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An analysis of temperature breaks in the summer fruit export cold chain from pack house to vessel

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Abstract

There is great concern in the fruit industry that too much fruit and money is lost each year due to breaks occurring in the export cold chain of fresh fruit. Therefore, the CSIR (Council for Scientific and Industrial Research) and Stellenbosch University were approached to do research on this problem. This particular study focuses on the cold chains of table grapes, summer pears and plums as these fruit are especially sensitive to temperature.

Observations were made on fruit farms, in pack houses, in cold stores as well as in the Port of Cape Town. From these observations it was clear that protocols are not always followed and fruit quality is sometimes neglected because of pressure to speed up the exporting process. In order to analyse the export cold chains of these fruit types, temperature trials were conducted and temperature data received from exporting companies was analysed. The data was analysed from the cold store up to the point where the vessel sailed out of the Port of Cape Town. From the analysis it became clear that too many cold chain breaks occur during fruit exports from South Africa, especially during the loading of containers at cold stores.

As a final output to the study, a good cold chain practice guide for the export of table grapes was developed with the aim of assisting the fruit industry in minimizing these cold chain breaks. The guide was developed with simplicity to ensure easy understanding under all role-players in the industry.

This study was a small step in the right direction, but it should be highlighted that the complexity of the problems in the fruit cold chains are substantial and further research will have to be done in order to eliminate the occurrence of these cold chain breaks.

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Chapter 1: Introduction

1.1 Introduction

The South African fresh fruit industry can be dated back to 1652 when Jan van Riebeeck arrived in the Cape and found that there was no edible fruit growing in the wild. The Cape's potential as a fruit producing area was soon realised. By August 1652, the first quinces were planted, thereby sowing the seeds for today's fruit industry worth billions of Rand (HORTGRO, n.d).

In February 1892, fresh fruit was successfully exported from South Africa for the first time, arriving in England as fresh and tasty as the day they were picked. This was a great breakthrough as all prior exporting efforts had failed (HORTGRO, n.d).

Today the fruit industry of South Africa is a substantial source of employment and in March 2009 the industry as a whole was measured to be worth more than 12.8 billion Rand (HORTGRO, n.d). In 2012 the deciduous fruit industry (except table grapes) alone measured to be worth 9.8 billion Rand and employed 105 949 labourers with 423 798 dependants (HORTGRO, 2012). Soft fruit such as apples, pears, table grapes, plums, peaches, nectarines and apricots account for approximately 15% of South Africa's income from exported agricultural products (HORTGRO, n.d).

Due to the fact that the export fruit industry of South Africa has become so economically important, it is critical to continuously improve the export supply chain in order to maintain its competitive position. It has been identified that a significant amount of South African fruit being exported never reaches the end customer and results in large amounts of money being lost. The main reason for these losses is breaks in the export cold chain resulting in a loss of fruit quality.

To address this problem Stellenbosch University together with the Council for Scientific and Industrial Research (CSIR) have been working on a project to identify breaks in the fresh fruit export cold chains and develop best practices for eliminating and minimizing these breaks. This specific study will form part of and enhance the bigger project, which started in 2012.

1.2 Goal and problem statement

The South African fruit industry is concerned that a significant amount of exported fruit is lost every season due to breaks in the export cold chain. This concern prompted the current research.

The cold chains of summer pears, plums and table grapes are the specific focus of this study. The aim of the study is to identify breaks in the cold chains of these fruits and to provide the industry with a best practice guide in order to minimize these breaks.

1.3 Research Questions

1.3.1 Main Research Question

What opportunities, from a supply chain perspective, are available to the South African fresh fruit industry to minimize the breaks that occur in the export cold chains of summer pears, plums and table grapes?

1.3.2 Sub Research Questions

1.3.2.1 What are the breaks that occur in the export cold chains of fresh fruit from South Africa?

1.3.2.2 Where in the export cold chain do these breaks occur?

1.3.2.3 Are there currently any efforts being made to improve the quality of the cold chain performance of fresh fruit exported from South Africa?

1.3.2.4 What best practices should be applied to minimize the breaks in fresh fruit export cold chains?

1.4 Data sources

Firstly, secondary information was gathered to gain knowledge of the fruit industry of South Africa as a whole as well as specifically the cold chains of summer pears, plums and table grapes. This information consists of a mixture of quantitative as well as qualitative data. Sources of this information include the internet, books and articles.

Further secondary research was done in order to conclude the literature review of this study. Qualitative data was gathered from previous studies that are of a similar nature to get an indication of what and how much has already been done globally regarding this topic. Sources of this information include the internet, books and articles.

Primary research information was gathered by means of observations and personal interviews. Observations were made on several fruit farms, at pack houses and cold stores between the months of November 2012 and March 2013. Table grapes were observed in the Orange River region, Hex River Valley as well as Vredendal. Plums were observed in Paarl, Wellington and Robertson whereas Ceres, Wolseley and Paarl were visited for the observation of summer pears. Qualitative as well as quantitative data was gathered through these visits. Qualitative data was gathered through observing the procedures followed in the pack houses and cold stores as well as through interviews with personnel, such as pack house and cold store managers. Quantitative data was gathered through ambient and fruit pulp temperature measurements taken inside the pack houses and cold stores.

Quantitative primary research information was further gathered from data collected throughout the supply chain of the fruit from the moment the fruit is loaded into the container at the cold store until it is removed from the container at the overseas receiver after being transported by sea. Temptale temperature monitors were placed into some fruit cartons of certain pallets. In most cases Temptales were placed in the first pallet loaded into a container (at the cooling unit) as well as in the last pallet loaded (at the door of the container). Some Temptales measure the pulp temperature of the fruit, known as probes, while others measure the ambient temperature around the fruit; ambient loggers. In addition, some Temptales monitor the ambient temperature as well as the relative humidity. On one occasion, Temptale probes were placed in all 20 pallets of a container to be able to see how the fruit pulp temperature differs between the pallets based on their location in the container. From this data it is possible to identify whether breaks occur and what the severity of the breaks are from the time that the container leaves the cold store until it arrives at the overseas receiver.

The main quantitative data analysed for this study included temperature data received from fruit exporting companies.

1.5 Structure

1.5.1 Chapter 2: Research design and methodology

Chapter 2 includes a discussion of the flow of the study and the methodology followed in the research.

1.5.2 Chapter 3: Literature review

Chapter 3 includes a background on the South African fresh fruit industry as a whole, a discussion of similar studies done recently, as well as a definition of a basic fruit export cold chain. The roles of the Port of Cape Town and the PPECB in the cold chain are also

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discussed. Finally, international best practices performing well in other countries are suggested.

1.5.3 Chapter 4: Discussion of fruit cold chains

Chapter 4 contains a discussion of the fruit export cold chains of the three fruit types focussed on during this study; namely table grapes, summer pears and plums.

1.5.4 Chapter 5: Data Analysis

In Chapter 5 the results of the temperature trials conducted and data received from exporting companies are discussed. The data is illustrated by graphs and tables.

1.5.5 Chapter 6: Interpretation of results

Chapter 6 includes the interpretation of the graphs illustrated in Chapter 5. Possible reasons for the outcomes of the data are also suggested in this chapter.

1.5.6 Chapter 7: Development of a good cold chain practice guide

Chapter 7 consists of solutions suggested to minimize the breaks identified in the fruit cold chains. A good cold chain practice guide was developed which includes best practices that are performing well in other countries.

1.5.7 Chapter 8: Conclusions and recommendations

The last chapter is a summary of the findings in this study and recommendations for the implementation of the good cold chain practice guide. It also includes the challenges experienced during the study and suggestions for future work.

Chapter 2: Research Design and Methodology

2.1 Introduction

This chapter includes a chronological, step-by-step discussion of how the study was executed. The types of data gathered and sources of data are also explained.

2.2 Literature Review

Secondary research was done by reading up on topics related to the study. Sources of information included the internet, books as well as articles. Several goals were met through the literature review, which are summarised in Chapter 3, namely:

- The researcher gained background knowledge on the South African fruit industry and developed an understanding of the terminology used in the industry.
- Qualitative data was gathered on previous studies that are of a similar nature to gain an understanding of what and how much has already been done globally regarding this topic.
- A good knowledge of the basic flow of the export cold chain of fresh fruit was developed.
- An understanding of the cold chain operations, monitoring and challenges at the Port of Cape Town was developed.
- The role of the PPECB in the export cold chain of fresh fruit was defined.
- International best practices were researched.

Although the literature review includes some quantitative data, the majority of the chapter contains qualitative information.

2.3 Observation of the fruit export cold chain

Primary research was conducted by observing fruit cold chains. Observations were made at fruit farms, in pack houses and cold stores, as well as at the Container Terminal of the Port of Cape Town. Through these observations, first-hand experience was gained on the flow of the fruit in the cold chain as well as the roles of labourers in the fresh fruit export cold chain. It also enabled comparisons to be made between what is supposed to happen in the cold chain (learnt from secondary research) and what actually happens in practice (seen through observations). These observations thus served as the main source for identifying temperature breaks in the cold chain.

2.3.1 Farm visits

Farms serve as the starting point for the cold chain of fresh fruit. It is here where the fruit is harvested. Once the fruit has been picked, the cold chain begins. The researcher had the opportunity to witness and experience the picking process of table grapes, plums as well as summer pears. Measurements were taken of the outside temperature during the picking process, the ambient temperature of the pre-cooling rooms as well as pulp temperatures of fruit inside the pre-cooling rooms. These measurements resulted in quantitative primary data.

During these farm visits, informal interviews were conducted with various people working on the farms, such as farmers, pickers, packers, logistics personnel, PPECB personnel, etc. Valuable qualitative primary research data was gained from these interviews.

2.3.2 Pack house and cold store visits

Once the fruit has been harvested, it is moved from the vineyard or orchards to a pack house. At the pack house, the field heat is removed through pre-cooling where after the fruit is packed. Not all farms have their own pack houses, in which case the fruit must be transported to a nearby pack house.

Once the fruit has been packed, it is moved into a cold store where the pulp temperature is reduced to a so-called optimum storage temperature. Most farms do not have their own cooling facilities so the packed fruit is sent to a nearby cold store.

Approximately nine days were spent making observations in fruit pack houses and cold stores in the Western Cape as well as the Northern Cape. During these visits, aspects such as the pulp temperature of the fruit (before and after being packed), sugar levels, fruit pressure as well as the ambient temperature of pack houses and cold stores were measured. These measurements resulted in quantitative primary data.

Once the fruit has been cooled down to its optimum storage temperature in the cold store, the fruit pallets are moved to an area known as the holding room where the fruit is maintained at this temperature until it is loaded onto a truck or into a container for transport to the port. The loading of fruit pallets into reefer containers was also observed. The time it took for containers to be loaded was observed and pulp temperatures of the fruit were measured just before loading.

Aside from observing the loading process, temperature monitors known as Temptales, were inserted into certain fruit cartons of specific pallets. Some of these Temptales measured the pulp temperature of the fruit (probes), while other Temptales measured the ambient temperature inside the specific carton as well as the relative humidity (ambient loggers). These measurements resulted in valuable quantitative primary data.

Just as with the farm visits, qualitative primary research was done in the form of informal interviews conducted in the pack houses and cold stores. PPECB personnel, logistics personnel, pack house- and cold store managers as well as packers were amongst the people interviewed here.

2.3.3 Port visit

The researcher had the opportunity to visit the container terminal at the Port of Cape Town. Through this visit the flow of reefer containers through the port from the moment it enters the port gate up to the point of being loaded onto the ship was observed. This visit ensured the development of an understanding of the port operations.

Table 2.1 summarises all the visits made at farms, pack houses, cold stores and the port.

Table 2.1: Cold chain observations

Date	Facility	Region	Fruit type involved	Reason for visit
11/12/2012	Novo Pack House and Cold store	Paarl	Plums	Observations in pack house and cold store.
11/12/2012	Slent Farm	Paarl	Plums	Observation of picking process.
12/12/2012	Sonlia Pack House	Wellington	Plums	Observations in pack house and cold store.
18/12/2012	Karstens Farm	Kanoneiland, Upington	Table grapes	Observation of pack house and cold store, Temptales placed in one container.
19/12/2012	Ebenhaeser Farm	Kakamas, Orange River Region	Table grapes	Observation of picking process and pack house.
19/12/2012	Dassierant Farm	Kakamas, Orange River Region	Table grapes	Observation of pack house, cold store as well as loading of containers.

Date	Facility	Region	Fruit type involved	Reason for visit
19/12/2012	Groot Gariep Cold Stores	Kakamas, Orange River Region	Table grapes	Observation of offloading of trucks, cold stores as well as loading of containers.
19/12/2012	Arendsnes Farm	Blouputs, Orange River Region	Table grapes	Observation of pack house and placing of temperature monitors in one container.
14/01/2013	Novo Pack House and Cold Store	Paarl	Pears	Observations in pack house and cold store.
17/01/2013	Ceres Fruit Growers Pack Houses and Cold Stores	Ceres	Pears	Observations in pack houses and cold stores.
23/01/2013	Ceres Fruit Growers Pack Houses and Cold Stores	Ceres	Pears	Temptales placed in two containers.
24/01/2013	Wolfpack Pack House	Wolesley	Pears	Observations in pack house.
01/02/2013	Novo Pack House	Paarl	Plums and grapes	Temptales placed in two containers (one plum container and one grape container).
11/02/2013	Novo Pack House	Paarl	Plums	Temptales placed in one container.
20/02/2013	Port of Cape Town	Cape Town	N/A	Observations of container terminal operations.
21/02/2013	Sonskyn Farm	Robertson	Plums	Observations made in pack house and Temptales placed in one container.
21/02/2013	Meerlust Farm	Hex River Valley	Grapes	Temptales placed in one container.
22/02/2013	Hexkoel Cold Store	Hex River Valley	Grapes	Temptales placed in all 20 pallets of one container.

Date	Facility	Region	Fruit type involved	Reason for visit
21/03/2013	Ceres Fruit Growers Pack Houses and Cold Stores	Ceres	Pears	Temptales placed in one container.
11/04/2013	Hexkoel Cold Store	Hex River Valley	Grapes	Temptales placed in one container.

2.4 Gathering of quantitative data

The majority of the quantitative data gathered for this study consists of the readings from temperature monitors. These monitors record the temperature every 20 or 30 minutes for the whole journey of the fruit, usually from the point of being loaded into a container truck at the cold store in South Africa up to the point where the monitor is removed at an overseas destination. The temperature data is sent from overseas to South Africa via electronic mails. The data includes temperature measurements in degrees Celsius as well as the time each measurement was taken.

Some of the data gathered for the purpose of this study resulted from temperature monitors inserted into fruit pallets, while most of the data was received from external fruit exporting companies.

2.4.1 Data gathered from self-inserted Temptales

The researcher personally inserted temperature monitors known as Temptales into eleven containers. The locations where these Temptales were inserted can be seen in Table 2.1 discussed earlier in this chapter. Temptales were placed in table grape, summer pear as well as plum containers. The number of Temptales for which data was received from their overseas destinations, was a disappointing 42 out of the 74 Temptales inserted. Although the exporters went beyond their duties to ensure retrieval of the data, the receiving depots claimed that they could not find the monitors. This is puzzling as each carton in which a Temptale was inserted was clearly marked with green stickers and pictures were taken of the Temptales inside the carton as proof. As this data was gathered by the researcher herself, it can be defined as primary quantitative data.

2.4.2 Data received from external companies

Most of the quantitative data used in this study consists of the data received from two external fruit exporting companies who monitor the temperatures of the fruit they export. As this data was gathered for purposes other than the study, it can be defined as secondary quantitative data.

2.5 Analysis of quantitative data

2.5.1 Formatting the data

Once the data had been gathered from both the Temptales inserted by the researcher as well as the data received from external companies, the next step was to format the data in Excel in such a way that it could be analysed. Formulas were constructed in Excel to identify where breaks in the cold chain occurred.

In order to examine the fruit cold chain for temperature breaks, an upper limit for the air temperature had to be chosen to define what qualifies a break. Several people; both scientists and experts from the fruit industry, were consulted on this matter. From a scientific perspective, the optimum air temperature inside a reefer container should not exceed 1°C, otherwise fruit quality might be compromised (Dodd, 2013). From a practical perspective, this is not always realistic. Temperature alone is also not the only factor that needs to be taken into account when defining a break in the cold chain. The period of time the temperature rises above the limit plays an important role in the fruit quality as well. A compromise between the strict scientific criteria and what is seen as acceptable by the fruit industry was finally chosen. The formulas were constructed to indicate a break every time the temperature readings were higher than 2°C for longer than 90 minutes (Roxburgh, 2013).

Table 2.2 illustrates the final format used for presenting the data in Excel.

Table 2.2: Example of format used in Excel to present data

Fruit type	Container nr	Type of Sensor	Position in Container	Observation nr	Date and Time	Temperature (°C)	Location in journey	Break
Grapes	TRIU8755578	Ambient	Last pallet loaded, 3rd carton from top.	1	22/01/2013 06:12	-0.33	Cold store	no
Grapes	TRIU8755578	Ambient	Last pallet loaded, 3rd carton from top.	2	22/01/2013 06:42	-0.39	Cold store	no

2.5.2 Analysing the data

After formatting the data, graphs and tables were constructed from the data. These representations made it easier to understand the data. The programs in which the graphs were drawn are Excel and Tableau.

2.6 Discussion of findings

Once all the data had been analysed and the graphs were drawn, the data had to be interpreted. A summary was made of all the key findings and possible reasons for the outcome of the data were suggested.

