Fungi Spread Affected By Distance From Hand Dryer

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Abstract

Hand dryers are commonly installed and used in public washrooms as an alternative to paper towel dispensers, often with the intention of being more environmentally friendly. However, they also have the potential to widely distribute fungi around the washroom environment, which may deposit onto surfaces and get carried from place to place. Using a bread model, this study investigated whether distance from a hand dryer affects the amount of fungi dispersed onto a surface while the hand dryer is running. Various species of mould growth, including *Penicillium expansum* and *Aspergillus flavus*, were observed amongst the bread slices. The percent coverage of mould growth on bread slices was tracked over an observational period of 11 days, and an average growth rate for each treatment distance from the hand dryer ($n = 4$) was calculated. A one-way ANOVA was performed, and determined that differences in growth rate between varied distances from the hand dryer were statistically insignificant ($p = 0.1216$). There is no difference in the amount of fungi dispersed onto a surface with different distances away from the hand dryer.

Introduction

Hand washing is a key step in maintaining personal hygiene and preventing the spread of infectious disease such as COVID-19 (Jess & Dozier, 2020). It is an essential practice to prevent the transmission of harmful microorganisms, and thorough hand drying is a crucial step in this process. Many studies have shown that fungi spread is more effective on wet surfaces compared to dry surfaces (Todd et al., 2010). Ineffective hand drying results in wet hands, which poses a higher risk of infection and increases the potential for cross-infection (Gammon & Hunt, 2019).

While paper towels are traditionally used for hand drying in public washrooms, many public washrooms often only provide electronic hand dryers as the means to dry our hands. These electronic hot air dryers are convenient, environmentally friendly, and help people reduce the need to touch surfaces after they wash their hands (Carvalho & Abrahao, 2017). Despite these good intentions, studies have shown that there are risks for maintaining personal hygiene. Previous studies, including one conducted by Alharbi et al. (2016) have shown that hot air dryers have the potential to deposit pathogenic fungi onto our hands and greatly distribute the fungi around the environment whenever they are running. High levels of fungi were also found in the air flow from the outlet nozzle (Alharbi et al., 2016). This raises concerns about the effectiveness of this hand drying method for personal hygiene, especially in public washrooms, as multiple people may use the same dryer consecutively. This study examined whether the spread of fungi from electronic hand dryers in public washrooms is dependent on distance from the hand dryer source. A bread model was used to simulate the fungal spread and measure the extent to which the fungi can travel through the air. Previous studies have suggested that hand dryers are capable of dispersing droplets that contain fungi (Best & Redway, 2015; Dawson et al., 2016), therefore it was predicted that areas closer to the hand dryer source would have greater fungal spread onto a surface.

Methods

Bread Preparation

Sliced white bread from Cobs Bread was used for this experiment to ensure that mould growth would be minimally suppressed by preservatives (Legan et al., 1993), and minimally affected by wild grain (Sjövall et al., 2000). 500 µL of sterilised water was pipetted into each ziploc containing a slice of bread to create an environment suitable for mould growth. Previous studies have found that humid environments elicit mould growth on bread (Alpers et al., 2021).

Treatment

Four trials were conducted in this experiment. Each trial had 3 treatments, where a slice of bread was placed at one of the following distances from the hand dryer while the hand dryer was running: 0 m from the hand dryer (directly underneath it), 1 m from the dryer, or 2 m from the dryer. The control slice was exposed to the washroom environment without the hand dryer running. Then, bread slices were placed at their respective treatment distance, and the hand dryer was run for 15 seconds. Each trial was conducted 5 minutes after the previous trial in order to reset the environment of the washroom. The experiment was conducted in the public women's washroom on the 4th floor of the Biological Sciences Building at the University of British Columbia on February 27th, 2023. The model of the hand dryer was the Dyson Airblade™ V Quiet Low Voltage Hand Dryer HU02, Nickel - 307174-01.

Incubation

Immediately after exposing the bread slices to the washroom environment at their respective treatment distances, the bread slices were sealed into moistened ziploc bags to isolate each bread sample and prevent cross-contamination. They were then placed into a 25°C incubator, as bread mould fungi such as *Penicillium expansum* and *Aspergillus flavus* have ideal growth temperatures between 25-33°C (Holmquist et al., 1983; Tannous et al., 2016).

