Coloring of Satsuma Mandarin (Citrus Unshu Marc.) With Ethylene

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In Satsuma mandarin (Citrus unshu Marc.), many changes such as lowered acidity, increased sugar concentration, rind and flesh coloring, softening of texture and effusion of aroma take place as the fruit matures on the tree.

These changes, however, do not always occur at the same time. Among them, coloring delays due to high temperature in the fall in the west-southern parts of Japan.

Even though the fruit has matured internally and tastes good, it is not regarded as completely matured externally.

This phenomenon is especially remarkable in early maturing varieties raised recently and planted in large quantities in this region.

Coloring of Satsuma mandarin consists of two phenomena: increasing carotenoids and decreasing chlorophyl in the rind. High temperature in the fall disturbs greatly the latter.

If the chlorophyl in the rind is decomposed artificially, the fruit retains an attractive color after the end of September though this time depends on the variety and climatic condition of the year where the tree is grown. Thus, a study of coloring of Satsuma mandarin was undertaken.

Coloring methods developed in the U.S.

It was customary in California to hasten the coloration of green lemons by means of blue-flame kerosene stoves placed directly in the room where the fruit was stored or in the basement beneath it.

For some time it was thought that the change in color was caused by the temperature and humidity condition in the heated rooms but later it was believed that combustion products were responsible for the expedition of coloration.

Denny[3)] determined that effective constituent must be among the unsaturated hydrocarbon and found that ethylene, even in low concentration, caused green lemons to turn yellow.

After the development of the petroleum industry and procurement of ethylene became easier, coloring of the fruit using ethylene was generally practiced not only for lemons but also for other citrus fruits.

Two coloring methods were developed in the U.S. One is the so-called shot method. In this method, ethylene is usually introduced from a gas cylinder into the tight room at about 200 to 250 ppm to the air of the room. Before CO_2 concentration of the room becomes higher than 1 per cent, the room is ventilated with fresh air. Then ethylene is introduced into the room again. Usually, these operations are repeated four to 10 times at intervals of six to eight hours. The fruit is treated in contact with ethylene intermittently.

The other is the trickle method, the latest improved way of coloring which requires rooms equipped with air-conditioning apparatus to maintain the requisite constant atmospheric conditions. Ethylene gas is not introduced "shot" but is continuously added or trickles to the circulating air at a rate of 20 to 30 ppm.

Special devices are necessary to accurately measure the amount of ethylene gas released into the entering air. The constantly changing air prevents the accumulation of CO_2 in the room. It is claimed that coloring time by this system is reduced to 24 to 48 hours.

Recently, two companies in Japan began to sell the coloring equipment by the trickle method and the coloring of Satsuma mandarin is gradually being popularized among growers in the west-southern parts of Japan.

Ethylene treatment for 15 hours

The underlying principle of the two methods developed in the U.S. is to apply the ethylene to the fruit at the atmosphere of high O_2 and low CO_2 concentration.

It was known experientially that the sensitivity of fruits to ethylene is diminished at a low O_2 tension or high partial pressure of CO_2.

According to Burg and Burg[2] O_2 is a substrate in the reaction activated by ethylene and CO_2 inhibits the action of ethylene by competing with the olefin for the receptor site.

In carrying out an investigation of applying these coloring methods to Satsuma mandarin, the author[4] found that O_2 and CO_2 concentration in the atmosphere was not a definite factor in the coloring with ethylene.

The fruit was enclosed in jars with rubber lids through which ethylene was injected with a syringe. When the jar was left covered, there was no change in the rind color. One day after treatment the lid was removed, exposing the fruit to the air. This caused the fruit to degreen in a few days and subsequently hastened coloration.

The time of opening the lids is important in this method. Following the result of experiments in which the lids were opened at six hour intervals after injecting ethylene, opening the lids 12 to 18 hours caused the greatest chlorophyl decomposition as shown in Fig. 1.

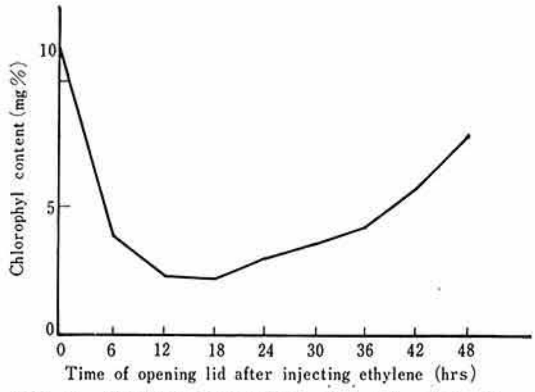

Fig. 1. Relation of the time of opening lids after injecting ethylene and chlorophyl decomposition in the rind of Satsuma mandarin

In this case, of course, the atmosphere in the jar was greatly changed by the respiration of the fruit as shown in Fig. 2. When the lid was opened in 12 hours, the air in the jar contained O_2 10.4 per cent, CO_2 9.8 per cent and in 18 hours O_2 6.5 per cent, and CO_2 14.2 per cent.