2.7 Development of best practice guide for fruit export cold chain

The final outcome of the study was the development of a best practice guide for the fruit export cold chain from the point of harvesting the fruit to the port from where it is shipped overseas. The aim of the guide is to supply the fruit industry of South Africa with a practical and visual guide for each step in the cold chain to minimize the occurrence of temperature breaks in the chain and raise the quality level of South African fruit. The guide is meant for everyone working in the fruit export cold chain and is developed in a simple, easy-to-read format. The guide developed during this study focuses specifically on practices for the table grape industry.

The development of the best practice guide meant that each step in the fruit export cold chain had to be critically reviewed to identify where temperature breaks were observed. The steps in the cold chain are discussed separately, starting with the harvesting of the fruit on the farm and ending with the fruit being transported to the port before being shipped

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overseas. The guide is split into two columns. The left hand column shows what not to do whereas the right hand column shows good practice. The guide highlights actions that will lead to temperature breaks occurring in the cold chain in the column on the left hand side ("what-not-to-do" column) and for each of these actions, the correct execution of the action is illustrated on the right hand side ("what-to-do" column). The whole guide is supported with visual illustrations for easy understanding of the steps to follow to minimize the occurrence of temperature breaks.

A workshop was held on 3 October 2013 with the aim of testing the credibility of the practice guide with experts in the fruit industry. Positive feedback was received after presenting the guide to those present at the workshop and the feedback from the workshop was incorporated into the guide.

2.8 Conclusions and Recommendations

The last chapter of the study includes a discussion of the overall conclusions of the whole study. Recommendations are also suggested for the fruit industry to follow in order to minimize cold chain breaks. Finally, the challenges experienced during the study are mentioned and suggestions are made for future studies on this topic.

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Chapter 3: Literature Review

3.1 Introduction

This chapter aims to give the reader an understanding of the South African fruit industry as a whole, with a focus on table grapes, summer pears and plums. Relevant cold chain best practices implemented on an international level were also investigated. The whole chapter can be described as secondary research from sources such as books, articles, journals and the internet.

3.2 Background to the fresh fruit industry of South Africa

South Africa's diverse landscape is not only known for its beauty, but also for its delivery of some of the world's most delicious fruit of excellent quality. The success of the South African fruit industry can be explained by the combination of the Mediterranean climate, steep hillsides, excellent soils and over 100 years of experience (South African Fruit, 2010).

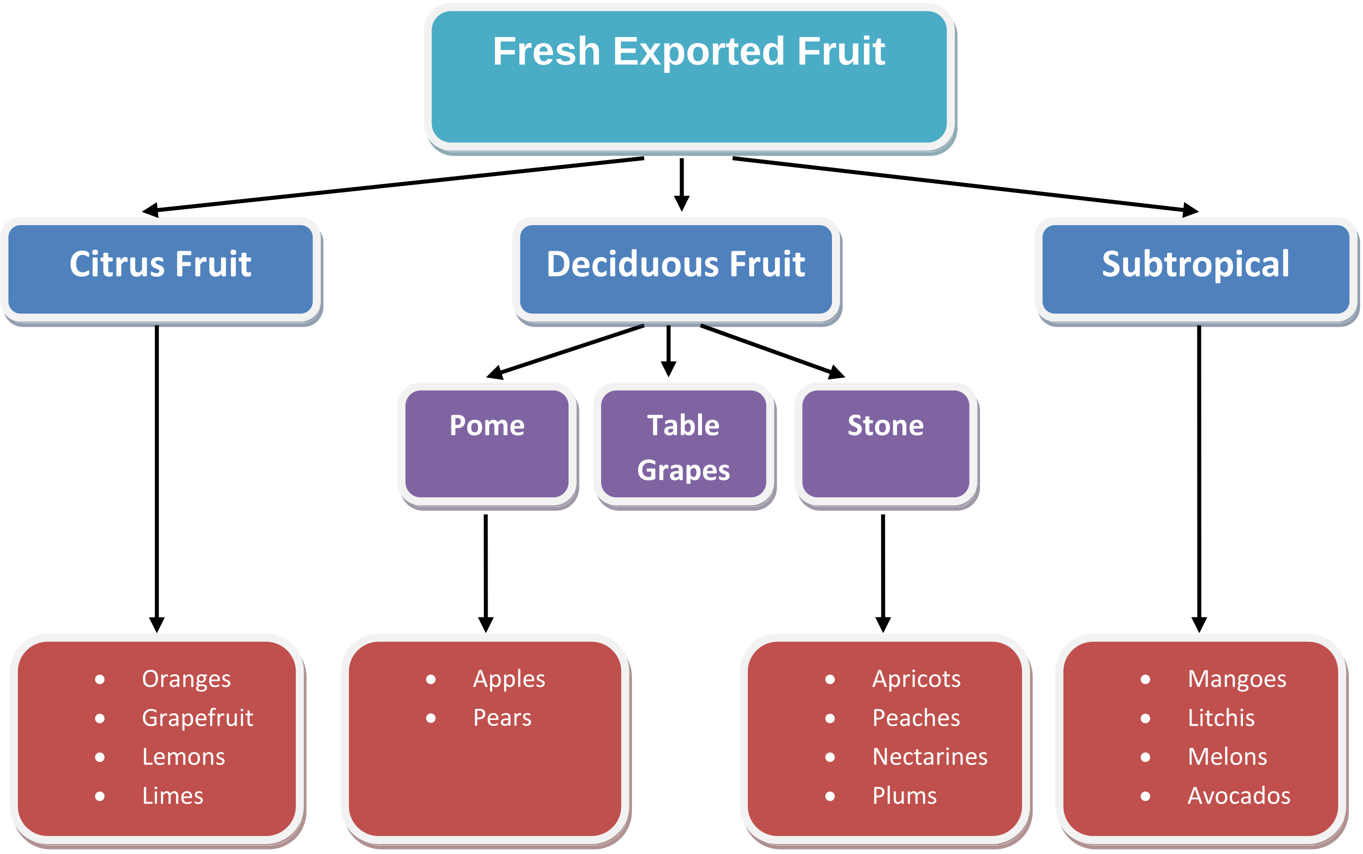
The South African fresh fruit industry is of great economic importance to the country as the industry employs approximately 460 000 people. This figure includes only the direct employment on farms and in pack houses and excludes logistics personnel (Davids, 2013).

South African growers are determined to produce fruit of a high quality, which is ethically cleared and safe, whilst preserving the environment. The industry is in close relationship with the South African government, striving to achieve a future of stability for all South Africans involved in the industry. Education, housing and farm management are some of the opportunities provided in the industry (South African Fruit, 2010).

South Africa produces vast amounts of fruit every year, significantly more than what is consumed by the country's population. Fruit production in South Africa increased from 2.7 million tons in 1981 to 3.5 million tons in 1991, and 5.5 million tons in 2011. Since the fruit sector was deregulated in 1997 the production of fruit grew with an average annual rate of 3.16% between 1997 and 2011. There are three main reasons for the increased production since 1997. Firstly, export opportunities in the traditional export markets such as Europe have increased as well as in the emerging markets such as the Middle and Far East. Secondly, fruit production practices have improved over the last decade. Thirdly, the export cold chain has improved and transport has become more efficient (Ntombela, 2012). The bulk of the fruit produced in South Africa is exported, mainly to European markets. Exports to the emerging markets such as Africa and the Far East have also started to grow over the last few years. During 2011, 5.5 million tons of fruit were produced of which only 803 248 tons were consumed by the local market. The rest of the fruit was exported (Ntombela, 2012). The export market is thus an important factor in the sustainability of the fruit industry as a whole (van Dyk & Maspero, 2004).

South African fruit is strongly demanded in the northern hemisphere because of the high quality of the fruit as well as the fact that South African fruit, being grown in the southern hemisphere, is available in the opposite season than that of fruit grown in the north. It is, however, extremely important for South Africa to maintain the quality of its fruit as it competes for market share with countries in the southern hemisphere such as Chile, Australia, New Zealand, Brazil and Argentina (van Dyk & Maspero, 2004). The export volume of deciduous fruit during 2012 was 848 585 tonnes (HORTGRO, 2012), (SATI, 2012).

Many varieties of fruit flourish in South Africa because of the ideal climate and soil characteristics. Deciduous fruit, citrus and subtropical fruit all contribute to the country's exporting richness. Figure 3.1 illustrates the different fruit varieties exported from South Africa.



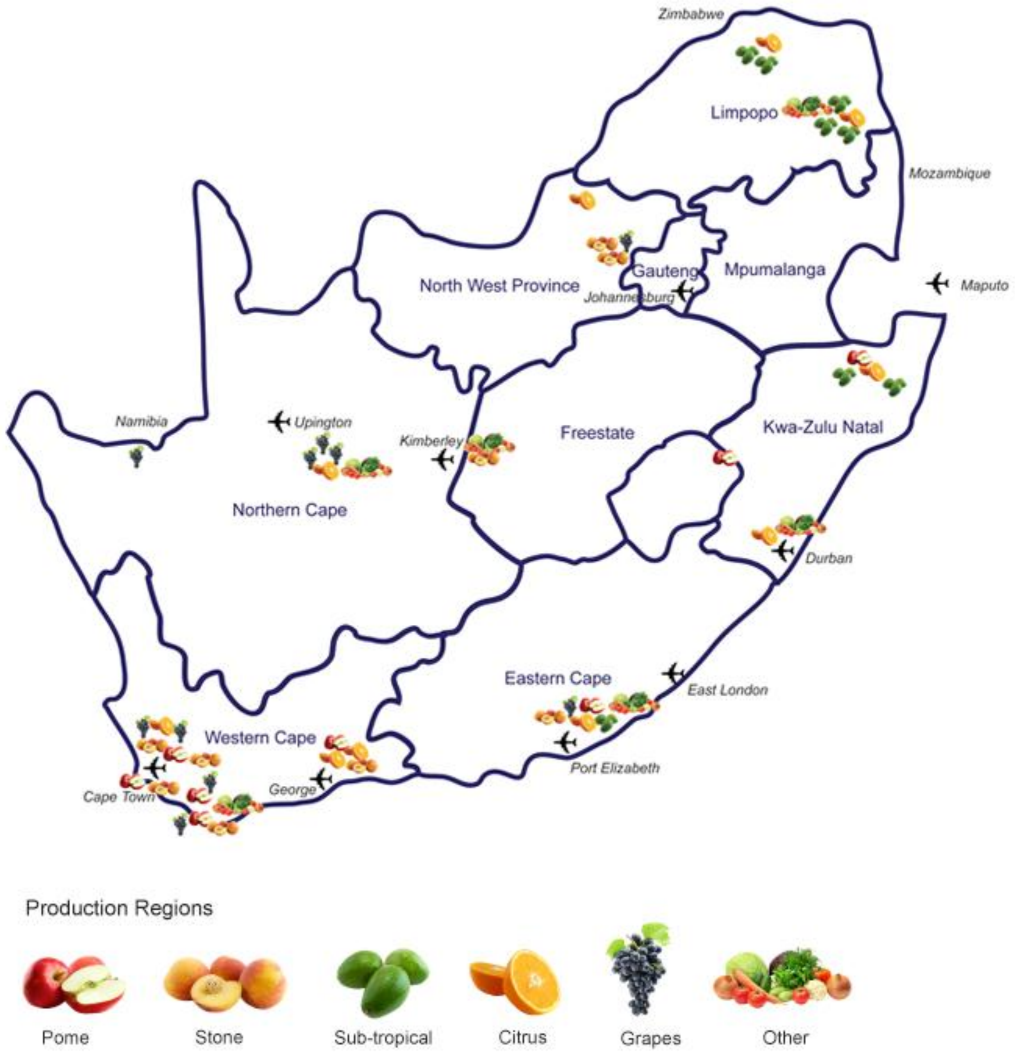
Adapted from: (van Dyk & Maspero, 2004)

Figure 3.1: Fruit varieties exported from South Africa

This particular study focuses on table grapes, plums and summer pears which all belong to the deciduous fruit family. Deciduous fruit includes fruit that grow on trees, bushes or vines and lose their leaves seasonally and shed fruit when the fruit is ripe. Pome fruit, stone fruit and table grapes together make up the category of deciduous fruit. Plums belong to the stone fruit category, whereas pears fall under the pome fruit category.

During the 2011/2012 season the total production of deciduous fruit increased by 3% and the total volume of deciduous fruit exported from South Africa increased by 8% (Davids, 2013). Cartons passed for export increased from 2010/2011 to 2011/2012 seasons. Pears increased with 1%, table grapes with 6% and plums with 1% (HORTGRO, 2012), (SATI, 2012).

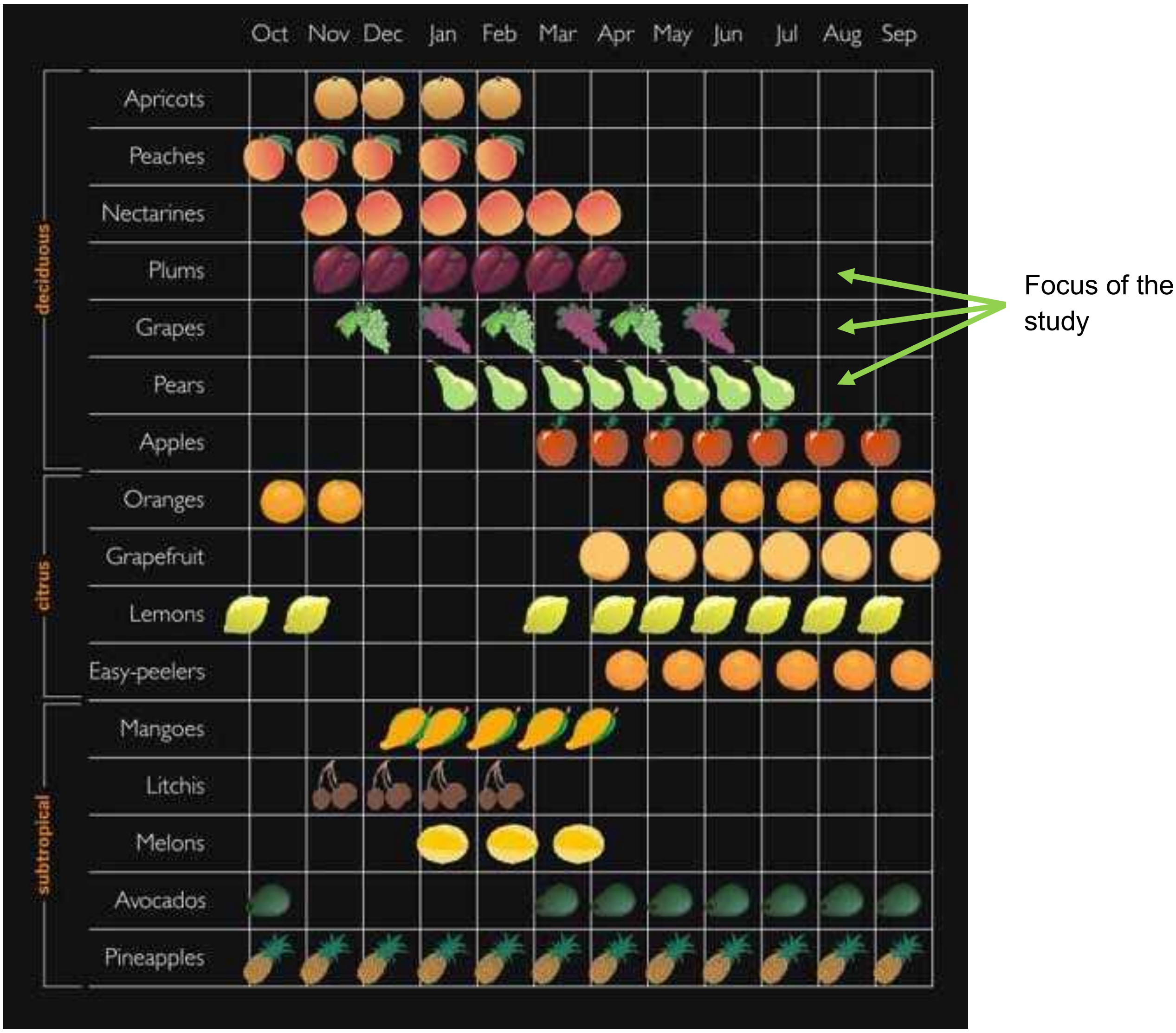
Figures 3.2 and 3.3 illustrate where and when each fruit type is produced in South Africa.



(PPECB, 2013)

Figure 3.2: Map of fruit production in South Africa

Figure 3.3 illustrates the fruit calendar for fruits exported from South Africa.



(van Dyk & Maspero, 2004)

Figure 3.3: Fruit Calendar of South Africa

3.2.1 Table grapes

Table grapes, along with apples, can be described as the most important deciduous fruits for South Africa on the export front. During the 2011/2012 season, 25 872 of the 77 805 hectares of deciduous fruit planted belonged to that of table grapes, which accounts for approximately 33% of the total area of deciduous fruit planted during that season (HORTGRO, 2012). The on-farm number of table grape labourers employed during this season was 62 870 in total, of which 50 999 were seasonal and 11 871 permanent labourers (SATI, 2012). Fifty-six percent of South African table grapes are exported to Europe, 21% to the United Kingdom, 14% to the Far East, 5% to the Middle East, 2% to Russia, 1% to the Indian Oceans islands as well as 1% to Africa (SATI, 2012).

During the 2011/2012 season 306 265 pallets of table grapes were exported from South Africa. This figure is rather large when compared to the biggest exporting figures of 1 254 033 pallets of citrus fruit and 459 686 pallets of pome fruit, which both include several fruit types, while table grapes are a fruit type on its own (Davids, 2013).

The season of table grapes in South Africa stretches from October to May the next year (van Dyk & Maspero, 2004). The Orange River Region is the main production area of table grapes in South Africa. Other production areas include the Olifants River Region, the Hex River Valley, the Berg River Region and the Northern Province Region (SATI, 2012).

