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Characterization of Fungi at Daycare Centers: A Systematic Review

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Abstract. Exposure to indoor airborne fungi may cause the occupant to get allergy reactions and asthma symptoms. Children may be more susceptible to the adverse effects of airborne fungi than adults due to their age and vulnerability. This study systematically reviews the characterization of fungi and the parameter affecting the characteristic of fungi at daycare centers. This systematic literature review used PRISMA (Preferred Reporting Items for Systematics Review and Meta-Analyses). All the articles related to the characterization of fungi at daycare centers published from 2011 to 2021 were analyzed and reviewed from an electronic database such as Google Scholar, Science Direct, Scopus, Taylor & Francis and SpringerLink. In this systematic review, fifteen studies that complied with the inclusion and exclusion criteria were chosen for the review. The median value of indoor fungi concentration from included studies was 317.25 CFU/m³ and ranged from 3.4 CFU/m³ (in Khorramabad, Iran, in July) to 47 581 CFU/m³ (in Taiwan). The findings indicate that Penicillium, Cladosporium, and Aspergillus are typically observed in daycare facilities. This review aims to present a thorough overview of the current understanding of the characterization of fungi at daycare centers and help researchers determine their focus areas when conducting studies in this field.

INTRODUCTION

Indoor air quality (IAQ) is a term that refers to the air quality inside and around buildings and structures, with a particular emphasis on how it affects occupant health and comfort. Humans spend more than 80% of their time indoors; thus, it has been gaining increasing attention from the public.[1]. Three common airborne pollutants exist: particulate matter, biological agents, and hazardous substances. In this study, the research focuses on fungal bioaerosol pollutants. Fungal exposures are receiving more attention as an occupational and public health hazard due to the significant prevalence of fungal contamination in buildings.[2].

Indoor sampling of fungal aerosols is usually carried out when there is suspected or known fungal growth in the indoor environment to identify the exposure level. While assessing fungal exposure, building factors such as water damage or moldy odor are consistently reported [3] Another study has proven similar findings that dampness can affect the occupants' fungal exposure or allergic reactions. In addition, factors like outdoor fungi and air exchange rates that can affect fungal exposure should be considered. The prevalence of moisture, where mold can easily develop on indoor surfaces in the tropics, is a well-known source of indoor fungi [4].

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In developing countries, children spend much time in school, which often lasts 8 to 10 hours per day and 40 to 50 hours per week; school and daycare facilities serve as major environments for the children [5]. The quality of the indoor environment has a considerable impact on student attendance and performance. Children are more susceptible to illness, absence, and asthma attacks when their school's indoor air quality is poor. [6]. Since children are more susceptible than adults to developing health problems due to potential environmental exposures, public premises that children frequent require to increase the indoor air quality. Therefore, ensuring a healthy indoor environment for children at schools or daycare centers (DCC) is necessary [7] Infectious illnesses are more common among children who attend daycare centers. The infectious disease affects them twice as much as children at home [8] Prolonged exposure to moisture and mold has been associated with an increased risk of asthma development and exacerbation, as well as dyspnea, cough, wheezing, respiratory infections, and dermatitis for allergic people [9].

It is vital to identify airborne fungi that affect children's health in daycare centers to prevent disease and various symptoms in children. Additionally, this inquiry was conducted to aid in the creation of future reference criteria. This investigation was also carried out to facilitate the development of criteria for future reference. This research aims to conduct a comprehensive analysis of the characterisation of fungi in indoor buildings at daycare centres (DCC) in terms of concentration and species of fungi to systematically review the parameter affecting characteristics of fungi in indoor buildings at daycare centres (DCC) in term of ventilation rate, human occupancy, and climate factor. Lastly, to determine the correlation between the characterisation of fungi and parameters affecting the characteristic of fungi in indoor buildings at daycare centres (DCC).

