rh. mucilaginosa* dominated not only the house dust but also the leaves of the indoor plants, although the fraction of this species in the yeast communities inhabiting the leaves of outdoor plants usually does not exceed 5%. The indoor plants also contained more eurybiotic ascosporous yeasts of the species *Debaryomyces hansenii* than the outdoor plants did. On the other hand, the flower pot soil did not contain the yeast-like fungus *Trichosporon pullulans*, although it is a common inhabitant of forest litter and the upper horizons of various soils in the Moscow region.

To conclude, unlike the epiphytic yeast communities of outdoor plants, those formed on indoor plants are less abundant and diverse. The leaves of indoor plants lack the typical epiphytic yeasts *Cr. laurentii*, *Rh. fujisanensis*, and *M. pulcherrima*, and the flower pot soil contains little, if any, of the typical pedo- and atmobionts *Cr. terricola, Cr. podzolicus*, and *Tr. pullulans*. At the same time, the indoor plants and the flower pot soil contain anamorphous ascomycetous opportunistic pathogens capable of growing at 37°C, which are very rare in natural soils and on outdoor plants. In the species composition of yeasts, the indoor plants, flower pot soil, and house dust are considerably closer to each other than to the respective substrates in natural environments (Fig. 3).

The anthropogenic yeast communities formed in domestic interiors differ from the respective natural communities in both abundance and in species composition. This fact should be taken into account when searching for mycogenic allergens in cases of patients genetically prone to atopic allergy.

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