Effects of UV Irradiation on Penicillium Strains Isolated from a Bread Plant and the Application to Bakery Products

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Received 20 June, 2018/Accepted 16 May, 2019

We tested treatment with UV irradiation for controlling the growth of bread mold. First, we analyzed the sterilizing effect of a dose of approximately 25 mJ/cm² radiation on nine Penicillium and two Talaromyces strains that were isolated from a bread-manufacturing plant. The P. cherme-sinum and P. paneum strains were sterilized completely at that dose, while it was only partially effective against P. corylophilum. P. chrysogenum and P. decumbens were sterilized at a dose of approximately 120 mJ/cm², while T. amestolkiae was sterilized at approximately 150 mJ/cm². Sterilization of T. cecidicola and P. hispanicum required more than 200 mJ/cm² of radiation. These results suggest that UV resistance varies depending on the species and the strains. We also carried out UV irradiation of bread at 70 mJ/cm²: a dose at which the taste of bread is not affected; we observed that mold growth was delayed visibly compared to the non-irradiated bread. These results suggest that UV irradiation at 70 mJ/cm² is effective at delaying mold growth, though it does not cause complete sterilization. This method should prove useful for extending the shelf-life of bread.

Key words: UV irradiation / Penicillium / Mold / Bread.
The UV dose was varied between 5 mJ/cm² and 225 mJ/cm². After irradiation, petri dishes were incubated at 25°C for a week, and the number of mold colonies present was counted.

Fig. 1 shows the UV sterilization test results for each strain. *P. chermesinum* and *P. paneum* were nearly completely sterilized at a dose of 25 mJ/cm² (Fig. 1 (a)-(c)). In contrast, two *P. corylophilum* strains were sterilized at an irradiation dose of 25 mJ/cm², while the other required a dose of 50-100 mJ/cm² (Fig. 1 (d)-(f)). *P. chrysogenum* and *P. decumbens* required approximately 120 mJ/cm² (Fig. 1 (g)-(h)) and *T. identificatus* as *Talaromyces*, only anamorphic conidia, and no ascospores were observed on the PDA plate. These molds were inoculated on potato dextrose agar (PDA) and incubated at 25°C for a week. The conidia were suspended in saline with 0.05% Tween 80. Conidia suspensions were filtered through a sterile gauze to remove mycelial fragments. The media was then diluted, and the fungal conidia were counted. Suspension of each conidia (0.1 ml; about 10⁸ spores) was inoculated on PDA that had been poured into a 6 cm diameter petri dish. These petri dishes were irradiated in a box with a UV lamp (Handy UV Lamp SLUV-6, 254 nm, AS ONE). The UV dose was varied between 5 mJ/cm² and 225 mJ/cm². After irradiation, petri dishes were incubated at 25°C for a week, and the number of mold colonies present was counted.

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observed, UV tolerance would have been expected to further increase. Therefore, further examinations are necessary.

Fungal spore concentrations have been shown to exert a considerable impact on the effect of UV sterilization (Elamin et al. 2018). Similarly, in the present study, fungi with a higher spore concentration required higher UV irradiation for sterilization. However, the outcome was reversed in the case of *P. hispanicum*. In the case of *P. corylophilum*, 3 strains were tested and the level of UV irradiation necessary for sterilization varied among them. The reasons underlying such results are unclear.

**FIG. 1.** The number of colonies of each strain after different doses of UV irradiation.

(g) *P. chrysogenum* YKP012  Symbols (initial conidia count) \[\times 460; \triangle 1000; \bullet 1800\]
(h) *P. decumbens* TYP009 Symbols (initial conidia count) \[\times 640; \triangle 1400; \bullet 3100\]
(i) *T. amestolkiae* AKP001 Symbols (initial conidia count) \[\times 1600; \triangle 2800; \bullet 3700\]
(j) *T. cecidicola* TKP003 Symbols (initial conidia count) \[\times 1600; \triangle 2800\]
(k) *P. hispanicum* YKP011 Symbols (initial conidia count) \[\times 730; \triangle 1500; \bullet 2800\]
Non-uniform distribution of spore fluids or partially higher spore concentrations due to failure to uniformly smear the fungus on the medium may account for these results.

