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Application of Postharvest Technologies for Vegetable Crops in Taiwan

Tsu-Tsuen Wang
Department of Horticulture, National Taiwan University, Taiwan, ROC

Abstract

The production of vegetables in Taiwan has the following characteristics: year-round production, multiple weather conditions, plentiful in species, and small farm system. Vegetable production and marketing teams are formed by growers that produce same kinds of vegetable in a region. It is a very common type of professional vegetable grower's organization. They market their products under the same brand name by cooperative marketing. Due to faulty handling systems, vegetable crops suffered significant losses after shipment to Taipei in the 80's. The recognition and application of postharvest technology in the late 80's helped to improve the quality of vegetables and reduced the losses. The development of precooling methods, from top-icing and hydrocooling to forced-air cooling and vacuum cooling were considered as significant progresses in the postharvest technology in Taiwan. The extensive use of refrigerated storage by the growers helped maintaining the freshness of harvested vegetables. Both controlled and modified atmosphere storage systems had been studied and promising results were reported for short term storage of leafy vegetables. A high-temperature storage system, based on the thermo-dormancy phenomenon, was developed to extent the storage life of garlic bulbs in Taiwan.

Vegetable Production in Taiwan

Taiwan is an island with total area about 36,000 square kilometers. It locates across the tropics and the subtropics and the weather condition allows Taiwan to produce vegetables year-round. More than 70% of the island is covered by hills and high mountains. On the southern-west side of the island, there is a vast plain, which is the major location that most of the vegetables are produced. Most of the warm-season vegetables are grown in the summer, from May to September; and many cool-season vegetables are grown during the winter. In the summer, some of the cool-season vegetables such as cabbage and tomatoes are moved to the mountain region, where the temperature is cooler in the summer. Due to its multiple weather conditions, there are over 180 vegetables listed in literature, and there are about 100 kinds of vegetable sold regularly in the market.

In 1961, the total planting area of vegetables was about 90,000 ha and the total production of vegetables was about 500,000 tons. The area increased rapidly in the 60's and 70's, reaching a peak of 240,000 ha in 1980 and remained at that level for about 10 years. The total production

increased rapidly during this period reaching over 3,000,000 tons in 80's. After 1990, the total area began to decrease gradually. Currently, the planting of vegetables in Taiwan is about 150,000 ha and the annual production was about 2,500,000 tons (Fig. 1 and Fig. 2). The decrease in both planting area and total production was due to the adjustment from over-production to a stable balance state.

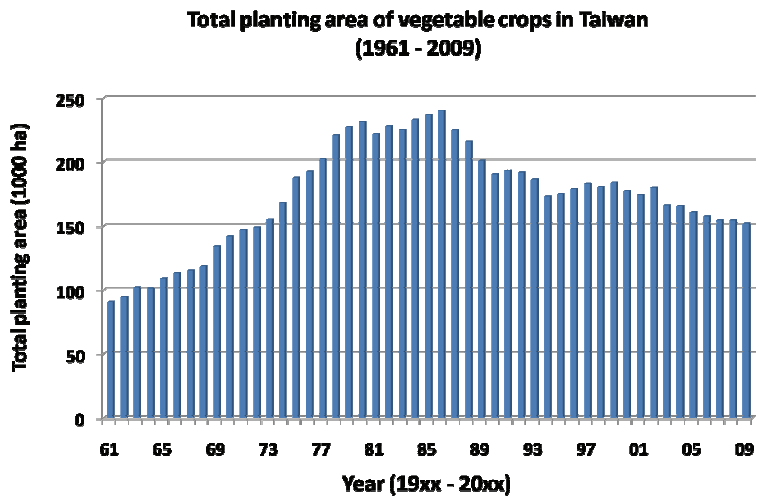


Fig. 1. Changes in total planting area of vegetable crops from 1961 to 2009 in Taiwan (Source: Agricultural Yearbook, COA)

