Chapter 37 – Fresh Fruit and Vegetables

The transport of fresh fruit and vegetables is complicated because each variety has widely differing requirements for safe preservation. The rate at which living fruits and vegetables age and are attacked by microorganisms depends upon the environment during storage and transit. During these periods, the quality and condition of fruits and vegetables are maintained by retention of their optimum temperatures. For safe carriage, this will usually require the commodities to be pre-cooled and maintained at that temperature prior to being loaded into the transport unit, whether that is a reefer or a refrigerated container.

Reefer containers are not designed to cool the cargo, but only to maintain the cargo temperature. They are not to be used as cold storage, where temperature of the cargo is brought down rapidly using powerful heavy-duty refrigeration machinery.

All fresh fruits and vegetables are living products that respire. Respiration is a complicated sequence of chemical reactions involving conversion of starches to sugars and the oxidation of those sugars to obtain energy. Normal respiration results in the fruit and vegetables consuming oxygen and giving off carbon dioxide, water, ethylene and varying, but significant, amounts of energy in the form of heat.

Figure 37.1: Fruit and vegetable warehouse.

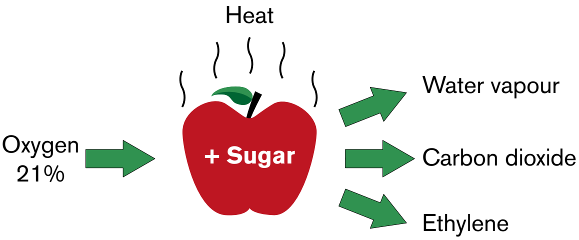

Figure 37.2: Process of respiration in fruits.

The higher the ambient temperature surrounding the commodity, the greater the temperature of the commodity itself and consequently the higher its rate of respiration.

Fruits and vegetables also transpire, which is the loss of water by evaporation that occurs once the fruit or vegetable is removed from the tree or plant that provided water during its growing period. The storage/carriage conditions for fruit and vegetables should be such that excessive water loss does not occur as a result of transpiration.

37.1 Temperature

It is essential to understand that published values of optimum temperatures for storage or transit of fruit and vegetables are not absolute and the accurate optimal requirements are dependent on the variety, climate and other details of the produce. The optimum and required transport temperature should be provided in writing by the shipper who will, or should, have full knowledge of the history of the produce and the temperature that must be maintained by the carrier throughout the period it is under their control.

Optimum temperatures promote low rates of respiration, extend storage life and, in addition, reduce the rate of development of microorganisms. In general, the higher the temperature, the faster the growth of moulds and bacterial infections.

37.2 Freezing Points

The lowest safe limit of temperature for each commodity is its highest freezing point. This temperature is invariably slightly below 0°C, the freezing point of pure water, as natural juices contain dissolved substances in solution that have the effect of lowering the freezing point. Therefore, in general, the sweeter the produce, the lower the freezing point. However, it must be remembered that stalks of fruit contain much less sugar and may freeze at a higher temperature than the fruit itself, resulting in death of the stalk tissue with possible detrimental consequences for other parts of the fruit and a likely loss of market value when the fruit is restored to ambient temperatures.

37.3 Chill Damage

Chilling is another factor that affects the lower safe limit of carriage temperature of some produce. This is a reduction in temperature that does not reach the freezing point of the produce. Numerous commodities, particularly those grown in tropical climates from plants originating from the tropics, are easily affected by low temperatures and are inclined to tissue damage at temperatures well above their freezing point. Typical symptoms include pitting of surface tissues, discolouration of flesh and an increased susceptibility to decay.

37.4 Air and Moisture Considerations

Relative humidity

Relative humidity is the ratio of the water vapour pressure present in air at an existing temperature to the water vapour pressure that would be present if the air were saturated at the same temperature. Relative humidity is usually expressed as a percentage, with saturated air equalling 100% relative humidity.

A difference of vapour pressure may cause water vapour to move from or to the produce within the ambient air. The water retention capacity of air is directly proportional to the temperature of the air, eg a volume of air at 90% relative humidity at 10°C contains a greater mass of water than the same volume of air at 90% relative humidity at a temperature of 0°C.

