

## Yeast-like fungi isolated from indoor air in school buildings and the surrounding outdoor air

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A total of 111 isolates of yeast-like fungi and yeasts belonging to 40 species of 19 genera were identified in indoor air and outdoor air. Only one species, *Kluyveromyces marxianus*, was recorded in both types of air and seasons (spring and autumn). *Kluyveromyces lactis* and *Yarrowia lipolytica*, a species having the greatest symbiotic abilities, dominated in indoor air and outdoor air, respectively. Intensely used rooms, especially those with limited access of air, have the broadest range of species of yeast-like fungi. A comparison of both habitats shows that school rooms pose a greater epidemiological risk of yeast-like infections than outdoor air. The indoor as well as outdoor mycobiota undergoes phenological changes although it is determined by other biotic and abiotic factors.

**Key words:** yeast-like fungi, school, indoor air

### INTRODUCTION

Fungal spores and mycelium fragments constitute the greatest part of bioaerosols in indoor air (Krzysztofik 1992). They use air as a vector between living organisms and water, soil and abiotic ecosystem components (Dynowska, Ejdys 1999). Similarly to outdoor air, indoor air aerosol contains biological particles. Fungal spores in indoor air are consistent with the seasonal development of individual species in nature (Twarużek 2006).

The accumulation of cellulose and lignin sources: construction wood, furniture (Zyska 2001), plywood, paper, fireboard and chipboard (Miklaszewska, Grajewski 2006), as well as other sources: plaster, paint (Zyska 2001; Grajewski, Twarużek 2004), provides favourable conditions for the development of indoor fungi. Although the taxonomical range of the mycobiota of different types of air is very broad, moulds dominate in it (Zyska 2001; Ejdys 2007; Topbas et al. 2006). However, the

prevalence of yeast-like fungi does not exceed 10% in indoor air in buildings having normal humidity and temperature parameters (Ejdys 2007) and can reach a maximum of 20% in particularly damp rooms (Meklin et al. 2002). This is surprising given special enzymatic abilities and a high rate of proliferation and growth of yeast-like fungi. They have been isolated from biotic and abiotic ecosystem components in all climatic zones (Dynowska 1995; Kurnatowska 1998; Bogacka, Matkowski 2001; Arias et al. 2002; Nagornaya et al. 2003; Biegańska 2006). A large group of potentially pathogenic species mostly of the genera *Candida*, *Cluyveromyces*, *Debaryomyces*, *Rhodotorula*, *Pichia*, *Trichosporon*, *Sacharomycopsis* (Dynowska 1995) and recently also *Saccharomyces* (Dynowska et al. 2006) or *Zygoascus* (Brandt et al. 2004) has been identified within yeast-like fungi. They are usually an aetiological factor in mycoses and, less frequently, in mycoallergies. As they can produce toxins (e.g. candoxins), the species can cause mycotoxycoses and increase micro-organism sensitivity to some bacterial infections (Dynowska 1995).

Age is the main physiological factor of the school period that predisposes to fungal infections. The risk of mycoses increases as other epidemiological factors occur, e.g. a child spends time in a large same-age group in the same rooms for several hours. Children spend between 5 and 9 hours on the school premises daily and it is of mycological importance how clean school buildings and their surroundings are.

Heavier than mould spores, spores of yeast-like fungi are located in the lower part of the air column (Stach et al. 2004). They can rise up to a height of >1.5m as a result of air currents related to human movement (Kurnatowska 1999). The two most important infection portals, the nose and the mouth, are located at this height in primary school children. Therefore, a high accumulation of yeast-like fungi in the air can pose a serious threat to the health of children inhaling this air (Kurnatowska 1999; Meklin et al. 2002).

## MATERIAL AND METHODS

Schools in Olsztyn (165 000 inhabitants) and Dobre Miasto (11 000 inhabitants) were selected. Both Olsztyn and Dobre Miasto are situated in the Pojezerzie Olsztyńskie lakeland. Lower temperatures and a shorter vegetation period in comparison with other parts of Poland are observed in the area (Kondracki 2002).

Yeast-like fungi occurring temporarily in outdoor and indoor air were examined. Fungi were collected in May (central heating switched off) and in November (heating operating).

