RESEARCH ARTICLE

Evaluation of air quality in food courts by determining the presence of airborne bacteria and fungi

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Abstract:

Bacterial and fungal bioaerosols are ubiquitous in the environment. Humans are frequently exposed to bioaerosol-derived airborne pollutants that cause respiratory illness. Therefore, investigation of microorganisms in the air environment is essential for assessing air quality and controlling potential health risks. The study aims to a) identify airborne bacteria and fungi and b) examine the relationship between airborne bacteria and fungi concentrations with environmental factors from the selected UiTM Puncak Alam food courts. Air samples were collected using the M Air T™Milipore Air Tester. The temperature, relative humidity, and population density were recorded. The findings showed *Staphylococcus* spp. (63.1%) and *Bacillus* spp. (28.8%) were found to be the most prevalent bacteria. The dominant isolated fungi were *Aspergillus* (53.8%), *Fusarium* (20.5%), and *Penicillium* (18.8%). There was a substantial variation in the concentration of airborne microorganisms between indoor and outdoor food courts. However, the microbes discovered were not tested for their pathogenic attributes. The acquired results indicated that food courts at UiTM Puncak Alam are hygienic, as the concentration of microorganisms is below the maximum suggested range. In conclusion, continuous preventive measures, such as ventilation system maintenance and scheduled regular cleaning must be employed to control all variables that accelerate microbial growth.

Keywords: Airborne bacteria and fungi, air quality, microbiological assessments.

1. INTRODUCTION

Particulate matter can be found in both indoor and outdoor environments. It comprises airborne microbes, particles, gases, vapours, and fragments (Kim, K-H et al., 2018, Duchaine, C and Roy, C.J. 2022). Bioaerosols containing viruses, bacteria, and fungi are significant from a public health perspective. The diameter of bioaerosol particles is typically between 0.3 to 100.0 µm, which is considered the human respirable size fraction (1.0 to 10.0 µm). The size of a single bacterial cell ranges from 0.5 to 2.0 µm in airborne microorganisms that are aggregated into bigger particles. The larger particles are typically deposited on surfaces like soils, dust, saliva, and water droplets, whilst the smaller particles (1.0 - 5.0 µm) remain in the air (Stetzenbach, Buttner& Cruz, 2004). Several studies indicate that temperature, relative humidity, moisture, air exchange rate, carbon dioxide, and the number of people and animals are the most significant environmental factors that have a positive or negative correlation with microbial growth and spore disposal (Zhu et al., 2003; Makinen, Juvonen, Jokelainen, Harju, Peitso, Bloigu, Silvennoinen-Kassinen, Leinonen, & Hassi, 2009; Rajasekar & Balasubramanian, 2011; Kim, Nakajima, & Higuchi, 2009; Mandal & Brandl, 2011, Duchaine C, Roy CJ., 2022). Human actions like speaking, sneezing, coughing, walking, washing, and using the toilet can generate airborne particles (Mandal & Brandl, 2011). During sneezing, for instance, millions of microscopic water droplets containing a virus or bacterial particles are discharged at 100 metres per second. However, when it is dry, the size of droplets drops from 10-100 µm to 1-4 µm. Humans act as hosts to most non-pathogenic microorganisms and in some cases, these microorganisms are beneficial to the body. Nevertheless, there is also a probability of pathogenic microorganisms carried in the human body. A variety of potentially infectious microorganisms can be transmitted from human to human through coughing, sneezing and talking. Mostly, these microorganisms are from the respiratory tracts of the infected individual. Pathogenic bacteria such as Haemophilus influenza, Streptococcus pneumonia, Moraxella catarrhalis and Streptococcus pyogenes are some examples of air-associated bacteria. Those organisms can act as normal flora of human mucous membrane, respiratory tract or skin and have the potential for transmission via the air (D'Arcy, Canales, David, & Lai, 2012). Airborne and air-associated diseases are common problems to human health. Exposure to molds and other microbial agents increases the risk of an abnormal conditions such as hypersensitivity, pneumonitis, tuberculosis, chronic rhinosinusitis and sinusitis. According to a report by World

Health Organization (WHO, 2011), lower respiratory tract infections are the leading cause of death in low-income countries (11.3 %). However, the impact of the Covid-19 pandemic causing an increase in TB death according to the World Health Organization's 2021 Global TB report.

