UK P&I CLUB

Carefully to Carry

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Fresh fruit and vegetables

The shipper should have full knowledge of the history of the produce and which temperature must be maintained by the carrier throughout the period under his control

The transport of fresh fruit and vegetables is a complicated topic. Differing fruit and vegetables have widely varying requirements for their safe preservation. The rate at which living fruits and vegetables age and eventually submit to senescence (old age), attack by micro-organisms and inevitable demise depends upon the environmental status afforded during storage and transit. During which periods the quality and condition of fruits and vegetables are maintained by retention at all times of their optimum temperatures. For safe carriage this will usually require that the commodities are pre-cooled and maintained at that temperature prior to being loaded into the transport unit, be it refrigerated ship, container or other mode of transport. Refrigerated systems used in transportation of commodities only have the capacity to adjust minor reductions of, and to maintain, the product temperature.

All fresh fruits and vegetables are living products and their life processes continue after harvest; the two most important being respiration and transpiration. The former being a complicated sequence of chemical reactions involving conversion of starches to sugars and the change of those sugars into energy. The normal respiration results in the fruit and vegetables consuming oxygen and giving off carbon dioxide; water; and varying, albeit immense, amounts of heat. The higher the ambient temperature surrounding the commodity the greater will be the temperature of the commodity itself and consequently the larger its rate of respiration. The second process, transpiration, is the loss of water by evaporation which will occur once the fruit or vegetable is removed from its tree or plant which has been the source of water during its formative period. Thus the storage/carriage conditions afforded the produce should be such that excessive water loss does not ensue.

Temperature

Many reference books include tables which provide data, including optimum temperatures, for the safe storage of commodities. Other publications specifically list the optimum transit (carriage) conditions. The storage data may, depending upon the commodity, refer to long term refrigerated storage requirements with any period quoted being that from

"The carrier shall properly and carefully load, handle, stow, carry, keep, care for and discharge the goods carried."

Hague Rules, Articles iii, Rule 2

Carefully to Carry Advisory Committee

This report was produced by the Carefully to Carry Committee – the UK P&I Club's advisory committee on cargo matters. The aim of the Carefully to Carry Committee is to reduce claims through contemporaneous advice to the Club's Members through the most efficient means available.

The committee was established in 1961 and has produced many articles on cargoes that cause claims and other cargo related issues such as hold washing, cargo securing, and ventilation.

The quality of advice given has established Carefully to Carry as a key source of guidance for shipowners and ships' officers. In addition, the articles have frequently been the source of expertise in negotiations over the settlement of claims and have also been relied on in court hearings.

In 2002 all articles were revised and published in book form as well as on disk. All articles are also available to Members on the Club website. Visit the Carefully to Carry section in the Loss Prevention area of the Club website www.ukpandi.com for more information, or contact the Loss Prevention Department.

harvesting to entry into the marketing chain. Published data applicable to sea-going carriage requirements may indicate slightly higher optimum temperatures. However it is essential to understand that published values of optimum temperatures for storage or transit are not absolute – the accurate optimal requirements are dependent upon varietal, climatic and other details of the produce. The optimum and required transport temperature of fruits and vegetables should be provided in writing by the shipper who will, or should, have full knowledge of the history of the produce and which temperature must be maintained by the carrier throughout the period under his control. Optimum temperatures determine low rates of respiration extend storage life and in addition reduce the rate of development of micro-organisms. Generally speaking the higher the temperature the faster will be the growth of moulds and bacterial infections.

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 the natural juices contain dissolved substances in solution which have the effect of lowering the freezing point. Thus generally speaking the main contents being sugars the sweeter the produce the lower the freezing point. Nonetheless it must also 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 consequences when the fruit is restored to ambient temperatures with likely loss of sound market values.

Chill damage

A second factor which establishes the lower safe limit of carriage temperature of some produce is that of chilling, which is a reduction in temperature that does not reach the freezing point of the produce. Numerous commodities especially those grown in tropical climates, or alternatively from plants originating from the tropics, are easily affected by low temperatures and inclined to injury to their tissues at temperatures well above their freezing point. Typical symptoms not only include pitting of surface tissues, discolour of flesh but also an increased susceptibility to decay.

Relative humidity

Relative humidity may be defined as the ratio of the water vapour pressure present in air at an existing temperature to the water-vapour pressure which would be present if the vapour were saturated at the same temperature. Relative humidity is usually expressed as a percentage.

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, i.e. an air mass at 90% relative humidity at +10°C contains a greater mass of water than a similar air mass at 90% relative humidity at a temperature of 0°C.

Nonetheless 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 when compared with the same air being at 0°C and 90% relative humidity.