Koch sedimentation method was used to obtain the material. Petri dishes with both types of Sabouraud's medium (chloramphenicol and Rose-Bengal) were exposed at each site in three replicates. Thirteen sites were established around the school building and the gymnasium in Olsztyn (school A) and twelve in Dobre Miasto (school B). Dishes were placed at building corners, at half the wall length, 1.5 m away from the wall. Samples were also taken from the internal patio in school A. The exposure time was 10 min. A total of 13 different areas inside the school were selected on the ground floor (classroom, women's toilet, men's toilet, corridor and

sports changing room) and in the basement (cloakroom) as well as in the newly refurbished common room for PE teachers (school A only). Samples containing both media were placed directly on the floor diagonally in two corners of each room. The exposure time was 30 min. Humidity and temperature were measured at each site.

Samples were incubated at 37°C for the first three days and transferred to room temperature for 72 hours. Isolates of yeast-like fungi and yeasts were inoculated on Sabouraud's medium without antibiotics. Media containing antibiotics that could affect typical fungal properties were not used (Dynowska 1991-1992).

After pure bacteria-free strains were obtained, microcultures were established on Nickerson agar. Fungi were inoculated on glass slides covered with a thin layer of the medium (ca. 2 mm). Two-three drops of broth with serum (1:1) were placed on the inoculation site. Microcultures were incubated at 37°C for a period from 48 to 72 hours.

Macroscopic features (size, colour, shape, texture, smell of the colony), microscopic features (shape and size of budding cells, blastospores and chlamydozoospores, the diameter of pseudohyphae and hyphae) and biochemical features obtained on bio-Mérieux API-tests (API 20C, API 20C AUX) were used for identification. CHROMagar (bio-Mérieux) was used to differentiate individual species of the genus *Candida*. CHROMagar was treated as an auxiliary test as it does not yield accurate results in mixed-species isolations (Bouchara et al. 1996). Photographic documentation was made throughout the process.

Yeast-like fungi and yeasts were determined using the following keys: Kreger - van Rij (1984), Barnett, Payne and Yarrow (1990), and Kurtzmann and Fell (2000).

## RESULTS

A total of 111 isolates of yeast-like fungi and yeasts belonging to 40 species (+ 1 undetermined) of 19 genera were obtained (Tab. 1). The greatest numbers of representatives were recorded for the genera *Kluyveromyces* and *Pichia* (6 species), followed by *Candida* (5), *Debaryomyces* (4) and *Rhodospiridium* (2). Other genera occurred incidentally. *Kluyveromyces* was one of the most frequently recorded genera (24 isolates) as regards the quantity; fungi of the genera *Debaryomyces* and *Pichia* were recorded slightly less frequently (18 and 15 isolates, respectively).

*Kluyveromyces lactis* dominated in both schools. It was, however, isolated only from indoor air when central heating was on. *D. polymorphus* was also recorded only in autumn, but it was present indoors and outdoors. Only one species, *Kluyveromyces marxianus*, was recorded in both types of the air and in both seasons.

Three groups of survival in air were distinguished: I – species isolated only from indoor air, II – species isolated only from outdoor air, and III (Tab. 1) – species that survived in both types of air aerosol. Group I was the most numerous one (20 of the 40 taxa identified in the study). Group III was only 20% and comprised the following fungi: *Aureobasidium pullulans*, *Debaryomyces occidentalis*, *D. polymorphus*, *Kluyveromyces marxianus*, *Oosporidium margaritifera*, *Pichia membranifaciens*, *Saccharomycopsis capsularis*, *Yarrowia lipolytica*. Although it was recorded six times