South Africa produces several cultivars of both white and red table grapes, with the white cultivar, Thompson Seedless (Sultana), being the most popular (HORTGRO, 2012). The industry also continues to replace seeded cultivars with new seedless varieties (Davids, 2013).

Table grapes are extremely perishable as they are highly susceptible to a post-harvest fungal rot caused by the fungal pathogen, Botrytis cinerea (commonly called grey mould). This pathogen is controlled through storing the fruit in low temperatures with sulphur dioxide (SO_2) sheets or pads (some of the common brand names are Uvasys and Protecu). The SO_2 sheets are placed inside the poly bag which holds the grape bunches. Once the sheet is inserted, the poly bag is sealed. As the SO_2 sheets react with water in the air around the grapes they release gaseous sulphur dioxide. This SO_2 gas kills off any exterior infection of Botrytis (Dodd, 2013).

Botrytis cinerea hardly grows at all at 0˚C. This is why it is so important to keep table grapes as close to 0˚C as possible. Any breaks in the cold chain which raise the fruit temperature will trigger the growth of Botrytis, if it is present (Dodd, 2013).

3.2.2 Summer pears

Pome fruit can be described as a type of fruit produced by flowering plants. Apples and pears are the main pome fruits grown in South Africa.

Pears are one of the most important deciduous fruits for South Africa on the export front. During the 2011/2012 season, 11 700 of the 77 805 hectares of deciduous fruit planted belonged to that of pears, which accounts for approximately 15% of the total area of deciduous fruit planted during that season. The on-farm number of pear labourers employed during this season was 14 780 with 59 118 dependants (HORTGRO, 2012).

Sixty percent of South African pears are exported to Europe and Russia, 14% to the Far East and Asia, 11% to the United Kingdom, 9% to the Middle East, 3% to the USA and

Canada, 2% to Africa and the final 1% is exported to Indian Ocean Islands (Fresh Produce Exporters Forum, 2013).

South African pears are mainly produced in the Western Cape. Production areas of pears include Ceres, Elgin, Langkloof East, Groenland, Wolseley, Tulbach and Villiersdorp. Ceres is by far the biggest production area, planting 5.3 million of the 14.5 million pear trees planted during the 2011/2012 season (HORTGRO, 2012).

The pear season of South Africa stretches from January until July each year. Summer pears are harvested in the beginning of this season followed by winter pears (van Dyk & Maspero, 2004). South Africa produces several cultivars of both summer and winter pears, with the pear cultivar, Packham's Triumph, representing the largest volume (HORTGRO, 2012). The summer pear varieties produced in South Africa include Early Bon Chretien, Bon Chretien, Bon Rouge, Rosemarie, Flamingo, Beurre Hardy, Doyenne du Comice, Sempré, Victoria Blush and Harrow Delight (HORTGRO, 2012).

3.2.3 Plums

Plums belong to the stone fruit category. Stone fruit can be defined as fruits in which an outer fleshy part surrounds a shell (the pip or stone) with a seed inside.

Plums are also a popular exporting fruit in South Africa, although not exported in such big volumes as table grapes and pears. During the 2011/2012 season, 4 814 of the 77 805 hectares of deciduous fruit planted belonged to that of plums, which accounts for approximately 6% of the total area of deciduous fruit planted during that season. The on-farm number of plum labourers employed during this season was 6 373 with 25 493 dependants (HORTGRO, 2012).

Seventy-four percent of South African plums planted in the 2011/2012 season were exported. Most of these plums were exported to Europe and Russia, which accounted for 50% of the plums exported, the United Kingdom accounted for 26% of the exported plums and the Middle East received 15% of the South African exports (Fresh Produce Exporters Forum, 2013).

The plum season in South Africa stretches from November until April the next year (van Dyk & Maspero, 2004). Plums are grown in the Western and Eastern Cape. Both these provinces produce a wide variety of red, purple and yellow plums. Popular cultivars of red or purple plums with yellow flesh include Fortune, Laetitia, Pioneer, Sapphire, Flavor King as well as Southern Belle. The most popular cultivars of yellow skin and yellow flesh plums produced in South Africa are Songold and African Pride (South African Fruit, 2010).

Table 3.1 summarises the general information regarding table grapes, summer pears and plums discussed earlier. It is important to note that the information on pears included in the table includes both summer and winter pears. The reason for this is the fact that little statistics exist on summer pears alone as some varieties such as Packham's Triumph are harvested during the summer and winter pear seasons (January to July) (Dole South Africa, 2013).

Table 3.1: Summary of 2011/2012 table grape, pear and plum seasons

	Table grapes	Pears	Plums
Hectares planted in 2011/2012 season	25 872	11 700	4 814
On-farm labourers employed in 2011/2012 season	62 870	14 780	6 373
Number of pallets or cartons exported in 2011/2012 season	306 265 pallets / 53 million cartons (standard equivalent cartons of 4.5kg)	14 227 837 cartons (standard equivalent cartons of 12.5kg)	9 526 529 cartons (standard equivalent cartons of 5.25kg)
Export destinations	Northern Europe, United Kingdom, Far- and Middle East.	Europe, Russia, Far East, Asia, United Kingdom, Middle East, USA, Canada, Africa, Indian Ocean Islands.	Europe, Russia, United Kingdom, Middle East.

(HORTGRO, 2012), (Fresh Produce Exporters Forum, 2013), (SATI, 2012)

3.3 Defining the export value/cold chain of fresh fruit

The export cold chain of fresh fruit can be described as the movement of fresh fruit from the farm (production area) to the market, through various storage and transport mediums, whilst maintaining the fruit at the optimum storage temperature and relative humidity at all times (PPECB, 2013).

Each step in the export cold chain of fresh fruit is discussed in the following paragraphs.

3.3.1 Pre-cooling

The first step of good cold chain management occurs directly after the fruit has been harvested. Once the fruit has been picked, it should be transported immediately from the vineyards or orchards and placed into a pre-cooling unit. The main purpose of the pre-cooling unit is to remove the field heat from the fruit as soon as possible.

A pre-cooling unit is a refrigerated room, which normally forms part of the pack house building. Pre-cooling could be done through several ways with hydro-cooling, vacuum cooling and forced air cooling being the most popular methods. The temperature inside a pre-cooling unit is maintained above dew point, usually between 15°C and 18°C. During pre-cooling a minimum humidity level of 80% is acceptable whereas 90% ± 5% is the optimum (PPECB, 2013). These humidity levels can be achieved through the use of “wet walls” or fogging systems.

Pre-cooling is critical for an effectively managed cold chain. Fruit cooled rapidly after harvest definitely have longer shelf lives than those which are immediately moved to the pack house to be packed. Grapes deteriorate more in one hour at 32°C than during one day at 4°C or a full week at 0°C (Thompson *et al*, 2008).

3.3.2 Pack house

Once the field heat has been removed, the fruit crates are transported into the pack house by forklifts to be packed. Summer pears, however, may be stored in cold stores and packed at a later stage as demanded by the market. Inside the pack house the fruit is sorted into grades for local and export markets and is placed into the correct type of packaging as required by exporters for the different markets. Fruit is usually placed into cartons which are stacked into pallets.

Unfortunately, most pack houses in South Africa tend to be warmer than ideal, which leads to a rise in the pulp temperature of the fruit and results in a break in the cold chain. Pack houses should be maintained at a temperature below 25°C (PPECB, 2013).

3.3.3 Inspection

Once the fruit has been packed, samples are drawn from the packaged goods and the fruit is inspected by the Perishable Products Export Control Board (PPECB). The purpose of this inspection is to evaluate the quality of the fruit according to the market requirements. The sugar level of the fruit is measured as well as the pressure. Other aspects of the fruit that are inspected include colour, size, blemishes and firmness.

The PPECB is an independent South African service provider of quality certification and cold chain management services for producers and exporters of perishable food products. The role of the PPECB is discussed in section 3.7 of this chapter.

3.3.4 Cold storage

The cooling process occurs in two stages. The first stage involves the fruit pallets being moved into a refrigerated room known as a cold store where the pulp temperature of the fruit is brought down to an optimum low temperature as prescribed by PPECB's protocols. Cold stores in the fruit industry usually run at a room temperature of 0°C.

Forced air cooling (FAC) is the most common method of cooling used in fruit cold stores. The process of FAC involves the fruit being placed into cooling tunnels where additional fans are used to blow cold air (minus 2°C for fruit with an optimum storage temperature of minus 0.5°C) to create a low pressure across the pallet forcing the cold air through the fruit cartons. This method of cooling increases the surface area that is cooled which results in the fruit being cooled down to the optimum storage temperature up to ten times faster than normal room cooling. The required temperature is usually achieved within 24 to 48 hours (Freiboth, 2012). Once the optimum pulp temperature is reached throughout the total load within the tunnel, the FAC fans must be switched off to prevent high rates of product moisture loss and to minimize chilling or freezing injury (PPECB, 2013).

The second stage of the cooling process involves the fruit being moved to a holding room. The function of the holding room is to ensure that the fruit comes out of a FAC tunnel at its optimum temperature. A maximum fluctuation from the optimal temperature allowed by the PPECB inside the holding room is 5% (PPECB, 2013). The fruit is kept in the holding room until it needs to be loaded onto a truck, which will transport it to a port.

Table 3.2 illustrates the optimum storage temperatures for table grapes, summer pears and plums as prescribed by the PPECB.

Table 3.2: Optimum storage temperatures for table grapes, summer pears and plums

Fruit type	Optimum storage temperature (pulp temperature)
Table grapes	-0.5°C
Summer Pears	-1.5°C
Plums	-0.5°C in most cases. Varies according to cultivar and voyage.

(PPECB, 2013)

3.3.5 Inspection

Before being transported to the port, the temperature of the fruit is measured to ensure that it has been cooled to the optimum temperature in the cold store. The pallets and packaging are also checked against the required standards. In the case where a refrigerated truck is used as mode of transport, the truck itself is inspected. In most cases, however, the fruit is transported in a refrigerated container (commonly referred to as a reefer container) on a truck where only the container is inspected. The cooling unit of the container or refrigerated vehicle is inspected to ensure that it operates within the design parameters and specifications (PPECB, 2013).

3.3.6 Loading of a container

Once the fruit and the container have been cleared by the inspector, the pallets are loaded into the container by forklifts. This process must occur as quickly as possible as the fruit normally stands in an unrefrigerated area while waiting to be loaded.

It is critical that the container is not pre-cooled before the fruit pallets are loaded into it. The reason for this is the fact that condensation will occur once the container doors are opened and the cold air inside the cooled container comes into contact with the warmer outside ambient temperature. This condensation problem leads to moisture on the fruit loaded into the container, which will have a negative effect on the quality of the fruit.

3.3.7 Transportation to the port

Once the fruit has been loaded and the door of the reefer container locked, the truck departs to the port. In the event of the journey taking longer than two hours, a generator set (genset) is required to maintain the prescribed temperature within the container. A genset can be defined as a device installed in some trucks which acts as a source of power to reefer containers during transit. Each reefer container has its own refrigeration system, but requires a power source to function. While in transit on the truck, the genset is this power source. The goal of the genset is not to cool down warm fruit, but to maintain the temperature during the transit of already cooled fruit. PPECB allows a container to be unrefrigerated for a maximum of six hours from the moment the fruit is removed from the cold store until it is plugged in at the stack. Two of these six hours are reserved for the journey on the road, while the rest of the time is reserved for activities such as queuing at the port gate and waiting for the container to be offloaded. This means that gensets are not required for journeys shorter than two hours (Freiboth, 2012).

3.3.8 Export Port

On arrival at the port the container is offloaded from the truck and transported to a specific location in the reefer stack where the container is plugged in and monitored to remain at its optimum temperature. The reefer stack is the area in the port allocated specifically for reefer containers. The area is equipped with a power source for each reefer container entering the stack. Once the container is placed in its specific location in the stack, the container is plugged into the power source of the stack and the temperature of the reefer container is monitored throughout its stay in the stack. The system used for this monitoring at the Port of Cape Town is known as the Refcon system. The Refcon system is discussed in section 3.6 of this chapter.

3.3.9 Loading onto a vessel

When the vessel arrives and is ready for loading, the container is removed from the reefer stack and transported to the quay. The container is loaded onto the ship by a gantry crane. The container is again plugged in and monitored at the optimum temperature throughout the journey.

3.3.10 Import port

On arrival at the destination port, the container is offloaded from the ship and put into a reefer stack until it is collected by the receiver.

3.3.11 Inspection

Once offloaded, the fruit is again inspected. This inspection is conducted by the receivers of the fruit, often referred to as "Category Managers". The aim of the inspection is to ensure that the fruit is of the quality standard prescribed by the supermarket.

3.3.12 Cold store and distribution centre

Once cleared from inspection, the fruit pallets are transported to a cold store from where they are taken to a distribution centre and finally delivered to the respective supermarkets.

3.3.13 Inspection

On arrival at the supermarket, another inspection is conducted by the supermarket to ensure that the quality of the fruit is up to their required standards.

3.3.14 Supermarket

Once cleared from inspection, the fruit is unpacked and displayed in the supermarket to be sold as quickly as possible.

3.3.15 Consumer

Finally, the consumer buys the fruit from the market. The consumer either eats it immediately or stores it at home before consuming.

Figure 3.4 illustrates the process just discussed.

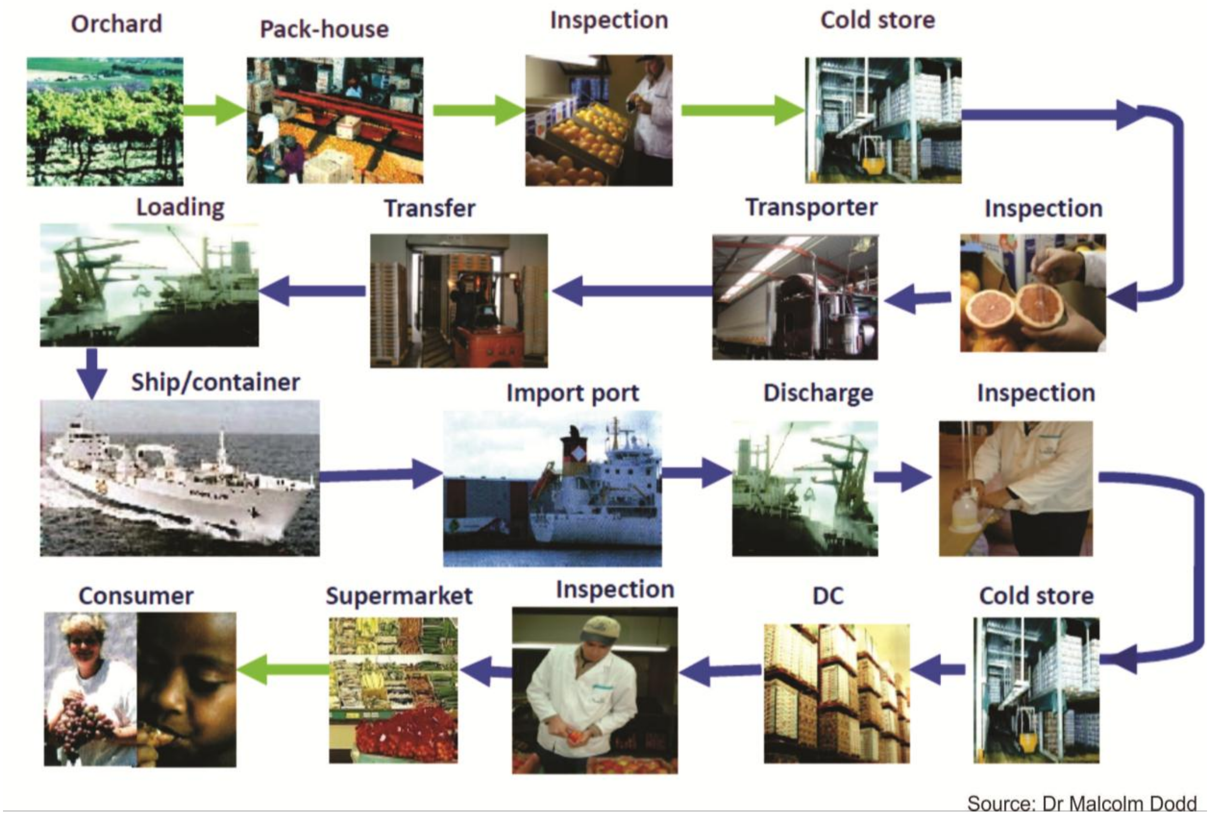


Figure 3.4: The export fruit logistics cold chain of South Africa

3.4 Temperature and Relative Humidity (RH) as main factors in preserving the quality of fresh fruit

3.4.1 Temperature

Fruit is alive and thus uses up oxygen and gives off carbon dioxide. Once harvested, the fruit must be kept alive for a long time. Fruit starts loosing quality and freshness from the moment it is picked as it is removed from its sources of water and nourishment. Fruit can be described as climacteric or non-climacteric. Climacteric fruit is defined as fruit of which the ripening process continues after the fruit has been picked. On the other hand, the ripening process of non-climacteric fruit stops as soon as the fruit has been picked. Summer pears and plums are climacteric fruit, while grapes are non-climacteric. The fruit will inevitably die (Jobling, n.d.). Therefore, effective postharvest management and cold chain maintenance is critical in order to postpone this death for as long as possible. The most important factor in postharvest management is temperature management (Jobling, 2002).

