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# 学 位 論 文 要 旨
# Dissertation Abstract

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学位論文題目：
Title of Dissertation　Development of Coated Paper Containing 1-Methylcyclopropene (1-MCP) Inclusion Complex in α-Cyclodextrin as a New Functional Packaging
(新規機能性包装材としての1-メチルシクロプロペン包接α-シクロデキストリン含有塗布紙の開発)

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Over the last few years, the demand of Japanese fruits is increasing which some of them are exported to overseas. During postharvest and transport handling, decreasing fruit quality is greatly impacted by ripening, senescence and decaying which caused by the action of ethylene. Among the ethylene control technologies in extending postharvest shelf life of fruit, 1-methylcyclopropene (1-MCP) has gained more attention to prolong the shelf life of fruit by binding the ethylene receptor. Currently, 1-MCP is commercially available in the form of inclusion complex powder with α-cyclodextrin (α-CD) as wall material and effective to preserve fruits during storage. However, there are very few studies on the release behavior of 1-MCP from inclusion complex powder and development a new controlled release packaging containing 1-MCP during transport handling.

In this study, 1-MCP was encapsulated into α-CD as wall material through molecular encapsulation technique. The effect of humidity and temperature storage on the release rate of 1-MCP in an α-CD inclusion complex powder were investigated using a dynamic vapour sorption (DVS) system at 40, 50, and 60 °C with stepwise humidity changes (20% RH for 2 h to 40, 50, 60, and 80% RH for 2 h, respectively). The release rate constant of 1-MCP from inclusion complex powders increased linearly with moisture concentration at 40, 50, and 60% RH. The release rate constant of 1-MCP from the inclusion complex powders was well correlated with a first-order release rate equation. The highest release rate constant of 1-MCP was $7.5\times10^{-2}$ $s^{-1}$ for 80% RH at 60 °C. The activation energy of 1-MCP release at 80% RH was 32.9 kJ/mol. These findings showed that 1-MCP inclusion complex in α-CD has a potential as an active compound that could be incorporated into active packaging systems where storage condition below 60% RH is needed.

Development a 1-MCP controlled release system on coated paper was proposed to improve the release and inhibit the collapse behaviour of 1-MCP inclusion complex powder. 1-MCP coated paper was produced using shellac as the coating material. The formation of 1-MCP coated paper was done by dissolving a weight of 1-MCP inclusion complexes powder into 0.5 mL of shellac solution (35 %wt. in ethanol) and the mixture was stirred using a vortex machine at room temperature for 1 min to produce a 1-MCP slurry, which was then poured onto 100 $cm^2$ of white paper. The effect of humidity and temperature on the release of 1-MCP from the coated paper was also investigated using a dynamic sorption system (DVS) with same conditions as previous. The release rate kinetic data were simulated using an Avrami equation with a mechanism release number n of 1.26. In addition, the dynamic release of 1-MCP from the coated paper was mainly affected by humidity, for which the release rate constant could be correlated with moisture concentration in humid air. The activation energy of 1-MCP release at 80% RH was 46.8 kJ/mol.

Finally, the effectiveness of 1-MCP coated paper had been applied in apple during storage time. The effect of 1-MCP coated paper on apple storage was evaluated by measuring the ethylene production rate, flesh firmness, and titratable acidity (TA) of apple. Initially, apple were stored at 4°C for initial 15 days. Thereafter, apples were transferred to 20°C storage temperature for another 15 days. After this treatment, the first analysis of quality of apple was conducted immediately. The remain apples were kept stored at 20°C for another 15 days to evaluate the shelf life of apple, and the physicochemical properties of apples were also measured as the second analysis. Ethylene production rates of apple were significantly affected with 1-MCP coated paper. The values were 0.22 nL/g FW/h at 50 mg of 1-MCP powder and 44.7 nL/g FW/h at 0 mg of 1-MCP powder after 15 days at 4 °C and 15 days at 20 °C. The other properties of apple such as flesh firmness and TA also indicated that 1-MCP coated paper could delay fruit softening during storage time.

Thus, 1-MCP inclusion complex in α-CD has a potential as an active compound to delay the ripening on fruit. Furthermore, the release of 1-MCP could be controlled by coating paper with shellac solution and promising to produce a new functional packaging for fruit.