Table 1  
Yeast-like fungi in May and November in indoor air and outdoor air

No	Species	Number of isolates							
		Indoor air				Outdoor air			
		School A		School B		Around A		Around B	
		May*	Nov.	May	Nov.	May	Nov.	May	Nov.
1	<i>Arxula adeninivarans</i> van der Walt, Smith & Yamada		1 <sup>III**</sup>						
2	<i>A. terrestris</i> van der Wald, Smith & Yamada					1			
3	<i>Aureobasidium pullulans</i> Arn			2 <sup>II,V</sup>		2		3	
4	<i>Candida albicans</i> Berkhout								1
5	<i>C. glabrata</i> Meyer & Yarrow	1 <sup>V</sup>	1 <sup>II</sup>						
6	<i>C. rhagii</i> Jurzitza, Kühlwein & Kreger-van Rij				1 <sup>II</sup>				
7	<i>C. solani</i> Lodder & Kreger-van Rij			1 <sup>III</sup>					
8	<i>Candida utilis</i> Lodder & Kreger-van Rij			1 <sup>II</sup>					
9	<i>Cystofilobasidium informominiatum</i> Hamamoto, Sugiyama & Komagata	3 <sup>IV,V</sup>	1 <sup>VII</sup>						
10	<i>Debaryomyces hansenii</i> Lodder & Kreger-van Rij		1 <sup>V</sup>	1 <sup>I</sup>	3 <sup>II,V</sup>				
11	<i>D. occidentalis</i> Kurtzman & Robnett				1 <sup>IV</sup>			1	
12	<i>D. polymorphus</i> Price & Phaff		1 <sup>II</sup>		4 <sup>I,III,VI</sup>	2		3	
13	<i>D. venrijae</i> Abadie, Pignal & Jacob		1 <sup>II</sup>						
14	<i>Geotrichum clavatum</i> de Hoog, Smith & Gueho							2	
15	<i>Kluyveromyces blatae</i> Henninger & Windisch						1		
16	<i>K. lactis</i> van der Walt		6 <sup>III,IV,V,VI</sup>		6 <sup>II,III,IV,V</sup>				
17	<i>K. marxianus</i> van der Walt				3 <sup>III</sup>	1	1	1	2
18	<i>K. thermotolerans</i> Yarrow		1 <sup>I</sup>		1 <sup>III</sup>				
19	<i>K. wickerhamii</i> van der Walt			1 <sup>V</sup>	1 <sup>V</sup>				
20	<i>K. yarrowii</i> van der Walt, Johannsen, Opperman & Halland				1 <sup>II</sup>				
21	<i>Kluyveromyces</i> sp.								1
22	<i>Leucosporidium scottii</i> Fell, Statzell, Hunter & Phaff					1			
23	<i>Lipomyces starkeyi</i> Lodder & Kreger-van Rij			1 <sup>V</sup>					
24	<i>Mrakia frigida</i> Yamada & Komagata	1 <sup>IV</sup>		1 <sup>II</sup>					
25	<i>Nadsonia commutata</i> Golubev	2 <sup>V</sup>							
26	<i>Oosporidium margaritifera</i> Stautz				1 <sup>VI</sup>			1	
27	<i>Pichia anomala</i> Kurtzman				1 <sup>II</sup>				
28	<i>Pburtonii</i> Boidin, Pignal, Lehodey, Vey & Abadie						1		
29	<i>Pdelftensis</i> Bebech					1			
30	<i>P.farinosa</i> Hansen	2 <sup>IV,V</sup>		2 <sup>IV,VI</sup>	3 <sup>II,V,VI</sup>				
31	<i>Pguilliermondii</i> Wickerham						2		
32	<i>Pmembranifaciens</i> Hansen			1 <sup>VI</sup>	1 <sup>I</sup>		1		
33	<i>Rhodospiridium dacryoideum</i> Fell, Hunter & Tallman	1 <sup>III</sup>							
34	<i>R. toruloides</i> Banno	1 <sup>IV</sup>							
35	<i>Rhodotorula glutinis</i> Harrison			1 <sup>V</sup>					
36	<i>Saccharomyces bayanus</i> Saccardo						1		
37	<i>Saccharomycopsis capsularis</i> Schöningg				1 <sup>VI</sup>				1
38	<i>S.vini</i> van der Walt & Scott								2
39	<i>Yarrowia lipolytica</i> van der Walt & von Arx				2 <sup>II,VI</sup>				6
40	<i>Zygoascus hellenicus</i> Smith					1	2		
41	<i>Zygosaccharomyces rouxii</i> Yarrow						3		
	Total	11	13	12	30	6	15	8	16
		66				45			

Abbreviations: \* - isolation month; \*\* - number of isolates indoors: I-classroom, II-women's toilet, III-men's toilet, IV-corridor, V-cloakroom, VI-sports changing room, VII-common room (PE teachers).