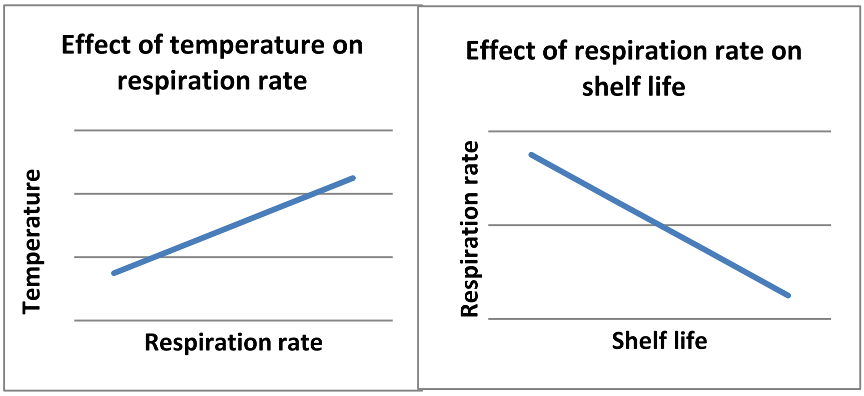
Temperature management of fresh fruit is not as simple as keeping the temperature of all fruit as low as possible after harvesting. There are optimum storage temperatures for all produce. It is critical that all role-players involved in the cold chain are aware of these optimum temperatures and closely follow the PPECB protocols for each fruit type.

Temperature management is important for two reasons; its impact on the rate of respiration as well as on the growth rate of postharvest micro-organisms (Jobling, n.d.).

3.4.1.1 Rate of respiration

Respiration in fruit is a chemical process where fruits convert sugars and oxygen into carbon dioxide, water and heat (Becker & Fricke, n.d.).

The rate of respiration is an indication of the deterioration rate of fresh fruit. Temperature has a direct effect on the rate of respiration, and therefore, an increase in temperature will cause an increased rate of respiration, which will result in faster deterioration of fresh fruit (Jobling, n.d.). A higher respiration rate thus results in a shorter shelf life. Figure 3.5 illustrates the relationship of respiration with that of temperature and shelf life.



(Nelson, 1983)

Figure 3.5: Relationship of respiration rate with that of temperature and shelf life

It is important to note that not all fruit types respire at the same rate when the temperature is held constant.

It is also true for most fruit types that the higher the rate of respiration, the higher the rate of perishability will be. Plums are relatively perishable as they respire at a medium rate and therefore have a relatively short shelf life. Summer pears, on the other hand, have a low relative perishability as they respire at a low rate and therefore have a longer shelf life. However, no matter what the respiration rate, when there is a rise in temperature, there is a significant increase in respiration. Table grapes, however, are one of the exceptions to this rule. Grapes are highly perishable, but not because of a high respiration rate. In fact, grapes respire at a very low rate because of its non-climacteric nature. Grapes are considered extremely perishable because they are highly susceptible to a post-harvest fungal rot caused by the fungal pathogen, Bortytis cinerea (commonly called grey mould). Infection by this fungal pathogen is not influenced by the respiration rate of the fruit.

Fruit continues to respire throughout its post-harvest life and therefore it is critical to maintain low fruit pulp temperatures throughout the cold chain to keep the rate of respiration as low as possible in order to extend its shelf life.

3.4.1.2 Growth rate of post-harvest micro-organisms

Post-harvest rots and micro-organisms in fruit is a problem that should be avoided as far as possible through good cold chain management. Along with chemical treatment, temperature management is the solution to this problem. In some cases, particularly soft fruit, there is no chemical treatment available and temperature management is the only tool available for disease control (Jobling, n.d.).

Fruit is susceptible to diseases caused by a range of bacteria and fungi. Generally, fruit tends to be more susceptible to fungal diseases rather than bacterial ones. The reason for this is the fact that fruit normally contains high levels of acid which makes them resistant to bacteria. As the fruit ripens this resistance does, however, become weaker. Ripe fruit is less acidic, have softer skins, higher sugar levels and weaker natural defence barriers (Jobling, n.d.).

The growth rate of both bacteria and fungi increases with an increase in temperature and can be controlled by managing the temperature (Jobling, n.d.). By storing and transporting fruit at its optimum storage temperature diseases in fruit can be kept to a minimum. Effective temperature management throughout the cold chain thus also plays an important role in the health of fruit.

3.4.2 Relative humidity

The criticality of maintaining an optimum level of relative humidity during the storage and transport of fresh fruit is often underestimated and neglected. For effective cold chain management it is important to grasp the benefits of maintaining optimum relative humidity levels in terms of fruit quality and shelf life.

Relative humidity can be defined as “the ratio of water vapour present in the air relative to the maximum amount of water vapour which can be present in the air, considering that the temperature and atmospheric pressure are held constant" (PPECB, 2013). The main factors affecting the relative humidity of the atmosphere include temperature fluctuations and temperature differences.

To understand the importance of relative humidity during cold storage of fresh fruit, the nature of relative humidity should be discussed. A large percentage of fresh fruit consists of water. Within the intercellular spaces of fresh fruit, the relative humidity is approximately 100%. The natural movement of water vapour is from a high pressure (high RH) to a low pressure (low RH). When the relative humidity in the atmosphere is less than 100%, water vapour will thus move out of the fruit into the atmosphere. When too much water vapour moves out of the fruit, through a process called respiration, the product is influenced negatively. These negative effects include shrivelling, desiccation, weight loss, loss of appealing appearance, as well as decreased eating quality. The nature of the skin of some fruit types do, however, prohibit water vapour moving out of the fruit to some extent. Practical steps that can be taken to minimize the loss of water includes applying of artificial waxes, the use of polyethylene packaging as well as maintaining the surrounding atmosphere at a high relative humidity (PPECB, 2013).

On the other hand, it is also possible for the relative humidity of the surrounding atmosphere to be too high. Because of the fact that fruit are living creatures, they have the ability to absorb water from the surrounding atmosphere. When the surrounding air is oversaturated with water vapour, the product will absorb some of the moisture in the air, which will also have negative effects on the quality of the fruit (PPECB, 2013).

It is, therefore, critical to know the optimum relative humidity for each fruit type and to maintain the surrounding atmosphere at this optimum. For fresh fruit the optimum level of relative humidity is 90% with a maximum deviation of ±5%.

3.5 The role of the Port of Cape Town in the cold chains of plums, table grapes and summer pears

The economic status of a country is greatly dependant on the effectiveness of the ports in its region. World container port throughput volumes grew six fold from 85 million TEU's (standard container volume) in 1990 to 531 million TEU's in 2010. It is, therefore, of critical strategic importance that the capacity and efficiency of South Africa's container terminals and the supporting transport system to and from the terminals are of international standard (Anon., 2011).

Ninety-five percent of all trade to the Southern Africa region passes through ports in this region. South Africa currently has seven commercial ports, namely Durban, Cape Town, Richards Bay, Saldanha, Port Elizabeth, East London and the new Port of Ngqura. All of these ports are operated by Transnet Port Terminals (TPT) who handles all container, mineral bulk, agricultural bulk, and roll-on/roll-off (RoRo) operations. TPT operates container terminals at Ngqura, Port Elizabeth, Cape Town and Africa's busiest port, Durban (Daynes, 2013). Each of these container terminals utilizes the Navis system, which provides integrated real time shipping information. The Navis System is discussed in section 3.6 of this chapter.

The Port of Cape Town will be the focus of this study as most of the deciduous fruit produced in South Africa is exported through the Cape Town Container Terminal.

3.5.1 Background on Port of Cape Town

The Port of Cape Town dates back to 6 April 1652 when Jan van Riebeeck arrived in Table Bay and established Cape Town as a station for ships coming from the Netherlands on their way to West India (Anon., 2012). Today the Port of Cape Town has grown to be one of South Africa's most important links in foreign trade.

The port currently has two major docks; namely the Duncan Dock and the Ben Schoeman Dock. The Duncan Dock is used for the working of general cargo into a choice of undercover, open or cold storage facilities. The Ben Schoeman Dock is home to the container terminal. The port operates 24 hours a day, seven days a week and also provides maritime services which include port navigation, pilotage, towage, mooring, pollution control, security and a 200 tonne floating crane (Transnet, 2012).

The core trade business of the Port of Cape Town includes container handling, the fruit export industry, the ship repair industry, break bulk, the fishing industry, bulk oil as well as cruise liners (Transnet, 2013).

The Cape Town Container Terminal has recently undergone a five-year expansion and construction programme of R5.4 billion, which commenced in January 2008. The main goal of this expansion programme was to transform South Africa's second largest container facility into a modern world class facility that is capable of handling nearly double its cargo capacity; from 740 000 twenty foot equivalent units (TEU's) to 1.4 million TEU's per annum (Supply Chain Online, 2013).

3.5.2 Port as critical node in the cold chain performance of exported fruit

The Port of Cape Town is one of the preferred ports to export fruit from South Africa because of the fact that the distance from Cape Town to Europe and northern America is shorter than from the Port of Durban. Fruit is consigned via the Port of Cape Town from as far as Limpopo, Mpumalanga and Swaziland. Therefore the Port of Cape is a critical node in the fruit export industry of South Africa (Transport, 2005).

3.5.2.1 The reefer stack

The reefer stack at the Port of Cape Town plays the biggest role in the cold chain of fresh fruit entering the port for export purposes. This is the area of the port where refrigerated (reefer) containers are plugged in and monitored at specific optimum temperatures to preserve the quality of the produce inside the containers. The temperature and functioning of containers plugged in at the reefer stack are monitored by the Refcon system. The Refcon system is discussed in section 3.6 of this chapter.

The reefer stack at the Port of Cape Town is divided into two sections; the 501 Reefers and the West Coast Reefers. The 501 Reefers is the area where rubber-tyred-gantry cranes (RTGs) are used for the movement of the reefer containers. This area is equipped with approximately 2800 plug-in points for reefer containers (Salasa, 2013).

The West Coast Reefers can be described as the area in the container terminal where reefers are stacked and moved by straddle carriers. This area is equipped with approximately 900 plug-in points for reefer containers (Salasa, 2013).

As part of the expansion programme at the Port of Cape Town, Transnet recently invested in 28 RTGs to replace straddle carriers. RTGs are much larger than straddle carriers and can therefore span over more containers than the straddle carriers. RTGs are able to build stacks of six rows wide, five containers high and 30 deep (Ngcobo, 2010). Straddle carriers can also stack five containers on top of each other, but they require an aisle between every two rows of containers (Ngcobo, 2010). By making use of RTGs many more containers can thus be stacked on the same surface area. This is highly beneficial for the Port of Cape Town where space is a problem. A lot of critique has, however, been aimed at the transition to RTGs for two reasons. Firstly, the manoeuvrability of the RTGs is much lower because of their big size. Secondly, the equipment is more sensitive to wind leading to longer and more delays than before (Salasa, 2013). With the Port of Cape Town being plagued by the South Easter in the summer months, which is the port’s busiest months, 200 working hours were lost during 2011 in this critical time as opposed to only 90 lost hours in 2010 (using the old, less sensitive equipment) (Jacka, 2011). The negative effect of the wind on the operations at the Port of Cape Town is discussed in more detail in section 3.5.4.2 of this chapter.

Table 3.3 draws a comparison between the two reefer stacks at the Port of Cape Town.

Table 3.3: Comparison of reefer stacks at Port of Cape Town

Name of reefer stack	**501 Reefers**	**West Coast Reefers**
Reefer plug-in points	2800	900
Equipment used	RTG's	Straddle carriers
Density of stack	Very high	Medium
Manoeuvrability of equipment used in stack	Low	High
Wind sensitivity of equipment used in stack	High	Medium
Monitored by Refcon	Yes	Yes

(Salasa, 2013)

3.5.3 Port expansion by Transnet

Recently the Port of Cape Town container terminal has undergone major upgrades to increase capacity and redesign the infrastructure. Initially Transnet had plans to reclaim 300m seaward for additional stacks. These plans were turned down after an ecological impact study was conducted.

The approved five-year expansion scheme for the container terminal started in January 2008. R5.4 billion was budgeted to increase the container handling capacity of the port from the initial 700 000 standard containers (TEU's) per year to 1.4 million TEU's per year. By June 2011, R3.127 billion of the budget was already spent and the project was said to be on track (Williams, 2011).

Firstly, the berth capacity was improved. This entailed a ten meter extension of the quay wall at a depth of 15.5 meters over the full 1 137 meter length of the quay and enabled the terminal to receive and service large new-generation vessels carrying up to 8 000 containers (Engineering News, 2013).

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The yard equipment capacity has also been improved in terms of straddle carriers replacing RTG's as explained in section 3.5.2.1 of this chapter. The stack capacity was further increased by removing non-essential infrastructure and the reefer (refrigerated) stacking area has been increased with an additional 936 RTG reefer points. The ship-to-shore cranes were also replaced with six Liebherr super post-Panamax cranes with twin-lift capability.

On 1 September 2011, a new entrance of R12 million for container carrying trucks entering the port via Duncan Road was opened at the container terminal with the aim to relieve congestion and reduce long delays at the port. The new entrance consists of five lanes, whereas the preceding entrance had only two (Williams, 2011). One of the lanes is reserved for abnormal cargo. Each lane has a kiosk which serves the entering trucks. This means that truck drivers no longer have to disembark from their vehicles, which saves a lot of time (FleetWatch, 2011).

An extensive programme has been implemented to recruit crane operators. The container handling business measures productivity in crane moves per hour (GCH). During the second quarter of 2011 the port achieved 28.7 GCH against a target of 26. Overall cost of business is effectively reduced by speedy movement of containers by the crane operations. The ship working hours (SWH) indicates the number of containers that had been moved by the number of cranes working on the ship in one hour. The Cape Town Container Terminal achieved 58.2 moves against a target of 44 during the second quarter of 2011 (Craemer Media Reporter, 2011).

Another key performance indicator for a container terminal is truck turnaround time (TTT). The TTT for the port during the second quarter of 2011 was 32.2 minutes against a target of 35 minutes (Craemer Media Reporter, 2011).

Transnet Port Terminals revealed that they seldom receive complaints about any cargo backlogs due to infrastructure or capability reasons. Although not completely finished it is therefore clear that Cape Town Container Terminal is currently quite capable of satisfying customer needs (Birkenstock, 2013).

Figure 3.6 illustrates the expansion plan implemented at the Port of Cape Town.

(Transnet, 2013)

Figure 3.6: Expansions done at Port of Cape Town

3.5.4 Factors effecting cold chain performance at the port

3.5.4.1 Delays entering the port gate

The majority of containers transported, enters the port via trucks which occasionally leads to extreme congestion at the port gate, especially during peak fruit seasons. Trucks can wait in queues for hours to enter through the port gate. These delays lead to major breaks in the cold chain as most of the trucks carrying fruit containers come from cold stores less than two hours travel time away from the port and therefore do not make use of gensets. When these delays occur at the port, the fruit temperature will rise as there is no genset to operate the refrigeration unit of the container (Coetzee, 2012).

As mentioned earlier, the entrance of the port was upgraded to a new five-lane entrance which replaced the previous two lanes. Although this is a substantial improvement and operates well, there is still much room for improvement when compared to South Africa's new Port of Coega. The truck entrance at the Port of Coega has an overhead scanning facility which scans the trucks' information and container content and automatically directs the driver to an allocated stacking area (Haasbroek, 2012).

3.5.4.2 Wind delays at the Port of Cape Town

Wind delays at the Port of Cape Town have always been a major factor contributing to delays in loading and offloading of cargo at the facility, ultimately negatively affecting the quality of perishables inside reefer containers. The situation, however, appears to be worse this year. In October 2012, 233 production hours were lost versus 54 hours in October 2011. In January 2013, 272 hours were lost, while only 142 hours were lost in January 2011 (ftwonline, 2013).

The industry mostly affected by the wind delays is that of perishable produce, and therefore this is a real concern to the export cold chain of fresh fruit such as summer pears, plums and table grapes (ftwonline, 2013). Because of the fact that most of South Africa's deciduous fruit comes from the Western Cape, vessels are obliged to call at the Port of Cape Town despite the wind conditions, to load the perishable fruits for export. The speeding up of vessels to counter the time lost with delays at the Cape Town port is a costly exercise seldomly invested in. This means that most of the time perishables arrive at their destination much later and at a lower quality than desired (ftwonline, 2013).

With the recent upgrading of the container terminal at the Port of Cape Town straddle carriers were replaced with rubber-tyred-gantry (RTG) cranes in an effort to densify the stack (Venter, 2013). Carriers and shippers are, however, not pleased with the decision of the port moving away from straddle carriers as the RTGs are brought to a halt a lot sooner in windy conditions than the straddle carriers (Marle, 2013). The straddle carriers can operate in wind speeds of up to 85km per hour, while the RTGs automatically cut out if wind speeds exceed 60km per hour (Venter, 2013). A wind of 60km per hour can be described as a breeze in windy Cape Town and wind speeds are often much higher. This meant that the port was shut for 40 days during November and December 2012 alone, in the middle of the peak shipping season for most fresh fruits (Marle, 2013). The general manager of operations of Capespan, Deon Joubert, stated the following about the upgrading of the port: "We have a situation where the port has installed new quay cranes, which are very efficient, and backed them up with RTGs, which are not. I really hope that sense will prevail and the port will invest in some straddle carriers" (Marle, 2013).

The port has recently, however, stated that they have engaged with the supplier of the RTGs who have proved to them that the RTGs have the capacity to operate at wind speeds of up to 90km per hour (Venter, 2013). The port also stated that they therefore now know that the equipment can handle the wind, but the operators are still in the process of getting used to handling the equipment, and as the training and experience have improved, the cut-off speed for operations has also improved. The RTGs are reportedly now stopped at wind speeds of around 72km per hour (Venter, 2013).

Figure 3.7 is a picture of a straddle carrier while Figure 3.8 is a picture of a rubber-tyred gantry crane.

