Precooling before Shipment for Preserving Post-Harvest Quality of Vegetables in Japan

By KIYOHISA OGAWA

The 4th Research Division, Institute of Agricultural Machinery

In recent several years, precooling facilities have increased rapidly according to the promoted joint-marketing of vegetables in response to enlarging vegetable-producing area, increasing distances to markets, and increasing competitions among producing areas. By 1975, agricultural cooperatives which set up precooling facilities with the government subsidy reached more than 80 in number, and the total floor space of the facilities accounted for nearly 10,000 m², as shown in Table 1.

The precooling treatment is to cool vegetables as soon as possible after their harvest with the purpose of minimizing their loss by inhibiting their respiration and transpiration, and of preventing quality deteriolations due to putrefaction, etc. by suppressing microbial activities. Combination of pre-cooling and low-temperature transport makes it possible to practice long-distance transport and to supply fresh vegetables produced in every areas to consumers throughout a year. Harvesting works concentrated in early morning in case without precooling facilities can be mitigated, making it easy to expand the size of farm management, and that the harvesting can be done even in high temperature midsummer season enables to diversify kinds of vegetables to be grown and extend the cropping season.

Target temperature of precooling is generally 0–5°C, but with vegetables sensitive to the chilling injury it is about 7°C.

Methods of precooling presently used in Japan are of air cooling, vacuum cooling, and hydrocooling types. The hydrocooling is useful, as compared to other types, for fruit-vegetables and root-vegetables which have low surface to volume ratios, but it has a risk of microbial contamination of cooling water and a problem of residual water clung on vegetables. Therefore, only a few facilities of this type exist in Japan. The present report will deal with air cooling and vacuum cooling methods.

Table 1. Precooling facilities subsidized by the Government (till 1975)

Prefecture	No. of agri. cooperative association	Room cooling m²	Vacuum cooling no. of unit	Principal vegetables precooled
Iwate	10	1078.6	—	Strawberry, Lettuce, Cucumber
Miyagi	4	567.5	—	Strawberry, Cucumber
Nagano	23	4167.4	6	Lettuce, Celery, Spinach
Kochi	18	1740.4	—	Cucumber, Green pepper
Kagoshima	9	524.0	—	Green pea
other 11	17	1909.4	—	miscellaneous
Total	81	9987.3	6	

From the data of Ministry of Agriculture and Forestry

Air cooling

This type account for the largest number of facilities in Japan at present. It utilizes the cool air produced by the heat exchange with the refrigerant of refrigerator. Of the two types, room cooling and forced air cooling, the former represents the majority, but in recent years the latter also appeared in 2–3 places.

1) Room cooling

An example of the structure is given in Fig. 1 and Plate 1. Pallets mounted with vegetable containers are arranged at adequate intervals in a single or double stories in a cooling room. The air, cooled by the cooling unit, is blown down into a cooling room through the cooling air inlet duct, and then circulated back to the cooling unit through the outlet opening, after passing by the pallets. To facilitate the cooling, vegetable containers have ventilating openings (holes), and they are placed on pallets with intervals.

A facility with 100 m^2 of floor space shown in Fig. 1 has a capacity of cooling 3,000 cases of lettuce (30 tons) from above 20°C to 3°C in about 12 hrs, with a refrigerator of 50,000–80,000 kcal/hr[1,2].

The facilities of this type have advantages that diverse kinds of crops can be treated, and more than two different kinds of crops can be treated at the same time, because the temperature of cooling air can be changed, and, unlike the hydrocooling type, no wetting of vegetables takes places. However, more time is required, as compared with other methods, because vegetables are indirectly cooled by convection of air and an uneven distribution of cooling effect is liable to occur due to the difficulty for uniform circulation of cooling air in a cooling room. For example, it was reported that in cooling lettuce to 5°C it took 12 hrs at upper pallets and 10 hrs at lower pallets[3]. Depending on the relative position of cooling air inlet duct to outlet opening, the dead space is formed, which causes a delay in cooling[3]. Regarding the effect of cultural management on the cooling, a report says that spinach grown with heavy application of fertilizers and irrigation water is slow in cooling, and also the difference in harvesting time in a day causes a difference[2].