Table 2  
Co-occurrence of species of yeast-like fungi

No	Name of the species	Occurrence			
		single	two species	three species	four species
1	<i>Arxula adenivorans</i>	X			
2	<i>Arxula terrestris</i>		•		
3	<i>Aureobasidium pullulans</i>	X		•	
4	<i>Candida albicans</i>				•
5	<i>Candida glabrata</i>		•		
6	<i>Candida rhagii</i>		•		
7	<i>Candida solani</i>	X			
8	<i>Candida utilis</i>		•		
9	<i>Cystofilobasidium informominiatum</i>	X	•		
10	<i>Debaryomyces hansenii</i>	X		•	
11	<i>Debaryomyces occidentalis</i>	X			
12	<i>Debaryomyces polymorphus</i>	X	•	•	•
13	<i>Debaryomyces venrijae</i>		•		
14	<i>Geotrichum clavatum</i>	X			
15	<i>Khuyvermyces lactis</i>	X			
16	<i>Khuyvermyces marxianus</i>	X		•	
17	<i>Khuyvermyces thermotolerans</i>	X			
18	<i>Khuyvermyces wickerhamii</i>	X			
19	<i>Khuyvermyces yarrowii</i>	X			
20	<i>Khuyveromyces blatae</i>	X			
21	<i>Khuyveromyces</i> sp.		•		
22	<i>Leucosporidium scotti</i>	X			
23	<i>Lipomyces starkeyi</i>			•	
24	<i>Mrakia frigida</i>	X			
25	<i>Nadsonia commutata</i>	X			
26	<i>Oosporidium margaritifera</i>	X			
27	<i>Pichia anomala</i>	X			
28	<i>Pichia burtonii</i>	X			
29	<i>Pichia delfensis</i>	X			
30	<i>Pichia farinosa</i>	X		•	
31	<i>Pichia guilliermondii</i>	X			
32	<i>Pichia membranifaciens</i>	X			
33	<i>Rhodospidium dacryoideum</i>	X			
34	<i>Rhodospidium toruloides</i>	X			
35	<i>Rhodotorula glutinis</i>			•	
36	<i>Saccharomyces bayanus</i>	X			
37	<i>Saccharomycopsis capsularis</i>				
38	<i>Saccharomycopsis vini</i>				
39	<i>Yarrowia lipolytica</i>		•	•	•
40	<i>Zygoascus hellenicus</i>	X			
41	<i>Zygosaccharomyces rouxii</i>	X			

indoors, *Y. lipolytica* never occurred on its own (Tab. 2). It co-occurred with one species, *Saccharomycopsis vini* or *Khuyveromyces* sp., two species, *D. polymorphus* and *K. marxianus*, and even three species, *C. albicans*, *D. polymorphus* and *S. capsularis*. It was also always isolated in indoor air with other species: *Candida rhagii* or *D. polymorphus*. Nine of the 40 determined taxa co-occurred with at least one species (22.5%).

More fungi were isolated in both indoor and outdoor air in autumn than in spring (68.9% and 65.2%, respectively). No relationship was observed between high prevalence of fungi and species differentiation in indoor air. The difference between the occurrence frequency of fungi in spring and autumn did not exceed 1.5%.

Table 3  
Species diversity and the directions of the world

North-west		North		North-east	
species	school, isolation month	species	school, isolation month	species	school, isolation month
<i>D. polymorphus</i> <i>Z. hellenicus</i> <i>A. pullulans</i>	S-1,Nov.* S-1,May S-1,May			<i>A. terrestris</i> <i>D. polymorphus</i> <i>K. blattae</i> <i>S. bayanus</i> <i>Z. hellenicus</i> <i>C. albicans</i> <i>D. polymorphus</i> <i>S. capsularis</i> <i>S. vini</i> <i>Y. lipolytica</i>	S-1,Nov. S-1,Nov. S-1,Nov. S-1,Nov. S-1,Nov. S-2,Nov. S-2,Nov. S-2,Nov. S-2,Nov. S-2,Nov.
West		Patio		East	
<i>K. marxianus</i> <i>P. guilliermondii</i> <i>P. membranifaciens</i> <i>A. pullulans</i> <i>D. occidentalis</i> <i>K. marxianus</i> <i>O. margaritififerum</i>	S-1,Nov. S-1,Nov. S-1,Nov. S-2,May S-2,May S-2,May S-2,May	<i>A. pullulans</i> <i>G. clavatum</i>	S-2,May S-2,May	<i>P. burtonii</i> <i>P. guilliermondii</i> <i>Z. rouxii</i> <i>A. pullulans</i> <i>L. scottii</i> <i>P. delftensis</i> <i>D. polymorphus</i> <i>K. marxianus</i> <i>Y. lipolytica</i>	S-1,Nov. S-1,Nov. S-1,Nov. S-1,May S-1,May S-1,May S-2,Nov. S-2,Nov. S-2,Nov.
South-west		South		South-east	
<i>G. clavatum</i> <i>Kluyveromyces</i> sp. <i>Y. lipolytica</i>	S-2,May S-2,Nov. S-2,Nov.	<i>Z. rouxii</i> <i>K. marxianus</i>	S-1,Nov. S-1,May	<i>A. pullulans</i> <i>S. vini</i> <i>Y. lipolytica</i>	S-1,May S-2,Nov.