In order to improve air quality concurrently with the management of microbial distribution in the environment, it is important to control factors that contribute to the problems. Several factors including humidity, temperature, air exchange rate and human activities can influence microbial growth. Observations have been made in previous studies where there is a relationship between outdoor and indoor air due to the flow of contaminants outdoors and indoors (Zhu et al., 2003).

2. MATERIALS AND METHODS

2.1 Study locations

The Universiti Teknologi MARA (UiTM) Puncak Alam was selected as a sampling location for this research. The study was conducted between March to April 2013. There were four food courts located in UiTM Puncak Alam. Two food courts are located at Plaza Satelit B (PSB). The indoor cafe (namely Pendeta café) is situated on the third floor and the open food court is situated on the second floor. Pendeta cafe is equipped with an air-conditioning system while the open food court is ventilated with a fan. Two food courts were situated in students' residential areas where both food courts were in the Kompleks Kemudahan Pelajar Angsana and Kompleks Kemudahan Pelajar Rafflesia respectively. Those indoor food courts were built with the same design with 2729.5 m^2 areas and can accommodate 650 students at one time. PSB open court was categorised as an outdoor food court while Pendeta Cafe, Rafflesia food court and Angsana food court were categorised as indoor food courts.

2.2 Microbiological air sampling

A total of 120 air samples were collected from all food courts in UiTM Puncak Alam. The sampling was divided into two categories: indoor (60 samples) and outdoor food courts (60 samples). From the 60 samples taken for indoor food courts, there were 48 samples from Angsana and Rafflesia food courts and another 12 samples were from Pendeta Cafe. All 60 samples for outdoor food courts were taken at the PSB food court. For each category, the number of bacteria and fungi plates was equally divided to 30 plates each.

The airborne bacteria and fungi were collected using M Air T™Milipore Air Tester at 1000 L for approximately 5 minutes at a 180 L/min air flow rate. The bacterial sample was collected on M Air T™ Cassette prefilled with Trypticase Soy Agar (TSA) while the fungal sampling used the M Air T™ Cassette prefilled with Sabouraud Dextrose Agar (SDA). All plates including negative control were sent to the laboratory for further investigations. All bacterial plates were incubated for 2 days at 37 ℃ while fungal plates were incubated for 3 to 5 days at 25℃. The incubation period is important to allow the bacteria and fungi to grow and form visible colonies. If the agar plate were left more than the appropriate time, the colony may merge with each other and may interrupt the colony counting. After the desired duration of incubation, the total number of bacteria and fungi colonies were counted from each plate. The value was recorded as colony forming unit per cubic metre (cfu/m^3).

2.3 Measurements of temperature, relative humidity and occupancy density

The relative humidity and temperature were measured using 3M™QUESTemp° 36nHeat Stress Monitor along with each sample collection. Occupancy density (number of people) within a 5 m radius away from the impactor was also recorded.

2.4 Isolation and identification of viable airborne bacteria and fungi

The isolated bacteria and fungi were identified at the genus level by using a conventional method. After the colony counts were performed, the bacterial colonies on TSA were subcultured onto Columbia Sheep Blood Agar (Thermo Scientific) and Mac Conkey agar to obtain pure colonies. Blood agar is a non-selective, differential medium which allows the growth of a wide variety of microbes while Mac Conkey agar acts as a differential medium and is selective for Gram-negative organisms. Both agar plates were incubated at 37℃ for 18 - 24 hours. The growing colonies were observed for plate culture morphology. A single colony was taken, and a gram stain was done to the identification of gram-positive or gram-negative bacteria. Further bacterial confirmation of oxidase-negative and gram-negative bacilli was carried out using RapID™ One System (REMEL). Prior to confirmation by RapID™ One System, the respective colonies were identified by the IMViC test. The coryneform bacteria and other irregular gram-positive bacilli were confirmed using RapIDTM CB Plus System (REMEL).