METHODOLOGY

The methodology used for this systematic literature review is PRISMA 2020 (Preferred Reporting Items for Systematic Review and Meta-Analyses) method [10] There are a few items listed in PRISMA 2020 checklists. The items are eligibility criteria, information sources, search strategy, selection process, data collection process and data item. The article was searched from various electronic databases from September to December 2021.The eligibility criteria are the inclusion and exclusion criteria that were set up before the search to make sure the searched articles are reliable and updated. After the eligibility criteria were set up, literature research was conducted on a few electronic databases as the information sources. A few search strategies were also set up before the research was conducted. One of the search strategies used in this systematic review is using the Boolean Expression with a combination of keywords. Table 1 shows the list of eligibility criteria, information sources, and search strategies used for the systematic review [10].

TABLE 1. List of eligibility criteria, information sources and search strategy.

Eligibility criteria	Information sources	Search strategy
1. The research article must relate to characterization of fungi at daycare centers.	1. Google Scholar	1. Characterization of fungi at daycare center."
2. The articles must be in English.	2. Science Direct	2. "Characterization of fungi" OR "fungi" AND "daycare center" OR "DCC"
3. The publication must be in between 2011-2021	3. Scopus	3. "Characterization of fungi" OR "fungi" AND "daycare center"
4. The article had to be full access or open access articles.	4. Taylor & Francis	4. "Characterization of fungi" OR "indoor air quality" AND "daycare center"
5. The sampling location must be kindergarten, daycare center or nursery.	5. Springer Link	5. "Indoor air quality" OR "fungal bioaerosol" AND "daycare center"

Data Collection Process

All the studies that had passed the selection process went through data collection. All the selected studies were exported to Mendeley. Then the duplicate articles were automatically removed by Mendeley. The articles were reviewed independently, and the information obtained was recorded. The data extraction form was created to extract the data systematically from the studies. The form was created to identify the outcomes of the studies [10].

Selection Process

All the articles or journals from search results went through the selection process. The title and abstract were initially screened and evaluated in the selection process. The studies not in field research of fungal bioaerosol, like from textbooks, guides, or reviews, were excluded. Studies that do not have quantitative data were not included in this review. The research must be conducted at the daycare centers, and other than that was also excluded. Inclusion and exclusion criteria stated in the eligibility criteria were used as a filter before the article was included in the selection process. The articles or journals that did not meet the criteria were excluded.

When the research was conducted from all the electronic databases mentioned in information sources, using the combination of keywords in the search strategy, the result was 2830 records of articles and journals found between the year 2011 to 2021. The filter was set for the type of articles and the year of publication across all search engines. Then, 2545 articles were removed for unrelated to the field of study, and 58 were removed for duplicates during the identification stage. Next, 227 potential articles were examined by screening the titles and abstracts and 122 articles were excluded. Another 16 articles were excluded at sought of retrieval for not having full-text articles. Ninety remaining articles were accessed for eligibility, and only 15 articles were included in this study. The flowchart selection process is shown in Fig. 1.