Thus the relative humidity of the air within a cargo compartment of a refrigerated vessel, insulated refrigerator container or trailer directly determines the retention of the condition of the products carried. Relative humidity below the optimum range will result in shrivelling or wilting in most produce. The maintenance of an optimum range of humidity is often one of the more 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 shrivel caused by moisture loss. Exceptions to the above 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 which may occur in various parts of the system, and the inevitable increase in the circulating air temperature at return compared with delivery, the result of removal of respiratory heat from the produce, only a small increase should be acceptable. The comparison of delivery air temperatures and return air temperatures being one of the critical monitoring requirements of carriage. As the majority of produce carried should be presented to the vessel/container or trailer as precooled, the exceptions will include cargoes of bananas, the field heat having already been removed. The circulating cooling air should therefore only be required to remove respiratory heat of the produce and the heat exchanged via exterior surfaces. A high velocity of circulating air should be unnecessary and in fact undesirable. Cooling air in modern 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 can be rendered useless if incorrect stowage of the produce eliminates or reduces efficient airflow which tends to follow the route of least resistance. 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 entering at a point of lowest pressure within the circulation and the polluted air exiting the system at a point of highest pressure, or alternatively by use of an auxiliary air system driven by separate fans.

Rates of respiration and heat generation

Fresh fruits and vegetables and similar produce are live and as with all living products respire, i.e. the process by which oxygen from the air combines with the organic material of the produce to form, ultimately, water and carbon dioxide. The by-product of this chemical reaction being energy released as heat. The rate at which fruits and vegetables produce heat varies, some have high rates of respiration and they require more refrigeration to maintain an optimum carriage temperature than those which respire more slowly. The rates of respiration are determined by temperature and as before noted 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. Produce with short storage expectancy will usually have higher rates of respiration, e.g. fresh broccoli, lettuce, peas and sweet corn. 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 upon its variety (cultivar), area of growth, the seasonal and climatic conditions experienced during periods of growth.

Climacteric fruit and vegetables

Some varieties of fruit and vegetables have rates of respiration which do not decline during their ripening period – that is between maturation and the onset of senescence. In fact their respiration rates increase, a critical event or period known as their climacteric. Produce may therefore be categorised as climacteric or non-climacteric. The former continuing to ripen post-harvest, where as the latter does not. The ripening processes include development of colour, texture (tissue softening) and flavour.

Many fruits are climacteric, such as peach, apricot, banana, mango, papaya, avocado, plum, tomato and guava and tend to ripen rapidly during transit and storage. Examples of non-climacteric fruit and vegetables include cucumber, grape, lemon, lime, orange, temple fruit (satsuma, tangerine, mandarin) and strawberry.

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 during transit at the recommended humidity and temperature. Whereas some weight loss will inevitably occur due to the loss of carbon during respiration, this will only be of relative minor proportions.

However, 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.

Supplements to refrigeration

Opportunities have been tried and tested to slow down ripening after harvest and thus extend the transit, storage and shelf life of fruit and vegetables – especially those in the climacteric category.

This can be achieved with controlled atmosphere (CA) storage and carriage; modified atmosphere packaging (MAP), storage and carriage (MA); or alternatively with edible coatings.

Basically and in all cases the atmosphere created is one of low oxygen (O_2) and high carbon dioxide (CO_2) when compared to atmospheric air. The low oxygen and high level of CO_2 depress the production of ethylene (C_2H_4), a gas emitted in small quantities by plant tissues, which accelerates during the ripening process and in turn expedites the process itself in the form of a chain reaction, especially true in the case of bananas.

Caution: Modified and controlled atmospheres are non-life supporting. Proper ventilation instructions of compartments/containers under CA/MA must be carefully followed prior to entry.

Edible coatings can create a modified atmosphere, 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.

It has been stated that edible coatings which should be 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.

Carriage of mixed produce

At times carriers are 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, if having the same temperature requirements, can be stowed together.

Cross tainting should be avoided at all costs whereby strongly scented fruit and vegetables are stowed together. The many products which produce considerable ethylene naturally, including apples, avocados, bananas, pears, peaches, plums, melons and pineapples should not be stowed with or in adjacent compartments to kiwi fruit, water melons, lettuce, carrots etc. which can all be seriously affected by the ethylene.

Two commodities that have produced substantial cargo claims, pears and kiwi fruit, are dealt with in this article. There is also a brief comment on research into procedures for the ocean carriage of particularly sensitive fruits. Some data in that section also covers the storage of 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.

There is a scientific procedure for determining the correct data for picking which is based on the starch content in the fruit. However, once the fruit has been picked, the starch is rapidly converted into sugar and it becomes impossible at a later date to determine whether the fruit was at a proper stage of maturity when picked. 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 mild species *monilinia fructigena* and *botrytis cinerea*. The latter species can grow at temperatures as low as -4°C and the growth of this organism can, therefore, 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 0°C to -1.1°C. It is therefore recommended the carrying temperature should be 0°C or marginally lower where ships have equipment which can control the delivery air temperature to plus or -0.2°C or better. The set points for the carriage of pears in containers should be 0.6° to 1.7°C.

