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# EVALUATION OF FUNGAL GROWTH (*PENICILLIUM GLABRUM*) ON A CEILING TILE

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## ABSTRACT

Laboratory studies employing static chambers have been undertaken to study the impact of different equilibrium relative humidities (RHs) and moisture conditions on the ability of a new ceiling tile to support fungal growth. Amplification of the mold, *Penicillium glabrum*, occurred at RHs above 85 to 90%. Conversely, at lower RHs, decreases were detected. The issue of survival vs. die-off may be important in the control of fungal contamination in building materials.

## KEYWORDS

biocontaminant, fungi, building materials, chambers, moisture, relative humidity, control

## INTRODUCTION

With individuals spending as much as 90% of their day indoors (Ott, 1988), exposure of building occupants to biological contamination of the indoor environment is a major health concern (Miller, 1990). Although some biocontaminants are transported indoors from outdoors, many are produced or amplified indoors. Building materials that have become contaminated and sustain a population of fungi are a significant source of indoor air contamination, and a number of investigators have studied fungal growth, water retention, and their interactions in buildings and building materials (West and Hansen, 1989; Coppock and Cookson, 1951). Contaminated ceiling tiles (Morey, 1988), as well as contaminated accumulated ceiling tile dust (Striefel, 1988), may pose a serious health threat.

Laboratory static chamber studies were undertaken to study the impact of different environmental factors on the ability of building materials to support fungal growth and amplification. This method has been demonstrated to be useful for the evaluation of microbial growth on materials (Foarde *et al.*, 1992). Previous results have demonstrated both organism and substrate differences. For instance, at high RH (97%), *Penicillium glabrum* was able to grow and amplify on both used and most new tiles, while *Aspergillus versicolor* was not (Foarde *et al.*, 1993). New experiments have been undertaken at a range of equilibrium RHs from 54 to 97% and the corresponding material moisture contents. The objective of the experiment described in this paper was to determine the impact of a range of RHs on the ability of the test organism to grow on new ceiling tiles.

## MATERIALS AND METHODS

Modified acrylic-walled desiccators (32 x 39 x 51 cm) were used to provide controlled environments for the fungal growth tests. Saturated salt solutions maintained specific RHs of 54, 70, 85, 90, 94, and 97% within each chamber (ASTM E104-85), which were in a dark, temperature-controlled (21 ± 3°C) room

during the experiments. Each static chamber was equipped with a hygrometer and three shelves on which building material samples were placed.

Samples of one type of new, Class A (light-commercial or residential use) ceiling tile were evaluated. It was fire-resistant, acoustical, washable, and composed of 20 - 60% mineral wool fiber and 4 - 10% hydrous aluminum silicate. The ceiling tiles were obtained as 30.5 x 61 cm boards and cut into 3.8 $cm^2$ blocks that served as the actual test samples.

The moisture content (MC) of the ceiling tile blocks was determined gravimetrically and reported as percent water on a dry basis. An alternative measure of moisture is water activity ($a_w$). Corry (1987) stated that $a_w$ is the proportion of "available water for biological reactions." $a_w$ is a useful laboratory measurement with limited field use. The ability of microorganisms to grow on foods has been related to water content through $a_w$ (Pitt, 1981). Because the ceiling tile blocks were at equilibrium with the chamber RHs, $a_w$ was, by definition, equal to RH/100%. For porous materials, MC and $a_w$ are related through the water adsorption isotherm, and different relationships are obtained for different materials. Because nutrient content varies widely for various building materials (and between clean and dirty materials), no single moisture measurement will unequivocally indicate whether microorganisms will grow in a particular situation or on a material. We have chosen to use MC in the present study because it is more common in the building industry, although $a_w$ is easily calculated from the chamber RHs.

*P. glabrum*, purchased from the American Type Culture Collection (ATCC) as *P. aragonense* (ATCC #4228) and re-identified by R.A. Samson of the Centraalbureau voor Schimmelcultures, Baarn, The Netherlands, was employed as the test organism. *P. glabrum* has been isolated from the indoor environment (Samson and van Reenen-Hoekstra, 1992), and has also been proposed as a causative agent of asthma in a saw mill (Comptois and Malo, 1990).