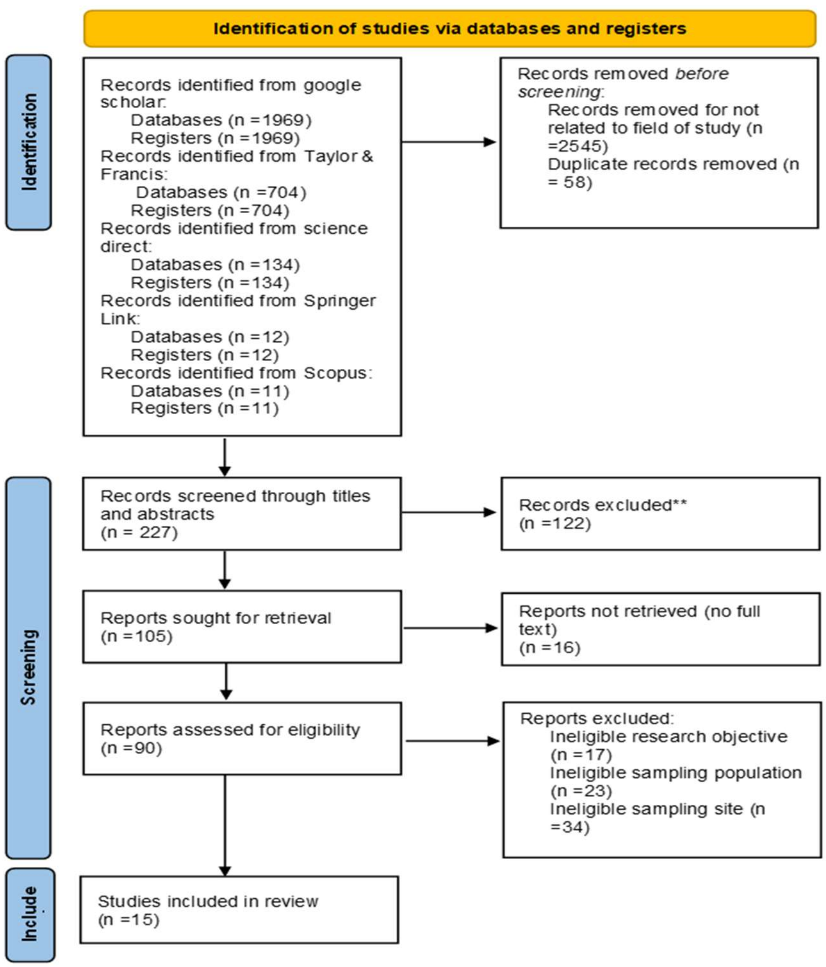

FIGURE 1. Process flowchart.

RESULT

For this systematic literature review, 15 articles were included from the literature research done on electronic databases. The 15 articles met all the inclusion and exclusion criteria set up earlier. Table 2 shows the distribution of articles included in this systematic literature review based on country and year. Table 3 shows the study characteristics. The study characteristic presents key characteristics from each article included in this study literature review. The main characteristic that was looked up from each article is the country where the studies were conducted, the season, if applicable, the predominant genera or species and the concentration of fungi from the research outcome.

TABLE 2. Distribution is based on country and year.

Country/ Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Iran							1	1		1		3
Korea				1	1		1					3
Portugal		1		1	1							3
Malaysia							1					1
Paris	1											1
Norway											1	1
Poland					1							1
Taiwan		1										1
Nigeria							1					1
Total	1	2	0	2	3	0	4	1	0	1	1	15

TABLE 3a. Study Characteristics.

Country	Title	Season	Predominant genera/species	Concentration
Nigeria	Analysis of Indoor Air Microflora of Some Daycare Centers in Ilorin South Local Government Area, Nigeria [11]	-	Aspergillus fumigatus, Aspergillus niger, Penicillium chrysogenum, Penicillium. sp., Aspergillus flavus	6 to 110 CFU/10 minutes
Taiwan	Airborne fungi and bacteria in child daycare centers and the effectiveness of weak acid hypochlorous water on controlling microbes [12]	Winter Spring	Cladosporium, Yeast, Nonsporium, Penicillium	8732 – 47,581 CFU/m^3

Table 3b. Study characteristics.

Country	Title	Season	Predominant genera/species	Concentration
Iran	Indoor and outdoor airborne bacterial and fungal air quality in kindergartens: Seasonal distribution, genera, levels, and factors influencing their concentration [13]	Summer Autumn	Aspergillus Cladosporium Penicillium	Indoor: 7 ± 6 CFU/plate/hr Outdoor: 12 ± 8 CFU/plate/hr
	Indoor air fungus bioaerosols and comfort index in day care child centers [14]	Winter Summer	Penicllium Cladosporium	Tarranom - 409.9 CFU/ m^3 Sina – 848 CFU/ m^3 Dariai-eMehr – 321.5 CFU/ m^3 Bagh-eKoodak – 1314.5 CFU/ m^3
	Indoor and Outdoor Air Fungus Bioaerosols in Khorramabad Day Care [15]	Spring Summer	Aspergillus niger Mucor Penicillium Aspergillus flavus Rhizopus Cladosporium Alternaria Fusarium species	Indoor: 175.58 CFU/ m^3 (May) Outdoor: 274.56 CFU/ m^3 (May) Indoor: 3.4 CFU/ m^3 (July) Outdoor: 7.8 CFU/ m^3 (July)
Korea	Indoor air quality of daycare center in Seoul, Korea [16]	-	-	310.0 CFU/ m^3
	Characterization of indoor air quality and efficiency of air purifier in daycare centers, Korea [1]	Summer Fall Winter	-	95.6 CFU/m^3 to 269.6 CFU/m^3
	Metagenomic insights into the bioaerosols in the indoor and outdoor environments of childcare facilities [17]	-	Aspergillus Alternaria Cladosporium Penicillium.	-

Table 3c. Study Characteristics.