Fungal colonies on SDA were counted and subcultured onto Malt Extract agar (MEA) for 3-5 days at 25℃. Fungal colonies growing on MEA media were picked for fungal slide culture and identification of fungal spores. The slide culture technique was done by preparing a Petri dish with filter paper that was soaked with water and an applicator stick on it. A 7 X 7 mm square of Sabouraud Dextrose Agar (SDA) was cut and placed onto a sterile glass slide and inoculated on the four sides of the agar block with spores or mycelial fragments of the fungus to be grown. Lastly, a sterile cover slip was placed onto the agar block and incubated for 3 to 5 days at 25℃. When enough growth was obtained, the coverslip was removed from the agar block and stained with Lactophenol cotton blue stain by allowing the fungi to absorb the stain for a few minutes and the fungal morphology was observed directly using a light microscope.

2.5 Statistical analysis

Statistical Package of Social Sciences (SPSS) software version 18 was used for analysing the data obtained. The normality of the data was assessed using the Kolmogorov-

Smirnov test. Mann-Whitney U test was used to compare the airborne bacteria and fungi in indoor and outdoor food courts and the Kruskal-Wallis test was used to differentiate airborne bacteria and fungi concentration from each food premises. Meanwhile, the Spearman Rank Correlation test was used to determine the correlation between airborne bacteria and fungi with temperature, relative humidity and occupancy density.

3. RESULTS AND DISCUSSION

3.1 Characterisation of airborne bacteria and fungi

Six bacterial genera and eight fungal genera were isolated from indoor food courts. *Staphylococcus* spp. (Figure 1A,2A) was most commonly isolated followed by *Bacillus* spp. (Figure 1B,2B), *Brevibacterium* spp., *Acinetobacter* spp., *Micrococcus* spp. and *Corynebacteria* spp. More than half (63.87 %) of the total colonies isolated from indoor food courts were *Staphylococcus* spp., a gram-positive cocci bacteria. *Bacillus* spp. (gram-positive sporulating rods) accounted for 29.0 % and 3.36 % of *Brevibacterium* spp. (gram positive bacilli) have been isolated. Only 0.84 % of *Micrococcus* spp. (gram-positive cocci) and *Corynebacteria* spp. (Gram-positive bacilli) have been isolated. *Aspergillus* spp. (Figure 1C,2C) was the most isolated fungal colony with 59.74 % and followed by *Penicillium* spp. (20.78 %, Figure 2D), *Fusarium* spp. (11.69 %, Figure 1D) and *Mucor* spp. (2.60 %). *Eurotium* spp., *Rhizopus* spp., *Trichoderma* spp. and *Monascus* spp. were also isolated which accounted only for 1.30 % respectively.

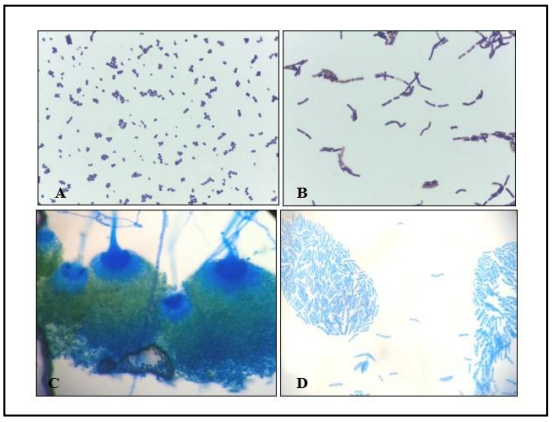

Figure 1: Microscopic morphology of bacteria and fungi; (A) *Staphylococcus* spp. shows gram-positive cocci in a cluster, (B) *Bacillus* spp. shows gram-positive bacilli with spores, (C) *Aspergillus* spp. shows a conidial head with conidia, (D) *Fusarium* spp. macroconidia

