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CHAPTER 8

OPTIMUM STORING AND SHIPPING CONDITIONS FOR THE EXPORT OF PERISHABLE PRODUCE FROM SOUTH AFRICA

Optimum product storage conditions and temperatures may vary between growing and climatic conditions as well as specific procedures and market requirements. A very typical example is that plum cultivars produced in California can be stored at minus 0,5°C but the same cultivars grown in South Africa must be stored at a dual temperature of minus 0,5°C for up to 10 days whereafter the temperature must be raised to plus 7,5°C. Optimum product and air temperatures for products produced in South Africa are summarised in Tables 1 to 7 as well as in Section 10 of this book. Three different temperatures are to be considered during the voyage i.e.:

a. DAT or the delivery air temperature. This is the temperature of the air just before it comes into contact with the product.
b. RAT or the return air temperature. This is the temperature of the air coming directly off the product.
c. Optimum product or pulp temperature. This is the actual temperature of the product flesh.

The optimum product temperature is the only temperature that can be specified and that must be very strictly maintained. The only way this can be done during the voyage is by constantly observing the RAT and by carefully controlling the DAT at or not more than 0,5°C colder than the specified optimum product temperature. Optimum product temperature is achieved when the RAT is at, but not more than 1°C above, the specified optimum product temperature. If the RAT is 1°C or warmer than the specified optimum product temperature, cold blasts (lowering of the DAT) must be applied. This means that the minimum DAT as specified in Tables 1 to 7 must be applied for 3 hours out of every 6 hours. Should the RAT not drop to within 1°C above the optimum product temperature within 24 hours (4 separate cycles of cold blast), the PPECB must be informed immediately.

IMPORTANT NOTE
Optimum product temperature specified for avocados and mangoes is also the temperature at which the DAT should be maintained. Detailed specifications will be given in the Board temperature letter to the Master. Extensive basic and applied research was done over decades to develop optimum storage and transport conditions for South African produced fresh produce. These conditions also take care of specific market requirements as is specified within different PPECB Handling Protocols.

1. TEMPERATURE REQUIREMENTS

Specific detailed handling storage and transport procedures are revised annually by the PPECB. Such procedures are available for most of the fresh and also other food produce. The following information gives only a very brief summary of product requirements.

1.1 Optimum storage and shipping temperatures and requirements per product

APPLES
Optimum storage temperature minus 0,5°C
Optimum storage RH 95%
All South African commercially grown apples are cold stored, transported and shipped to distant markets at a pulp temperature of minus 0,5°C. Storage life of all cultivars grown for export exceeds 4 months and this can be extended to more than 8 months by applying controlled atmosphere storage. Some cultivars, however, are more sensitive to higher storage and transit temperatures. Yellowing and softening may become a problem later during the season while physiological disorders such as bitter pit are also temperature related. Maintenance of pulp temperature at minus 0,5 ± 0,5°C at all times is therefore important with cultivars such as Golden Delicious and all Red types. Some of the Red types have lower sugar content and are therefore more susceptible to freezing injury when exposed to temperatures below minus 1,5°C.

APRICOTS
Optimum storage temperature minus 0,5°C.
Optimum storage RH 95%
Apricots are very sensitive to warm pulp temperatures and must be handled and stored at optimum conditions to reduce losses. All cultivars grown for sea export have a storage life of 28 days and more at a pulp temperature of minus 0,5°C. Apricots also have a relatively high rate of respiration and proper precooling and adequate air circulation through the carton is very important.

GRAPES
Optimum storage temperatures minus 0,5°C.

Optimum storage RH 95%

Grapes are non-climacteric fruit and therefore do not ripen after picking. They also have a low rate of respiration, but must be stored and shipped at a pulp temperature of minus 0,5°C and a relative humidity of 95%. This is to avoid decay (especially Botrytis cinerea) and desiccation of stems and berries. Grapes are packed in cartons in polyethylene bags containing a sheet of specially prepared paper that produces sulphur dioxide gas. Handling procedures, packaging, cooling rates and temperature regimes are all engineered to maintain optimum sulphur dioxide and humidity conditions around the grapes in the polybag. Although the generation of sulphur dioxide is carefully controlled and the release to the outside air much reduced by the polyethylene bag, grapes should not be shipped with sensitive products such as apples.

PEACHES AND NECTARINES

Optimum storage temperature minus 0,5°C.