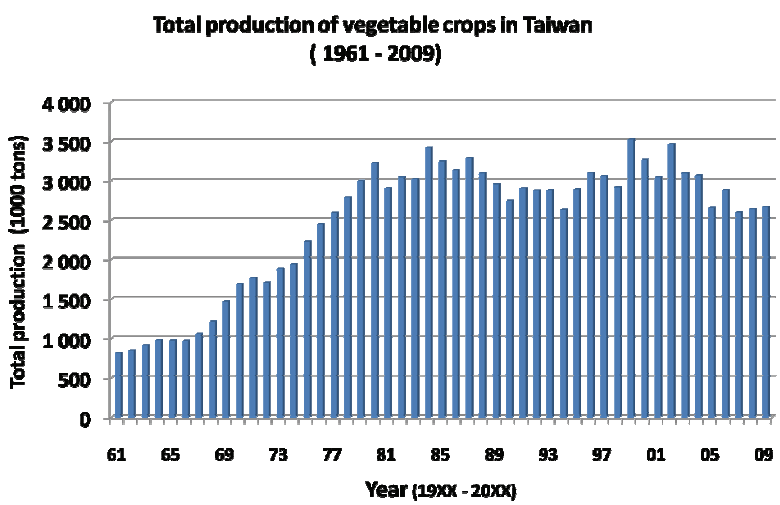


Fig. 2. Changes in total production of vegetable crops from 1961 to 2009 in Taiwan (Source: Agricultural Yearbook, COA)

Vegetable Grower's Organization and Marketing of Vegetables

Basically, most of the participants in Taiwan's agricultural production system are small farmers. Individual farmer grows their crop on a small piece of land with limited production. For vegetables, it is the grower's job to do all the harvesting and postharvest handling works. Although vegetable production areas are located sporadically all over the island, there is a tendency of centralization of specific vegetable production in a certain area. This is because many vegetables have specific demands for their growth condition, and require certain skill in their production. Therefore, vegetable growers in a region tend to grow the same kinds of vegetable that are familiar to them. As a consequence, "vegetable production and marketing teams" are formed nationwide in all major vegetable production area. This is a very common type of professional vegetable grower's organization in Taiwan. Team members produce the same kind of vegetable, grade and pack the product in uniform container and market the produce under the same brand name. This type of marketing is called "cooperative marketing", which comprises about 60% of the vegetables auctioned in the Taipei wholesale market. The cooperation among growers brings higher revenue to the grower and provides incentive to further improve their growth facilities as well as their postharvest handling techniques.

The distance between the southern end and the northern end of Taiwan is about 400 kilometers. Since the road system is well established all over Taiwan, it usually takes less than 8 hours for vegetables to be shipped from farm gate to destination market. Usually, vegetables were harvested in the morning, then went through all the handling procedures and finally packed in shipping containers. In the late afternoon, the packed vegetables were loaded onto truck and shipped to the destination market. The vegetables were sold to wholesale buyer the next day before day-break and arrived at the retail stand by the morning. Generally, it takes about one day for vegetables to reach the consumer.

The Need of Postharvest Technology for Vegetables

Vegetables are perishable agricultural products. During the postharvest handling and transportation period, severe losses may incur owing to various faulty handling practices as well as adverse environmental conditions. According to a study (Hsu, 1985), during the shipment of vegetables from the production area to Taipei city, the losses of celery, Chinese cabbage and Pak-choi were 18.69, 28.08 and 20.25%, respectively; and the loss of cucumber, sponge guard, egg plant and snap bean were 15.23, 10.42, 15.14 and 14.59%, respectively. The major causes of losses in leafy vegetables, listed by ranking, were mechanical damage, decay, water loss and yellowing. The major causes of losses in fruit vegetables were decay, weight loss, mechanical damage and insect pest. These results indicated the significance of postharvest losses in vegetables.

In the 1990's, the importance of postharvest technology was recognized, because postharvest technology emphasizes the maintenance of freshness of the produce and the reduction of

postharvest losses during handling and transportation. The improvement of handling methods will increase the revenue of the grower, reduce waste and provide fresh produces to the general public. Good practice of postharvest technology involves two aspects: the first is to carry out intensive training programs to establish correct understandings; and the second is to research and develop proper handling techniques that will improve the qualities of the produce. In the past 20 years, the application of postharvest technology had helped to improve the quality of vegetables a lot and as a consequence, the postharvest losses had been reduced.