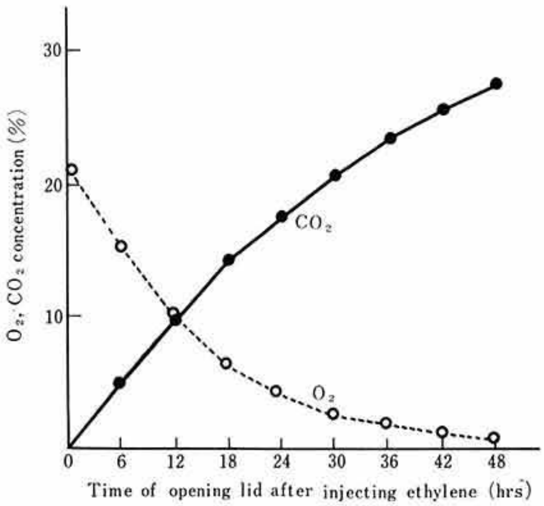

Fig. 2. Changes of O_2 and CO_2 concentration in the jar by the respiration of Satsuma mandarin

Carrying out the experiment in which the lid was opened 15 hours, average of 12 and

18 hours, after injecting the ethylene, it was found that 1,000 ppm of ethylene at about 25°C was most effective for the coloring of Satsuma mandarin.

Temperature higher than 30°C caused browning of button at calyx and lower than 15°C reduced the rate of expediting coloration. Also, it was discovered that temperature after opening the lid was important.

In order to determine ethylene concentration in fruits and jars, it was found that ethylene was absorbed rapidly through the rind and ethylene concentration inside and outside of the rind became almost the same in 150 minutes after the injection of ethylene.

After opening the lid, however, it seemed that most of the ethylene was released rapidly from the fruits. Physiological reactions of the fruit with the ethylene treatment for 15 hours regardless of O_2 and CO_2 concentration in the atmosphere is now under study.

In this method, the content of chlorophyl in the rind is not changed during the 15

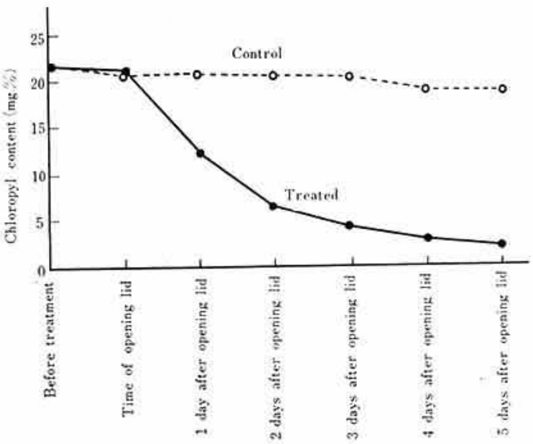

Fig. 3. Decomposition of the chlorophyl in the rind of Satsuma mandarin by the ethylene treatment for 15 hours

hours of ethylene treatment. After opening the lid and exposing the fruit to the air it decreased greatly as shown in Fig. 3 resulting in coloration of the fruit.

Practical convenient method of coloring by using a plastic film

Under the principle of the ethylene treatment for 15 hours, the author succeeded in developing the practical convenient method of coloring.

Instead of jars and rubber lids, the fruit in the container is sealed by 2 sheets of plastic film and water as shown in Figures 4 and 5. As the plastic film, polyvinyl chloride with a thickness 0.2 mm for agricultural use

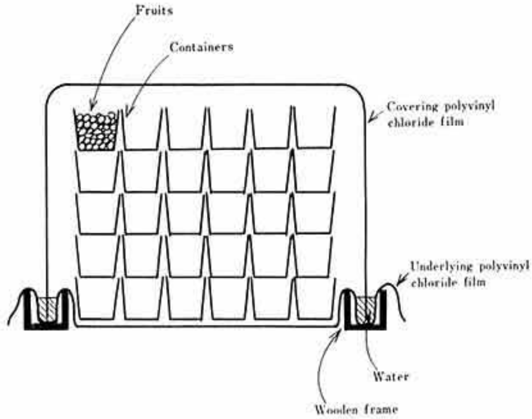

Fig. 4. A cross-sectional view of sealing Satsuma mandarin by two sheets of polyvinyl chloride film and water

Fig. 5. A photograph of the ethylene treatment of practical convenient method of coloring. Some 9.6 tons of Satsuma mandarin (20 kg × 480 containers) are treated with ethylene by using polyvinyl chloride films and water

is recommendable, though it permits loss of ethylene to some extent.

Ethylene is introduced from a can of 600 ml in volume which contains 4.2 l of ethylene. When two ethylene cans are released in the polyvinyl chloride film which covers 2.4 tons of the fruit (20 kg×120 containers), ethylene concentration becomes nearly 1,000 ppm giving satisfactory coloring.

After 15 hours following the injection of ethylene, the covered film removed from the water exposing the fruit to the air. As in the case of sealing jars and rubber lids, chlorophyl disappears and coloration is greatly hastened in about three days.

The author carried out the coloring of about 300 tons of Satsuma mandarin experimentally with a scale of 2.4 to 9.6 tons in 1970 and reported in 1971[4),5),6),7)]. Since then, the convenient method of coloring is rapidly spreading among growers and it is believed that nearly 10,000 tons of Satsuma mandarin were treated with ethylene by this method in the fall of 1971.

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