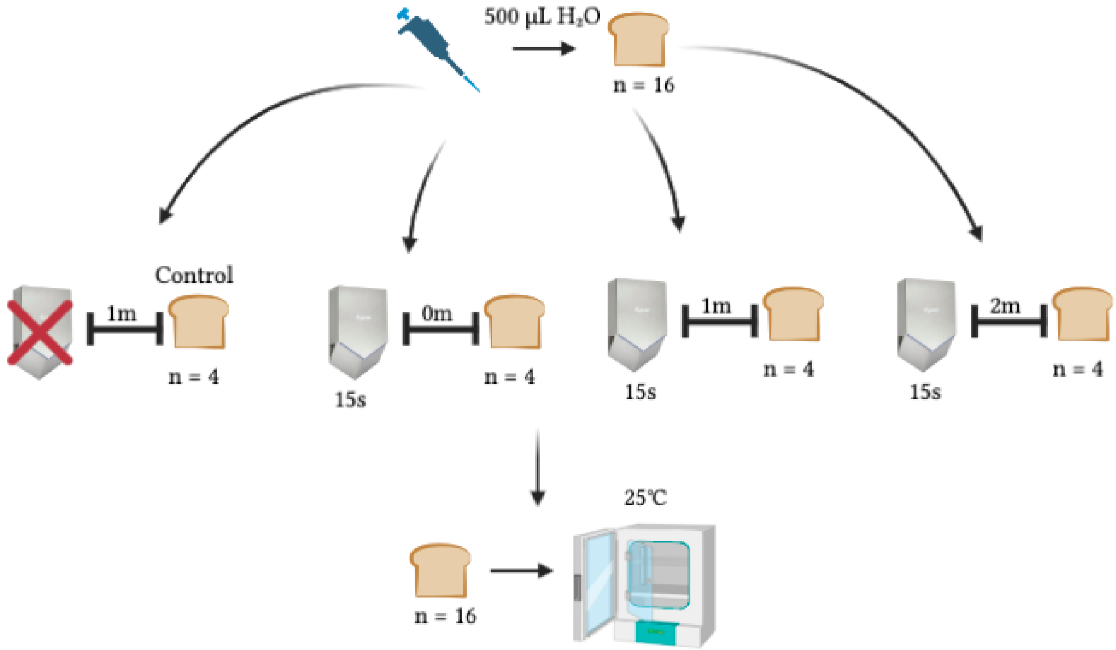

Figure 1. Diagram of the experimental treatments for each group.

Observation and Quantification

To track the progress of mould growth, photos were taken of each slice of bread every two days on Mondays, Wednesdays, and Fridays over the course of 11 days from February 28th to March 10th, 2023. Note that there was one extra day between Friday and Monday, due to the inability to enter the lab over the weekend to monitor growth. The photos were then processed in ImageJ, a Java-based image processing program, by measuring the total area covered by mould on each slice of bread. The surface area of each bread slice was then measured in order to calculate the percent coverage of mould, with the combined surface area of both sides of the bread being used in the calculations.

Statistical Analysis

The percent coverage of mould growth for each replicate and each treatment was plotted over the observation period of 11 days, then log-transformed. Linear regression was used to find the slope for each replicate. Prism, a programming software used for statistical computing and graphics, was used to perform a one-way ANOVA (analysis of variance) to compare the average growth rates of the replicates and identify the statistical significance of the data.

Results

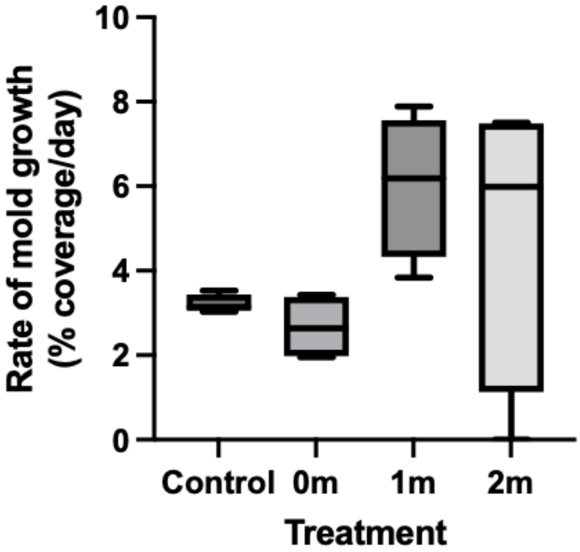

Figure 2. The rate of mould growth on bread slices in the four treatment distances (n = 4) over the observational period (t = 11 days). Error bars represent the 95% confidence interval. A one-way ANOVA test on the data resulted in a p-value of 0.1216.