Country	Title	Season	Predominant genera/species	Concentration
Portugal	Assessment and determinant of airborne bacterial and fungal concentrations in different indoor environments: Homes, child daycare centers, primary schools, and elderly care centers [18]	Winter	Penicillium sp. Cladosporium sp. Rhodotorula sp. Aspergillus Fusarium sp. Geotrichum sp. Alternaria sp. yeast	415 CFU/m^3
	Environmental And Ventilation Assessment in Child Day Care Centers in Porto: The Envirh Project [19]	Spring Winter	-	Nursery Spring:460 CFU/m^3 Winter: 313 CFU/m^3 Kindergarten Spring: 270 CFU/m^3 Winter: 510 CFU/m^3
	Indoor air quality in Portuguese children day care centers-ENVIRH [20]	Spring	-	Lisboa - 498 CFU/m^3 Porto- 300 CFU/m^3
Malaysia	Indoor airborne bacteria and fungi at different background area in nurseries and day care centers environments [21]	-	Rhizopus spp. Aspergillus spp. Penicillium spp.	ACK:210 CFU/m^3 ACG: 405 CFU/m^3
Paris	Assessment of indoor environment in Paris child day care centers [22]	Hot season Cold season	Penicillium Cladosporium Aspergillus	Cold season Playroom: 120 CFU/m^3 Bedroom: 76 CFU/m^3 Hot season Playroom: 409 CFU/m^3 Bedroom: 273 CFU/m^3
Norway	Spatiotemporal variation of the indoor mycobiome in daycare centers [23]	spring	Saccharomyces Mucor Cladosporium Malassezia Penicillium	-
Poland	Indoor air quality in urban nursery schools in Gliwice, Poland: Analysis of the case study [24]	Winter	-	1.8 to $3.4x10^2$ CFU/m^3

DISCUSSION

Geographical Distribution of Airborne Fungi

Figure 1 shows the geographical distribution of the cities and countries where indoor airborne fungi were studied at daycare centers. Studies included in this review are from all over the world. Countries with the most studies on airborne fungi at daycare centers are Iran (3 studies), Korea (3 studies), and Portugal (3 studies). Aside from that, one study was included from each country, including Malaysia, France, Norway, Poland, Nigeria, and Taiwan. Most countries conducted studies on airborne fungi at daycare centers from developed countries except for Malaysia and Nigeria developing countries. The study conducted in this country is possible because of their stable economy and government support for policymaking on indoor air quality [25] People are also becoming more aware of indoor air microbes because they can adversely affect their health [26].