The Development of Precooling Technology

Since maintaining low temperature is considered as the most important way of preserving the freshness of products, the application of precooling technology by removing field heat quickly from harvested produce to its optimum storage temperature is considered as a very important step in postharvest handling of vegetables. Several precooling methods are developed in the past (Kader, 2002), they are room cooling, forced-air cooling, hydrocooling, top-icing and vacuum cooling. Each method differs in its principle, cost, complexity in operation and cooling efficiency.

Taiwan's summer is hot, especially in the central and southern part, where most of the vegetables are grown. From climate statistics, each year, there were more than 180 days with average daily temperatures exceeding 30℃ in these area. In early days, great losses in both quantity and quality occurred when vegetables were harvested and transported during summer time.

Since precooling had already been a common practice in the U.S and other developed countries as an effective way of preserving freshness of harvested produces (Kader, 2002), the introduction and extension of precooling became an important task in the postharvest technology in Taiwan. The recognition of the importance of precooling by the growers and the widespread using of precooling methods symbolize the advancement of postharvest technology in Taiwan.

The earliest precooling equipment was built in 1970 in Chiayi County for the purpose of cooling asparagus, which was the most important export crop at that time. The precooling operation terminated several years later after the decline in the export market, and the equipment became obsolete and abandoned. In the mean time, all the vegetables circulated in domestic markets remained warm, and the concept of precooling was little known to the growers.

Beginning from 1980, agricultural engineers initiated studies on the precooling of vegetables in Taiwan (Lee and Lin, 2005). They focused on top-icing and hydrocooling, two methods that were affordable to the grower and were easy to carry out. In the late 80's, Taiwan's economy experienced a rapid growth, and the concept of precooling was introduced to growers through extension activities. The government helped organizations of vegetable growers to build cold storage rooms through subsidy, and the concept of temperature management began to form among the growers.

Starting from 1990, postharvest technologists and agricultural engineers worked together to develop suitable forced-air cooling method in order to improve the efficiency of precooling operation (Lee and Lin, 2005). After several tests and modification, a tunnel-type forced-air cooling method was established and non-head leafy vegetables could be cooled to 5℃ in 2 hours. Since vegetables that had been cooled by the forced-air cooling method remained fresh with very good quality after shipping in refrigerated vehicles, many institutions and the military non-staple food purchaser listed forced-air cooling as a prerequisite for the vegetable they bought. By 2000, there were many organizations and grower teams that use forced-air cooling as a part of their postharvest handling operation.

Vacuum cooling is the prevailing precooling method used in the US, European countries and Japan. Vegetables are cooled rapidly in a pressure-resistant chamber under vacuum. This method has the advantage of rapid, high capacity and suitable for pre-packaged vegetables. However, it involves more sophisticated technology and requires large capital investment, and the maintenance cost is rather high (Kader, 2002). Hence, vacuum cooling was not considered as a feasible recommendation for vegetable growers in Taiwan at earlier years. After forced-air cooling method became popular, the demand for a faster and more efficient cooling method appeared. Under the collaboration between researchers and equipment manufactures, the first set of home-made vacuum cooling equipment was successfully installed in 2001 (Lin et al., 2005). With this home-made vacuum cooling equipment, two pallets of packed vegetables could be cooled to 5℃ in 20 minutes. The advantage of vacuum cooling was widely acknowledged and more than 10 sets of vacuum cooling equipment were installed in the next 3 years. Many of the major vegetable growing organizations and suppliers had shifted from forced-air cooling to vacuum cooling in recent years. The vacuum cooling method was also used in cooling of packed head-lettuce, a vegetable crop that had high potential for foreign market.