(Coetzee, 2012)

Figure 3.7: Straddle carrier

(Coetzee, 2012)

Figure 3.8: Rubber-tyred gantry crane

Wind delays in the Port of Cape Town clearly impacts the fresh fruit industry negatively and therefore the quality of the exported fruit. It is crucial to identify a long-term solution to the wind problem in order to minimize the time the perishable cargo stands in the yard, decaying by the hour. Realising that the reefer peak season coincides with the region's windy season, Transnet resolved that reach stackers will be used in the RTG stack when RTGs are wind bound. In addition, six straddle carriers would be moved from Durban to Cape Town for the 2013/2014 season (Engineering News, 2013).

3.5.4.3 Delays during offloading

Once the reefer trucks have entered the port, they fall into yet another queue to offload the fruit container. During peak season, the number of reefer trucks entering the port is more than what the equipment can handle, which again causes delays. Just as with entering the port gate, this becomes a problem when the truck does not make use of a genset (Coetzee, 2012).

3.5.4.4 Faulty paperwork

Trucks arriving at the port with paperwork that is faulty is yet another source of delays at the port. These may include Container Terminal Orders (CTO's), mismatched shipping bookings and incorrect bill of ladings. Faulty documents can be ascribed to factors such as typing errors, miscommunication, or a driver misplacing the seal received with the container. The NAVIS system (discussed in section 3.6 of this chapter) has, however, eliminated some of the paperwork. CTO documents, for example, are no longer necessary as the NAVIS system captures this information electronically (Coetzee, 2012).

3.5.4.5 Unplugging of gensets

Once a reefer container is offloaded from a truck, the genset is no longer there to provide power to the refrigeration unit of the container. The temperature inside the container will thus start to rise, negatively influencing the quality of the fruit. It is therefore critical that the reefer container is moved to the reefer stack and plugged in as quickly as possible after being offloaded from the truck. This is, however, not always possible due to the large number of reefer containers entering the port during peak fruit seasons (Coetzee, 2012).

3.5.4.6 Plugging out of containers when leaving the reefer stack

Once the container is called to be loaded onto the ship, the reefer container is unplugged from the power source in the stack and moved to the quay for loading. This process sometimes leads to reefers being unplugged for long periods of time which leads to a break in the cold chain as the temperature of the fruit will rise. The container must therefore be loaded and plugged in on the vessel as quickly as possible.

3.5.4.7 Incompetent personnel

Incompetency in personnel may lead to extreme delays of port operations. From security personnel at the gate, all the way through to the crane operator, employees can have an impact on the intensity of delays (Coetzee, 2012). As part of the recent expansion programme implemented at the Port of Cape Town, human capital development was one of the areas invested in to address this issue. An extensive training programme, for example, was presented for operators of lifting equipment after the new RTGs were brought in.

3.5.4.8 Breakdown of equipment and machinery

The breakdown of critical equipment such as quay cranes and RTGs can result in large delays at the port. The maintenance of equipment and machinery is important to prevent breakdowns as far as possible (Coetzee, 2012).

3.6 The NAVIS and Refcon Systems in port operations

Both the NAVIS and Refcon systems support the logistical operations of containers at the Port of Cape Town.

The NAVIS Synchronous Planning and Real-time Control System (SPARCS) is a web-based terminal operating system developed to administer the movement of all container logistics and operations. This technology is fully operational in 21 marine and rail terminals in South Africa, including the Ports of Cape Town, Durban, Port Elizabeth as well as East London (Engineering News Online, 2010). Transnet Port Terminals (TPT) became the first port operator world-wide to manage the NAVIS system on more than one site from a central location, namely Durban (Engineering News Online, 2010).

The NAVIS system enables the monitoring of cargo along land transport routes and during ship loading. The system offers cargo related information from the time the cargo enters the port gate to the yard, to the vessel and vice versa. Clients can interact with the system through a customer access portal which enhances visibility for each link in the chain (Transnet, 2013). Other benefits that the NAVIS system offers include a paperless system which could eliminate costly errors, streamlined planning and scheduling because real-time tracking is available, as well as increased efficiency in managing and filling stockyard space (Engineering News Online, 2010).

Upgrading of the Navis system in April and May 2013 resulted in frustration as the system crashed with the implementation of the upgrade. In an attempt to stabilize the Navis system, some parts of the system were disabled. This meant that Transnet was unable to share tracking information for some of the temperature data gathered for this study. Unfortunately, the data for which no tracking information could be gathered, had to be excluded from the study.

While the NAVIS system offers real-time tracking of all cargo, the Refcon system offers effective managing of all reefer containers within a port. The Port of Cape Town has recently installed the Refcon (Version 6) system successfully.

The Refcon reefer monitoring system is a computer program which allows complete visibility of the status of reefer containers in the stack yard of a port. Before the Refcon system was installed in January 2013 at the Port of Cape Town, reefer containers had to be manually checked by employees on a continuous basis. It was difficult to know the functionality of each reefer container in the yard at all times, which caused delayed problem acknowledgement and repair of faulty reefers. With the Refcon system in place, it is possible for port operators to view the functionality of all reefer containers on their computer screens. The status of each container is illustrated by the colour of the container on the screen, for example, when the colour of the container on the screen is green, it means that the reefer is operating well and is at the right temperature. When the container is flashing red, it means that new alarms have been picked up and a static red container means that the alarms have been acknowledged. When the container on the screen is blue with a grey circle it means that operations are in progress to fix alarming situations on that specific reefer (Emerson Climate Technologies, 2012). Through this system complete control over all reefer containers can be obtained and problems with reefers can immediately be recognised and addressed.

The benefits offered by the Refcon system to the logistics operations at a port, are vast. Firstly, the quality of the cargo inside the reefers are preserved much better as the system alerts the user about any problem with the reefer before potential cargo damage occurs. Operational costs are lower as less time is consumed than when a manual system is used. The safety of the personnel is improved as the time spent in reefer areas or bays are minimized (Emerson Climate Technologies, 2012). Because of the fact that the Refcon system records container data and generates reports automatically, more accurate documentation results. Human errors are minimized as the system verifies all planning parameters and alerts any mismatches. In the end the system minimizes all cargo losses and ensures operations to be more efficient (Emerson Climate Technologies, 2012).

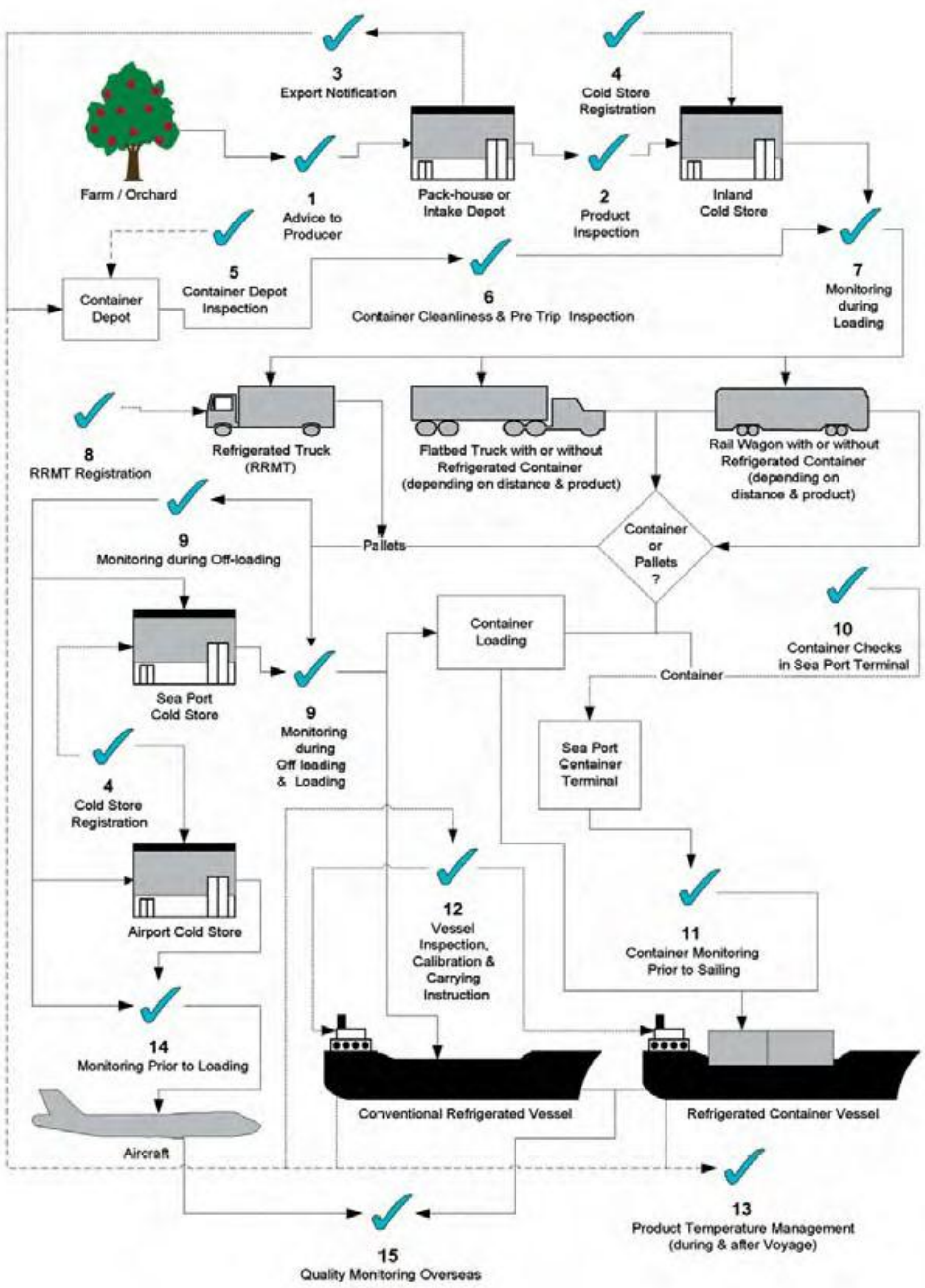
The challenge for the Port of Cape Town is now to encourage all shipping lines to install the required electronics (modems, controllers, etc) in their containers necessary for the Refcon system to work. To ensure the full benefits of the Refcon system, the port must ensure that the highest possible number of reefer containers are connected to and communicates on the Power Cable Transmission (PCT) (Emerson Climate Technologies, 2012). It was reported in 2013 that Refcon is installed on the vessels of 18 out of the world's top 20 shipping lines and that most of the world's top container ports make use of the Refcon system. Sixty percent of the world's reefer containers have been installed with the necessary remote monitoring modems (RMM) needed for Refcon to function. Although these statistics may appear positive, the Port of Cape Town faces challenges with the effectiveness of the Refcon system at the facility as many of the reefers entering their yard do not have the necessary modems installed. One of the biggest shipping lines in the world, Maersk, has recently moved away from the Refcon system. This is frustrating as the Port of Cape Town has only recently fully installed the Refcon system at the facility.

3.7 The role of the PPECB in the export cold chain

The Perishable Products Export Control Board (PPECB) is an independent South African service provider of quality certification and cold chain management services for producers and exporters of perishable food products. The PPECB basically controls all perishable exports from South Africa, which has a value of approximately R20 billion per year (PPECB, 2013).

The company employs more than 300 people, who deal with more than 200 products and 500 varieties. There are 50 service types, over 30 offices in eleven production areas, at more than 1500 locations (PPECB, 2013).

Eighty percent of the company's income is generated by the fruit industry. One of the services provided to the fruit industry includes inspections at the end-point of the cold chain of fresh fruit destined for export. These inspectors are stationed across South Africa at more than 1500 locations. In the fruit industry these inspections occur on farms, in pack houses, in cold stores as well as at loading depots. Figure 3.9 indicates the vast services delivered by PPECB in the cold chain.



(PPECB, 2013)

Figure 3.9: Services delivered by the PPECB

The greatest benefits resulting from the cold chain management services offered by the PPECB include reduced risks, reduced claims as well as quality assurance. Firstly, the PPECB reduces risks by preventing losses through identifying risks in the container-loading process. The key here is the fact that risks are managed prior to the export process, which potentially saves their clients millions of Rands. Possible risks that are managed by PPECB inspectors include faulty equipment and unfit vessels and containers. Secondly, the PPECB minimizes client claims by ensuring that all role-players in the cold chain adhere to the specific handling and temperature protocols. Quality is assured to importing countries as the cold chain assessments of the PPECB (handling protocols, temperature and equipment specifications) ensure that the specifications of the importing country are met.

Every year the PPECB publishes a so-called Blue Book which includes all the specific handling requirements and temperature protocols for the cold chain management of each perishable product. Table 3.4 contains some of the basic PPECB protocols for table grapes, summer pears and plums.

Table 3.4: Basic PPECB protocols for table grapes, summer pears and plums

	Table grapes	**Summer pears**	**Plums**
Optimum storage temperature	Minus 0.5°C (pulp temperature)	Minus 1.5°C (pulp temperature)	Varies according to cultivar and voyage.
Optimum storage relative humidity (RH)	95%	95%	95%
Storage life	4 months	10 weeks – 3 months	At least 28 days provided the correct storage temperature is applied.
Packaging requirements	Packed in cartons in polyethylene bags containing a sheet of specially prepared paper that produces sulphur dioxide gas.	Polyethylene bags have beneficial effects on storage and shelf life.	No specific protocol developed by the PPECB.

(PPECB, 2013)

Regulations and requirements for pre-cooling units, cold stores, and refrigerated road transport are also discussed in the PPECB Blue Book. Some of the important basic requirements in this regard are listed in Table 3.5.

Table 3.5: PPECB requirements for pre-cooling units, cold stores, and refrigerated road transport

Pre-cooling	• The process must be completed as fast as possible. • Minimum Relative Humidity of 80%. • Methods allowed: Forced Air Cooling, Hydro cooling, Room cooling.
Cold storage	• Maximum fluctuation of 5% from optimum cold store temperature. • Product temperature must be kept within ±0.5°C of the optimum storage temperature. • Constant Relative Humidity of 85% to 95%. • Doors only opened when absolutely necessary. • No warm product must be loaded into a store with product already cooled inside.
Refrigerated road transport	• Product temperature must be cooled down to optimum temperature before it can be loaded. • All refrigerated produce must be transported at the optimum temperature with a maximum deviation of ±0.5°C. • Loading must be completed within 30 minutes.

(PPECB, 2013)

3.8 International Best Practices

3.8.1 Logistical innovation at Port of Valparaiso, Chile

Chile has experienced enormous growth in terms of foreign trade over the last years and therefore the Chilean port industry implemented a revolutionary modernisation, in which the Port of Valparaiso has been a key role-player.

The Port of Valparaiso is Chile's main port of containerised cargo transfer. Over the last few years, a high flow of cargo vehicles overloaded the highways to and from the port. When the government realised that a maximum capacity of vehicles was soon to be reached in the streets of the city, they decided to build an alternative road for cargo vehicles, called the Southern Access.

The Southern Access was designed especially for cargo vehicles going to or leaving the port, allowing direct access to the port terminals and eliminating the need for trucks having to cross the city centre. The latest technology of traffic control, lighting and sign postings was implemented in the Southern Access, allowing safe journeys to and from the port, even in foggy conditions. The Southern Access is indicated by the yellow line in Figure 3.10.

(Moreno, et al., 2010)

Figure 3.10: Map of the Southern Access at the Port of Valparaiso

As part of the innovation programme at the Port of Valparaiso, an inland port logistics area, ZEAL, was built adjacent to the Southern Access road eleven kilometres away from the port terminals. Ninety hectares of land was gained to develop ZEAL. The inland port logistics area was developed in three stages (Zeal Valparaiso, 2012).

A facility was built for the control, coordination and supervision of incoming and outgoing cargo flows to and from the port terminals. The facility, for example, includes 34 modern platforms where mandatory inspections and controls are performed for imported or exported cargo. The truck traffic is controlled through a modern information system, Virtual ZEAL. All of the functions which were earlier controlled in the port are now concentrated in a much more efficient and orderly fashion at the ZEAL facility. The ZEAL facility has technically now become the entrance to the port. All of the paperwork and inspections are done at the facility and the trucks then travel under surveillance to the port (Zeal Valparaiso, 2012).

A modern and innovative transferring facility was also built for fruit. This facility maintains the cold chain through a cold storage area as well as energy supply points for refrigerated containers (Zeal Valparaiso, 2012). Containerised trucks filled with fruit, entering the facility, reverses into loading bays which are air locked. This enables fully refrigerated cross-docking of fruit pallets as the pallets make no contact with warmer outside temperatures. The door of the loading bay is only opened once the truck has reversed right against the walls of the loading bay. Figures 3.11 and 3.12 illustrate the nature of this refrigerated cross-docking area with air lock loading bays.

(Moreno, et al., 2010)

Figure 3.11: Air locked loading bays

(Moreno, et al., 2010)

Figure 3.12: Inside-view of refrigerated cross docking area

ZEAL serves as the entrance to the Port of Valparaiso and all the port activities are now concentrated at the one facility which is more efficient than before (Zeal Valparaiso, 2012).

The benefits of the ZEAL implementation include traceability of cargo, improvement of infrastructure and supervision conditions, better quality work spaces, truck reception capacity increase, release of areas for alternative use, detouring of trucks away from the city centre, increased vehicle attention velocity, concentration of cargo services, and safe administration of vehicle flow through the Southern Access (Zeal Valparaiso, 2012).

South Africa can definitely benefit from an innovation similar to that of ZEAL at the Port of Valparaiso as the same problem of cargo vehicle overloading occurs on South Africa's high-ways and in our port cities such as Cape Town and Durban.