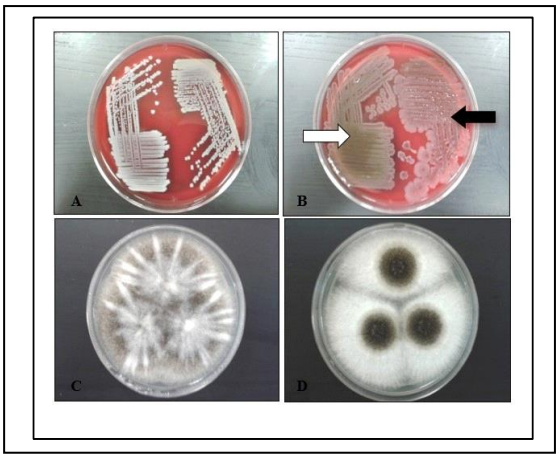

Figure 2: Isolated bacterial and fungal colony; (A) *Staphylococcus* spp. colony on Blood Agar with a whitish, flat and medium colony, (B) *Bacillus* spp. colony on BA with greenish, umbonate, medium and dry (white arrow), greyish, umbonate, large and mucoid colony (black arrow), (C) *Aspergillus* spp. colony on MEA after 8 days of incubation, (D) *Penicillium* spp. colony on MEA after 8 days of incubation.

In outdoor food courts, five bacterial genera and five fungal genera have been identified. The most frequently isolated bacterial genus is similar to indoor food courts which were *Staphylococcus* spp. (62.58%) and *Bacillus* spp. (28.39%). From 155 isolated organisms, only 3.87 % of *Micrococcus* spp. and *Corynebacteria* spp. were isolated respectively. The only gram-negative bacterium isolated was *Enterobacter* spp. (1.29 %). *Aspergillus* spp. is also the most frequently isolated fungal organism followed by *Fusarium* spp. (37.5%), *Penicillium* spp. (15%), *Rhizopus* spp. (2.5%) and *Botrytis* spp. (2.5%).

Overall, seven bacterial genera and nine fungal genera have been isolated from both indoor and outdoor food courts (Table 1). The most common isolated bacteria from all food premises were *Staphylococcus* and *Bacillus* while the most frequently isolated fungi were *Aspergillus*, *Fusarium* and *Penicillium*.

Table 1: Bacteria and fungi genera isolated from indoor and outdoor food courts.

Bacteria		
Genera	N = 274	Percentage (%)
***Staphylococcus* spp.**	173	63.1
***Bacillus* spp.**	79	28.8
***Micrococcus* spp.**	7	2.6
***Corynebacteria* spp.**	7	2.6
***Brevibacterium* spp.**	4	1.5
***Acinetobacter*spp.**	2	0.7
***Enterobacter*spp.**	2	0.7
Fungi		
Genera	N = 117	Percentage (%)
***Aspergillus* spp.**	63	53.8
***Fusarium* spp.**	24	20.5
***Penicillium* spp.**	22	18.8
***Mucor* spp.**	2	1.7
***Rhizopus* spp.**	2	1.7
***Eurotium* spp.**	1	0.9
***Trichoderma* spp.**	1	0.9
***Monascus* spp.**	1	0.9
***Botrytis* spp.**	1	0.9

3.2 Distribution of airborne bacteria and fungi in indoor and outdoor food courts

PSB open food court shows the highest concentration of airborne bacteria accounted for 453.33 cfu/m^3 while the lowest concentration of airborne bacteria is 7.78 cfu/m^3 from Angsana food court. The highest mean of bacteria concentration is from PSB open food court falls at 138.71 cfu/m3. In contrast, Rafflesia food court shows the highest mean fungi concentration which is 95 cfu/m^3 whereas PSB open food court had the lowest mean concentration of fungi which is 41.02 cfu/m^3. The highest concentration of airborne fungi is 266.67 cfu/m^3 and the lowest concentration of airborne fungi is 11.11 cfu/m^3 from the Rafflesia food court and PSB open food court respectively. Table 2 showed the concentration of bacteria and fungi in different food premises and Figure 3 showed the bar chart of the mean concentration of each food premises.