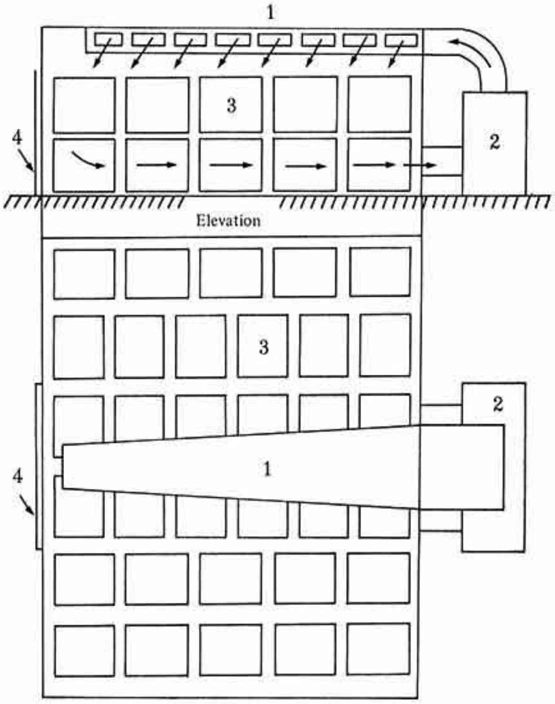

Fig. 1. Room cooling
1. Cooling air inlet duct 2. Cooling unit
3. Vegetable containers on pallet 4. Door

Plate 1. Inside of air cooling (room cooling) room

2) Forced air cooling

As the room cooling method takes time, the forced air cooling method, by which cooling air is forced to be introduced into vegetable containers, was devised, and it comes to be used in some places. It can reduce the cooling hours to 1/2–1/3 of that of the room cooling method[1,4], but there still remain problems to be solved as to the structure of containers (position and diameter of ventilating holes), arrangement of containers on pallets, deposite of pallets in a cooling room, and so on.

Vacuum cooling

When pressure of a closed vessel containing vegetables in it is reduced to a certain point, a rapid evaporation takes place. As the latent heat required for evaporation (heat of evaporation) is supplied by the vegetables, the temperature of vegetables goes down rapidly. Water boils at the temperature of 100°C under 1 atmospheric pressure, but the boiling occurs at lower temperatures at high mountains where atmospheric pressure is low. The vacuum cooling method is to induce a rapid evaporation at normal temperature by lowering the pressure extremely. Relation between the pressure and the boiling point of water is shown in Table 2. At the pressure of 4.6 mm Hg, the boiling point comes to 0°C. Because the cooling proceeds as the evaporation goes on, this method is suitable to leaf-vegetables which have higher surface to volume ratios, and water easily movable within plants.

Table 2. Relation of pressure and boiling point of water[5]

Pressure mmHg	Boiling point °C	Heat of evaporation kcal/kg
760.0	100	538.8
102.1	52	567.6
30.0	29	580.8
19.8	22	584.8
10.5	12	590.4
6.54	5	594.3
4.58	0	597.1

Time required for cooling is only 20–40 min.: very short as compared to the air cooling method. Although the loss of weight caused by the evaporation is inevitable, the wilting appearance is not recognized, because 1% of water causes 5–6°C of temperature lowering, and the total water loss during the treatment is less than 3–4%.

An example of the facility is shown in Plate 2 and 3. The main part of the facility consists of vacuum chambers which accommodate vegetables, vacuum pumps, condenser (cold trap) and refrigerator for it, and the control box. At present, in many cases, two vacuum chambers (2 m wide× 2.1 m high × 8 m long, accommodating 3.5 tons of lettuce) are equipped, and they are used alternately. About 35 tons of vegetables can be treated by 10 times of operation per day.

Packages and containers are required to have only small ventilating holes: few other limitations for them. The cooling can be done quickly, so that the limitation for the time of

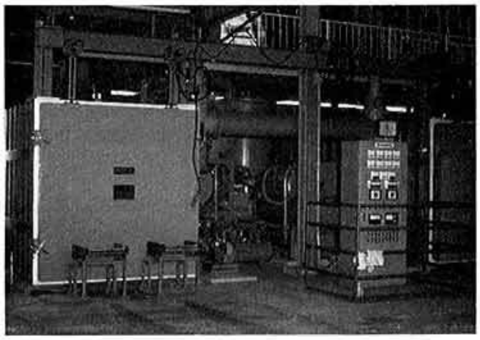

Plate 2. Vacuum cooling
left: Vacuum chamber. right: control box

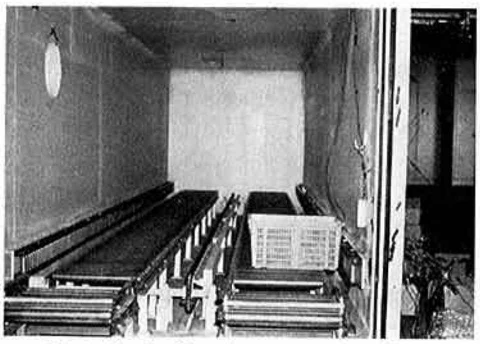

Plate 3. Inside of vacuum chamber

a day in receiving the material is also less. Accordingly, the use of this method tends to increase in areas producing mainly leaf-vegetables.