Pears may suffer chilling injury at temperatures below -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. Thus, claims for damage due to the delivery air temperature falling marginally below -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 fairly slow process. When checking a cargo shipped as pre-cooled, the ship's representative should ensure spear temperatures are taken at the centre of specimens selected for checking. Other points to be checked are the nature of the packaging and the general appearance of the fruit, particularly skin blemishes. Caution should be observed 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 unsatisfactory outturns occur it is essential that expert advice is obtained as soon as possible.

Kiwi fruit

These 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 thereafter stored at temperatures in the range -0.5°C to -1.0°C. Storage at 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. This will prompt rapid ripening. Particular care must therefore be taken when kiwi fruit is loaded, whether in containers, which is usual, or in conventional refrigerated ships to ensure that the atmosphere in contact with the fruit cannot be contaminated with the atmosphere from other sources, e.g. containers stuffed with cargoes such as apples which release considerable amounts of ethylene and even exhaust fumes from certain types of forklift. As it is necessary for the kiwi fruit to be carried using a fresh-air ventilation system, the possibility of cross contamination of 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 for expert advice to be obtained as soon as possible where damage is feared.

Recent developments in the carriage of delicate fruits, exotic fruits and similar products

World trade in delicate products such as strawberries and certain tropical fruits has expanded. The products concerned frequently have a short shelf-life and are therefore transported by air when the distance between the growing region and the market methods of extending the shelf life of delicate products to enable them.

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. Recent research has developed more sophisticated gas mixtures, for use in containers or similar carrying units, which will not only slow the ripening rate of fruit and the onset of senescence in other living products but also render such products less susceptible to decay and damage caused by micro-organisms, insects and physiological disorders.

Controlled or modified atmospheric systems involve original dosing to produce an atmosphere of the composition required and then monitoring the atmosphere with automatic analytical equipment which, coupled to recycling equipment, maintains the original composition of the atmosphere by removing the excess of some components and dosing to increase the concentration of others.

Research work carried out has 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.
- As levels of carbon dioxide in the range 10-15% *botrytis* rot of strawberries and some other fruit is substantially inhibited.

Storage of certain products in modified atmospheres can cause problems such as irregular ripening in bananas, pears etc. at low oxygen levels (2%). Development of black heart in potatoes and brown

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

heart in pears and apples at lowered oxygen levels are other examples.

Some products which clearly benefit from controlled-atmosphere storage are listed below, showing the optimum conditions for such storage, as reported by scientists in the USA.

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

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

The following table of temperatures, maximum storage/ transit and shelf life etc., is for guidance only. The required details of temperature and humidity should be provided in writing by the shipper who has the full knowledge of the product history. The shippers instructions should be maintained at all times.

Fresh fruit and vegetables	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 – non chilling-sensitive	90-240	-1.1 to +1	30 to 33.8	+1.1 to +2.2	34 to 36	-1.5	29.3	90 – 95
Apples – chilling sensitive	35 – 45	+1.5 to 4.5	34.7 to 40	+4.4 to +5.6	40 to 42	-1.5	29.3	90 – 95
Apricots	7 – 14	-0.5 to +1	31 to 33.8	+1.1 to +2.2	34 to 36	-1.1	30	90 – 95
Asparagus	14 – 21	+2.2	36	+2.2	36	-0.6	30.9	90 – 95
Avocados – Fuerte and Hass	21 – 28	+5 to +8	41 to 46.4	+5 to 12.8	41 to 55	-0.3	31.5	85 – 90
Bananas – green	14 – 21	13 to 14	56 to 58	13 to 14	56 to 58	-0.7	30.6	90 – 95
Blueberries	10 – 18	-0.5	31	1.1 to 2.2	34 to 36	-1.3	29.7	90 – 95
Carrots – topped	30 – 180	0	32	0.6 to 1.7	33 to 35	-1.4	29.5	95
Cherries – sweet	14 – 21	-1.1	30	1.1 to 2.2	34 to 36	-1.8	28.8	90 – 95
Clementines	14 – 28	4.4	40	3.3 to 4.4	38 to 40	-1	30.3	90 – 95
Coconut – flesh	30 – 60	0	32	1.1 to 2.2	34 to 36	-0.9	30.4	80 – 85
Corn – sweet	4 – 6	0	32	0.6 to 1.7	33 to 35	-0.6	30.9	90 – 95
Courgettes	14 – 21	7.2	45	7.2 to 10	45 to 50	-0.5	31.1	90 – 95
Cucumbers	10 – 14	10	50	10 to 11.1	50 to 52	-0.5	31.1	90 – 95
Dasheens	42 – 140	13.3	56	11.1 to 13.3	52 to 56	-	-	85 – 90
Garlic	140 – 210	0	32	0.6 to 1.7	33 to 35	-0.8	30.5	65 – 70