However, water is lost from produce at about double the rate when carried in a compartment whose air is at 10°C and 90% relative humidity than the same air at 0°C and 90% relative humidity.

The relative humidity of the air within a cargo compartment of a refrigerated vessel or insulated refrigerator container directly determines whether the condition of the products carried can be maintained. Over a period of time, the relative humidity inside a reefer chamber reduces, along with the moisture content in the cargo. The moisture in the air and the moisture released by the cargo due to respiration gets carried over onto the surface of the evaporator coil and settles as condensate. This condensate drips down to the drain pan and is led outside the chamber through a drain pipe. Sometimes, particularly in frozen conditions, when the refrigerant temperature is less than 0°C, the condensate may freeze on the surface of the evaporator tubes in the form of frost, creating a need for periodic defrosting. Frost formed over the evaporator coils has two detrimental effects: a) it blocks the airflow through the evaporator coils, affecting heat transfer and preventing the air from acquiring sufficient coldness from the refrigerant, and b) frost is an insulator and impedes heat transfer across the evaporator coils. Fruits and vegetables, being respiring cargoes, need frequent defrosting (every 4 to 8 hours).

Relative humidity below the optimum range will result in shrivelling or wilting in most produce. The maintenance of an optimum range of humidity can be difficult to resolve during the carriage of fresh produce.

Relative humidity of air of 85 to 95% is usually recommended for the carriage of most perishable produce in order to preclude/impede wilting or shrivelling caused by moisture loss. Exceptions to this include the carriage of onions, dates, coconuts, ginger rhizomes, yams, dried fruits and some horticultural produce. If the relative humidity increases to 100%, condensation may occur, which would increase the likelihood of mould growth within the compartment and on the produce itself.

Air circulation
The circulation of cooling air within cargo compartments must be kept at an even required temperature throughout. Despite variable heat leakages that may occur in various parts of the system, and the inevitable increase in the circulating air temperature on return compared with delivery, as a result of the removal of respiratory heat from the produce, only a small increase should be acceptable.

The comparison of delivery air temperatures and return air temperatures is one of the critical monitoring requirements of carriage.

The majority of produce carried, exceptions including cargoes of bananas, should be presented to the ship or container or trailer as pre-cooled with the field heat already removed. The circulating cooling air should, therefore, only be required to remove the respiratory heat of the produce and the heat exchanged via exterior surfaces. A high velocity of circulating air should be unnecessary and is undesirable. Cooling air in refrigerated vessels and containers is usually circulated vertically, from the deck/floor upwards. The system is designed to produce equal air pressures over the full area of the cargo space. However, any elaborate arrangement for air distribution may be rendered useless if incorrect stowage of the produce eliminates or reduces efficient airflow. The difficulties of properly and carefully stowing packages of fresh produce have become more complex with the use of palletised units and pallet boxes/bins.

Air exchange
During the carriage of fresh fruits and vegetables under ordinary conditions of refrigeration, accumulations of gases such as carbon dioxide (CO_2) and ethylene (C_2H_4) will occur. Undesirable odours, or volatiles, may also contribute to off-flavours and hasten deterioration of the produce. These problems can be prevented by repeatedly refreshing the circulating air within the holds by admitting atmospheric air into the system. The introduced air will enter at a point of lowest pressure within the circulation system and the polluted air will exit at the point of highest pressure. Alternatively, an auxiliary air system driven by separate fans may be utilised.

Rates of respiration and heat generation
The rate at which fruits and vegetables produce heat varies: some have high rates of respiration that require more refrigeration to maintain an optimum carriage temperature

than those that respire more slowly. The rates of respiration are determined by temperature and for every 10°C rise in temperature the rates may be doubled or, in some instances, tripled.

The storage life of produce varies inversely with the rate of respiration. This means that produce with short storage expectancy will usually have higher rates of respiration, eg fresh broccoli, lettuce, peas and sweetcorn. Conversely, potatoes, onions and some cultivars of grapes with low respiration rates have longer storage lives. The rate of respiration for any given product will depend on its variety (cultivar), area of growth and the seasonal and climatic conditions experienced during periods of growth.