Abbreviations: \*S-1 school 1, S-2 school 2.

The broadest taxonomical range of fungi in indoor air was recorded in the cloak-room (14 species) and in the women's toilet (13 species). Fungi isolated in the cloak-room did not occur in outdoor air (Tab. 1). Fewer species were recorded in the air in the corridor, men's toilet and sports changing room. The abundance of fungi in the classroom was almost three times smaller (five species): *D. hansenii*, *D. polymorphus*, *K. marxianus*, *K. thermotolerans* and *P. membranifaciens*. Only one species, *Cystophilobasidium informominiatum*, was identified in the PE teachers' common room. *Kluyveromyces lactis* was recorded in the air of five different rooms. *Pichia farinosa* was isolated slightly less frequently (4 rooms).

A certain relationship between the occurrence of yeast-like fungi and the site's microgeographic location was observed (Tab. 3). The greatest specific range was observed at eastern sites. A total of 22 isolated were recorded in the east, north-east and south-east. No fungi examined in the study were recorded in the samples at northern sites.

The amplitude of indoor air was the same in spring and in autumn when central heating was on (2.2°C) and ranged from 19.4°C to 21.6°C and from 18.4°C to 20.6°C, respectively. Relative air humidity ranged from 48% and 60% regardless of the season.

Temperature and humidity of outdoor air ranged considerably depending on site location. Temperature ranged from 21.2 to 33.6°C in Olsztyn and from 18.2 to 22.7°C in Dobre Miasto in spring, and was (14.2:22.7) and (8.3:14.2) in autumn. Air humidity was 33-67% (Olsztyn) and 42-50% (Dobre Miasto) in May. It was higher in November and was 46-65% in Olsztyn and 62-92% in Dobre Miasto.

## DISCUSSION

Current studies usually focus on threats posed by yeast-like fungi to human and animal health. Studies in applied mycology related to human economy are numerous (Hahn et al. 2006; Golubev et al. 2003; Angerbauer et al. 2008). However, up-to-date reports on basic research into natural habitats of yeast-like fungi that concentrates on humans are scarce. It is therefore difficult to determine whether 40 species of yeast-like fungi isolated in the study in urban conditions in Central Europe are an exceptional figure or if they are typical of this environment. The lack of reports on the occurrence of yeast-like fungi in air samples may be connected with methodological problems. Cultures should not be interfered with in the initial phase of incubation to avoid sample contamination and to identify the full mycobiota range. It is often possible to isolate yeast-like fungi only at the beginning of culture as fast-growing moulds destroy them. The use of substrates suitable for the development of moulds (Czapek-Dox) recommended in the Polish Standard (PN 89/Z04111/03) additionally promotes them. Incubation temperature (26°C) also promotes the majority of moulds and not only slightly more thermophilous fungi that also include some yeast-like fungi. For instance, *Arxula adenivorans*, which can grow up to a temperature of 48°C (Wartman, Kunze 2000; Kunze 2006), was obtained in the study by using an incubation temperature higher (37°C) than that recommended for the examination of air mycobiota.

A broad temperature range seems to be a key factor in the ecological success of *Kluyveromyces marxianus*, which was recorded in both types of air in spring and autumn. It can survive in different temperature ranges and can therefore function in water, on plants or in human or animal bodies (Dynowska 1995; Kurtzmann, Fell 2000). Broad enzymatic abilities allow it to ferment available sugars and different sources of carbon of both plant and animal origin. Its ability to colonise different ecological niches may also be attributed to the type of its reproduction. *Kluyveromyces marxianus* combines rapid reproduction by budding in favourable conditions with alterations of genetic information during unfavourable environmental changes by producing ascospores.