In this method air pressure is finally lowered to about 5 mm Hg. When the exhausting speed is increased to accelerate cooling velocity, yellowing of leaf surface is reported to occur[2]. Operational practices, including exhausting speed, suited to different kinds of vegetables are required to be established. Also, it was observed that the temperature of the material rises at the vicinity of air inlets when air pressure is returned to the normal atmospheric pressure after cooling[1,2,6]. Counter-measures are now being studied.

Prewetting and hydrovacuum cooling methods, in which water is supplied before or during the cooling to accelerate the cooling velocity, is being studied, but not practically used in Japan.

Layout of facilities and handling

An example of layout of precooling facility is shown in Fig. 2. The facility is divided into three parts: spaces for arriving materials, for cooling apparatus, and for shipment. A space for arriving materials should be wide enough to accommodate 70–80% of the total amount of materials to be received per day by considering the peak arrival of a day. It is better to adopt a one-way through passage system to avoid traffic confusion of arriving vehicles. Vegetables in containers, that came from farmers, are piled on pallets and carried into precooling chambers by forklifts (Plate 4). After the cooling, the containers, carried out by forklifts, are usually carried into trucks one by one, although in some cases containers as they are still on pallets are transferred into trucks. A sufficient number of forklifts and a wide space permitting smooth works of fork-lifts and accommodating several trucks at one time are required, because if much time is consumed for carrying-in and taking-out of containers to cooling chambers, not only the cooling hours will have to be limited, but also temperature of cooled vegetables may rise.

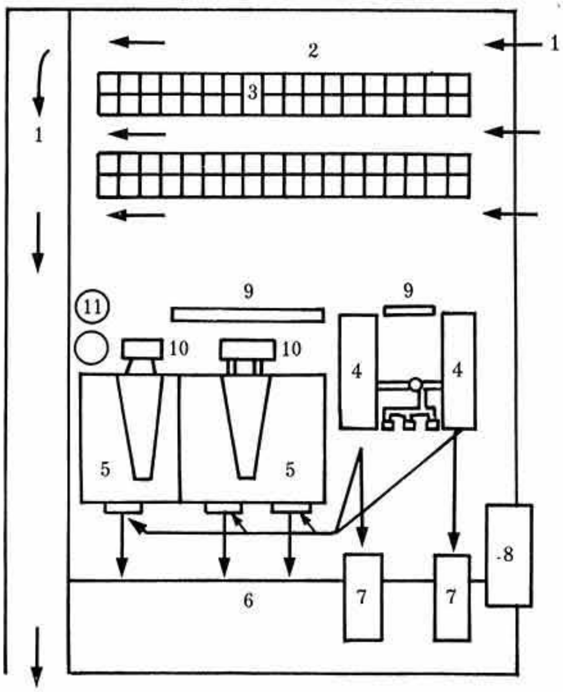

Fig. 2. Arrangement of precooling facilities
1. Passage for bring-in cars 2. Bring-in space 3. Pallet 4. Vacuum chamber 5. Cooling room 6. Shipping space 7. Truck 8. Office 9. Control box 10. Cooling unit 11. Cooling tower

Plate 4. Handling of vegetable containers by forklift

Cost of precooling

Cost of a precooling facility including incidental cost is nearly 74 millions Yen per one agricultural cooperative in an average of 16 agricultural cooperatives in Nagano Prefecture. Of this, about 40 millions Yen is an own allotment: a considerably large amount, but it corresponds to only 4.6% of the total sales value of vegetables per year. Cost of precooling including depreciation account is 41.17 Yen/10 kg in 1974, corresponding to 2.22% of selling price. On the other hand, the selling price of precooled vegetables are 112.5% and 106.2% of the non-precooled vegetables with lettuce and celery respectively. These prices are paying enough, and also indicate the high appraisal given to precooled vegetables.

Low temperature transport

Most of the precooled vegetables are transported with cares for keeping them cold, by the use of cold trucks or ordinary trucks covered with temperature-keeping sheets. However, after arrived at market, no special handling is made in most cases. A cold chain, which keeps entire route to consumers at low temperature, is desired to be developed in future.

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