Some varieties of fruit and vegetables have rates of respiration that do not decline during their ripening period but, instead, their respiration rates increase. This is a critical event or period known as their climacteric. Produce may, therefore, be categorised as climacteric or non-climacteric; the former continues to ripen post-harvest but the latter does not. The ripening processes include development of colour, texture (tissue softening) and flavour.

Many fruits are climacteric, such as peaches, apricots, bananas, mangos, papaya, avocados, plums, tomatoes and guavas, and tend to ripen rapidly during transit and storage. Examples of non-climacteric fruit and vegetables include cucumbers, grapes, lemons, limes, oranges, other citrus fruit (eg satsumas, tangerines, mandarins) and strawberries.

37.5 Weight Loss in Transit

Weight loss from harvested produce can be a major cause of deterioration during transit and storage. Most fruit and vegetables contain between 80 and 95% of water by weight, some of which may be lost by transpiration (water loss from living tissue).

To minimise loss of saleable produce weight and to preclude wilting and shrivelling, the produce must be maintained at the recommended humidity and temperature. While some weight loss will inevitably occur due to the loss of carbon during respiration, this should only be of relatively minor proportions.

The loss of water will not only result in weight reduction but also in produce of poor quality. Loss of moisture can often be minimised by the use of protective packaging to complement carriage under optimum temperature and humidity.

37.6 Supplements to Refrigeration

Different mechanisms have been tried and tested to slow down ripening after harvest and therefore extend the transit, storage and shelf life of fruit and vegetables, particularly those in the climacteric category. The most successful use:

- Controlled atmosphere (CA) storage and carriage
- modified atmosphere packaging (MAP)
- modified atmosphere (MA) storage and carriage
- edible coatings.

In all cases, the atmosphere created is one of low oxygen (O_2) and high carbon dioxide (CO_2) when compared to atmospheric air. This depresses the production of ethylene (C_2H_4), which accelerates during ripening and in turn expedites the ripening process itself in the form of a chain reaction, particularly in the case of bananas.

Modified and controlled atmospheres are non-life supporting. Proper ventilation procedures for compartments/containers under CA/MA must be followed prior to entry.

Edible coatings, which will have been tested and tailored for each product, are a simple, safe and relatively inexpensive means of extending the ultimate shelf life of fruit and vegetables provided there are good storage, shipping temperature and humidity controls.

Edible coatings act as a gas barrier, altering the internal atmosphere of the produce and creating an effect similar to that of modified atmosphere packaging (MAP), which can delay ripening of climacteric fruit, delay colour changes in non-climacteric fruit, reduce water loss, reduce decay and maintain quality appearance.

Under ideal conditions of temperature, humidity, atmosphere, packaging and stowing, apples can be preserved for as long as six months or more.

37.7 Carriage of Mixed Produce

Carriers are sometimes required to load and stow different produce in the same vessel, hold or cargo container. Should a mixture be necessary, it is essential that the produce is compatible in respect of:

- Temperature
- relative humidity
- odour production
- ethylene production.

Generally, deciduous fruits with the same temperature requirements can be stowed together.

Cross tainting, where strongly scented fruit and vegetables are stowed together, should be avoided.

Many products produce considerable quantities of ethylene naturally, including apples, avocados, bananas, pears, peaches, plums, melons and pineapples, and should not be stowed with or in adjacent compartments to kiwi fruit, watermelons, lettuce, carrots, etc, all of which can be seriously affected by ethylene.

Two commodities that have produced substantial cargo claims are pears and kiwi fruit.

Pears
Pears are shipped to Europe and North America from South Africa and Chile. They are also shipped in quantity from New Zealand and Australia. Although pears are considered to have a relatively long life, it is essential that they are picked at the right stage of maturity and pre-cooled if optimum life is to be achieved.