Mould Growth Rates

The average growth rate of mould was highest in the 1 m treatment, with a mean of 6.03 ± 1.66 % coverage/day, and a standard deviation of 1.70 (Fig. 2). The control group had a mean growth rate of 3.21 ± 0.22, and a standard deviation of 0.22. The 0 m treatment had a mean growth rate of 2.67 ± 0.76, and a standard deviation of 0.77. The 2 m treatment had a mean growth rate of 4.87 ±

3.46, and a standard deviation of 3.53. The amount of variation in growth rates among the replicates in each treatment (n = 4) increased with increasing distance away from the hand dryer (Fig. 2). The 2 m treatment had the greatest variability in growth rate amongst all treatments, with a standard deviation of 3.53 (Fig. 2). The results of this experiment are statistically insignificant, with a p-value of 0.1216 computed using a one-way ANOVA. The three treatment groups were not statistically different from each other.

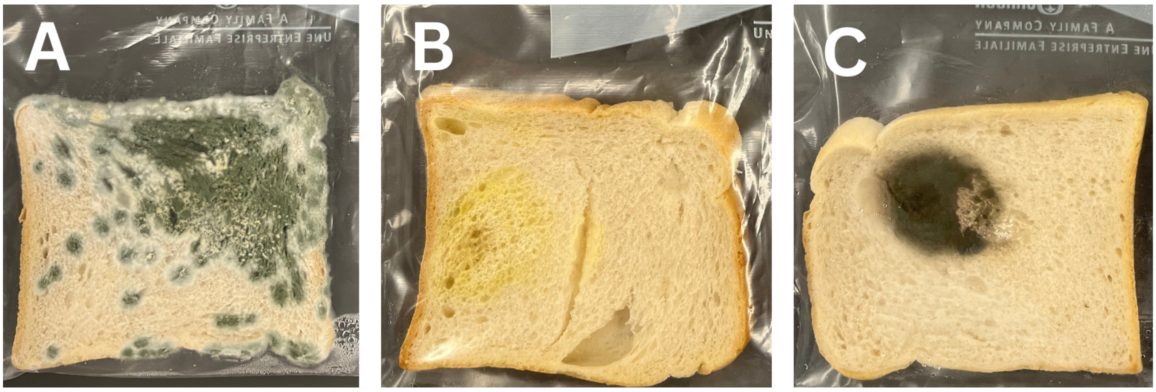

Figure 3. Different types of mould growth on bread on the 11th (and final) day of observation.

Mould Growth Characteristics

Visible mould growth first appeared on day 2 of the incubation period on replicate 3 of the 0 m treatment. Mould growth on other bread slices was then noted on subsequent days, and various types of mould growth were observed amongst the replicates. The majority of mould growth consisted of fuzzy, greyish-green coloured spores with white borders, indicating the *Penicillium* species (Fig. 3A). There were several appearances of the *Aspergillus* species, as indicated by its yellow appearance on the bread (Fig. 3B). Notable instances of black mould also appeared on a few replicates, which can be attributed to either the *Rhizopus* or *Cladosporium* species (Fig. 3C). Further testing is required to correctly identify the species.

Discussion

The results indicate that we cannot reject the null hypothesis that the amount of fungi dispersed onto a surface from a running hand dryer is not affected by distance from the hand dryer. Several sources of variation and error were possible.

Hand dryers with HEPA filters decrease the fungi load that can be deposited onto surfaces (Huesca-Espitia et al., 2018). Since the Dyson Airblade dryer used in this study has a HEPA filter, a possible explanation is that fungi is filtered from the air near the dryer, but not from the air further away beyond the dryer's range. The diagonal placement of the hand dryer due to the layout of the washroom used means that the furthest treatment group (2 m) was closest to a washroom stall. Flushing toilets generates aerosols that contain pathogens, and flushing systems used in commercial and office buildings were shown to produce more emissions in a previous study (Lai et al., 2018). Furthermore, fungi in the air near a toilet persists even after flushing (Barker et al., 2005), suggesting that the 2 m treatment group may have encountered higher concentrations of aerosolized fungi compared to treatments closer to the dryer.