3.8.2 Previous studies

In 2012 a preliminary study was done by Stellenbosch University in conjunction with the CSIR, which will eventually result in best practice operational procedures for the South African Fruit Export Cold Chain from the pack house to the vessel. This study particularly focussed on apples and winter pears since these were in season at the time of the study. The study also analysed historic data and found that for this data the majority of the breaks in the cold chains were observed at the port. Of the four supply chains investigated during this study, 65% of the containers experienced a break during the port segment, while only 8% of the containers experienced a break during the transport segment. It should, however, be noted that the containers were left to cool down first before temperature breaks were counted. Breaks during the cold store segment and the interface between the cold store and truck segments were thus dismissed during this study (Freiboth, 2012). A quarter of these breaks occurred during the hottest part of the day (between 11:00 and 15:00), which increases the impact of the break (Freiboth, 2012).

During this study a trial shipment was done with apples, which showed a significant difference between the ambient temperature around the fruit and the pulp temperature of the fruit. Breaks in the cold chain seem to have a more severe impact on the pulp temperature of the fruit than on the ambient temperature (Freiboth, 2012).

A Logistics and Cold Chain study was done by the Commonwealth Secretariat for the South African fruit export industry. The performance of the fruit industry of South Africa was compared with that of its major competing countries, New Zealand and Chile. The main finding of the study was the fact that in order for South Africa to hold onto its competitive position, the export infrastructure and systems of the fruit industry would have to be a focus area for improvement (Commonwealth Secretariat, n.d.). Four elements were investigated during this study, namely the pack house, road haulage, rail-based transport activities and cold store operations. In each of these elements South Africa performed on a much lower level than both Chile and New Zealand, except for rail-based transport activities where South Africa scored the highest (Commonwealth Secretariat, n.d.).

In 2004, a study was done by G.E. Burger at Stellenbosch University on the factors affecting shrivelling and discolouration of pears. The conclusions from this study again illustrate the importance of maintaining the export cold chain of fresh fruit to ensure fruit of high quality. Burger found that once the temperature of the cold chain was above 0°C, transpiration and respiration rates were high, resulting in weight loss of the fruit which leads to shrivelled fruit (Burger, 2004). By minimizing the rates of weight loss through an effectively maintained cold chain, the occurrence of shrivelling of pears during post-harvest activities can be lessened resulting in higher fruit quality and longer shelf life (Burger, 2004).

3.9 Conclusion

From the literature review it is clear that the export fruit industry of South Africa is an important contributor to the health of the country's economy. In order for the export industry to flourish, the fruit cold chains need to be effectively managed which means that the temperature of the fruit needs to be maintained at its optimum temperatures throughout the chain. A large number of role-players influence the effectiveness of fruit cold chains. Specific emphasis was placed on the supervising role of the PPECB and the importance of the efficiency of the port. Finally, international practices performing well in other countries were discussed.

Little research has been done on the effectiveness of the export cold chains of South African fruit, which makes this study valuable.

Chapter 4: Fruit Cold Chain from farm to port

4.1 Introduction

For the purposes of this study it was important for the researcher to have a good knowledge of each step in the fruit cold chains of specifically table grapes, summer pears and plums. Nine days were spent observing each step in the cold chains of these fruit types. Several farms, pack houses, cold stores and the Port of Cape Town were visited in order to conduct these observations. The primary goal of these observations was to gain a good understanding of the different fruit cold chains. A secondary goal was to be able to compare the literature with what happens in practice and to determine whether cold chain protocols are in fact being followed. Due to the fact that a lot of the steps in the cold chain of the three fruit types are similar, this chapter includes a discussion of the general fruit cold chain with reference to a specific fruit type where it differs from the generic cold chain. A detailed discussion of the three individual supply chains for table grapes, summer pears and plums can be found in Appendices A, B, C and D.

4.2 Fruit cold chain from farm to port

4.2.1 Picking of fruit

The cold chain of fruit begins directly after the fruit has been picked from the tree or vine. Fruit should be picked at the right maturity. The maturity of fruit is determined through a process known as maturity indexing through which internal as well as external factors are considered (Fruit South Africa, 2004). Internal factors determining the maturity of the fruit include pressure levels, stone quality as well as sugar levels. Sugar levels are the most important internal factor determining the maturity of table grapes, while for summer pears the sugar levels are not of great importance during this stage. External factors include fruit size, skin colour and firmness of the fruit (Fruit South Africa, 2004).

Different fruit cultivars reach the right level of maturity at different stages and, therefore, it is necessary to monitor the ripeness of the fruit regularly. Vineyards and orchards are divided into blocks and a certain number of fruit units are selected from each block for sampling. The first samples are taken three to four weeks before the fruit is expected to be mature and continues until it has been determined that the fruit is ready to be harvested (Fruit South Africa, 2004).

It is important for the fruit producer to accurately determine the number of pickers that will be needed. The reason for this is that the longer the fruit is kept on the tree or vine after being fully matured internally, the shorter its shelf life will be (Fruit South Africa, 2004). Fruit quality should not be neglected because of a lack of pickers.

Once the fruit is mature, it is picked. Summer pears and plums grow on trees and the picking process is assisted with ladders in order to reach the fruit at the top of the trees. Lightweight ladders are preferred to prevent trees from being damaged. The picking teams are split into two groups; namely ground pickers and top pickers. The fruit is picked one at a time, using the palm of the hand, by twisting and pulling the fruit downwards (Fruit South Africa, 2004). The fruit should be carefully placed into picking buckets, bags or baskets. Once a picking bag or basket has been filled, the fruit is deposited into a fruit bin. These bins are either made of wood or a synthetic material like plastic and should be lined with liners. They are placed in a strategic place in the orchard, usually at the end of a row of trees. Once a bin is filled, it is moved by a forklift to the nearby trailer. It is essential that the trailer is positioned somewhere in the shade to prevent the fruit from heating after being picked (Fruit South Africa, 2004). Once the trailer is full, the tractor either transports the fruit to the pack house on the farm or in the event where a farm does not have its own packing facilities, the tractor moves it to a place of shade on the farm where a truck will pick up the bins and transport them to a nearby pack house. The bins are moved to an undercover area in the orchard, where they are stacked in the shade. Wet blankets are thrown over each bin to prevent sunburn, rub marks and exposure to dust while waiting for a truck to transport it to a nearby pack house. Instead of blankets, wet hessian bags can also be used.

Table grapes on the other hand are harvested with trimming shears which have rounded tips to minimize the amount of fruit damaged during the picking process (Fruit South Africa, 2004). Each labourer is provided with a trimming shear and bunches are grasped by the stem and clipped free from the vine. Before picking the grapes, it should be determined whether the sugar level of the particular bunch has developed enough. This is determined by either the labourer tasting a grape from each bunch before it is picked or by testing the sugar level with a refractometer. A measure of 15 and higher on the refractometer indicates a high enough sugar level. Table grapes are non-climacteric fruit, which means that the ripening process stops as soon as the fruit has been picked (Fruit South Africa, 2004). This is the reason for grapes to be picked at the preferred sugar level – the sugar level does not change after being harvested. Plastic crates (Lugs) are used for the picking of table grapes. Because of the fragile nature of grapes, bunches are put into crates with much care. The crates are placed in the vineyards the evening before picking and on some farms a layer of bubble wrap is put on the base of each crate to protect the fruit from being bruised. When a crate has been filled, it is left in the shade of the vineyards to be collected by a tractor as quickly as possible.

Due to increasingly stringent market requirements vineyards and orchards can no longer be stripped of all the fruit in one visit. This results in pickers returning to the same vineyard or orchard two or three times as not all of the fruit from the same block mature at the same time (Fruit South Africa, 2004).

Because of the fact that all three of these fruit types are summer fruit it is critical that the fruit is picked during the early hours of the morning when the outside temperature is still cool. Most farms claim to follow the protocol to not pick their fruit when the outside temperature rises above 30°C. This protocol is especially important for table grapes as 85% to 95% of the pulp content of grapes consists of water and after being picked the fruit loses its ability to replenish the water lost due to high temperatures and low humidity. Grapes in the Orange River region, where extreme temperatures prevail, are therefore either picked during the night (with headlights) or early mornings when temperatures are cooler. This ensures that the fruit enters the cold chain with relatively low pulp temperatures, which is critical when considering lasting quality and freshness. It was, however, observed that these protocols are not always followed and fruit is sometimes being picked during the middle of the day in temperatures above 30°C. Neglecting the cold chain protocols can have major impacts on the shelf life of the fruit as the quality and freshness of the fruit will be reduced.

It is also of great importance for the fruit to be removed from the orchards or vineyards immediately after being harvested. Because tractors and trailers are sometimes occupied elsewhere on the farm, it was also observed that harvested fruit is sometimes left in the orchards or vineyards for several hours after being picked.

4.2.2 Transportation of fruit to the pack house

In the event where a farm does not have its own pack house facilities, the fruit must be transported by truck directly from the vineyards/orchards to a nearby pack house. In most cases table grape farms have their own pack houses on the farm and, therefore, there is no need for grapes to be transported by truck during this step. It is critical that the fruit is removed from the vineyards/orchards as quickly as possible after being harvested. Summer fruit is sensitive to warm temperatures and standing in the vineyard/orchard for long periods of time during the summer will have a negative effect on the quality of the fruit.

It is protocol that fruit should not be stored on the farm for longer than six hours when the pack house is situated within 40km of the farm. In areas more than 40km from the pack house, the fruit should be delivered within eight to ten hours from the time of picking (Colors, 2012).

Fruit bins should be loaded onto a truck while standing in the shade. Sponges should be placed on the bed of the truck underneath the bins as well as between bins to minimize fruit damage during transportation.

A curtain truck is the preferred option when transporting the fruit from the farm to the pack house. As the truck is not refrigerated it is protocol that if the farm is further than 40km from the pack house, the fruit should be transported in the early morning in order to reach the pack house before 09:00 (Colors, 2012). In the event of using a flatbed truck, sand-free canvases should cover the bins. The canvas should be tightly secured to prevent fluttering and damaging of the fruit. It was observed that very little of the fruit is transported to the pack house in the early morning as the protocol states. Fruit is often picked during the morning and transported to the pack house in the afternoon. This creates a problem as the fruit is transported in unrefrigerated trucks during warm conditions.

In terms of table grapes the filled crates are loaded onto the trailer of a tractor, which is preferably covered with rubber mats on the base to ensure that the crates are kept as stable as possible in order to minimize fruit damage. The tractor slowly moves the crates filled with grapes to the pack house. This can be a problem in areas where high temperatures prevail as the fruit pulp can heat up en route to the pack house, which will increase the loss of moisture from the fruit (Fruit South Africa, 2004).

4.2.3 Moving of fruit into the pre-cooling room

On arrival at the pack house, it is critical that either the truck or tractor transporting the fruit from the orchard or vineyard, is parked in a place of shade outside the pack house to prevent fruit decay. Unfortunately, the receiving areas of pack houses tend to be an open area outside which is only covered by a roof which means that the area of shade is not always sufficient depending on the position of the sun. Figure 4.1 illustrates this matter.

Figure 4.1: Receiving area of pack house

The fruit should be offloaded from the truck or trailer as soon as possible. Most pack houses make use of the protocol to offload their fruit within 30 minutes after arrival at the pack house. During peak times a lot of trucks could arrive at the pack house at the same time, which will inevitably cause delays and failure to follow this protocol.

Fruit bins or crates are handled with care from the tractor or truck. Table grape crates are placed onto wooden pallets outside the pack house. Crates should be handled with care from the tractor to the storage room where they are placed onto wooden pallets. A standard of 60 crates are packed onto a pallet. The pallets are weighed to know the net weight of grapes picked.

Samples are drawn from the fruit to inspect the pressure, pulp temperatures and sugar levels of the fruit. Sugar levels are not as important with pears as they are with plums and table grapes. Only a few markets specify what sugar levels summer pears should have. The pressure level of summer pears, however, should be between seven and ten on a fruit pressure gauge. Once the fruit has been approved, the bins or crates are moved by tractors from the receiving area at the pack house into the pre-cooling room.

The pre-cooler is a room with a monitored temperature above dew point, usually between 15°C and 18°C. It was observed that the temperature inside a pre-cooling room can vary depending on the distance of the fruit from the fans. Those fruit closest to the fans can be up to 5°C cooler than those furthest from the cooling fans. This is problematic as it leads to the fruit coming out of the pre-cooler unevenly cooled.

The aim of the pre-cooling room is to remove the field heat from the fruit as quickly as possible by reducing its pulp temperature. The humidity levels should be maintained between 85% and 95% inside the pre-cooling room. This is especially critical for table grapes to prevent the grape stems from drying out. These high humidity levels can be achieved through the implementation of “wet walls” or the use of fogging systems. Humidity levels that are too high (near 100%) may lead to condensation. The room temperature will rise slightly after the fruit have been placed inside the pre-cooler as the pulp temperature of the fruit coming in, is normally much higher than the room temperature of the pre-cooler because of the field heat in the fruit. The pulp temperature of the fruit coming into the pre-cooling room depends on the conditions the fruit was picked in, the type of truck it was transported on to the pack house, as well as the time it took for the fruit to be offloaded at the pack house.

As the density of summer pears are relatively high when compared to other fruit types such as plums and table grapes, pears take longer to cool down when placed into the pre-cooling room. Because of this, some pack houses stack the incoming pears in the pre-cooling room only along the sides of the room close to the cooling unit. This ensures that the field heat is removed from the fruit as soon as possible. Other fruit types with lower densities can be stacked towards the middle of the pre-cooling room. Figure 4.2 is a picture taken of a pre-cooling room to illustrate this.

Open area where cool air is less effective than along the sides of the room. Pear bins are only stacked along the sides of the room because of the high density of the fruit.

Figure 4.2: Pre-cooling unit stacked with pears

The pulp temperature of fruit should be reduced to between 15°C and 20°C inside the pre-cooler before it can be packed.

4.2.4 Packing of fruit

Once the field heat has been successfully removed from the grapes, the fruit is ready for the packing process. Table grape crates are mostly moved on a conveyer belt from the pre-cooler straight into the pack house. On the other hand, summer pear and plum bins are moved by forklifts from the pre-cooling room into the pack house. In some cases where the pre-cooling room and the pack house are not situated next to each other, the bins are transported with large tractors to enable moving more bins at a time. Since the bins are moved by a tractor means that the fruit will have to wait longer than those that are moved by forklifts. In the event where the pre-cooler and the packing line are situated within the same building, the fruit can stay inside the pre-cooling room for longer. The bins are transported by forklifts from the pre-cooling room into the pack house as needed on the packing line. Figure 4.3 is a picture illustrating this.

Figure 4.3: Bins being transported into the pack house shortly before packing

The PPECB protocol states that the temperature inside a pack house should be kept below 25°C. This is, however, often neglected and most pack houses visited were observed to be at temperatures of around 30°C. This is a definite break in the cold chain which needs to be addressed. Pack houses should be equipped with a sufficient air conditioning system inside the packing area.

Table grape crates entering the pack house are removed from the conveyer belt. The first step of the packing process of table grapes inside the pack house is to cut the bruised, blemished and malformed grapes off each bunch. This is achieved with the same trimming shears used in the vineyards. Hereafter the grapes are sorted and graded on the basis of quality, appearance and size (Fruit South Africa, 2004). Each cultivar has different specifications regarding berry diameters based on export markets' requirements. Berries are generally categorized into sizes ranging from regular (R) to large (L), extra-large (XL) and double extra-large (XXL) (Hall, 2012). The colour of the plastic crate identifies the size category of the grapes it contains, for example, grapes of regular size (R) are placed into blue crates. After being trimmed and categorised, the crates are put back onto the conveyer belt to proceed to the packing stations. There are several packing stations with labourers packing grapes for various markets. Each market has its own specifications in terms of grape quality, size and packaging. Grape bunches are either packed into carton boxes or punnets depending on the market requirements. Once a box or punnet has been filled with grapes, it is closed and a sticker, as prescribed by the market, is placed onto the packaging.

In terms of plums, a bin is put onto a machine which slowly tips the bin to roll the plums onto a conveyer belt. The conveyer belt feeds the fruit to a station where the fruit is sorted by labourers into local and export fruit. The one side of a pack house is dedicated to export packing stations while the other is for local packing. Usually the amount of fruit packed for the export market is far more than that of the local market and therefore there are fewer local packing stations than those dedicated for export markets. All the damaged and sub-standard fruit is placed on a separate conveyer belt which ends up falling into a bin. These fruits are either thrown away or sold to hawkers at a low price. Once the local and export fruit have been separated from each other, the local fruit moves along its own conveyer belt to be packed at one end of the pack house, while the export fruit moves along another conveyer belt to the other end of the pack house. On these conveyer belts, each plum is weighed, counted, checked for the right colour under infra-red lights as well as sorted according to size. Plums with similar characteristics move on the same route to the same packing stations. Each packing station is dedicated to a specific market and packed into the correct packaging as required by that specific market.

For summer pears the packing line begins with a machine mechanically picking up the bin and slowly tipping it to roll the pears into a waterline. The water pumped into the waterline is not chilled before the pears are placed into the line; the cooled pears coming from the pre-cooling room results in a drop in the temperature of the water. The pears are washed by moving through the chlorified waterline. The waterline vibrates to ensure that the fruit is washed clean from sand and dust. Figure 4.4 is a picture taken to illustrate the vibration within the waterline.

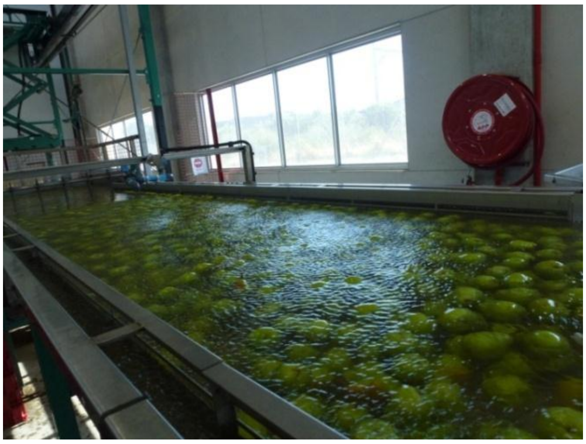


Figure 4.4: Waterline vibrating to clean pears

After being washed, the pears are dried by a unit blowing cold air. Cold air is used to ensure that the fruit stays cool. The reason for drying the pears is to prevent fungal growth and in the event where post-harvest treatments are applied, the fruit should be dry (Fruit South Africa, 2004). Once the pears have been dried they move along the line to be pre-sorted into class 1, 2 and 3 categories, class 1 being the highest quality. The pears are sorted by labourers in the pack house who check the fruit for sunburn and bruises. The class 1 pears are packed for either export or local markets, the class 2 pears are sold to hawkers, and the class 3 pears are used for the production of juice.