Optimum storage RH 95%

Peaches and nectarines differ in appearance, but the physiology of the fruits are much the same. Peaches and nectarines are therefore handled and stored similarly although different cultivars may respond differently during storage and transport. Most cultivars of peaches and nectarines may develop a physiological disorder known as woolliness. This situation is characterised by a lack of juice at the eating (ripe) stage. Maturity, storage and ripening temperatures are important factors in the development of this disorder. Woolliness can be controlled effectively by delaying precooling to allow the fruit to ripen up slightly before storage. Prompt and fast cooling to a pulp temperature of minus 0,5°C after the initial delay period is very important. A very strong interaction exists between maturity, temperature and storage period. For this reason every consignment, container and shipment must be considered individually. Special instructions, when necessary, will therefore be formulated.

PEARS

Optimum storage temperature minus 0,5°C.

Optimum storage RH 95%

All commercially grown South African pears are cold stored, transported and shipped to distant markets at a pulp temperature of minus 0,5°C. Storage life differs between cultivars and ranges from 10 weeks to 10 months. Fast precooling to minus 0,5°C immediately after picking and maintenance of the cold chain is of paramount importance. Summer pears are however stored and shipped at minus 1,5°C to avoid ripening. Controlled atmosphere (CA) storage may double the storage life of most of the pear cultivars. Packaging in polyethylene bags also has beneficial effects on storage and shelf life, but affects cooling. Forced air cooling and correct handling procedures are required to maintain quality. The Summer Pear cultivars are very sensitive to temperature fluctuations and must be properly precooled and handled carefully. The maximum pulp temperature of these cultivars must be 0,5°C at loading with an optimum of minus 1,5°C. Packham's Triumph pears, on the other hand, can be stored for very long periods but are more susceptible to freezing because of relatively low sugar content.

PLUMS

Optimum storage temperature varies according to cultivar and voyage.

Optimum storage RH 95%

Locally grown plums can be cold stored for at least 28 days provided the correct storage temperature is applied. Some of the commercial cultivars except Golden King develop physiological breakdown of the flesh when cold stored at minus 0,5°C for more than 10 days. This disorder is very effectively controlled by raising the temperature from minus 0,5°C to 7,5°C 10 days after picking. This concept is referred to as "dual temperature storage". Accelerated ripening associated with the development of heat of respiration occurs at 7,5°C. It is therefore necessary to again reduce the carrying temperature to minus 0,5°C after approximately 7 days at 7,5°C. The application of these temperatures sometimes varies because of different cultivar reaction, length of voyage and market requirements.

1.2 Optimum shipping temperatures for sea export

Optimum carrying temperatures, minimum air delivery temperatures and fresh air circulation rates for regular atmosphere storage and sea transport of perishable products from South Africa are summarised in the following tables. These conditions were developed and tested for large distant sea voyages.

1.3 Cargo mixes and compromise temperatures for Indian and Atlantic Ocean destinations

Exporters of perishable and other food products to East and West African and Indian Island destinations often need to mix different products into one container or ship's deck. The reason for this is the relatively smaller markets or small orders by specialized buyers such as oil rigs and hotel groups. In some cases cost of shipment and product also play a role, whilst it is also difficult to obtain specialised equipment to destinations not often frequented by regular sailings. A positive factor however is that the voyage times normally vary between five and fourteen days. Serious quality problems however often occur with products transshipped in an in between port before it reaches the final destination. A unique product temperature compromise system was developed over many years to supply these markets. These recommendations are summarised in Table 4.7. It is however important to keep in mind that:

- The listed mixes may not be the best compromise for all the products under all conditions.
- The products must always be handled and stored under optimum conditions.
- Special care must be exercised when containers or produce are transshipped in a different port. In transit storage and handling and delays in on going shipments must be carefully considered and managed.
- Exporters must ensure that their importers are well informed on the post discharge handling and storage of the produce. In many cases refrigeration is not continued after discharge. This results in an increase in temperature and excessive condensation especially in coastal areas and tropical climates.

1.4 Compromise temperatures for air freight

Maintenance of optimum product temperatures for air freight is not always possible. Produce move quickly through the airports and must many a time be mixed to ensure optimum utilization of available storage and air freight space. The best compromise temperature ranges per product groups are summarised in Table 7. These recommendations must be strictly applied to minimize quality losses.

2. TAINTS, CROSS TAINTS AND FOREIGN ODOURS

These are all different names for basically the same phenomena. In essence it means that a product acquires a non typical taste or odour. This non typical odour many a time comes from a different product where this odour is very typical. One example is where butter absorbs the odour from onions stored in the same environment. Foreign taints may also come from other sources such as chemicals and paints used for sealing and protection of the cold storage, container or deck structure. Strong odour is also sometimes present in the atmosphere, especially in the port environment, fresh and food produce must never be handled in or exposed to any polluted environment.