Pears are susceptible to various physiological disorders caused by chilling, excess atmospheric CO_2 and skin contact (bruising). They are also subject to microbiological damage resulting from infection by various organisms prior to harvesting. The two most serious types of disease are caused by the fungal species *Monilinia fructigena* and *Botrytis cinerea*. The latter species can grow at temperatures as low as minus 4°C (–4°C) and therefore growth can only be controlled by low temperature storage. The rate of decay increases rapidly as the temperature rises. As invasion usually occurs through damaged tissue, the proper selection of fruit at the packing station is of paramount importance.

The prescribed temperature for the carriage of pears is between 0°C and minus 1.1°C (–1.1°C). Therefore, it is recommended that the carrying temperature should be 0°C, or marginally lower where ships have equipment that can control the delivery air temperature to plus or minus 0.2°C (–0.2°C) or better. The set points for the carriage of pears in containers should be between 0.6 and 1.7°C.

Pears may suffer chilling injury at temperatures below minus 1.5°C (–1.5°C). Certain fruit can tolerate lower temperatures and, even if freezing occurs, very slow thawing at low temperatures can result in the fruit remaining undamaged. Therefore, claims for damage due to the delivery air temperature falling marginally below minus 1.5°C (–1.5°C) for short periods must be viewed with some scepticism.

Because of their comparatively large size and high thermal capacity, cooling of individual fruits through the whole tissue is a relatively slow process. When checking a cargo shipped as pre-cooled, the ship's representative should ensure that spear temperatures are taken at the centre of specimens selected for checking. Other aspects to be checked are the nature of the packaging and the general appearance of the fruit, particularly skin blemishes. Caution is required when attempting to assess the maturity of the fruit and a surveyor should be consulted if in doubt.

Pears are susceptible to damage if the CO_2 concentration in the atmosphere rises much above about 1%, so it is necessary to maintain fresh air ventilation at regular intervals when carrying this cargo.

Where issues occur it is essential that expert advice is obtained as soon as possible.

Kiwi fruit

Kiwi fruit are mainly shipped from New Zealand and California and, increasingly, from Chile. They have a long storage life if picked at the right stage of maturity and stored at temperatures between minus 0.5°C (–0.5°C) and minus 1.0°C (–1.0°C). Storage at a temperature only slightly above this range (+3°C to +4°C) will substantially reduce the storage life.

Kiwi fruit are particularly sensitive to traces of ethylene in the atmosphere, which will prompt rapid ripening. Particular care must, therefore, be taken when kiwi fruit is loaded to ensure that the atmosphere in contact with the fruit cannot be contaminated with the atmosphere from other sources, eg from containers stuffed with cargoes such as apples, which release considerable amounts of ethylene, and even from exhaust fumes from certain types of forklift. As it is necessary for kiwi fruit to be carried using a fresh-air ventilation system, the possibility of cross contamination with the atmospheres from different cargoes must be considered carefully at the time of loading.

Kiwi fruit are also subject to microbiological deterioration, primarily due to invasion by *Botrytis cinerea*.

It is again of paramount importance to obtain expert advice as soon as possible where damage is feared.

Carriage of delicate fruits, exotic fruits and similar products
World trade in delicate products such as strawberries and certain tropical fruits has expanded, although the products concerned frequently have a short shelf life.

It has been known for many years that increasing the CO_2 concentration in a cargo space will depress the metabolic rate of living natural products and this fact has been utilised when carrying apples from Australia to Northern Europe and during storage worldwide. Research has led to the development of more sophisticated gas mixtures, for use in containers or similar carrying units, that not only slow the ripening rate of fruit but also render such products less susceptible to decay and damage caused by microorganisms, insects and physiological disorders.

Controlled or modified atmospheric systems involve initial dosing to produce an atmosphere of the composition required, followed by monitoring. The composition of the atmosphere is automatically maintained using analytical and recycling equipment to remove the excess of some components and increase the concentration of others, as required.

