# Optimization of IR and UV-C Radiation as Surface Decontamination Techniques for Fresh Produces Using a CFD Approach

トリヴィッタヤシル, ウィパウィ

氏　　名　：Vipavee Trivittayasil (ウィパウィ トリヴィッタヤシル)

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（CFD を用いた青果物の赤外線・紫外線照射殺菌法の最適化）

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## 論　文　内　容　の　要　旨

The objective of this study is to develop the practical application of IR and UV-C radiation as surface decontamination techniques for fresh produces. Although the germicidal effect and merits of IR and UV-C radiation have been long known, the difficulty lay in the development of the actual application as there were concerns regarding produce damage due to high temperature of IR and overexposure to UV-C. This study employed a Computational Fluid Dynamics (CFD) approach to simulate the temperature and radiation dose distribution during the treatment. The inactivation characteristics of common mold conidia under different conditions were investigated and expressed using mathematical equations. The optimization study of the treatment conditions was performed using the simulation tool and storage tests. The proposed condition was expected to contribute as one of non-chemical surface decontamination techniques of fresh produces.

For IR, a fig fruit was used as the treatment target. The heat transfer simulation of an agar and a fig fruit treated by IR heating was developed using a CFD approach. The time-temperature predictions for both agar and fig models were proven to be accurate with root mean square error of less than 2 ˚C and 4 ˚C for agar model and fig model, respectively. The inactivation effect of IR heating (peak wavelength of the lamp was 0.96 μm) on two kinds of mold conidia (*Cladosporium* sp. and *Penicillium* sp.) was investigated on a growth medium. The treatment time of 40 s and 60 s was required for one log reduction in the viable count of *Cladosporium* sp. and *Penicillium* sp., respectively at the heating distance of 90 mm. The first order reaction equation could accurately describe the process with root mean squared logarithmic error of 0.74 and 0.45 for *Cladosporium* sp. and *Penicillium* sp., respectively. The combined model of both heat transfer and microbial inactivation was constructed, enabling the analysis of the treatment efficiency on a fig. It was found that the inactivation was greater at low-intensity and long-time rather than high-intensity and short-time. Finally, the practical implementation of the treatment was performed. The quality of fig fruits during storage was assessed after being treated with different levels of IR heating. The results showed that the treatment was most effective as the maximum surface temperature reached 50 ºC, because the decay incidence was significantly low from this temperature onwards. Also, the treatment at this temperature did not affect other quality indices, which were weight loss, flesh firmness, color and visual evaluation, as much as the higher temperature groups.

For UV-C, multiple strawberries were used as the treatment targets. A UV-C simulation model using a CFD approach with the discrete ordinate radiation model was developed. The developed model was used to optimize various treatment parameters. When a single UV radiation source was located over a strawberry, the orientation of strawberry which its calyx lay sideways enabled the most radiation exposure. The introduction of the film tray, whose material allowed the radiation to partially pass through, helped to enable a uniform dose distribution on radiated samples without manual rotation. For nine strawberries on the

film tray and the radiation sources from the top and bottom directions, the best configuration providing the most uniform dose distribution was the 4-lamp model with the horizontal distance between lamps of 300 mm. Finally, the storage tests with different doses of UV-C treatment were performed on strawberries. Throughout the storage, the treatment group with dose of 0.4 kJ $m^{-2}$ showed the greatest reduction in percentage of mold infection. The dose of 1.0 kJ $m^{-2}$ or higher was found to induce undesirable decoloration and shriveling of calyxes. No effects on titrable acidity and firmness were found at any dose of treatment.