2.1 Products that very easily absorb taints are:

- Dairy products - The foreign taint molecules easily and permanently attach to the fatty acids in the product.

- Meat – especially meat with a high fat content absorbs all odour from fruits, vegetables and other chemicals.
- Fruit – especially Golden Delicious apples absorb all odour from the environment and packing material. Even some printing inks used on the carton label may taint apples and other fresh produce.
- Vegetables – especially those vegetables that are eaten fresh such as carrots and tomatoes.
- Nuts, as with dairy products, the taint molecules permanently attach to the fatty acids in nuts.

2.2 Products that easily give off taints or odour:

- Chemicals – especially paints, silicone, rubber, petroleum products, exhaust gasses and many more.
- Marine products – all fresh and frozen fish and other marine products
- Onions and garlic
- Potatoes, especially when over stored
- Capsicum or peppers
- Citrus fruit- the various oils in the skin of citrus fruit can cause severe taints in dairy and meat produce

2.3 Methods of testing for taints

There may be many very sophisticated tests for odour, but these are usually very slow and costly. Many a time a taint can disappear, especially when the product is cooked. The conditions must therefore also be evaluated to determine the possible taint risk.

2.4 Mixing of produce in storage and transport spaces

Many taint and cross taint tables can be found in literature but temperature incompatibility rules out certain product mixes. Products that may or may not be stored and transported together are summarised in Tables 9 and 10.

3. TIME TEMPERATURE TOLERANCES

3.1 Definition

Time temperature tolerances (TTT's) refer to the total time that a refrigerated perishable product can be without cooling during the handling and loading process. It can also be defined as the total cumulative time in the breaks in the cold chain. TTT's are based on product requirements and not on logistical processes and least to provide for operational inadequacies.

3.2 Effect of temperature fluctuations

Temperature increases in both chilled and deep frozen perishable products can have a very negative effect on product quality, eating quality, food safety and cosmetic appearance. Fresh produce are still alive and metabolic rates increase with an increase in temperature. This results in accelerated ripening and moisture losses. Microbiological spoilage also increases in both fresh and frozen produce when the product temperature increases. Fluctuating product temperatures also cause moisture of condensation to form on the packaging material and the product. This moisture can result into microbiological growth (rots and decay), can turn into ice inside and onto deep frozen produce.
It is therefore essential to maintain constant temperatures as soon as the cold chain is initiated. This is not always possible especially if the product is transferred between different refrigerated environments or during handling and transport. Maximum exposure times and temperature increases that can be tolerated by the product are specified as Time and Temperature Tolerances (TTT's). These TTT's may however vary according to product, ambient condition, handling method, equipment etc. TTT's for various products are defined in PPECB Handling Procedure documents within the ISO 9001-2000 system. TTT's were calculated for different products and types. Different criteria must be used for different products and conditions. Some of the important criteria considerations are:

- Inherent product requirement e.g. degreened citrus fruit or past maturing summer pears.
- Effect of increased temperature on fruit ripening (avocado and mango).
- Effect of increased temperature on condensation (waste in polybag packed grapes) and frost formation (icing of deep frozen produce)
- Efficiency of refrigeration unit to recool the product to the optimum temperature
- Cooling rate of the carton and pallet as affected by ventilation and position.

3.3 Specific product requirements

3.3.1 **Deciduous and citrus fruit** – The minimum time it takes for the temperature of the fruit in the center of the pallet to show an increase in product temperature. The TTT for this product group is a maximum period of six (6) hours taking into account product respiration and packaging.

3.3 General TTT breakdown per action

3.1.1 **Container handling – deciduous and citrus fruit**

		6 hour TTT	**3 hour TTT**
Loading of container out of cold store		1 hour	1 hour
Transport of container to the port terminal		2 hours	-
Handling of container in the port terminal		1 hour	1 hour
Loading on to vessel		2 hours	1 hour
	Total	**6 hours**	**3 hours**

3.1.2 **Conventional deck loading**

It is impractical to measure and apply TTT's during the loading of conventional decks. The rule on maximum pulp temperature increases therefore applies. Decks must be closed and recooling commenced as soon as the following pulp temperatures, are reached:

- All fruit not packed in polyethylene bags except
- Subtropical fruit 12°C
- All subtropical 5°C above the temperature
- All fruit packed in polyethylene bags 8°C
- Pulp temperature in center of pallets No increase

TABLE 1

Optimum carrying and minimum delivery air temperatures (degrees Centigrade - °C) and fresh air ventilation (cubic meters per hour – $m^3.h^{-1}$) for the carrying of South African fresh fruit for export under non-cold treatment conditions.