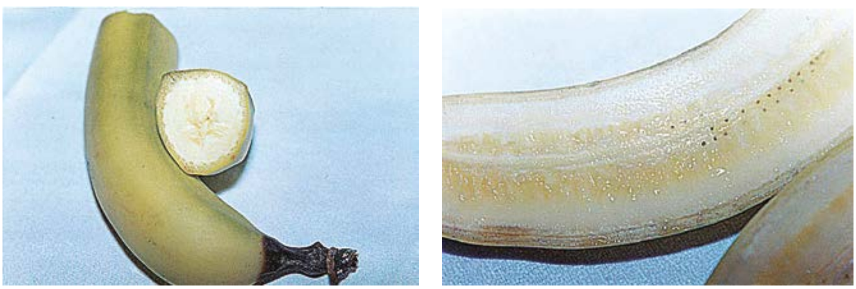

Figure 37.3: Prolonged exposure to high levels of carbon dioxide can cause bananas to become 'green ripe' with soft ripe pulp and green skin.

It has also been established that:

- Ethylene gas, which promotes ripening of fruits, is less effective in atmospheres containing less than 1% carbon dioxide
- if the CO_2 content of the atmosphere is too high, serious physiological damage may result
- at levels of CO_2 in the range of 10 to 15%, *Botrytis* rot of strawberries and some other fruit is substantially inhibited.

Storage in low oxygen levels (2%) can cause problems such as irregular ripening in bananas, pears, etc and the development of black heart in potatoes and brown heart in pears and apples.

Table 37.1 lists some products that benefit from controlled atmosphere storage, showing the optimum conditions for such storage.

Commodity	Temp °C	% O_2	% CO_2
Apples	0.5	2 to 3	1 to 2
Kiwi fruit	0.5	2	5
Pears	0.5	2 to 3	0.1
Strawberries	0.5	10	15 to 20
Nuts/dried fruits	2.25	0.1	0.1
Bananas	12 to 15	2.5	2.5

Table 37.1: Products that benefit from controlled atmosphere storage.

The addition of carbon monoxide at levels of 1 to 5% in atmospheres containing 2 to 5% oxygen has been shown to reduce discolouration of damaged or cut lettuce tissue. At levels of 5 to 10%, it will inhibit the development of certain important plant pathogens. Use of this gas has been the subject of experimentation in some countries.

Table 37.2 lists optimum temperatures, maximum storage, transit and shelf life, etc for a wide range of commodities. This is for guidance only and details of the required temperature and humidity should be provided in writing by the shipper, who has full knowledge of the product's history. The shipper's instructions should be followed at all times.

Commodity	Approx max storage, transit and shelf life	Optimum transit temperature		Container temperature set points		Highest freezing points		Relative humidity
	Days	°C	°F	°C	°F	°C	°F	%
Apples – chilling, sensitive	35 to 45	+1.5 to 4.5	34.7 to 40	+4.4 to +5.6	40 to 42	-1.5	29.3	90 to 95
Apples – non-chilling, sensitive	90 to 240	-1.1 to +1	30 to 33.8	+1.1 to +2.2	34 to 36	-1.5	29.3	90 to 95
Apricots	7 to 14	-0.5 to +1	31 to 33.8	+1.1 to +2.2	34 to 36	-1.1	30	90 to 95
Asparagus	14 to 21	+2.2	36	+2.2	36	-0.6	30.9	90 to 95
Avocados – fuerte and hass	21 to 28	+5 to +8	41 to 46.4	+5 to 12.8	41 to 55	-0.3	31.5	85 to 90
Bananas – green	14 to 21	13 to 14	56 to 58	13 to 14	56 to 58	-0.7	30.6	90 to 95
Blueberries	10 to 18	-0.5	31	1.1 to 2.2	34 to 36	-1.3	29.7	90 to 95
Carrots – topped	30 to 180	0	32	0.6 to 1.7	33 to 35	-1.4	29.5	95
Cherries – sweet	14 to 21	-1.1	30	1.1 to 2.2	34 to 36	-1.8	28.8	90 to 95
Clementines	14 to 28	4.4	40	3.3 to 4.4	38 to 40	-1	30.3	90 to 95
Coconut – flesh	30 to 60	0	32	1.1 to 2.2	34 to 36	-0.9	30.4	80 to 85