Table 2: Concentration of airborne bacteria and fungi in different food premises.

Micro-organisms	**Locations (No of Samples)**	**Concentration (cfu/m^3)**		
		Min.	**Max.**	**Mean±SD**
Bacteria	Angsana (12)	7.78	88.89	50.56 ± 24.89
	Rafflesia (12)	32.22	90.00	61.11± 21.49
	Pendeta (6)	87.78	256.67	138.71± 60.71
	PSB (30)	38.89	453.33	122.56± 88.30
Fungi	Angsana (12)	21.11	87.78	50.55 ± 18.61
	Rafflesia (12)	27.78	266.67	95.00 ± 74.07
	Pendeta (6)	38.89	65.56	50.74 ± 10.42
	PSB (30)	11.11	112.22	41.02 ± 28.57

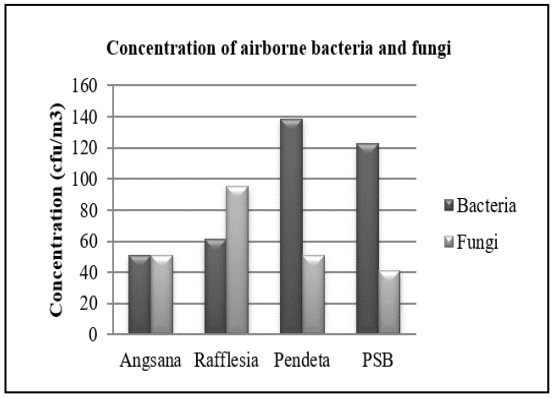

Figure 3: Mean concentration of airborne bacteria and fungi in Angsana food court, Rafflesia food court, Pendeta Cafe and PSB open food court

Based on Table 3, there was no significant difference between indoor and outdoor food courts for airborne fungi concentration as the p-value was 0.18 (> 0.05). On the contrary, there is a significant difference between indoor and outdoor airborne bacteria concentration as the p-value is 0.01 which is less than 0.05. The differences between indoor and outdoor bacteria and fungi concentrations were shown in Figure 4.

Table 3: Mann-Whitney test of concentration of airborne bacteria and fungi between indoor and outdoor food courts.

Miro-organisms	**Conditions (No of samples)**	**Mean ± SD**	**p value**
Bacteria	Indoor (30)	72.41 ± 46.96	p = 0.01
	Outdoor (30)	122.56 ± 88.30	p < 0.05 is significantly different
Fungi	Indoor (30)	63.82 ± 54.04	p= 0.18
	Outdoor (30)	41.02 ± 28.57	p > 0.05 is not significantly different

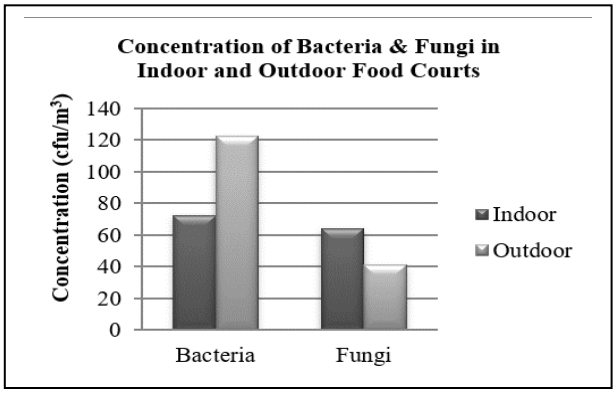

Figure 4: Comparison of airborne bacteria and fungi in indoor and outdoor food courts

3.3 Relationship between airborne bacteria and fungi concentration with temperature, relative humidity and occupancy density

The lowest temperature recorded was 22.5 ℃, while the highest temperature was 28.5 ℃. The mean temperature falls at 26.3 ℃. The lowest relative humidity recorded was 60 % and the highest relative humidity was 96 %. Mean relative humidity falls at 77.4 %. The numbers of people present during the sampling were from 3 to 105 people with a mean fall of 36 people.