PRODUCT	OPTIMUM CARRYING TEMPERATURE °C	MINIMUM AIR DELIVERY TEMPERATURE °C	FRESH AIR CIRCULATION $m^3.h^{-1}$	NOTES 1
Apples: All cultivars Granny Smith - Pre Optimum	Minus 0,5 Plus 1,5	Minus 1,5 Minus 1,5	None None	
Apricots	Minus 0,5	Minus 1,0	None	
Cherries	Minus 0.5	Minus 1,0	None	
Grapes	Minus 0,5	Minus 1,5	None	
Nectarines	Minus 0,5	Minus 1,0	None	
Peaches	Minus 0,5	Minus 1,0	None	
Pears: All cultivars Summer pears	Minus 0,5 Minus 1,5	Minus 1,0 Minus 1,5	None None	
Plums	Variable	Minus 1,0	15	5
Prunes	Minus 0,5	Minus 1,0	None	

NOTES – TABLE 1

Note No. 1 Fresh air ventilation or intake rates for containers are given as cubic meters per hour ($m^3.h^{-1}$). Conventional shipping spaces shall be ventilated at such a rate as to always keep the carbon dioxide (CO_2) concentration in such spaces below 0,5 percent (%). Fresh air ventilation shall be applied in the regular atmosphere mode only. For controlled and modified atmosphere, the specifications of the equipment suppliers shall apply.

Note No. 5 Plum shipping temperatures shall be determined by cultivar and maturity on a single or triple temperature regime and shall be selected by the exporter from the updated list of reefer codes as maintained by the Board.

TABLE 8
Perishables which may, or may not, be stowed under chilled conditions in the same space.

	APPLES	AVOCADOS	EGG FRUIT	GRAPES	GRAPEFRUIT	GREEN PEPPERS	GREEN BEANS	LEMONS	LITCHIS	MANGOES	NECTARINES	ORANGES	PEACHES	PEARS	PINEAPPLES	PLUMS	TANGERINES	FLOWERS (CUT)	FLOWERS (BULB)	TOMATOES GREEN	TOMATOES RIPE	VEGETABLES ROOT	VEGETABLES LEAF
APPLES	X	N	N	Y	N	N	N	N	Y	N	Y	N	Y	Y	N	N	N	Y	N	N	N	Y	Y
AVOCADOS	N	X	N	N	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N
EGG FRUIT	N	N	X	N	N	Y	N	N	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N
GRAPES	Y	N	N	X	N	N	N	N	Y	N	Y	N	Y	Y	N	N	N	Y	N	N	N	Y	Y
GRAPEFRUIT	N	N	N	N	X	N	N	Y	N	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N
GREEN PEPPERS	N	N	Y	N	N	X	N	N	N	N	N	N	N	N	Y	N	N	N	Y	N	Y	N	N
GREEN BEANS	N	Y	N	N	N	N	X	N	N	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N
LEMONS	N	N	N	N	Y	N	N	X	N	N	N	N	N	N	Y	N	N	N	N	Y	N	N	N
LITCHIS	Y	N	N	Y	N	N	N	N	X	N	Y	N	Y	Y	N	N	N	Y	N	N	N	Y	Y
MANGOES	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
NECTARINES	Y	N	N	Y	N	N	N	N	Y	N	X	N	Y	Y	N	N	N	Y	N	N	N	Y	Y
ORANGES	N	Y	N	N	N	N	Y	N	N	N	N	X	N	N	N	N	Y	N	N	N	N	N	N
PEACHES	Y	N	N	Y	N	N	N	N	Y	N	Y	N	X	Y	N	N	N	Y	N	N	N	Y	Y
PEARS	Y	N	N	Y	N	N	N	N	Y	N	Y	N	Y	X	N	N	N	Y	N	N	N	Y	Y
PINEAPPLES	N	N	Y	N	Y	Y	N	Y	N	N	N	N	N	Y	X	N	N	N	Y	N	Y	N	N
PLUMS	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	X	N	N	N	N	N	N	N
TANGERINES	N	Y	N	N	N	N	Y	N	N	N	N	Y	N	N	N	N	X	N	N	N	N	N	N
FLOWERS (CUT)	Y	N	N	Y	N	N	N	N	Y	N	Y	N	Y	Y	N	N	N	X	N	N	N	Y	Y
FLOWERS (BULB)	N	N	Y	N	N	Y	N	Y	N	N	N	N	N	N	Y	N	N	N	X	N	N	N	N
TOMATOES (G)	N	N	N	N	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	X	N	N	N
TOMATOES (R)	N	N	Y	N	N	Y	N	Y	N	N	N	N	N	N	Y	N	N	N	N	N	X	N	N
VEGETABLES (ROOT)	Y	N	N	Y	N	N	N	N	Y	N	Y	N	Y	Y	N	N	N	Y	N	N	N	X	Y
VEGETABLES (LEAF)	Y	N	N	Y	N	N	N	N	Y	N	Y	N	Y	Y	N	N	N	Y	N	N	N	Y	X

