Effect of 1-Methylcyclopropene Release from Inclusion Complexes Powder on the Quality of Tomato by Short-Term Treatment

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Abstract. Effect of 1-MCP release from inclusion complexes in α-cyclodextrin (α-CD) on tomato during storage at room temperature was investigated. Fourteen tomatoes in each closed polystyrene box were treated with 5, 15 and 30 mg of 1-MCP inclusion complex powders, respectively. 1-MCP treatment was carried out for 24 h using closed type of polystyrene boxes. Then, the tomatoes were moved to the polystyrene box with holes to continue storage time. The visible colour test was done after 6, 12 and 18-dyas storage time. The average values of red colour index, a* were 21.5, 23.9 and 30.3 for the untreated tomatoes after 6, 12 and 18-days storage, respectively. 1-MCP treatment shows significant effect on the colour change during storage. The results indicated that the treatment of 1-MCP in tomatoes was useful to delay the ripening and prolong shelf life after post-harvest processing.

1. Introduction
Tomato (Lycopersicon esculentum L.) is a fruit that can be classified into climacteric fruit in which the ripening process is influenced by ethylene production during post-harvest processing[1][2]. The shelf life of tomato in normal condition is very short, caused by the degradation of its quality after only one week without any treatment. Ethylene is a plant growth hormone that is responsible in the ripening process of climacteric fruit by signaling the precursor of ethylene during storage time [3]. In the case of tomato, the ethylene production is lower than other climacteric fruit: 4.4 μL ethylene/hr/kg at 30°C. Despite low production of ethylene, ethylene can play a role in the process of tomato maturation during storage time. Furthermore, ethylene also promotes ethylene formation as autocatalytic formation and components of fruit ripening, including physiological changes in fruit colour, texture and flavour [1][4][5][6].

Preservation process of tomato to delay ripening using 1-methylcyclopropene (1-MCP) has attracted attention. 1-MCP has been shown as suitable inhibitor of ethylene and oxygen production in fruit and vegetable preservation [7]. It also prolongs the postharvest life, provides flexibility of storage, distribution and retail handling time [8][9]. Moreover, 1-MCP is safe and has been registered as an active ingredient for horticultural products. The use of 1-MCP in tomato or climacteric fruit can maintain the quality and extend the shelf life of fruit. Many studies have reported the effectiveness of 1-MCP to delay ripening and improve the quality of climacteric fruits, including tomato, during post-harvest processing.
Several studies have shown the usefulness of 1-methylcyclopropene in maintaining quality and delaying the ripening of climacteric fruit. Since the discovery of 1-methylcyclopropene as ethylene inhibitor, development of 1-methylcyclopropene for active packaging to extend the shelf life and maintain the quality of fruit has increased [10]. In the last decade, 1-MCP has been successfully produced in the form of inclusion complex powder by molecular encapsulation with α-CD as wall material. α-CD is appropriate supramolecular material compared to other material as wall material to encapsulate 1-MCP [9]. Transformation of 1-MCP gas into powder form with the encapsulation process has many advantages, such as safe handling, easy process, storage and transportation [11][12]. In addition, the encapsulation process can increase the stability of 1-MCP from environment conditions such as temperature and humidity. Now, 1-MCP inclusion complex powders are commercially traded under the name of SmartFresh™. Releasing of 1-MCP from inclusion complex will have great impact on climacteric fruit like tomato [13][14].

In Japan, normally, tomato is produced around May until August. However, there are several companies which can produce tomato all the time using greenhouse technology. The main problem faced by farmers is maintaining the quality of tomato during distribution. Moreover, the type of packaging material also affects the quality of fruit during handling. Therefore, the aim of this study is to investigate the effect of 1-MCP release from inclusion complexes powder on the quality of tomato during storage time using different types of polystyrene box.

2. Materials and Experimental Methods

2.1. Materials
1-MCP was produced in the Kagawa University laboratory of food engineering by synthesis reaction using phenyllithium solution in dibutyl ether and 3-chloro-2-methylpropene (98%). Those chemicals were purchased from Wako Pure Chemical Industries, Ltd. (Osaka, Japan) and Sigma-Aldrich Japan K. K. (Tokyo, Japan). Isobutylene standard gas (100µL/L) was purchased from Sumitomo Seika Chemical Co., Ltd. (Osaka, Japan). α-Cyclodextrin (99%) from Cyclochem Co., Ltd. (Kobe, Japan) was used for encapsulation. The green tomatoes were purchased from Tokuju Corporation (Kagawa, Japan). Polystyrene boxes used for storage of tomato were obtained from Kaneka, Co., Ltd. (Tokyo, Japan).

2.2. Experimental methods

2.2.1. Synthesis and encapsulation of 1-MCP
In the synthesis reaction, 5.9 mL of 3-chloro-2-methylpropene was injected to 25 g of phenyllithium solution with feed rate of solution, 0.098mL/min using micro syringe pump. After injection for 1h, the reaction was continued for 2 h. During this reaction, N₂ was flushed into reaction bottle to remove benzene and the solvent of dibutyl ether. The synthesis reaction was done at 35°C. Encapsulation process of 1-MCP inclusion complex with α-CD as wall material was formed in laboratory by following previous research with minor modifications [11]. It was performed in the closed bottle by transferring of 1-MCP from reaction bottle with different driving force of gas between encapsulation bottle and reaction bottle.