To study fungal growth at a single RH, chamber-conditioned (for 72 h), sterile ceiling tile blocks were inoculated (on the non-white, unfinished side) with approximately 1.0 x $10^5$ colony forming units (CFUs) suspended in 10 $\mu$l of sterile water and placed in the static chambers. Uninoculated control blocks were also placed in each chamber. Triplicate blocks were removed for quantitation on days 1, 7, 14, 21, and 28. To quantify the growth, the blocks were removed from the chambers, weighed, and placed in sterile receptacles containing phosphate-buffered saline with 0.1% Tween 80. The filled receptacles were shaken on a wrist-action shaker for 30 minutes to facilitate extraction, then the extract was diluted and plated on Sabouraud dextrose agar. Plates were incubated at room temperature for at least 1 week. CFUs were quantitated shortly after visible growth was first observed and again as moderate growth became apparent.

## RESULTS AND DISCUSSION

The water adsorption isotherm data for this ceiling tile over the test RH range of 54 to 97% are presented in Fig. 1. The MC was constant at 2% at the lower RHs of 54 and 70%, demonstrated a

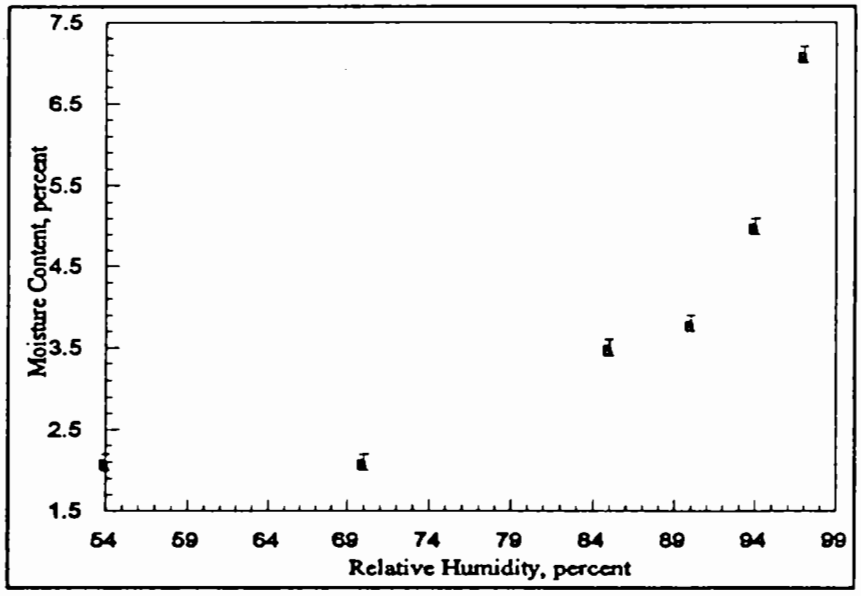


**Figure 1**. Water adsorption data for new Class A ceiling tile

slight increase at 85 and 90%, followed by a much steeper increase to 94 and 97% RH. At 90% RH the moisture content was 3.8%, while at 94 and 97% RH, the MC was 5.1 and 7.2%, respectively.

Table 1 shows the static chamber test results for new Class A tiles inoculated with *P. glabrum*. No growth or a decrease in CFUs below the detection limit (2.5 log CFUs) was obtained within the test period in chambers with RH ≤ 85%. Fungal amplification (an increase in CFUs by at least 1 order of magnitude in the test period) was measured in chambers with RHs of 90% and greater. The minimum RH for growth was therefore between 85 and 90%.