Additionally, air flowed from the sides of this Dyson hand dryer model at an angle, such that the air trajectory was angled towards the ground. As such, air flow may have hit the ground in between treatment groups, which would not have allowed consistent air flow, and therefore consistent fungal load, from the closest treatment group to the furthest treatment group.

Another possible source of error is the difference in bathroom activity between replicates. Since particles persist in the air and gradually decline with time (Barker et al., 2005), some replicates may have experienced higher fungi count when a toilet was used right before the replicate was conducted, compared to replicates where no recent activity occurred beforehand.

Discontinuous air flow from the hand dryer could have affected the results as well. Within the 15 seconds the hand dryer was run for each replicate, air flow during some trials stopped briefly before quickly resuming. This discontinuous air flow can affect both the distance and quantity of fungi dispersal from the hand dryer, as airborne microbe dissemination can vary greatly with air speed (Fujiyoshi et al., 2017). This could have caused a greater variability within the 4 replicates of each treatment, therefore increasing the standard deviation of the results. Furthermore, the results of this study showed that the amount of variation in growth rates among the replicates in each treatment ($n = 4$) increases with increasing distance away from the hand dryer, which shows that air flow consistency could have affected the results. Brief pauses in air flow from the hand dryer can interrupt the flow and travelling of fungi, thereby increasing the variability of spread as distance from the hand dryer increases.

A notable observation in this study was the several different species of mould that appeared on different bread slices. Since different species have different growth rates, like *Penicillium* compared to *Rhizopus* (Sautour et al., 2002), this may have influenced the growth rate results. An improved design may be to conduct the experiment in a sterile room and release only one specific species of fungi, so the effects of distance are better tested.

Conclusion

Based on the data from this study, we fail to reject the null hypothesis that the amount of fungi dispersed onto a surface from a running hand dryer is not affected by distance from the hand dryer. Results were not statistically significant ($p = 0.1216$), and did not show any correlation between increasing distance from the dryer and fungal load. Sources of variation and error from the environment and dryer design may have led to failure to achieve significant results.