The airborne bacteria concentrations were range from 7.78 cfu/m3 to 453.33 cfu/m3 with a mean of 97.48 cfu/m^3. Besides that, the airborne fungi concentrations were range from 11.11cfu/m^3 to 266.67cfu/m^3 with mean concentration 52.42cfu/m^3. All data obtained were summarised in Table 4.

Table 4: Descriptive data of temperature, relative humidity, occupancy density, airborne bacteria concentration and airborne fungi concentration

Variable	N	Min.	Max.	Mean±SD
Temperature (℃)	120	22.5	28.5	26.3±1.5
Relative humidity (%)	120	60.0	96.0	77.4±9.4
Occupancy Density	120	3	105	36±25
Concentration of airborne bacteria (cfu/m^3)	60	7.78	453.33	97.48±74.54
Concentration of airborne fungi (cfu/m^3)	60	11.11	266.67	52.42±44.37

Tables 5 and 6 showed the Spearman rank correlation test result for indoor and outdoor food courts respectively. The results showed the relationship between microbial concentrations with environmental factors in each location. For indoor food courts, bacterial concentrations show negative correlation with temperature (r=-0.476; p=0.008) and positive correlation with occupancy densities (r=0.568; p=0.001) while fungal concentrations have a positive correlation with relative humidity (r=0.579; p=0.001). In contrast, only relative humidity influences fungal concentrations (r=0.459; p=0.011) for outdoor food courts.

Table 5: Correlation test between temperature, relative humidity, and occupancy density with airborne bacteria and fungi concentration at indoor food courts.

Factor	Parameter	r	p-value	Conclusion
Temperature	Bacteria	-0.476	0.008	There is a significant (p<0.05), negative fair correlation
	Fungi	-0.228	0.225	There is no significant (p>0.05), no correlation
Relative Humidity	Bacteria	-0.195	0.301	There is no significant (p>0.05), no correlation
	Fungi	0.579	0.001	There is a significant (p<0.05), positive good correlation
Occupancy Density	Bacteria	0.568	0.001	There is a significant (p<0.05), positive good correlation
	Fungi	-0.325	0.080	There is no significant (p>0.05), no correlation

Table 6: Correlation test between temperature, relative humidity, and occupancy density with airborne bacteria and fungi concentration at outdoor food courts.

Factors	Parameter	r	p-value	Conclusion
Temperature	Bacteria	-0.047	0.807	There is no significant (p>0.05), no correlation
	Fungi	-0.004	0.982	There is no significant (p>0.05), no correlation
Relative Humidity	Bacteria	-0.152	0.421	There is no significant (p>0.05), no correlation
	Fungi	0.459	0.011	There is a significant (p<0.05), positive fair correlation
Occupancy Density	Bacteria	0.222	0.239	There is no significant (p>0.05), no correlation
	Fungi	-0.297	0.110	There is no significant (p>0.05), no correlation

3.4 Discussions

In general, the most isolated bacteria in both food courts were *Staphylococcus* spp. (63.1%) followed by *Bacillus* spp. (28.8%). *Aspergillus* spp. accounts for 53.8% of the most frequently isolated fungi from both food courts. *Fusarium* spp. and *Penicillium* spp. account for 20.5% and 18.8% respectively. This finding was similar to other studies where *Staphylococcus* spp., *Bacillus* spp., *Micrococcus* spp.,

Streptococcus spp., *Corynebacteria* spp., *Acinetobacter* spp., *Pseudomonas* spp., *Aspergillus* pp., *Penicillium* spp., *Fusarium* spp., and *Cladosporium* spp. are among the most isolated organisms from air environment (Awosika, Olajobu & Amusa, 2012; D'Arcy et al., 2012; Mandal & Brandl, 2011).

