damage the plants so severely that the plants die. However, research and development on methods and equipment for fruit harvesting is in progress and it is believed that some equipment of commercial importance will become available.

Handling of Product

Fruits and vegetables, after harvesting, are living tissue until some processing or preparation step inactivates the life processes by heat or chemical means. This is a very important fact and one which is often disregarded to some extent when handling methods are established for raw produce. Also, most of these products are quite susceptible to microbiological contamination and invasion. Injury to the product during harvest or handling enhances undesirable biological reactions and allows easy entrance of microorganisms. Therefore, these problems should be given adequate consideration when handling methods are being established.

In general, the industry is interested in mechanized handling of raw material in order to reduce costs. Bulk handling and large tote boxes which hold several hundred pounds of product and can be readily moved by lift or fork truck are attracting the interest of the processor. Lug boxes of metal and wood, as well as baskets and hampers, are being designed to allow easier loading, transporting and unloading. Effort has been expended to develop containers which will allow handling and transporting of raw material with a minimum amount of damage to the product. For example, lug boxes have been made shallower to reduce the undesirable effect of the weight of the product resting on the materials at the bottom of the container. Hampers and baskets have also been designed which reduce damage to the product.

Precooling Methods for Raw Fruits and Vegetables

Harvesting operations should be synchronized with factory production and capacity. Invariably the raw product will remain in better condition on the plant in the field than when harvested and held for the processing operation. On the other hand a sound and economic commercial operation must have a continuous and adequate supply of raw material. This latter concept, when applied on a practical basis, results in occasional gluts of raw material which cannot be immediately processed. When the fruit or vegetable, for example, peas or strawberries, is highly perishable, some means of cooling and holding the raw material under refrigeration should be employed if the product cannot be processed within a few hours after harvest.

Cooling and holding the raw material at a temperature near the freezing point is an effective method for reducing undesirable chemical changes and microbial activities to a minimum. Raw produce which is not cooled respires with the release of heat. As the product becomes warmer respiration as well as microorganism activity increases.

The method of cooling the product varies with different raw material. Shelled peas and lima beans are sometimes washed, filled into lug boxes holding 30–40 lb and covered with a shovelful of crushed ice. As the ice melts the product is cooled. This method is not the most desirable for peas, especially if the peas are slightly over-mature. The main objection to this method is that, as the ice melts, the peas are covered with a film of water and the more mature peas absorb water. This results in swelling of the cotyledons and rupture of the skin. When these peas are processed the cotyledons separate, resulting in a high percentage of skins and splits in the finished product.

Another method which is effective for peas and lima beans is the use of a precooling flume. With this method the product is washed and then flumed in water at 33 F. The length of the flume will depend upon the time required to cool the product and the amount of product being cooled. Generally the product is cooled in about three or four minutes and after cooling the product is held in cool storage at about 33 F. Precautions which should be taken in the use of this method include strict sanitation of the cooling flume, change of cooling water before off-flavor and microorganism build-up occurs and the practice of precooling only lots of product which have been freshly vined. If the raw material is of good quality and the conditions of flume operation desirable, the precooled product can be held for 18–24 hr without serious reduction in product quality. A Thermoscrew can be substituted for the flume for precooling raw product.

Other methods of cooling include subjecting the produce to cool air under either natural convection or forced circulation. It should be remembered that the amount of biological or chemical change in live plant tissue is a function of temperature. Therefore, it is very important to quickly lower the temperature of the raw material in order to reduce respiration and microorganism activity.

The practice of precooling does not improve the quality of the raw material. Some chemical changes continue in the product. On the other hand this practice is justified from an economic standpoint since it avoids the spoilage of raw material during periods when harvest exceeds or cannot be closely synchronized with the factory operation.

Insect and Other Contamination Problems

The problem of insect control in the production of fruits and vegetables is continuous and of vital importance to the frozen food packer. Insect infestation of frozen fruit and vegetable products comes under the jurisdiction of the Federal Food and Drug Act. If the Food and Drug Administration finds that a frozen product is infested with insects, the product will be condemned and destroyed even though it may otherwise be of excellent quality. Frozen foods condemned because of insect infestation are a total loss to the processor. Not only the cost of raw material but processing supplies and labor are involved. Therefore, insect control should be assured if the crop is contracted and the degree of insect infestation should be determined if the raw product is purchased on the open market.

Other contamination problems may be development of mold growth due to poor harvesting or handling practices. Spray residue problems have become increasingly important to the frozen fruit and vegetable packer. Guidance with these problems can be obtained from the spray manufacturers and the Food and Drug Administration.

BASIC PRINCIPLES

Vegetables

The quality of the final product cannot be any better than that of the raw material. Frozen vegetables compete in the market with many other products and must be of high quality to command a premium price. A fine product can be assured only by giving careful attention to every step from choosing the seed to display in the store.

Maturity of the harvested vegetable is especially important in freezing preservation because it affects quality of the final product in many ways. For example, the texture of the final product may be adversely affected if the raw material is allowed to mature until it becomes soft. The blanching operation during preparation for freezing further softens the vegetable. Furthermore, the formation of large ice crystals in the intercellular spaces of the tissue during freezing and storage causes rupture of some cells and loss in turgidity of others due to osmotic effects. This also tends to soften the tissue. On the other hand, when some vegetables become over-mature their pericarp is so tough that the overall quality is decreased.