After being sorted, only the class 1 pears move along to the packing stations. The class 2 and 3 pears move along other conveyer lines to appropriate areas. The class 1 pears move over scales positioned within the conveyer belt. The pears are weighed and moved to the correct packing stations accordingly. For some pear cultivars, the fruit is also checked for colour by an infra-red lighting system. Once the pears arrive at the packing stations, labourers begin the process of packing the pears into the respective packaging as required by each market. The fruit is graded at each packing station on a number of factors including blemishes, colour, rub marks and size. Buyers order specific volumes of small, medium and large fruit units (Fruit South Africa, 2004).

The majority of the packing stations are allocated for export markets as the number of fruit being exported is much larger than those sold locally. It seems that the cardboard boxes used as fruit packaging tend to have very few holes to support the cool airflow through the fruit during its voyage. Figure 4.5 is an example of a carton with only a few holes.

Figure 4.5: Carton used as packaging

Once a cardboard box is filled with fruit, a labourer places a label onto the carton which contains important information such as the cultivar, the class category, the count number, the farm of origin and the name of the pack house.

Once the carton box arrives at the end of the conveyer belt, it is weighed and stacked onto a wooden pallet. Cartons for the same market are placed onto the same pallet. The number of cartons stacked onto a pallet depends on the size and depth of the cartons used. Plastic or cardboard corner pieces (angle boards) are placed over the fully stacked pallet, which is secured with securing strips. On each pallet a thermocouple is inserted into the fruit in a carton at the centre of the pallet to enable the monitoring of pulp temperatures in the cold store (Fruit South Africa, 2004). A ventilated top sheet or pallet cap is placed over the top of the pallet. Finally, a pallet identity sticker is placed on all four sides of the pallet. This sticker contains all the relevant details about the fruit being transported (Fruit South Africa, 2004).

Some pack houses have separate rooms where all the cartons are stacked and stored. The cartons are hung onto an air-conveyer which follows a route into the pack house. The cartons are taken down by labourers and filled with fruit. The carton store is usually unbearably hot. This means that the temperature of the cartons used as packaging can be unnecessarily warm. This is not ideal when the goal is to keep the pears as cool as possible throughout the supply chain. The cooling time of the fruit could be shorter if the cartons used are already cool at the start of the packing process.

4.2.5 Palletisation

Once the cardboard boxes have been filled and labelled, they are either put back onto the conveyer belt to proceed to the place of palletisation or, when each packing station has its own place of palletisation next to the station, the labourer stacking the pallet collects the box from the station and stacks it onto the pallet.

Each labourer is typically responsible for the pallets of a specific market. Cardboard boxes for the same market are stacked onto the same pallet. The number of cartons stacked onto a pallet depends on the size and depth of the cartons used. Plastic or cardboard corner pieces (angle boards) are placed over the fully stacked pallet which is secured with securing strips. (Fruit South Africa, 2004). As the boxes are stacked higher and higher, a labourer straps the pallet to ensure stability during the voyage. A ventilated top sheet or pallet cap is placed over the top of the pallet. Finally, a pallet identity sticker is placed on all four sides of the pallet. This sticker contains all the relevant details about the fruit being transported (Fruit South Africa, 2004). On each pallet a thermocouple is inserted into the fruit in a carton at the centre of the pallet to enable the monitoring of pulp temperatures in the cold store (Fruit South Africa, 2004).

A problem noticed in some pack houses was the high temperature of the fruit after being palletized. The temperature inside a pack house should never exceed 25°C. One specific pack house claimed to follow a protocol that the pulp temperature of their summer pears should not rise above 12°C during the packing process, and should therefore not leave the pack house with pulp temperatures higher than this temperature. Observations made, however, tell a different story. Pulp temperatures of four pears from four different pallets arriving at the cold store were measured and showed respective temperatures of 15.5°C, 17°C, 29.2°C and 29.5°C. Pulp temperatures measured in the same pack house just before the fruit was placed onto the packing line showed temperatures of 6.8°C, 7.2°C and 17.1°C respectively. These differences in temperatures between measurements taken just before packing and just after packing illustrates the large impact that the room temperature of the pack house has on the pulp temperature of the fruit. Figure 4.6 is a picture of one of the measurements being taken just after the packing process. This indicates that the temperature of the pack house is much too high and protocols are not being followed leading to breaks in the cold chain.

Figure 4.6: Pulp temperature measured on arrival at the cold store after being packed

The same procedure was followed at another pack house where pulp temperatures of fruit were measured just before and just after the packing process. The pulp temperature of a pear just before being placed on the packing line measured 4.2°C whereas the measurement taken just after the packing process was 14.4°C. Figure 4.7 illustrates the measuring of the pulp temperature of pears.

Figure 4.7: Measuring the pulp temperatures of pears just before being packed

Most pack houses follow the protocol that the process of packing to full palletisation should not take longer than three hours.

4.2.6. Moving of pallets from the pack house into the holding room

Once enough pallets have been filled, they are transported from the pack house into a refrigerated holding room. The temperature of the holding room is monitored to be between 8°C and 12°C. The holding room prevents temperature shock, which occurs when the grapes are put straight into the cold store with a room temperature of 0°C. By first being put into the holding room, the fruit is cooled down systematically.

The holding room has two main functions. Firstly, the cold store normally uses a forced-air tunnel cooling system, which means that the tunnel should be completely filled with pallets for the cooling to be effective. Therefore, pallets are kept in the holding room until there are enough pallets to fill a tunnel. When pallets are put into the tunnels one by one as they come out of the pack house, the cooling tempo will not be constant.

A second function of the holding room is to store pallets that have already been cooled down in the cold store. This is done to ease space management in the cold store. A holding room can thus be used directly before or after pallets have been placed in the cold store.

In the case where a pack house does not have its own cold store, the holding room comes in handy to keep pallets at a temperature of around 8°C. When the holding room is filled with pallets, the pallets are transported by refrigerated trucks to a nearby cold store.

The holding room also serves as a place of inspection. Pallets are kept in the holding room until the PPECB inspector has approved each pallet.

It is important to note though, that not all pack houses make use of holding rooms. During these circumstances pallets are moved straight from the pack house into the cold store and straight out of the cold store into the staging area or container.

Figure 4.8 is a picture illustrating a holding room for fruit pallets.

Figure 4.8: Holding room for fruit pallets

4.2.7 Moving of pallets from the holding room into the cold store

Once the number of pallets is sufficient to fill a tunnel and have been approved in the holding room, they are ready to be moved into full refrigeration in the cold store. The pulp temperature of table grapes and plums must according to PPECB protocols be brought down to minus 0.5°C whereas summer pears must be cooled to a pulp temperature of minus 1.5°C (PPECB, 2013). The humidity of a cold store should be maintained between 85% and 95% which is achieved by the implementation of “wet walls” or fogging systems (Hall, 2012).

Pallets should be lined up in the direction of the airflow within the room, not across it (Hall, 2012). It is also important to realise the importance of keeping the door of a cold store closed and opening it only when absolutely necessary.

In most cases forced-air cooling is used in cold stores. Pallets are stacked inside tunnels which need to be completely filled before the cooling process is effective. The pallets are stacked tightly against each other to prevent the air from taking shortcuts around the pallets. By stacking them tightly, the air is forced to go through the fruit cartons. Once filled with pallets the tunnel is closed and the temperature of the grapes is reduced to 0.5°C. Once the desired temperature has been reached, the refrigeration of the tunnel is switched off.

Forced-air cooling tunnels have large fans in the ceiling of the tunnel pulling the warm air out of the tunnel as quickly as possible while at the same time cool air is circulated through the pallets inside the tunnel. It is important to stack the pallets in a manner which supports effective airflow through the tunnel for the fruit to cool down as quickly as possible. Figure 4.9 is a picture taken of an empty tunnel to illustrate the fans in the ceiling of the tunnel indicated by red arrows.

Figure 4.9: Empty forced-air cooling tunnel

The tunnel must be completely filled with pallets as the fruit will not be cooled effectively when the tunnel is only half full.

Figure 4.10 indicates a forced-air cooling tunnel in action while Figure 4.11 illustrates a forced-air cooling tunnel opened after the fruit has reached the ideal temperature and is ready to be moved to either the holding room or into a container.

Figure 4.10: Forced-air cooling tunnel in action

Figure 4.11: Tunnels opened after cooling

The more tunnels there are inside the same cold store, the longer it takes for the fruit inside the tunnels to cool down. The reason for this is that the incoming fruit raises the temperature of the cold store and the more fruit is stored in the cold store, the more the temperature of the cold store rises and the longer it takes for the temperature to drop. In newer facilities the rooms will be smaller, containing only one tunnel or a few tunnels to minimize this problem. Figure 4.12 illustrates the effect that entering fruit has on the temperature of the cold store. The temperature of this particular cold store was set at minus 4°C, but the warmer fruit entering the cold store caused the room temperature to rise as high as 0.74°C.

Figure 4.12: Room temperature of cold store illustrating effect of warm fruit entering the cold store

Interestingly the forced-air cooling tunnels in some pack houses do not completely cover the fruit pallets as illustrated in Figure 4.13.

Figure 4.13: Forced-air cooling tunnels only covered at the top of the tunnel

The fruit must be cooled down to the required pulp temperatures before the refrigeration can be switched off and opened.

4.2.8 Moving cooled pallets from cold store back to the holding room

Some pack houses make use of holding rooms where pallets are stacked once the pulp temperature of the fruit have been reduced to its optimal storage temperature. The use of a holding room enables better space management inside the cold store. Instead of the cooled fruit standing in an opened tunnel in the cold store after being cooled, the pallets are moved to a holding room. Through this process, the tunnels in the cold store are available for incoming fruit. The pallets will stay inside the holding room until a loading instruction is received.

4.2.9 Staging of pallets inside staging area

Once the loading instruction has been received, the fruit pallets are moved by forklifts into the staging area. A staging area is a room where pallets are staged per container the day before those pallets are loaded. The pallets for each container are stacked according to the specific location indicated in the staging area. Figure 4.14 illustrates the marked floor of a staging area where the "1" indicates the specified area for the 20 pallets to be loaded into the first container scheduled to arrive at the cold store the next day. The 20 pallets are stacked in a row behind each other. In the same way, all the other pallets to be loaded the next day are stacked per container. The temperature of the staging area is also set to maintain the fruit at its optimum temperature. By making use of a staging area, the loading process is simplified and time is saved.

Figure 4.14: Pallets stored in staging area ready for transportation

It is important to note that not all cold stores make use of holding rooms. In this event the pallets are moved straight out of the cold store into the loading area.

4.2.10 Pallets moved from the staging area to the loading area

Once the truck arrives at the cold store, the pallets are moved from the staging area or cold store into the loading area. The loading areas of South African cold stores tend to be outside and only covered by a roof, which means that the pallets are staged outside in the shade. It was observed that the ambient temperature of some of the loading areas were very high. Pallets are moved straight out of the cold store into the loading area where they wait to be loaded into the container. This is a definite break in the cold chain as the pulp temperatures of the fruit rise before being loaded into the container. The time that the pallets stand outside in the loading area, where no cooling is available, depends on the time it takes for the paperwork to be done and the container to be approved by the PPECB.

4.2.11 Loading of pallets

Before a container can be loaded, the container should be inspected to determine whether it is clean, undamaged and whether the refrigeration unit is in good working condition. The pulp temperature of the fruit is also measured by a PPECB member. Once the container and fruit have been approved, the loading process can proceed.

Forklifts transport the pallets from the loading area into the container. It is extremely important that the pallets are loaded correctly into the container to achieve maximum airflow through the container. A maximum of 20 pallets should be loaded into a container.

It was observed that the time spent to load a container varies considerably. Some loadings took only 15 minutes, while other loadings took as long as 45 minutes. Because most of the loading points are not temperature controlled, it is safe to assume the shelf life of fruit being loaded into a container within 15 minutes will be longer than those waiting in the loading area for up to 45 minutes.

4.2.12 Journey of container from the cold store to the port

Once the fruit pallets have been loaded onto the truck, the truck leaves the cold store embarking on a journey to the port. In situations where this journey takes less than two hours, a generator set (genset) is not required. A genset supplies the refrigeration unit of the container with power and thus enables the container to cool down during the journey on the truck. During short journeys this is, however, not necessary. The doors of the truck are closed tightly and the fruit should stay cool inside the container for these short periods of time. The container will only be plugged in at the port.

For journeys longer than two hours, however, a genset is required. This increases the transport costs considerably. Under these circumstances, the container is set to 0°C once the fruit pallets have been loaded and the doors of the container have been closed.

Arriving at the port gate, the truck joins the queue waiting to offload cargo. This queue can sometimes mean delays for hours. When a truck without a genset is delayed at the port gate for several hours, unable to plug in the container, the temperature inside the container will rise and the quality of the fruit will be negatively impacted.

Figure 4.15 illustrates delays at the port gate because of a long queue of trucks waiting to offload cargo.

Figure 4.15: Trucks queuing to offload cargo at port

4.2.13 Plugging in of container in reefer stack

Once the truck finally reaches the first position in the queue and enters the container terminal, the container is removed from the truck by a straddle carrier and placed onto a truck-like vehicle, known as a Mafi, which is only used to transport containers within the port. The Mafi transports the container to the reefer stack where a rubber-tyred gantry crane places the container in a specific location indicated for that container. The container is then plugged in and monitored by the Refcon system and port operators. (The Refcon system was discussed in the Literature Review of this study).

4.2.14 Loading of container onto vessel

The next step in the cold chain is for the reefer containers to be loaded onto the vessel. The reefer container is lifted out of the stack by a rubber-tyred gantry crane and is once again placed onto a Mafi which transports the container to the quay. A large quay crane lifts the container off the Mafi and places it onto the vessel. The container is finally plugged in on the vessel. Once all the containers have been loaded onto the vessel, the long ocean journey begins.

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4.3 Conclusion

From the discussion in this chapter of the observations made, it is clear that there are numerous opportunities for improvement in the export cold chain of fresh fruit, specifically in the beginning stages of the cold chain. It is evident that protocols are not always followed and that not all role-players in the fruit industry realise the importance of their roles in maintaining the cold chain.

Chapter 5: Data Analysis

5.1 Introduction

Quantitative data was gathered in two forms during this study. Firstly, temperature trials were conducted by the researcher during the 2012/2013 fruit season. Secondly, temperature data was received from two exporting companies who monitor the temperature of the fruit they export from South Africa. The latter forms the majority of the data for this study. In this chapter both datasets are illustrated in the form of graphs and tables, starting with the temperature trials.

5.2 Temperature trials

Temperature trials for the purpose of this study can be defined as "the placement of temperature monitors inside fruit cartons, which enables monitoring of the fruit temperature throughout the export cold chain". These monitors can either measure the fruit pulp temperature or the ambient temperature in the carton around the fruit. Some monitors can also measure the relative humidity in addition to the ambient temperature.

The monitors used for the trials conducted during this study are known as Temptales from a company called Sensitech. Temptale monitors with probes to measure fruit pulp temperature (referred to as "probes" for the remainder of the chapter) as well as monitors that measure both ambient temperature and relative humidity (referred to as "ambient loggers" for the remainder of the chapter) were used in the trials. Both probes and ambient loggers were placed inside specific fruit cartons of specific pallets. The monitors were placed in the third carton from the top of selected pallets and they were specifically placed in those cartons which face the middle of the container once loaded. The intervals at which the probes and ambient loggers should log the temperatures are typically set at 20 or 30 minutes.

Figures 5.1 and 5.2 illustrate the exact locations where the monitors were inserted in the fruit pallets. Figure 5.1 illustrates monitors inserted in the first pallet (pallet 1) loaded, while Figure 5.2 illustrates monitors inserted in the last pallet loaded (pallet 20).

Figure 5.1: Monitors placed in third carton from top of pallet facing the middle of the container (first pallet loaded).

Figure 5.2: Monitors placed in third carton from top of pallet facing the middle of the container (last pallet loaded).

The temptales were inserted once the fruit pallets had been moved out of the cold store just before being loaded into the container. The temperature was monitored throughout the journey up to the point where the temptales were removed on arrival at the destination country. The temptales were then plugged into a computer to download the data, after which the data was electronically mailed back to the researcher for analysis. Disappointingly, only 57% of the data monitors inserted into fruit cartons were retrieved.

Figure 5.3 is a picture taken during a pear trial of a probe and ambient logger inserted into a summer pear carton.