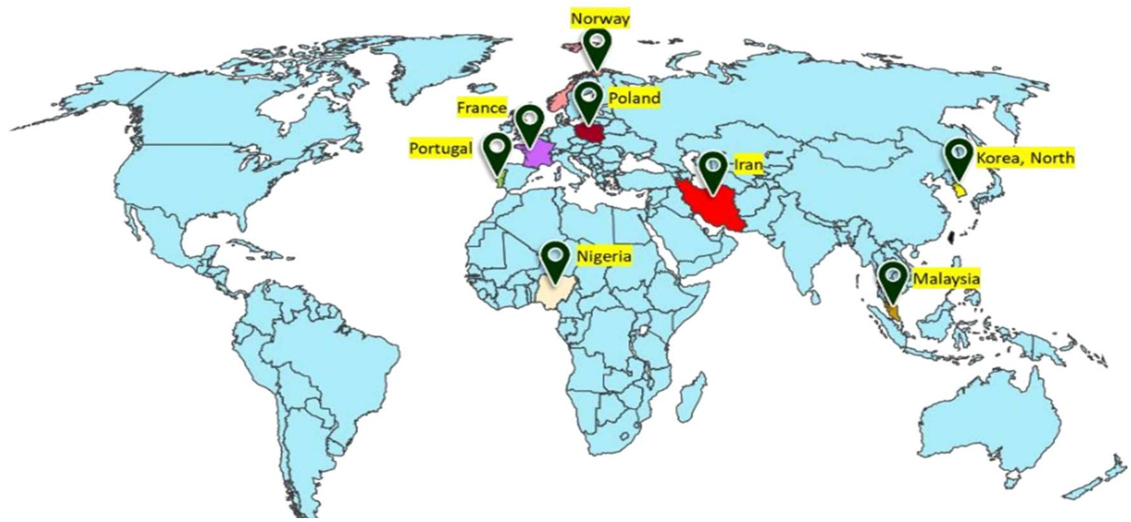

FIGURE 2. Geographical distribution of indoor airborne fungal studies.

Ventilation

Ventilation systems significantly influence the amounts of pollutants found in indoor air. Several researchers have reported the relationship between the level of fungal concentration indoors and the ventilation methods. There are a few ventilation modes, such as natural, mechanical, or hybrid. The fungal level was lower in a hybrid ventilation system, implying that pollutants were reduced more effectively [26] Ventilation is also found can prevent the growth of mold [16]. In Paris, 75% of childcare centers used mechanical ventilation. Mechanical ventilation has lower ventilation rates. However, research demonstrates that contaminants are eliminated during air recirculation, improving indoor air quality. [27]. However, ventilation can allow harmful substances to enter if not adequately designed, installed, maintained, or operated. Chen et al. found in the study at a child daycare center without air-conditioning (CDCCNAC) that the indoor airborne fungi were relatively high on Monday in both winter and spring. The fact that the concentration of outdoor fungi was higher on Monday, particularly in the CDCC-NAC, may help to explain why fungal counts were higher on that day. In addition, the interaction between fungi and active human activities such as housekeeping and vehicles may have contributed to this situation. The high concentration of fungi outdoors may infiltrate classrooms through the CDCC-NAC doors and windows, resulting in a Monday fungal count peak [12].

Human Occupancy

In this article review, a few studies research human occupancy and airborne air fungi. Humans significantly impact the microbial composition and concentrations in indoor air via resuspension and direct shedding. However, baseline quantitative information study on fungal emission and human occupancy is limited [28]. Hoposdky et al. found that the average ratio of fungi concentration occupied to vacant was 15. The median occupied I/O ratio was 5 times higher than the vacant I/O ratio [28]. Previous research has demonstrated that resuspension and human shedding are two critical sources of airborne microbes, and the occupancy-related increases are consistent with this finding [28].

Outdoor Concentration

The ratio of concentration indoor fungi to outdoor fungi (I/O) can be used to determine the outdoor concentration. Fungi carried through the indoor air may originate within or outside the building. In cases when the I/O ratio is lower than one, most of the fungi come from outdoor environments. If the I/O ratio is more than one, the contributions from indoor sources are higher [29] According to Chegini et al. findings, the I/O ratio for 12 kindergartens ranged from 0.1 to 4.5 for the four months the study was conducted (August, September, October, and November) [13] In Sepahvand et al.'s study, the I/O ratio of all samples was more than 1, which means the indoor source is the main priority rather than the outdoor, where the presence of people and a low ventilation rate can contribute to an increase in the concentration of airborne fungi and a decrease in the quality of the air inside the building [15].

Water Damage and Moisture Problem

Water damage in the ceilings and walls of daycare centers can play a role in the growth of airborne fungi. Fungi can only grow and proliferate inside a building if the environment is damp and organic materials are present. Numerous factors can cause the moisture content of building materials to reach unacceptably high levels. [31]. A leaking installation can cause water damage, while another factor is that room air condensed on cold surfaces within the structure. When condensation causes elevated moisture levels in building materials, the moisture level fluctuates based on temperature and relative humidity. [30].

Hwang et al. discovered that fungal levels in water-damaged facilities were substantially higher than in non-damaged facilities (p=0.045). According to the study, in 25 daycare centers, the I/O ratio was 0.8; however, in the facilities with water damage, the value increased to more than 1. Shahidah and Shukri conducted the study at two daycare centers. The fungi concentration at the ACG daycare center was double that of the ACK daycare center, even though the mode of ventilation and the number of occupants were similar. It could be caused by moisture and building material that absorbs moisture. Furthermore, the ACG is in a residential area where fungi can come from nearby bathroom doors or windows [21]. From 15 chosen studies, only a few researchers documented the water damage or moisture problem [16], [21] [23] [12] Water damage and moisture problems are essential and should be noted in future research.