The product should be handled as gently as possible during harvesting and transporting to the plant. Bruising of the tissue causes release of enzymes which may catalyze a variety of undesirable reactions. An anaerobic-type of respiration frequently develops at bruised spots. This produces an off flavor which may permeate the vegetable and also encourages an undue increase in the microbial population.

Time and temperature are the two dangers which must be guarded against between harvesting and the start of cleaning. It must be remembered that the harvested vegetable is a living, respiring tissue. If oxygen is available, the natural sugar is used up and the raw material loses characteristic flavor. When oxygen becomes depleted off flavors may be formed. One of the products of respiration is the release of energy. This is manifested by a rise in temperature. At the higher temperature the respiration rate is greater. Thus the vegetable temperature will rise at a logarithmic rate and the quality will be decreased accordingly. A higher temperature favors bacterial action which usually results in off flavors such as souring. Therefore the objective is to process at once or apply artificial cooling.

The main purpose of the cleaning step is the removal of soil and juice from the surface. This decreases the possibilities of off flavor in the product and greatly reduces microbial contamination. This latter is important. It is true that bacteria cannot multiply at temperatures below 15 F and some may even be killed during frozen storage. However, the remaining bacteria become viable upon thawing the product and they find an excellent medium in which to multiply and cause chemical changes.

All living tissue contains a wide variety of enzymes, organic molecules which catalyze chemical reactions. Such enzymatic action gives rise to undesirable chemical changes in the frozen vegetable. These are sometimes a degradation of color or softening of texture but almost invariably a development of off flavor. Lowering the product temperature into the freezing zone greatly decreases the rate of enzyme activity. However, some activity is still shown at −40 F and many raw vegetables would become unacceptable after one month storage at 0 F.

If possible the enzymes are inactivated by a heating process called *blanching*. This inactivation shows a hyperbolic relationship with heating time. Thus, most of the inactivation may be accomplished in about one minute but complete inactivation would require many minutes. Such a long blanch would overcook the product so the time chosen is a compromise.

Two references may give conflicting recommendations as to blanch time for a specific vegetable. A single expert may give a range, for example, 2–3 min. This lack of agreement and precision is primarily due to the usual biological variation in concentration and types of enzymes present in the raw material as a result of differences in variety, soil, climate, and maturity. Blanching times listed in the literature should be used as a guide by the processor in developing the specific blanching requirements for his particular conditions.

In addition to its effect on enzymes, the blanching step destroys almost all yeasts and molds and greatly reduces the bacterial population. The important point is that many bacteria remain. Unless the blanched vegetables are cooled rapidly these bacteria can multiply and cause spoilage. Cooling the product to 50 F before filling into packages would essentially control this problem. If the product is filled warm and the rate of heat removal from the packages is low, the vegetables may undergo bacterial spoilage in the freezer.

Quick-freezing or the rapid solidification of the product is not as critical in the case of vegetables as with some other products. The physical and physico-chemical changes caused by slow freezing evidently are not great enough to appreciably alter product quality. Of far greater importance here is speed of handling the vegetable from harvesting to cooling of the final product to the freezing point.

Fruits

It is just as important to obtain a high quality raw material as in the case of vegetables.

Harvesting of fruit at just the right maturity for freezing is a difficult problem. The cell wall of a fruit is generally less rigid than that of a vegetable. Therefore, the physical and physico-chemical changes caused by freezing and thawing are even more marked in fruits.

Fruits contain a large variety and concentration of enzymes. The enzyme giving the chief cause for concern is the one catalyzing the browning reaction. This involves a combination of atmospheric oxygen with catechol-tannins present in the tissue to yield highly undesirable brown reaction products. Blanching, because of its cooking action and softening effect on the texture of fruits, is rarely used to control this enzyme.

The browning reaction can be delayed by depressing the *pH* of the fruit with citric acid. This is especially useful during preparation for freezing. Sulfur dioxide in the form of the sulfite ion may be applied to the fruit in most States. An effective but somewhat expensive method for controlling browning is the addition of synthetic ascorbic acid (Vitamin C). This compound acts as an oxygen acceptor to prevent other oxidations. Physical exclusion of oxygen is also effective. This is very effective when the cut fruit is packed in a metal can, covered with sugar sirup and hermetically sealed. Some ascorbic acid is frequently incorporated into the sugar sirup.

A high quality product is obtained by picking sound fruit at the correct maturity, handling it gently to avoid bruising, and preparing for freezing as rapidly as possible. Holding the packaged fruit at a temperature just above freezing for an hour or so may improve flavor and texture by allowing the sugar to penetrate into the fruit.

PROCESSING OPERATIONS

Dry Cleaning of Raw Material

Many of the fruits and vegetables require special cleaning at the time of harvest or during the initial processing operation. Cleaning is usually accomplished by air flotation and screening or sizing. In cleaning, the product falls through an air stream moving at a velocity great enough to pick up the light pieces of debris. However, the raw product is heavier and passes on through the air stream. Screening is usually accomplished by using two shaker screens. One has openings large enough to allow the raw product to drop through but retain larger pieces of debris, while the lower screen is of such a gauge the product is retained but small pieces of foreign material will drop through.

Washing

Washing of fruits and vegetables is a very important operation. Equipment used for washing varies with different products. These include reels and shakers in which water sprays are directed against the raw material and immersion type washers. The latter range from simple water flumes to elaborate immersion washers through which the product is mechanically fed and agitation of the water is accomplished by the use of high pressure water pumps or air agitation.