Corn – sweet	4 to 6	0	32	0.6 to 1.7	33 to 35	-0.6	30.9	90 to 95
Courgettes	14 to 21	7.2	45	7.2 to 10	45 to 50	-0.5	31.1	90 to 95
Cucumbers	10 to 14	10	50	10 to 11.1	50 to 52	-0.5	31.1	90 to 95
Dasheens	42 to 140	13.3	56	11.1 to 13.3	52 to 56	–	–	85 to 90
Garlic	140 to 210	0	32	0.6 to 1.7	33 to 35	-0.8	30.5	65 to 70
Ginger rhizomes	90 to 180	13.3	56	12.8 to 13.3	55 to 56	–	–	85 to 90
Grapefruit	28 to 42	13.3	56	14.4 to 15.6	58 to 60	-1.1	30	85 to 90
Grapes	56 to 180	-1.1	30	1.1 to 2.2	34 to 36	-2.2	28.1	90 to 95
Guavas	14 to 21	10	50	9 to 10	48 to 50	–	–	85 to 90
Kiwi fruit	28 to 84	0	32	1.1 to 2.2	34 to 36	-0.9	30.4	90 to 95
Kumquats	14 to 28	4.4	40	4.4	40	–	–	90 to 95
Lemons	30 to 180	12.2	54	10 to 12.8	50 to 55	-1.4	29.4	85 to 90
Lettuce – iceberg	10 to 18	0	32	1.1 to 2.2	34 to 36	–	–	90 to 95
Limes	42 to 56	9 to 10	48 to 50	9 to 10	48 to 50	-1.6	29.1	85 to 90
Lychees	21 to 35	1.7	35	1.7 to 2.2	35 to 36	–	–	90 to 95
Mandarins	14 to 28	7.2	45	7.2	45	-1.1	30	90 to 95
Mangoes	14 to 25	13.3	56	12.8	55	-0.9	30.4	85 to 90
Melons – honeydew	21 to 28	10	50	7.8 to 10	46 to 50	-1	30.3	85 to 90
Mineolas	21 to 35	3.3	38	3.9 to 6.7	39 to 44	-1	30.3	90 to 95
Nectarines	14 to 28	-0.5	31	-0.6 to ±1	31 to 32	-1	30.3	90 to 95
Onions – dry	30 to 180	0	32	0.6 to 1.7	33 to 35	-0.8	30.6	65 to 75
Oranges – blood	21 to 56	4.4	40	4.4 to 6.7	40 to 44	–	–	90 to 95
Oranges – California and Arizona	21 to 56	6.7	44	6.7 to 7.8	44 to 45	-0.8	30.6	85 to 95
Oranges – Florida and Texas	56 to 84	1.7	35	1.1 to 2.2	34 to 36	-0.8	30.6	85 to 95
Oranges – Jaffa	56 to 84	7.8	46	7.8 to 10	46 to 50	-0.7	30.6	85 to 90
Oranges – Seville	90	10	50	11	52	–	–	85 to 90
Parsnips	120 to 150	0	32	0.6 to 1.7	33 to 35	-0.9	30.4	95

Peaches	14 to 28	-0.5	31	0.6 to 1.7	33 to 35	-0.9	30.4	90 to 95
Pears – Anjou	120 to 180	-1.1	30	0.6 to 1.7	33 to 35	-1.6	29.2	90 to 94
Pears – Bartlett	70 to 90	-1.1	30	0.6 to 1.7	33 to 35	-1.6	29.2	90 to 94
Peppers – sweet	12 to 18	10	50	10	50	-0.7	30.7	90 to 95
Peppers – hot	14 to 21	10	50	10	50	-0.7	30.7	90 to 95
Pineapples	14 to 36	10	50	10	50	-1.1	30	85 to 90
Plantains	10 to 35	13	57.2	14	57.2	-0.8	30.6	85 to 90
Plums	14 to 28	-0.5	31	1.1 to 2.2	34 to 36	-0.8	30.6	90 to 95
Potatoes – seed	84 to 175	4.4	40	5	41	-0.8	30.5	90 to 95
Potatoes – table	56 to 140	6	42.8	7	44.6	-0.8	30.5	90 to 95
Satsumas	56 to 84	4	39	4	39	–	–	85 to 90
Sweet potatoes	90 to 180	14	57	14	57	-1.3	29.7	85 to 90
Tangerines	14 to 28	7	42.5	7	42.5	-1.1	30.1	85 to 90
Tomatoes – green	21 to 28	13.3	56	13 to 14	56 to 58	-.5	31.1	90 to 95
Tomatoes – turning	10 to 14	9	48.2	10.6	51	-0.5	31.1	90 to 95
Ugli fruit	14 to 21	4.4	40	5	41	-1.1	30.1	90 to 95
Watermelons	14 to 21	10	50	8 to 10	46 to 50	-0.4	30.9	85 to 90
Yams – cured	49 to 112	16	61	16	61	-1.1	30.1	70 to 80