Both indoor and outdoor food courts showed similar organisms isolated which are Staphylococcus spp., *Bacillus* spp., Micrococcus spp., and *Corynebacteria* spp. However, two distinct gram-negative bacteria have been isolated from both food courts, which are *Acinetobacter* spp. (1.68%) from indoor food courts and *Enterobacter* spp. (1.29%) from outdoor food courts. Overall bacteria species isolated in this study have also been found in other studies, except for *Brevibacterium* spp. isolated from indoor food courts, was rarely isolated from the previous study and only found in a study by Chan et al., (2009). *Brevibacterium* spp. is a gram-positive rod bacterium that is commonly isolated from clinical specimens such as peritoneal fluid (Gruner et al., 1993; Brzostowicz et al., 2003). Some of the *Brevibacterium* species are considered the normal flora of the skin. *B. Casei* is the most frequently isolated species in the genus and is known as the opportunistic pathogen and frequently causes sepsis in patients with AIDS (Brazzola et al., 2000; Janda, Tiperneni& Novak, 2003).

Gram-positive cocci were the dominant bacterial species isolated during the study period. This finding was consistent with other studies conducted in the office, school, university and residential areas as Staphylococci are normally widespread in nature (Mandal & Brandl, 2011). However, the high level of these bacteria would indicate high-density occupancy and inadequate ventilation (Hussin et al., 2011). *Bacillus* spp. accounted for the next most isolated bacteria in this study. *Bacillus* spp. can form endospores which allow them to tolerate extreme environments and are easily dispersed in the air (Chan et al, 2009). Members of the *Bacillus* are widely distributed in nature, but some of the species are opportunistic to humans and animals (Hussin et al., 2011). *B. subtilis* for example has the potential to be the cause of food contamination, but this species rarely causes food poisoning (Ryan et al., 2004). The third most isolated bacteria are *Micrococcus* and *Corynebacteria*. But both species are most frequently isolated from the outdoor food courts. Similar to the bacteria species mentioned before, many species of *Corynebacteria* and *Micrococcus* exist as a part of the normal flora of the skin (Hussin et al., 2011). Only 1.5% of gram-negative bacteria are isolated from a total number of bacteria isolated which have the potential to cause infection to humans. The low percentage of gram-negative bacteria detected can be due to bacterial damage during sampling. It is well known that some bacteria especially gram-negative bacteria can be damaged by the sampling technique currently used (Chang & Chou, 2010). Furthermore, the culture-based method does not account for viable but non-culturable microorganisms that still have the potential to cause disease (D'Arcy et al., 2012)

During the study period, airborne fungi, *Aspergillus* spp. was the predominantly isolated genera. This finding was also reported by Hussin et al., (2011) where in their study, *Aspergillus* spp. was the predominantly isolated fungi. The second most frequently isolated fungus was *Fusarium* spp. and the next was *Penicillium* spp. The most abundant fungi in the atmosphere such as *Aspergillus* and *Penicillium* produce high numbers of small and light spores, and this certainly favours their dominance in these environments (Cabral, 2010). *Aspergillus* and *Penicillium* are significant indoor allergens (Hussin et al., 2011). Therefore, it is essential to identify the species of *Aspergillus* genera since some species of *Aspergillus* such as *A. flavus* and *A. versicolor* has allergenic, toxigenic, and infectious effects. Furthermore, exposure to large concentrations of the spores of *Aspergillus* can result in aspergillosis (Pradub & Wattanachai, 2012). Almost all the previous studies have listed *Cladosporium* species as one of the most frequently isolated airborne fungi (Pradub & Wattanachai, 2012; Rajasekar & Balasubramanian, 2011; Hussin et al., 2011; Yassin & Almouqatea, 2010; Abdel Hameed et al., 2009; Lee et al., 2006) but in the present study, no *Cladosporium* spp. have been isolated.

Generally, it was found that indoor and outdoor airborne bacteria were significantly correlated. This trend was observed in the present study. Furthermore, the concentration of airborne bacteria was higher in outdoor food courts compared to indoor food courts. This trend also has been stated in a previous study conducted in Kuwait where the outdoor total bacteria concentrations for the four different areas were usually higher compared to the indoor concentrations (Yassin & Almouqatea, 2010). This condition occurs because the people passer-by the food court and there are pathways of outdoor sources.