The Development of Storage Technology

The purpose of storage is to put produces in a suitable environment to maintain the freshness and to extend the duration of its availability. Based on the complexity of technology involved, storage methods for horticultural products can be grouped as common storage, refrigerated storage and controlled atmosphere storage. Although fresh vegetable crops are produced year-round in Taiwan, there are still situations that storage of harvested products is needed. In the summer, unexpected weather changes such as typhoon and torrents of rain sometimes cause sudden shortage of fresh vegetables. Therefore, short storage of leafy vegetables, ca. 1-3 weeks, is required in the summer as a preventive operation. On the other hand, underground and durable vegetables such as carrot, potato, onion and garlic are produced in the spring; long term storage of these crops are required to maintain a constant and stable supply of these crops to the market.

The most common type of storage method used by growers and shippers are refrigerated storage. The installation of mechanical refrigerated storage was very common among professional vegetable growers. Larger cooperative farms had bigger storage facilities. These cold storage

rooms served mainly for short-term storage of vegetables, such as leafy crops. It is also used as temporary storage space for packed vegetables waiting for shipping and used for the purpose of room cooling of harvested vegetables. Commercial refrigeration companies are running their business in many vegetable production areas. They provide large rooms for the long-term storage of durable vegetables mentioned above. Researchers at the Food Industry Research and Development Institute located at Hsinchu City had established a databank regarding the storage of vegetables crops in Taiwan (Chen and Liu, 1993; Chen et al., 2005). It has the information on the optimum storage temperature, relative humidity and maximum storage life of 83 vegetables.

Controlled atmosphere (CA) storage is an advanced cold storage technique that manipulates the compositions of the atmosphere surrounding the product, usually to a lower oxygen and a higher carbon dioxide concentration. Crops that are responsive to these atmospheres will have slower metabolic rate and hence longer storage life. A CA storage room is an air tight cold storage room with special equipments to monitor and to control the atmosphere composition inside the storage room. From 2000 to 2004, Huang et. al (2005) studied and established a simplified CA storage facilities for the storage of leafy vegetables. The facility was built inside a commercial cold storage room, either by plastic tent or by steel sheets. The capacity was 10 -20 tons. A number of ice-water ducts were installed inside the facility to maintain a stable temperature. An atmosphere controlling system composed of automatic gas monitor, nitrogen generator, carbon dioxide cylinder and ethylene absorbent was connected to the facility. According to their report, under the condition of 3-4℃, 2-3% O_2 and 5-6% CO_2 , < 0.2 ppm C_2H_4 ; a mixture of leafy vegetables including leafy lettuce, Pak-choi, leaf mustard, Chinese kale and cabbage were stored successfully for up to 3 weeks with > 80% of the crops still salable. They suggested that this is a workable system that can be used in short-term storage of leafy vegetables.

Modified atmosphere (MA) storage is a simplified form of controlled atmosphere storage. Products are sealed in plastic bags and stored in cold storage room. The composition inside the bag will reach a steady state similar to that of a CA condition by the action product respiration and the gas movement across the membrane. Lin (2000) reported that a modified atmosphere storage system was studied by using a zeolite-containing PE bag together with a moisture-absorbing cotton cloth. The storage temperature was 1-2℃. In this experiment, non-head leafy vegetables, including spinach, Chinese kale, Chinese mustard, Pak-choi, leafy lettuce and celery was stored for 20 days with salable rate of nearly 100%, which is much better than the result of regular PE beg storage. However, the author indicated that the initial quality of the vegetable was very critical to the success of this MA storage system.

The High-temperature Storage of Garlic Bulbs

In the literature, garlic bulbs usually can be stored at room temperature (25℃) for about 2 months. The bulb will sprout after the dormancy is over. The recommended condition for long-term storage of garlic bulb is 0-1℃, and the storage life is about 6 months. However, such storage condition is considered not feasible, because it occupied storage room for long time and

consumed a lot of electricity. Wang et al. (2005) reported that at temperatures above 30℃, garlic bulbs exhibit thermo-dormancy. This explained that garlic bulbs were stored at ambient air from May to September in Taiwan without problems, because the temperature in the summer is always between 30-35℃. The bulbs started to loss their quality after September when the ambient temperature drops below 30℃. By utilizing a heating system that maintain the temperature at 35℃, the bulbs can be stored to February with less than 25% loss (Wang et al., 2005). This high-temperature storage method was recommended to the garlic growers in Taiwan to extend storage life of their products.

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