Fresh fruit and vegetables	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	%
Ginger rhizomes	90 – 180	13.3	56	12.8 to 13.3	55 to 56	-	-	85 – 90
Grapefruit	28 – 42	13.3	56	14.4 to 15.6	58 to 60	-1.1	30	85 – 90
Grapes	56 – 180	-1.1	30	1.1 to 2.2	34 to 36	-2.2	28.1	90 – 95
Guavas	14 – 21	10	50	9 to 10	48 to 50	-	-	85 – 90
Kiwi Fruit	28 – 84	0	32	1.1 to 2.2	34 to 36	-0.9	30.4	90 – 95
Kumquats	14 – 28	4.4	40	4.4	40	-	-	90 – 95
Lemons	30 – 180	12.2	54	10 to 12.8	50 to 55	-1.4	29.4	85 – 90
Lettuce – Iceberg	10 – 18	0	32	1.1 to 2.2	34 to 36	-	-	90 – 95
Limes	42 – 56	9 to 10	48 to 50	9 to 10	48 to 50	-1.6	29.1	85 – 90
Lychees	21 – 35	1.7	35	1.7 to 2.2	35 to 36	-	-	90 – 95
Mandarins	14 – 28	7.2	45	7.2	45	-1.1	30	90 – 95
Mangoes	14 – 25	13.3	56	12.8	55	-0.9	30.4	85 – 90
Melons – Honeydew	21 – 28	10	50	7.8 to 10	46 to 50	-1	30.3	85 – 90
Mineolas	21 – 35	3.3	38	3.9 to 6.7	39 to 44	-1	30.3	90 – 95
Nectarines	14 – 28	-0.5	31	-0.6 to +/-1	31 to 32	-1	30.3	90 – 95
Onions – dry	30 – 180	0	32	0.6 to 1.7	33 to 35	-0.8	30.6	65 – 75
Oranges – Blood	21 – 56	4.4	40	4.4 to 6.7	40 to 44	-	-	90 – 95
Oranges – California and Arizona	21 – 56	6.7	44	6.7 to 7.8	44 to 45	-0.8	30.6	85 – 95
Oranges – Florida and Texas	56 – 84	1.7	35	1.1 to 2.2	34 to 36	-0.8	30.6	85 – 95
Oranges – Jaffa	56 – 84	7.8	46	7.8 to 10	46 to 50	-0.7	30.6	85 – 90
Oranges – Seville	90	10	50	11	52	-	-	85 – 90
Parsnips	120 – 150	0	32	0.6 to 1.7	33 to 35	-0.9	30.4	95
Peaches	14 – 28	-0.5	31	0.6 to 1.7	33 to 35	-0.9	30.4	90 – 95
Pears – Anjou	120 – 180	-1.1	30	0.6 to 1.7	33 to 35	-1.6	29.2	90 – 94
Pears – Bartlett	70 – 90	-1.1	30	0.6 to 1.7	33 to 35	-1.6	29.2	90 – 94
Peppers – sweet	12 – 18	10	50	10	50	-0.7	30.7	90 – 95
Peppers – hot	14 – 21	10	50	10	50	-0.7	30.7	90 – 95
Pineapples	14 – 36	10	50	10	50	-1.1	30	85 – 90
Plantains	10 – 35	13	57.2	14	57.2	-0.8	30.6	85 – 90
Plums	14 – 28	-0.5	31	1.1 to 2.2	34 to 36	-0.8	30.6	90 – 95
Potatoes – seed	84 – 175	4.4	40	5	41	-0.8	30.5	90 – 95
Potatoes – table	56 – 140	6	42.8	7	44.6	-0.8	30.5	90 – 95
Satsumas	56 - 84	4	39	4	39	-	-	85 – 90
Sweet potatoes	90 – 180	14	57	14	57	-1.3	29.7	85 – 90
Tangerines	14 – 28	7	42.5	7	42.5	-1.1	30.1	85 – 90
Tomatoes – green	21 –28	13.3	56	13 to 14	56 to 58	-.5	31.1	90 – 95
Tomatoes – turning	10 – 14	9	48.2	10.6	51	-0.5	31.1	90 – 95
Ugli fruit	14 – 21	4.4	40	5	41	-1.1	30.1	90 – 95
Watermelons	14 – 21	10	50	8 to 10	46 to 50	-0.4	30.9	85 – 90
Yams – cured	49 – 112	16	61	16	61	-1.1	30.1	70 – 80

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