Table 37.2: Guidance for the transportation of fruit and vegetables.

37.8 Table Grapes

Table grapes are a high value commodity that may be carried on pallets either in containers or in breakbulk refrigerated vessels.

As grapes do not continue to ripen once they have been cut from the vine, they must be harvested in fully mature condition. Grapes can easily be physically damaged and poor handling can result in a variety of physiological defects that make them more susceptible to microbiological invasion.

Even comparatively short periods of exposure at normal temperatures, say six hours at 20°C, can result in dehydration and browning of the stems which then often results in bunch 'shattering' during handling. It is, therefore, normal practice to cool grapes as soon as practicable after they have been harvested.

Weather conditions, particularly rain prior to and during the harvest period, can have a significant effect on the storage life of grapes, because wetted grapes are more susceptible to fungal invasion than grapes that have been harvested after a period of dry weather.

Various species of microorganisms will invade grapes and the most common found in transportation is *Botrytis cinerea*, which produces typical grey mould, white mould or some forms of berry rot. This organism can grow at a temperature as low as minus 4°C (–4°C). Fungal infection is more likely to arise if, during the growth period of the fruit, the weather has been wet, but *Botrytis* mould can also develop on grapes that have not been exposed to wet conditions before harvesting. It is impossible to completely control or arrest the spread of infection by this fungal mould, as it will tolerate high levels of sulphur dioxide treatment. Other species of microorganisms that cause deterioration include *Cladosporium herbarum*, *Alternaria* species, *Penicillium* species and *Aspergillus niger*. Identification of the infecting microorganism can only be determined by laboratory examination of specimens of the grapes concerned.

Grapes are stowed in refrigerated containers in pre-cooled conditions. At the normal temperatures for loading, the rate of metabolic heat production is low so there should be no heat load problems. The carrying temperature, ie the air delivery temperature, must be as low as possible and container units are normally set to 0°C. Although grape berries will not freeze at temperatures above approximately minus 2°C (–2°C), the stalks will freeze at minus 1.5°C (–1.5°C) to minus 2°C (–2°C). On thawing, the stalks blacken, shrivel and become brittle, so there can be substantial shatter (ie individual grapes becoming detached from the bunches) with overcooled fruit, even if the berries themselves are unaffected.

The lugs in which the grapes are packed must be carefully stowed and this is normally the responsibility of the shipper. The key responsibility of the ship is to ensure the carrying temperature (0°C) is maintained and that there is a legible record to confirm this.

Grapes infected with *Botrytis cinerea* will continue to deteriorate, even at 0°C, but the rate of deterioration falls as the temperature is lowered, which is why carriers are advised to keep grapes at the lowest practical temperature.

There are many types of physiological disorders that can result in commercial losses of grapes, although some of the causes arise during growing, harvesting and handling rather than during an ocean voyage. If, therefore, damage to grapes is reported, the Master should ensure that a surveyor is called in.

Surveyors should be able to recognise the various conditions of infection or deterioration and take adequate samples to enable specialists to assess the nature of any damage. In cases of fungal infection, it is important that samples are drawn illustrating each particular type of fungal deterioration so that the causative organisms can be identified. This is because the types of infection involved can provide an indication of the underlying cause.

Experience has shown that claims for damage to cargoes of grapes frequently concern shipments made from the same source at about the same time, which could mean there were problems with a particular harvest. It is important for owners to advise their Association as soon as any allegations of damage are received so that the information can be collated and an investigation begun to determine whether any particular pattern is involved.