TABLE 9
Commodities which may, or may not, be stowed in the same or adjoining spaces

	APPLES	BACON	BEEF (CHILLED)	BEEF (FROZEN)	BUTTER	CHEESE	EGGS	FISH (FROZEN)	GRAPES	MUTTON	ORANGES	PORK	PEACHES	PLUMS	POTATOES	VEGETABLES	ROCK LOBSTER
APPLES	X	N	BR	BR	N	N	N	SR	Y	N	Y	N	Y	Y	Y	Y	N
BACON	N	X	SR	Y	SR	Y	Y	SR	SR	SR	N	Y	SR	SR	SR	Y	SR
BEEF (CHILLED)	BR	SR	X	Y	Y	SR	Y	Y	Y	Y	N	Y	Y	Y	SR	Y	SR
BEEF (FROZEN)	BR	Y	Y	X	Y	SR	Y	Y	Y	Y	N	Y	Y	Y	SR	Y	SR
BUTTER	N	SR	Y	Y	X	SR	Y	Y	Y	Y	N	Y	Y	Y	N	SR	BR
CHEESE	N	Y	SR	SR	SR	X	N	N	SR	SR	N	SR	SR	SR	SR	Y	N
EGGS	N	Y	Y	Y	Y	N	X	SR	Y	Y	N	Y	SR	SR	N	SR	SR
FISH (FROZEN)	SR	Y	Y	Y	Y	N	SR	X	Y	Y	N	Y	SR	SR	SR	Y	Y
GRAPES	Y	Y	Y	Y	Y	SR	Y	Y	X	Y	Y	Y	Y	Y	Y	Y	Y
MUTTON	N	Y	Y	Y	Y	SR	Y	Y	Y	X	N	Y	Y	Y	SR	Y	SR
ORANGES	Y	N	N	N	N	N	N	N	Y	N	X	N	Y	Y	Y	Y	N
PORK	N	Y	Y	Y	Y	SR	Y	Y	Y	Y	N	X	Y	Y	BR	Y	SR
PEACHES	Y	Y	Y	Y	SR	SR	SR	Y	Y	Y	Y	Y		Y	Y	Y	Y
PLUMS	Y	Y	Y	Y	Y	SR	SR	Y	Y	Y	Y	Y	Y		Y	Y	Y
POTATOES	Y	SR	SR	SR	N	SR	N	SR	Y	SR	Y	SR	Y	Y		Y	N
VEGETABLES	Y	Y	Y	Y	SR	Y	SR	Y	Y	Y	Y	Y	Y	Y	Y		Y
ROCK LOBSTER	N	SR	SR	SR	BR	N	SR	Y	Y	SR	N	SR	SR	SR	N	Y	

Y = No danger of cross taint
SR = There is a slight danger of cross taint
BR = There is a danger of cross taint
N = Cross taint will in all probability take place.

TABLE 10
Frozen commodities which may, or may not, be stowed in the same spaces

	BEEF	BUTTER	FISH (WHITE)	FISH (SMOKED)	HORSEMEAT	MUTTON	PINEAPPLE CHIPS	PORK	ROCK LOBSTER	VEGETABLES	FRUITS AND JUICES
BEEF		Y	Y	N	Y	Y	N	Y	SR	Y	Y
BUTTER	Y		Y	N	SR	Y	N	Y	SR	Y	Y
FISH (WHITE)	Y	Y		SR	Y	Y	N	Y	Y	Y	Y
FISH (SMOKED)	N	N	SR		N	N	N	N	N	SR	SR
MUTTON	Y	Y	Y	N	Y		N	Y	SR	Y	Y
PINEAPPLE CHIPS	N	N	N	N	N	N		N	N	Y	Y
PORK	Y	Y	Y	N	Y	Y	N		SR	Y	Y
ROCK LOBSTER	SR	SR	Y	N	SR	SR	N	SR		Y	Y
VEGETABLES	Y	Y	Y	SR	Y	Y	Y	Y	Y		Y
FRUITS AND JUICES	Y	Y	Y	SR	Y	Y	Y	Y	Y	Y	

Y = No danger of cross taint
SR = Slight danger of cross taint
N = Decided danger of cross taint