Another ascomycete, *Kluyveromyces lactis*, occurs mostly in milk and milk-derived products (Kurzman, Fell 2000). Its relatively rare ability to ferment and assimilate lactose allows the species to dominate in environments where it is available. Small cartons of short-lifetime milk were distributed at school and the species was prevalent in the study. Food remains may also have been a source of and/or substrate for *Debaryomyces occidentalis*, *D. hansenii* or *Mrakia frigida*. Although they are used in biotechnology and the food industry (Mazurkiewicz-Zapałowicz 2006), they can also contaminate ready products (Moreira et al. 2001).

*Aureobasidium pullulans* and *Pichia farinose*, species dominating in school B in spring, may have come from outdoors. Soil, cereal crops and their products are natural environments of occurrence of these fungi (Twarużek 2006; Kurzman, Fell 2000). Pupils or the staff may also have been a source of them as these fungi have been isolated from people (Salkin et al. 1986; Bolignano, Criseo 2003; Garcia-Martos et al. 1996). The presence of *A. pullulans* in indoor air can intensify asthma symptoms (Niedorzytko et al. 2007) or lead to the development of pulmonary hypersensitivity to its spores (Temprano et al. 2007).

Conditions favourable for the occurrence and existence of different fungi are identified in intensely used rooms with a high through-put of people (cloakroom, walkways or passages). A broad range of fungi belonging to different systematic and ecological groups vegetates on organic matter from occupants' bodies (dead epidermis, saliva, hair) or clothes, shoes or functional items. As the occurrence of moulds having especially high toxinogenic abilities in such rooms shows, increased competition is also associated with mycobiota richness (Ejdys 2008). Organic compounds formed from lysis of dead fungal and bacterial cells accumulate in indoor aerosol with an abundant mycobiota. They can provide a particularly suitable substrate for the development of yeast-like fungi.

Fungi can increase survival potential in difficult environmental conditions by expanding their enzymatic range and entering symbiosis with other organisms, even other fungi. *Yarrowia lipolytica* occurred exclusively with other fungi in the study. Co-occurring species have a broader range of fermentation and assimilation abilities than *Y. lipolytica*, which does not ferment and its carbon sources are limited only to glucose and partly galactose.

The occurrence of organisms in the same habitat may show similar or overlapping parameters of their ecological niches. Fungi such as *Cystofilobasidium infirmominatum*, *Rhodotorula glutinis* and *Debaryomyces hansenii* were isolated from air in the cloakroom in the study. This seems to be connected with the fact that these fungi prefer similar organic compounds as the same set of fungi has been isolated from poultry meat (Deak 2001) and from human clinical material (Kurzman, Fell 2000; Desnos-Ollivieri et al. 2008; Ejdys 2008). Although the species have been isolated from plant material (Kurzman, Fell 2000; Golubev et al. 2003), their presence in school buildings is connected with the human body and its excretions or secretions rather than with plant tissues and can pose a potential threat to the health of building occupants.

Relatively constant temperature and humidity conditions in relation to outdoor sites are observed indoors. Moreover, light access is limited even on sunny days in the cloakrooms which are located in the basement. This may explain the indoor occurrence of yeast-like fungi that were not recorded in outdoor air. They may belong to "domestic fungi", such as *Aspergillus* or *Penicillium*, especially as permanent exposure of the cloakroom to outdoor air did not considerably influence the composition of the mycobiota of yeast-like fungi as shown by the absence of species that occurred in outdoor air at the same time.

Yeast-like fungi that occurred only in outdoor air samples may be treated as "field fungi". These fungi or only some of their strains are less sensitive to high daily temperature and humidity amplitudes, and, primarily, a large amount of ultraviolet radiation. They found the most favourable growth conditions at eastern localities where, while there is much light in autumn, temperature is higher than that at northern sites. Some fungi preferred western sites in spring.