Association between Characterization of Fungi and Parameter Affecting Characteristic of Fungi at Daycare Center

In this review, only a few studies investigated the correlation between the characterization of fungi and parameters affecting the characteristic of fungi. The characterization of fungi is based on the concentration of airborne fungi and species of fungi. The parameters affecting it are based on ventilation, temperature, relative humidity, and climatic factor. Only two of the studies identified an association between the temperature and the concentration of indoor airborne fungi. The temperature was significantly related by Chengini et al. (p=0.049) and Sephavand et al. (p<0.01) [13] [15]. However, J Madureira and Shin et al. found that the temperature did not correlate with indoor airborne fungi (p=0.20) [17][18]. The study conducted by J Madureira found that fungal concentration did negatively correlate with relative humidity (p=-0.08) [18]. On the contrary, Chengini et al. (p=0.44) and Hosaizandeh et al. (p=0.802) found no direct correlation [13] [14]. For climatic factors, no correlation is found between season and fungal bioaerosol contamination, proven by Sepahvand et al. study. For species, Fusarium fungi were only observed in spring and contaminated 6% of the samples [15]. For ventilation, no study provides quantitative data on the correlation between ventilation type and indoor airborne concentration. However, using air purifiers could reduce fungi indoor contamination by 55% [1].

Limitation and Recommendation

This systematic review has a few limitations. The major limitation was that heterogeneity analysis could not be done on all data since some studies lacked the required data depending on each objective of the included studies. As several studies did not specify the concentration of fungi or measure the fungal count in a different unit, not all research was included in this discussion. Other parameters, including ventilation, temperature, and humidity, cannot be analyzed due to the insufficient data provided by the researchers. Another limitation is that research on airborne fungi at daycare centers is quite limited. Many aspects can be improved for future recommendations. First, future researchers should observe and record the ventilation modes used at the daycare and water damage at the building. It is essential to analyze where the source of the indoor airborne fungi is. When we know the sources of fungi, it is easier to propose control measures to the sources. The daycare centers should imply mechanical ventilation to reduce the pollutant entering the building. However, mechanical ventilation should be inspected and maintained regularly. This study only represents a few selected daycare centers, and the condition may worsen in other areas. Thus, further studies need to be conducted to measure the exposure level of fungi in other areas.

CONCLUSION

In conclusion, this systematic review aims to help in providing a comprehensive overview of the existing knowledge on the characterization of fungi at daycare centers. The findings show that the median airborne fungi level was 317.25 CFU/m³, falling from 3.4 CFU/m³ (in Khorramabad, Iran, in July) to 47 581 CFU/m³ (in Taiwan). Most daycares did not exceed the recommendation limit by World Health Organization which is 500 CFU/m^3. However, some studies exceed the recommended limit. In a study by Chen et la., the concentration of fungi tenfold the average concentration in another study. This can be due to warm and humid weather in Taiwan that can promote the growth of fungal [12]. Penicillium, Cladosporium, and Aspergillus are among the most predominant fungus found at daycare center in these included studies.

This review also studies factors influencing the concentration of airborne fungi like temperature, relative humidity, season, ventilation, human occupancy, outdoor concentration, water damage, and moisture problem. Positive correlation on the concentration of fungi and temperature by Chegini et al. and Sepahvand et al. [13] [15] For relative humidity J Madureira found the fungi concentration negatively correlated with relative humidity [18] Among the 3 types of ventilation, hybrid is the most effective in reducing air pollutants. Using an air purifier can also reduce the concentration of fungi by 55% [1] For airborne fungi, 3 studies found the highest concentration in spring, highest in autumn 1 studies, and highest in hot climate 1 studies. The I/O ratio for fungi in 25 daycare centers was 0.8. However, the ratio increases to >1 for facilities with water damage 14 This study also recommends doing more research on airborne fungi at other places since the previous studies on airborne fungi at daycare center are quite limited.

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