In comparison, the concentrations of airborne fungi in indoor food courts are extremely higher compared to outdoor food courts. Analysis of the data also marked that the concentration of indoor airborne fungi was not significantly different ($p > 0.05$) from a concentration of outdoor airborne fungi. The high level of indoor fungal concentration might be caused by poor ventilation systems where the air currents by the air-conditioning system and fans can cause dust particulates to suspend and form airborne microorganisms (Rajasekar & Balasubramanian, 2011). In addition, the presence of carpets also can be home to dust-borne fungi and enhance fungal growth (Haleem Khan & Karuppayil, 2012). In another study, it was common that the total fungal concentration was higher in the outdoor environment compared to the indoor environment (Lee et al., 2006). In contrast, a study conducted in Kuwait also shows that the total indoor fungal concentration is higher compared to the outdoor fungal concentration (Yassin & Almouqatea, 2010).

Among all the food courts, Pendeta cafe shows the highest concentration of airborne bacteria. Pendeta cafe used air-conditioning system for ventilation. This factor may contribute to the high level of airborne bacteria concentration. Rafflesia food court showed the highest concentration of

airborne fungi compared to other food premises. This condition might be caused by the door of the food court being frequently open and sometimes left open for a long period. This factor may cause the fungal spores to flow into the food court.

In comparison between indoor and outdoor food courts, indoor food courts showed a relationship between temperature and occupancy density with bacterial concentrations while fungal concentration has been influenced only by relative humidity. For outdoor food courts, only relative humidity influences fungal concentrations. From that, relative humidity has been proven that as a crucial factor in fungal growth as it influences both indoor and outdoor fungal concentrations. The concentration of fungal spores depends on three important biological factors: (1) The magnitude of sporulation (the number of conidiophores and conidia formed in each conidiophore). (2) Spore release from the conidiophores influence directly by atmospheric relative humidity and air current. (3) Conidia dimensions and weight (Cabral, 2010). Indoor bacterial concentrations were significantly correlated to temperature and occupancy density. As the temperature is closely related to solar radiation, high temperature is always accompanied by an increase in solar radiation, which has bactericidal properties and causes a reduction in bacterial concentrations. Indoor bacterial concentrations were higher with an increasing number of occupants suggesting that the presence of humans could be a source of the bioaerosols in the indoor environments. Activities such as talking, sneezing, and coughing could generate and increase the human transmission of indoor bioaerosols. However, no significant difference was found in the indoor fungal concentrations with and without occupants. This finding was consistent with the latter study which showed similar results obtain (Hussin et al., 2011; Rajasekar & Balasubramanian, 2011).

4. CONCLUSION

Overall, the most frequently isolated airborne microbial were *Staphylococcus*, *Bacillus*, *Aspergillus*, *Fusarium* and *Penicillium*. The study demonstrated that the level of indoor airborne bacteria was strongly affected by temperature (inversely correlated) and relative humidity (positively correlated) while both indoor and outdoor airborne fungi concentrations were dependent on relative humidity. The concentrations of airborne fungi increased with relative humidity. There was also a difference between indoor airborne bacteria concentration with outdoor bacteria concentration. Airborne fungi showed no significant difference between indoor and outdoor fungi concentration. Although the level of airborne bacteria and fungi is within the recommended value, there are some recommendations that could be taken as preventive measures. Several factors including temperature, relative humidity, airflow, occupant density, ventilation, materials and furnishing should be considered. It is advised to keep the air-conditioning units switched on continuously as it can lead to condensation of water and increase the relative humidity upon switching off the air-conditioning. Regular cleaning is also important to prevent the accumulation of debris and particulate matter, but it is recommended to make a cleaning schedule during peak hours as the cleaning activities also can contribute to the level of bioaerosols concentration. Besides that, increasing kitchen ventilation is also crucial in maintaining the food court environment. For an indoor food court with potted plants, it is important to keep the houseplants that are watered regularly healthy as the soils may act as reservoirs of fungi. The use of carpet also can increase the fungal level, thus frequent vacuum cleaning may reduce the spore levels.

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