Table 1. Mean log CFUs (± 1 standard deviation) for *P. glabrum*

| DAY | 54% RH | 70% RH | 85% RH | 90% RH | 94% RH | 97% RH |
|---|---|---|---|---|---|---|
| 1 | 4.1 ± 0.1 | 3.9 ± 0.1 | 4.0 ± 0.1 | 4.1 ± 0.2 | 4.0 ± 0.3 | 4.0 ± 0.3 |
| 7 | 3.7 ± 0.1 | 3.2 ± 0.3 | 4.3 ± 0.7 | 4.0 ± 0.2 | 4.3 ± 0.2 | 5.1 ± 0.1 |
| 14 | 3.1 ± 0.5 | ≤2.5 ± na | 4.1 ± 0.5 | 4.9 ± 0.2 | 5.5 ± 0.1 | 5.7 ± 0.1 |
| 21 | 3.1 ± 0.2 | ≤2.5 ± na | ≤2.5 ± na | 5.5 ± 0.2 | 6.0 ± 0.2 | 6.2 ± 0.1 |
| 28 | ≤2.5 ± na | ≤2.5 ± na | ≤2.5 ± na | 5.4 ± 0.2 | 6.0 ± 0.1 | 6.2 ± 0.2 |

A comparison of the data in Fig. 1 and Table 1 shows that the minimum MC required for the organisms to grow on this type of ceiling tile should be between 3.6 and 3.8%, corresponding to an $a_w$ of between 0.85 and 0.90, or RH between 85 and 90%. The minimum $a_w$ for germination of *P. glabrum* has been shown to be 0.81 at 23°C (20 days). However, sporulation occurred only when the $a_w$ was at or above 0.86 (10 days, 23°C) (Mislivec and Tuite, 1970). The results of this experiment on ceiling tile agree with that result.

In the building and building materials industries, MC is the common measurement of a material's moisture. It is a practical and rapid measurement. It has been reported that a minimum MC of 10% was required for fungal growth on substrates such as leather, wool, cotton, wood, and cheese, and that a lower MC would limit fungal growth (Block, 1953). However, the data from this experiment indicate that the minimum MC for fungal growth on the ceiling tiles tested was considerably less than 10%. The differences in minimum MC required for fungal growth on ceiling tiles and other substrates reflect the fact that substrate materials can have significant impacts on the conditions required for fungal amplification.

## CONCLUSIONS

Previous results demonstrated that new ceiling tiles were able to support fungal growth at high RHs (97%) (Foarde *et al.*, 1993). That work also showed that used ceiling tile samples were more susceptible to fungal growth than the new ones. The data in the current experiment indicate that fungal growth (as measured by sporulation) can occur in ceiling tiles at equilibrium with RHs between 85 and 90%.

Block (1953) and Pasanen *et al.*, (1991) examined the influence of RH and MC on fungal growth and suggested that the RH of air did not directly influence the growth of fungi. Previous static chamber work by Foarde *et al.*, (1992) at non-equilibrium conditions showed that fungal growth appeared to correlate with material MC better than it did with chamber RH. The current data, generated under equilibrium conditions (in which case the MC and RH relationship is fixed by the adsorption isotherm such as the one in Fig.1), showed that fungal growth correlated well with both MC and RH. In summary, under

equilibrium conditions, RH (or $a_w$) and material MC are both effective measurements of the availability of water for fungal growth. However, under non-equilibrium conditions fungal amplification may be more closely correlated with material MC than RH.

In addition, and perhaps even more importantly, when conditions were unfavorable for growth (insufficient water in tiles at equilibrium with RHs ≤ 85%), culturable CFUs decreased more than 1 order of magnitude. Similar results were reported previously for wetted tiles that were dried rapidly (Foarde *et al.*, 1992). When the MC was lowered to below 3% within 3 days, culturable CFUs decreased almost 2 orders of magnitude within 10 days. This result is presumably a consequence of spore germination and subsequent inhibition of the resultant vegetative growth. Survival vs. die-off would appear to be an important element in the control of fungal contamination of building materials.

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17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Pollution | Pollution Control | 13B |
| Fungi | Stationary Sources | 06C |
| Construction Materials | Ceiling Tile | 13C |
| Test Chambers | Biocontaminants | 14B |
| Moisture | | 07D |
| Humidity | | 04B |

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