Phenological fluctuations are observed in the occurrence of fungi in outdoor air. The air is mycologically cleaner in winter than in summer. A greater number of spores are recorded in air in spring and autumn than in winter and summer (Kruczak et al. 2002). However, the greatest number of fungi in air is observed in autumn when all spring and autumn months are examined (Shelton et al. 2002; Daccaro et al. 2003). The results confirm this also in indoor air. There were fewer yeast-like



fungi indoors in spring than in autumn and the species were not the same as those when the heating was on. A decrease in building insulation by airing did not affect considerably the composition of the mycobiota as a small percentage of fungi occurred both indoors and outdoors. Phenological changes of the indoor mycobiota were most probably caused not as much by changes of abiotic factors (temperature, radiation, humidity) as is the case with the external environment but by occupant-related biotic factors. Pupils and the staff adapt their clothing and nutrition to the season; their immune systems also change. Changes in habitat parameters determine reorganisation of the species composition of all microorganisms, including fungi.

## CONCLUSIONS

1. Indoor air in school buildings having normal humidity and temperature parameters can abound in yeast-like fungi: as many as 28 species of yeast-like fungi belonging to 15 genera were recorded. A total of 20 species belonging to 14 genera were identified in outdoor air.
2. *Kluyveromyces lactis* dominated in indoor air while *Yarrowia lipolytica*, a species characterised by the greatest symbiotic abilities, dominated in outdoor air.
3. A comparison of both habitats shows that a greater epidemiological risk of infection by yeast-like fungi is observed indoors rather than outdoors.
4. Intensely used rooms, especially where light access is limited, have the broadest spectrum of species of yeast-like fungi and therefore pose the greatest potential risk to the health of children and the school staff.
5. Indoor and outdoor air mycobiota changes phenologically although it is determined by other biotic and abiotic factors.
6. Species of yeast-like fungi that occur only indoors may be classified as “domestic fungi” while species recorded in outdoor air may be considered to be “field fungi”.

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## Grzyby drożdżopodobne izolowane z powietrza budynków szkolnych i powietrza atmosferycznego wokół nich

### Streszczenie

Podobnie jak w powietrzu wewnętrznym, największą część bioaerozolu powietrza atmosferycznego stanowią elementy grzybni i zarodniki grzybów z różnych grup systematycznych. Duże zagęszczenie grzybów drożdżopodobnych w powietrzu może stanowić poważne zagrożenie dla zdrowia oddychających nim dzieci. Dlatego też postanowiono zbadać występowanie omawianych grzybów w powietrzu budynków szkolnych i wokół nich.

Materiałem do badań były grzyby drożdżopodobne występujące przejściowo w powietrzu wokół budynków szkolnych oraz w ich wnętrzu. Grzyby pobierano w maju (ogrzewanie wyłączone) i listopadzie (okres grzewczy). Materiał uzyskano metodą sedymentacyjną Kocha, eksponując płytki Petriego z podłożem Sabourauda z chloramfenikolem oraz z różem bengalskim, w trzykrotnym powtórzeniu na każdym stanowisku. Ogółem uzyskano 111 izolatów grzybów drożdżopodobnych i drożdży właściwych, należących do 40 gatunków zgrupowanych w 19 rodzajach. W obu porach roku i typach badanego powietrza notowano tylko jeden gatunek – *Kluyveromyces marxianus*.

Stwierdzono, że powietrze budynków szkolnych, o prawidłowych parametrach wilgotności i temperatury, może obfitować w grzyby drożdżopodobne – 28 gatunków drożdżaków z 15 rodzajów. W powietrzu atmosferycznym zidentyfikowano 20 gatunków z 14 rodzajów. W powietrzu wewnętrznym dominantem był *Kluyveromyces lactis*, natomiast w powietrzu zewnętrznym *Yarrowia lipolytica*, gatunek o największych zdolnościach symbiotycznych.

Porównując badane siedliska zauważono, że w sensie epidemiologicznym, pomieszczenia szkolne stwarzają większe możliwości zakażeń grzybami drożdżopodobnymi niż powietrze na zewnątrz budynków. Pomieszczenia intensywnie użytkowane, zwłaszcza z limitowanym dostępem światła, mają najszersze spektrum gatunkowe drożdżaków, a tym samym stanowią największe potencjalne zagrożenie dla zdrowia dzieci i pracowników szkoły.

Mikrobiota powietrza wewnątrz pomieszczeń i na zewnątrz ich podlega zmianom fenologicznym, chociaż jest determinowana przez inne czynniki biotyczne i abiotyczne. Do „grzybów domowych” można zaliczyć gatunki drożdżaków występujące tylko w pomieszczeniach, natomiast gatunki pochodzące z powietrza atmosferycznego można uznać za „grzyby polowe”.