2.2.2. 1-MCP treatment on tomato
Initially, fourteen tomatoes were placed in the closed polystyrene box (45 cm x 14.5 cm x 27.5 cm) and treated with 5, 15 and 30 mg of 1-MCP inclusion complex powder, respectively. The cap of the polystyrene box was modified with a rubber septum to inject distilled water. 1-MCP inclusion complex was put inside of the polystyrene box in the 250mL open bottle among the tomatoes. All polystyrene boxes were closed and injected with 50mL of distilled water through a septum in order to release 1-MCP from inclusion complexes powder. 1-MCP treatment was carried out overnight and then changed to the polystyrene box with holes (54 holes in each box with diameter of hole 2 mm) for continued storage time at 25°C.
2.2.3. Colour analysis
Visible colours were measured after 6, 12 and 18-days storage with a handy spectrophotometer (NF 333, Nippon Denshoku Industries, Co., Ltd., Tokyo, Japan). Before measurement, the colorimeter was calibrated using a standard with white \([L^* a^* b^*]\) and black \([L^* a^* b^*]\) ceramics to obtain optimum values. Results are the means value of the three replicates for each fruit and expressed as \(a^*\) values. The \(a^*\) value describes intensity of colour in red-green (\(a^* > 0\) for red, \(a^* < 0\) for green).

2.2.4. Firmness analysis
Fruit firmness was individually measured using penetrometer, a fruit pressure tester (Facchini srl, Italy). An 8 mm tip was used to measure the firmness of tomato with three replicates for each fruit.

2.2.5. Sugar content analysis
Sugar content was measured before and after treatment using an Abbe Refractometer (Atago™, Japan). The tomatoes were pre-mixed and filtered for analysis under the refractometer. Results are the means value of the three replicates for each sample and expressed as brix %.

3. Results and Discussion

3.1. Effect of 1-MCP treatment on the colour of tomato
Colour change in tomato was measured by a handy spectrophotometer with \(a^*\) value as parameter of red and green colours. The increasing \(a^*\) value indicates the development of colour change of tomato during storage time. The initial colour of tomato was measured as 0 day before the treatment. Concentration of 1-MCP during treatment were 4.3, 2.9 and 1.3 ppm for weight of powder: 30, 15 and 5 mg, respectively.

![Figure 1](image-url)

**Figure 1.** Colour changes of tomato under the treatment of 1-MCP with different amount at 25°C after: (a) 6 days; (b) 12 days; (c) 18 days.

Figure 1 shows detail the colour changes of tomato under treatment of 1-MCP in different amount (5, 15 and 30 mg of 1-MCP powder). The colour change in tomato with 1-MCP untreated increased
significantly compared to other conditions. At all data, different amount of 1-MCP showed significant increases a* value during storage time. However, tomato with 30 mg of 1-MCP treatment can delay the development of colour change longer than other condition. This finding indicated that 1-MCP suppressed the ethylene production in tomato during storage time. Previous studies also reported the similar effect of 1-MCP on the colour change of tomato during storage time.[15][16][17][18] Therefore, the development of colour change in tomato can be delayed by inhibiting ethylene action with 1-MCP treatment during storage time.

3.2. Effect of 1-MCP treatment on the softening of tomato
The flesh hardness analysis of tomato represented the softening process of tomato during storage time. Figure 2 shows the flesh hardness of tomato under treatment of 1-MCP after 6, 12 and 18-days storage time. The initial flesh hardness of tomato was approximately 7 kg and decreased gradually after storage time. The higher concentration of 1-MCP given to the sample, the less decreasing of tomato flesh hardness. This result showed that 1-MCP maintained the flesh hardness of tomato during storage time. The opposite result of 1-MCP effect on flesh hardness was reported by Tadesse et al. [19] They mentioned that 1-MCP did not affect the flesh hardness of tomato. Softening of tomato was influenced by external factors, such as storage condition and environment humidity. Moreover, the use of polystyrene box with holes during storage also can reduce CO₂ concentration. As mentioned in previous study, high concentration of CO₂ during storage affected colour change, flesh hardness, cell wall thickness, pectin content, vitamin C, skin colour and lycopene content [20].

![Figure 2](image-url)

**Figure 2.** Firmness analysis of tomato under the treatment of 1-MCP with different amount at 25°C after: (a) 6 days; (b) 12 days; (c) 18 days.

3.3. Effect of 1-MCP treatment on the softening of tomato
The sugar content in tomato depends on the metabolism of unloaded sugar. It also depends on the varieties of tomato. In addition, many factors affected the increasing of sugar content, such as starch accumulation, carbohydrate metabolism and organic compounds. Figure 3 shows the sugar content of
tomato under the different amount of 1-MCP treatment. As shown in Figure 3, 1-MCP treatment has no significant effect on the sugar content of tomato.

![Figure 3](image)

**Figure 3.** Sugar content in tomato under the treatment of 1-MCP with different amount at 25°C after: (a) 6 days; (b) 12 days; (c) 18 days.

3.4. **Effect of storage time on the quality of tomato**

In this study, the effects of storage time were investigated by keeping the tomato for 18-days. During a 6-day period of storage, three tomatoes in each sample were taken for further analysis.

![Figure 4](image)

**Figure 4.** Effect of storage time in colour change of tomato under 1-MCP treatment with different amount of 1-MCP powder.

Figure 4 shows the different colour change of tomatoes in a cross-sectional picture under treatment of 1-MCP in function of storage time. The result suggested that 1-MCP was effective to delay ripening and maintain the quality of tomato.
4. Conclusion
The results indicated that the treatment of 1-MCP in tomatoes was effective to delay the ripening and prolong shelf life after post-harvest processing. The effectiveness of 1-MCP treatment depended on the length of storage time. The treatment of tomato with 30 mg of 1-MCP powder delayed the ripening and flesh softening of tomato during storage time at 25°C for 18 days.

5. References

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