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Appendix

Graphs of Data

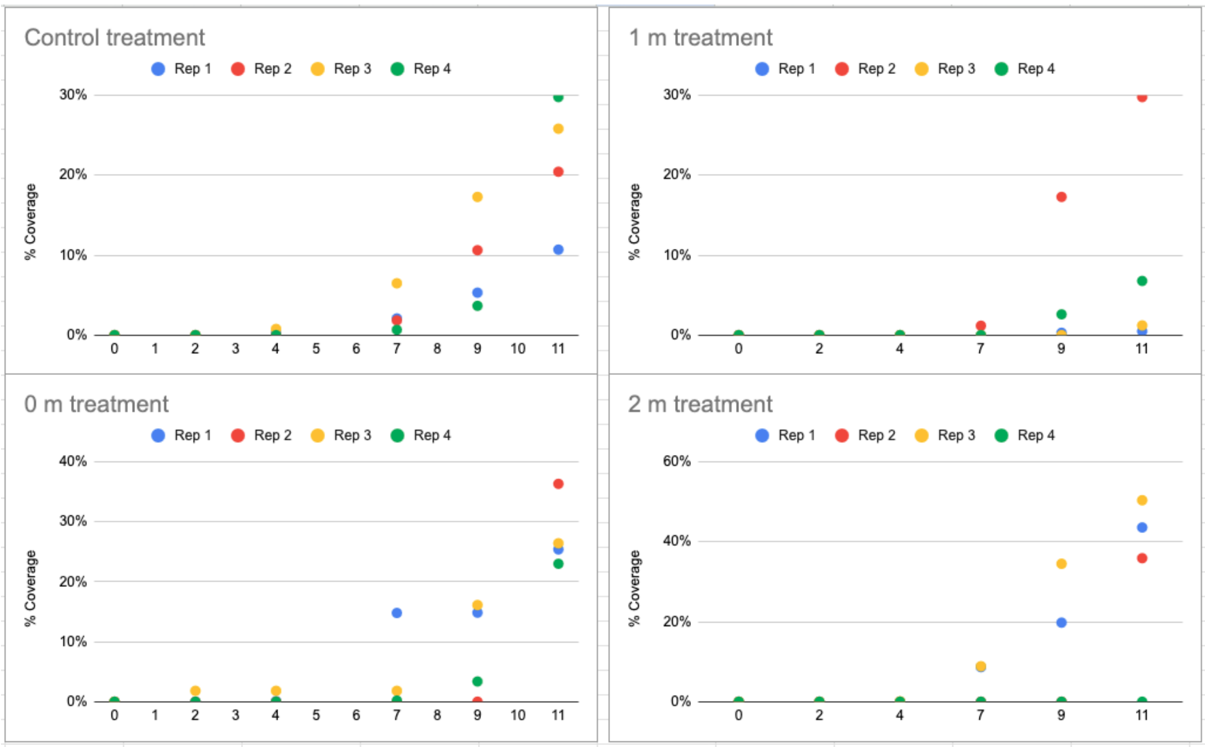

Figure A1: Growth rates of mould on bread over the duration of the experiment, where February 27, 2023 is day 0.

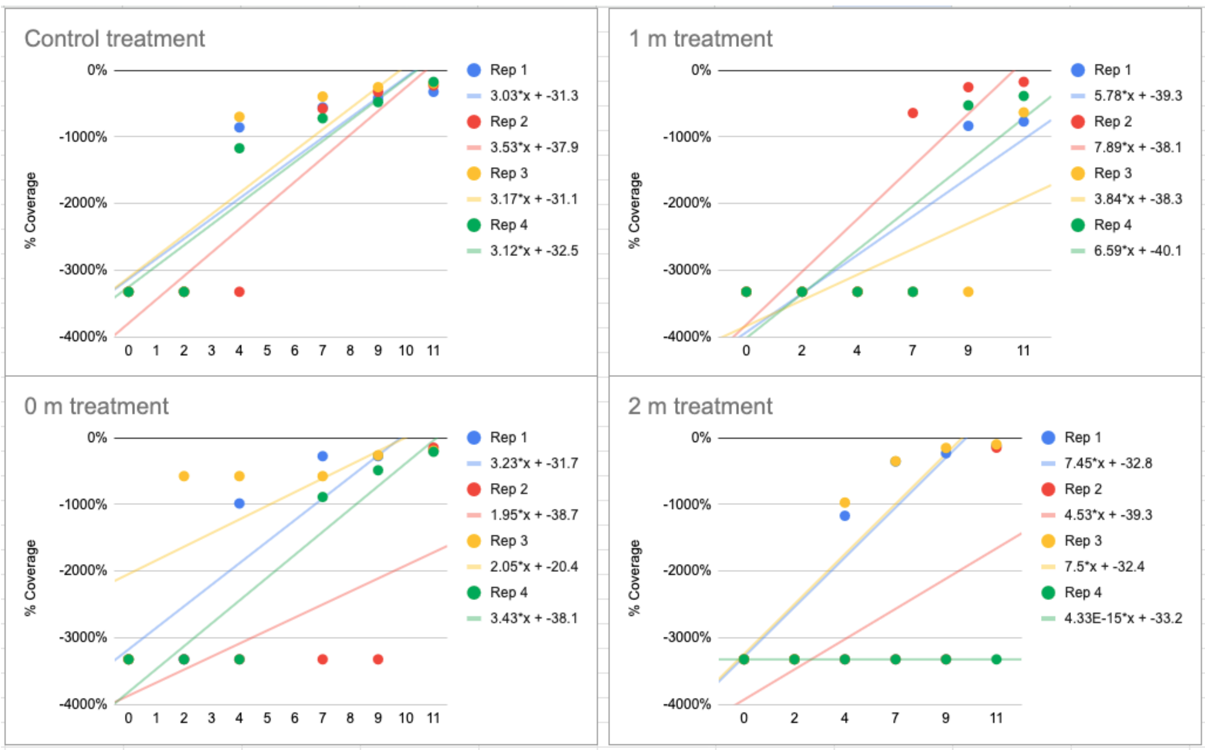

Figure A2: Log-transformed growth rates of mould on bread over the duration of the experiment, where February 27, 2023 is day 0.