It is well known that food constituents are altered and eating quality is degraded by UV irradiation. To address the concern that there is a risk of oxidized flavor in the white bread, we predetermined the level of UV that would have an insignificant effect on eating quality. When sensory evaluation was done for breads that were irradiated with UV radiation at 70 mJ/cm², 140 mJ/cm², and 210 mJ/cm², participants rarely detected any abnormal taste at 70 mJ/cm². However, with UV radiation at 140 mJ/cm², there were clearly abnormal opinions such as “tastes bitter” and “taste and aroma are light” began to appear in participants’ reports. At 210 mJ/cm², there were clearly abnormal opinions such as “causes tingling numbness”, “tastes like plastic” and so on. The results of our test showed that a UV dose of about 70 mJ/cm² does not have a significant effect on quality, so we decided that the effect of UV sterilization on mold on bread should be examined using this test condition.

The effect of UV sterilization on mold growing on bread was examined as described below. Pullman-type white bread loaves (size: 110 mm × 3500 mm × 110 mm) were prepared for the tests. Ten loaves of white bread were baked and cooled for about 110 minutes in the cooling area of a bakery and were contaminated naturally by mold. Five of ten loaves were irradiated with UV at 70 mJ/cm² using a UV sterilizer (IWASAKI ELECTRIC CO., LTD), that is operable in a bread production line. Fig. 2 shows a diagram of the UV sterilizer. Only the top surface of the white bread loaves is irradiated with UV. These ten loaves were then preserved for six days at room temperature, and the number of fungal colonies on the top of these loaves was counted to examine the effect of UV treatment. This test was conducted once in three factories (Fig. 3 (A) – (C)).

We initially thought that a UV dose of 70 mJ/cm² would be insufficient to sterilize bread and prevent mold growth; however, we found that a substantial amount of mold growth was reduced (Fig. 3). This test was conducted once in three factories (Fig. 3 (A) – (C)).

![FIG. 2. Diagram of a UV bread sterilizer. Sterilizers are set up above the conveyor line to irradiate on the top surface of white bread loaves. A: UV sterilizer (65 W × 3), B: Bread (Pullman white bread loaves), C: Conveyor.](image-url)

![FIG. 3. Comparison of the fungal colony count on the top of white bread, with and without UV treatment (control). UV dose: 70 mJ/cm² (A): A factory (B): B factory (C): C factory](image-url)
conducted three times, all of which showed that the detection of mold on bread with UV treatment was significantly delayed as compared to that without UV treatment, that is, mold did not appear for five days. Additionally, the number of colonies present was reduced by more than 80%. Taken together, these results show that UV irradiation at a dose of 70 mJ/cm² is effective at prolonging the shelf-life of the bread and reducing subsequent mold growth, although it does not sterilize the bread completely.

In this study, it was shown that the UV resistance of Penicillium varied among species or strain, and there were some high-resistance species that were almost as resistant to UV as A. niger. Therefore, it is difficult to sterilize all contaminating Penicillium on bread with a UV dose of 70 mJ/cm², a dose that has an insignificant effect on eating quality. Moreover, the surface of bread is unlevel, so, if a spore of fungi falls inside the bread, it might not be exposed to UV sufficiently. However, as the shelf life of white bread is several days, it is not essential to sterilize the bread perfectly. If the appearance of mold is delayed by a couple of days, it would be useful. To improve the use of UV irradiation in bread product lines, it is necessary to decrease the amount of mold on bread; by doing so, UV will be more effective. Therefore, it is important to use UV irradiation additively with keeping product lines in good sanitary condition.

REFERENCES