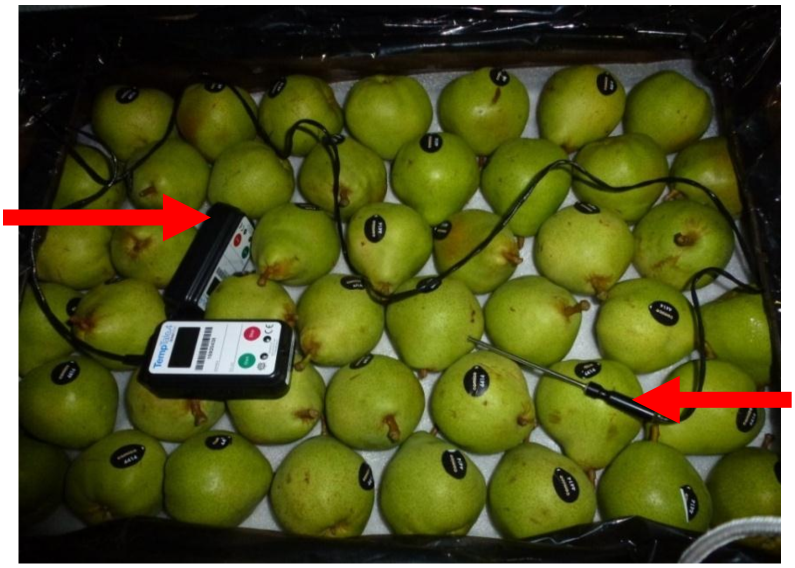

Figure 5.3: Probe and ambient logger inserted in summer pear carton

Table 5.1 indicates where the monitors were inserted and how many of them were retrieved.

Table 5.1: Probe and ambient logger information

Fruit type	Region	Date inserted	Number of Temptales inserted	Number of Temptales retrieved
Summer pears	Ceres	24 Jan 2013	4 p & 4 ah	1 p & 1 ah
Summer pears	Ceres	21 March 2013	2 p & 2 ah	1 p
Plums	Boland	1 Feb 2013	2 p & 2 ah	2 p
Plums	Boland	11 Feb 2013	2 p & 2 ah	none
Plums	Robertson	21 Feb 2013	2 p & 2 ah	2 p
Grapes	Orange River	18 Dec 2012	2 p & 2 ah	None
Grapes	Orange River	19 Dec 2012	2 p & 2 ah	2 p & 2 ah
Grapes	Boland	1 Feb 2013	2 p & 2 ah	2 p
Grapes	Hex River	21 Feb 2013	20 p & 2 ah	20 p
Grapes	Hex River	22 Feb 2013	4 p & 4 ah	4p & 3 ah
Grapes	Hex River	11 Apr 2013	4 p & 4 ah	2 ah

p:probe ah:ambient humidity logger

The results from two of the trials done are discussed below.

5.2.1 Blouputs trial – Table grapes from the Orange River Region

The first temperature trial was conducted in the Blouputs area of the Orange River Region. Four temperature monitors were inserted into one container; two probes and two ambient loggers. One probe and one ambient logger were placed in the first pallet loaded into the container, thus the pallet closest to the refrigeration unit. The remaining probe and ambient logger were inserted in the last pallet loaded into the container; thus, the pallet closest to the container door. All four monitors were placed in the third layer of cartons from the top of the pallet, in those cartons facing the middle of the container.

The aim with this trial was to compare the pulp and ambient temperatures with each other as well as to find out whether there is a difference between the temperatures in the back and front of the container.

The graph in Figure 5.4 illustrates the temperatures from when the container was loaded until the vessel sailed.

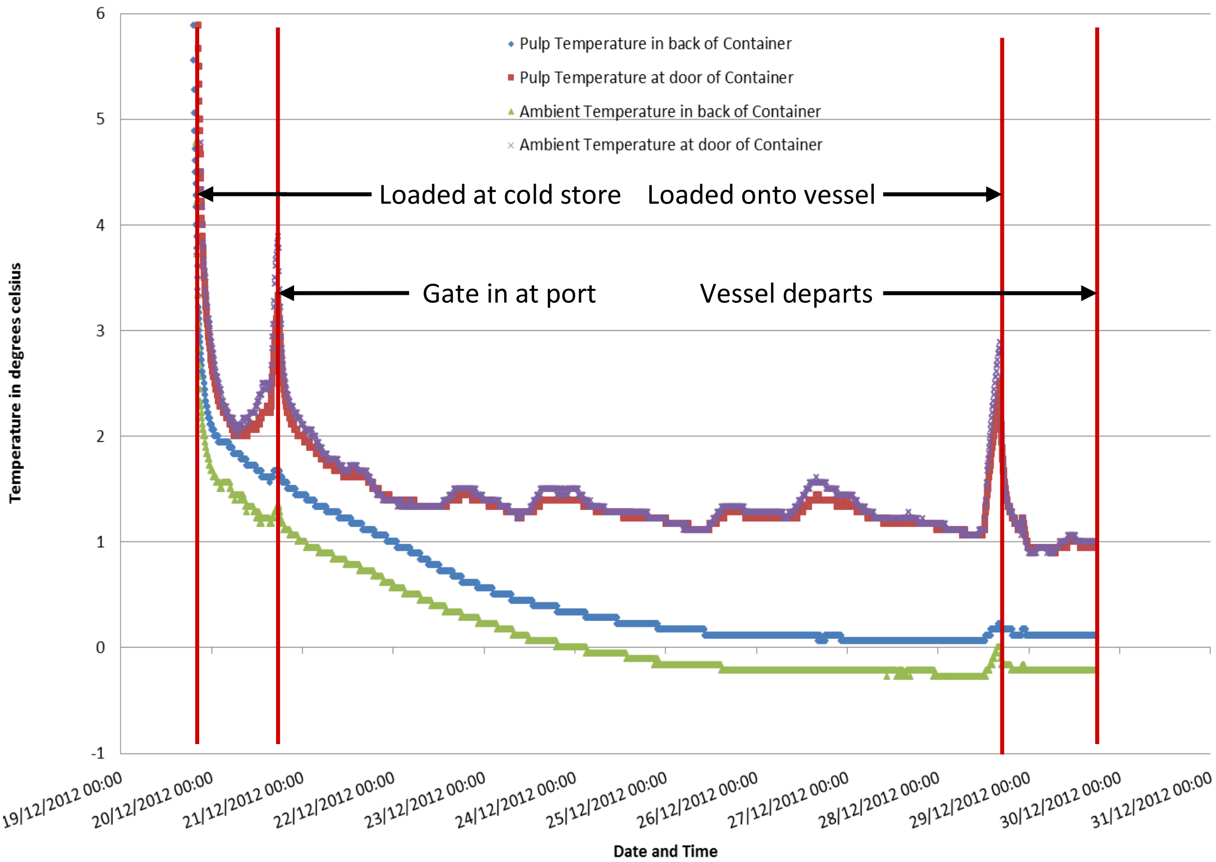

Figure 5.4: Graph illustrating pulp and ambient temperatures from when the container was loaded until the vessel sailed

The bottom two curves in the graph are for the probe and ambient logger inserted in the pallet at the closed end of the container, near the refrigeration unit, whereas the top two curves are for the probe and ambient logger inserted in the pallet closest to the door. It is clear that there is a definite difference between the temperatures at the two ends of the container. The ambient and pulp temperature at the closed end of the container, closest to the refrigeration unit, is about a degree less than the corresponding temperatures of the pallet closest to the door.

Specific instances during the cold chain are indicated on the graph; namely the loading time of the container, gate in time at the port, loading time of the vessel and the vessel departure time. It is clear from the graph that during the first three activities, the temperature rose and that the temperatures of the monitors inserted in the pallet closest to the door spiked much higher than those in the pallet near the cooling unit.

Figure 5.5 illustrates the temperature data for the whole voyage.

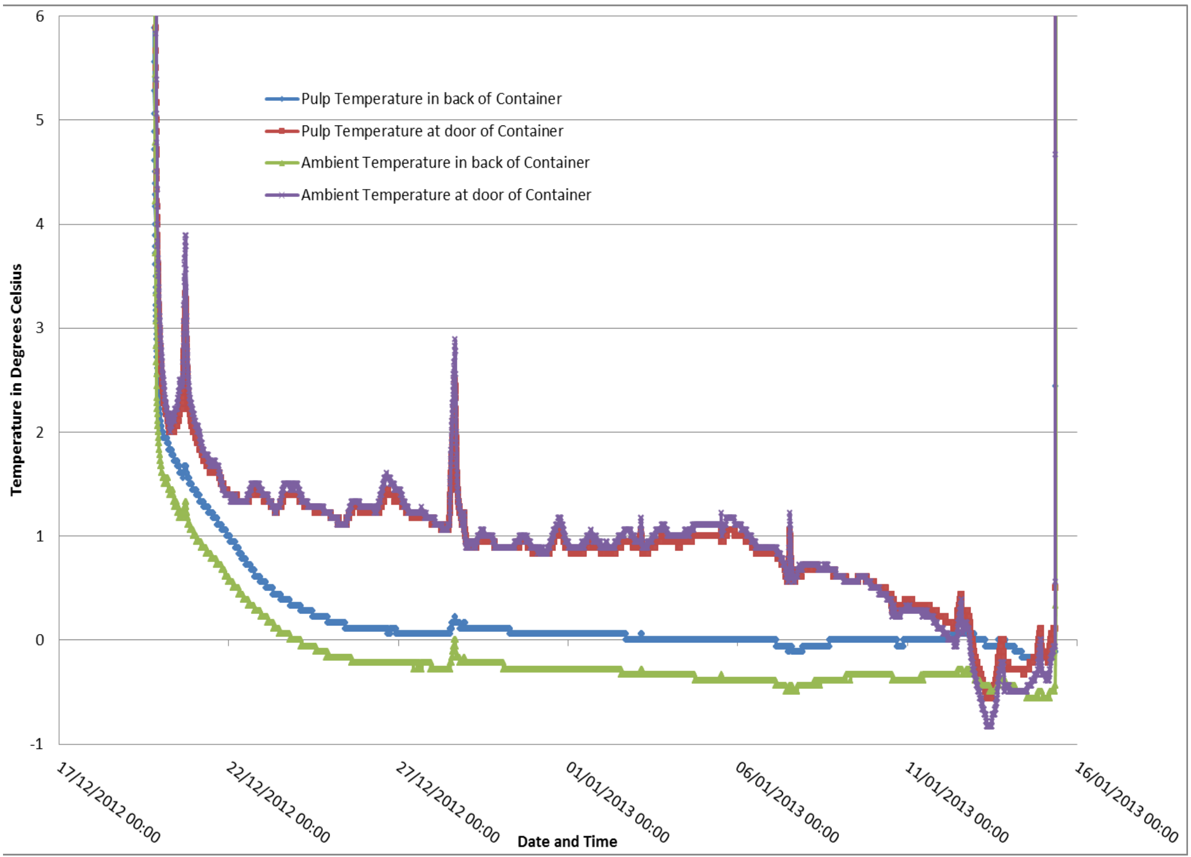

Figure 5.5: Graph of temperature data for the whole voyage

It is noteworthy that the fruit pulp temperature of the pallet at the door was above or at 1°C for about three quarters of the journey. The fruit pulp temperature was above 1°C for ten days and it took 18 days before the temperature started dropping significantly below 1°C. It is evident that the fruit was too warm when it was loaded and this graph shows clearly that the container does not have the ability to cool the pallets at the door to the required temperature of minus 0.5°C.

5.2.2 Hexkoel Trial – Grapes from Hexriver Region

The second temperature trial analysed, involved grapes from the Hexriver Region that were loaded at the Hexkoel cold store. Since the travel time from Hexkoel to the Port of Cape Town is not more than two hours (under ideal circumstances), a genset is currently not used.

For this trial a probe was inserted to measure the pulp temperature of each of the 20 pallets loaded into the container. Two ambient loggers were also inserted, one at the closed end of the container (pallet 1) and one in the pallet closest to the door (pallet 20). All of these monitors were inserted in the third carton from the top of each pallet, on the side of the pallet which faces the middle of the container. Unfortunately, only the data for the 20 probes was retrieved. The aim with this trial was to find out how the fruit pulp temperatures varied across and along the container. The grapes inside this container were packed in punnets.

Figure 5.6 illustrates the location of pallets 1 to 20 as loaded into the container.

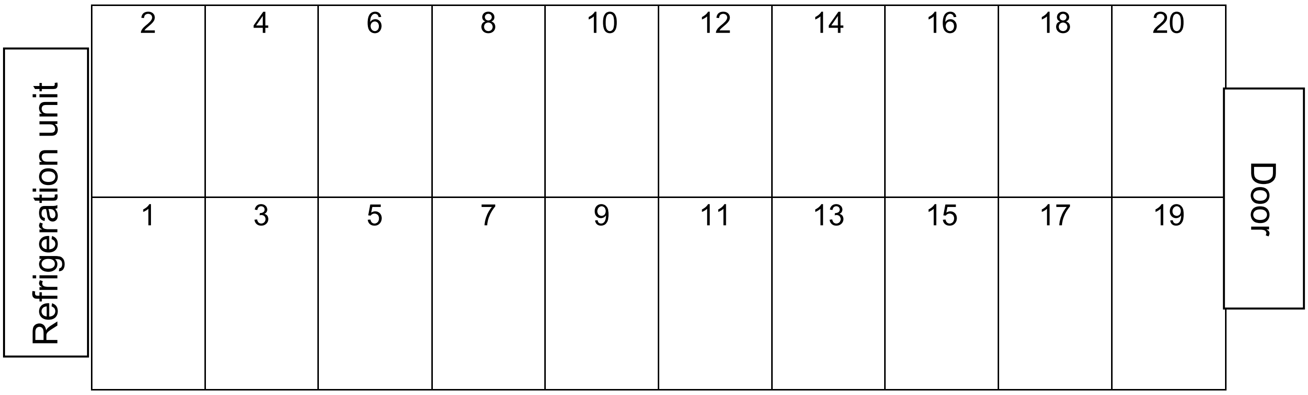

Figure 5.6: Illustration of pallet locations inside container

Figures 5.7 A to D illustrate the data from the Hexkoel trial. Graphs A and B specifically illustrate the temperature data from when the pallets were removed from the cold store until just before the vessel sailed. Graph A focuses on the pulp temperatures from the first ten pallets and Graph B on those of the last ten pallets loaded into the container.

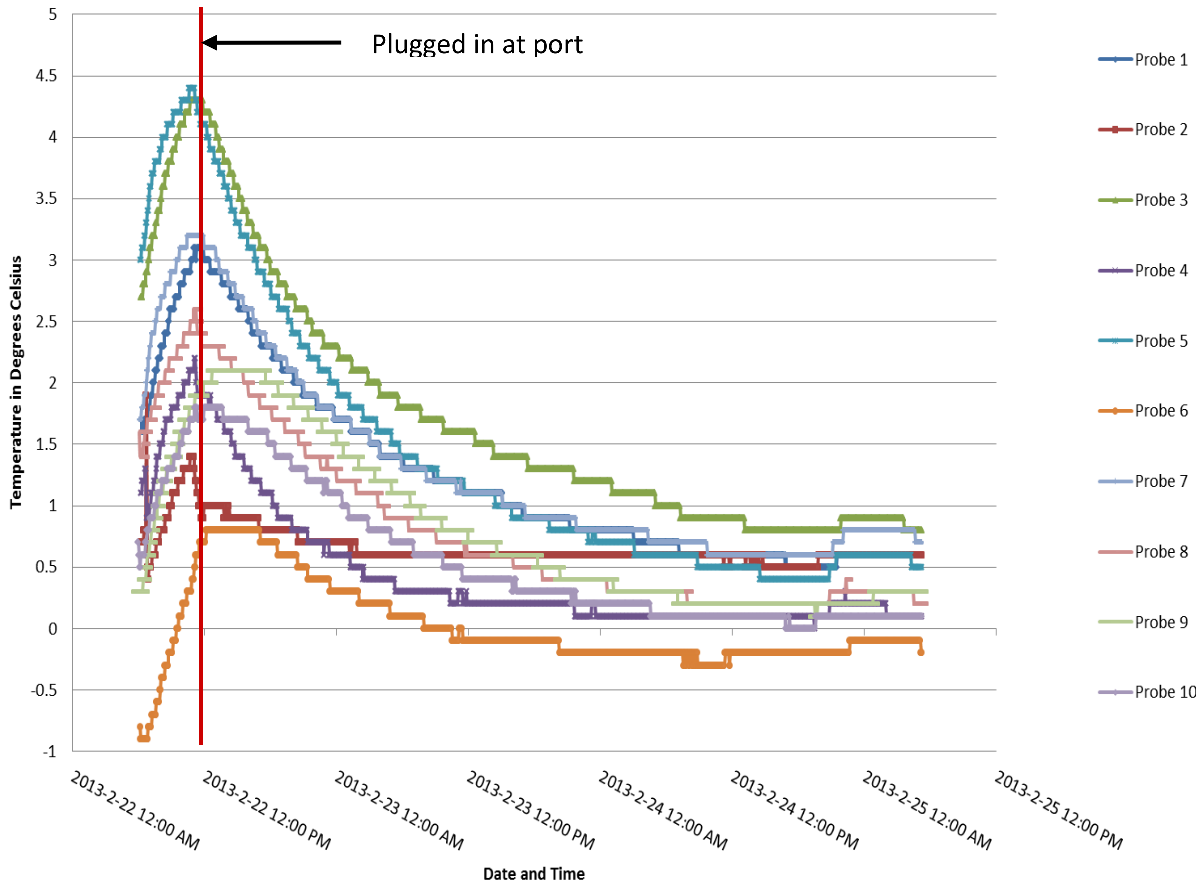

Figure 5.7 (A): Graph of pulp temperatures for first ten pallets loaded into the container (closest to the refrigeration unit) from when the pallets were removed from the cold store until just before the vessel sailed

From Figure 5.7 (A) it can be seen that although there is a big increase in the pulp temperature of the fruit before being plugged in at the port, the temperature of the fruit drops rapidly once the container has been plugged in.

Apart from pallet 6 which was colder than the required minus 0.5°C, all the other pallets were warmer, with pallets 3 and 5 more than 3°C warmer than the required PPECB protocol temperature. This could be due to the PPECB measuring the fruit pulp temperature in the middle of the pallet, while these probes were in the third layer of cartons from the top.

Figure 5.7 (B) illustrates the same information as in Graph A, but for the last ten pallets loaded into the container.

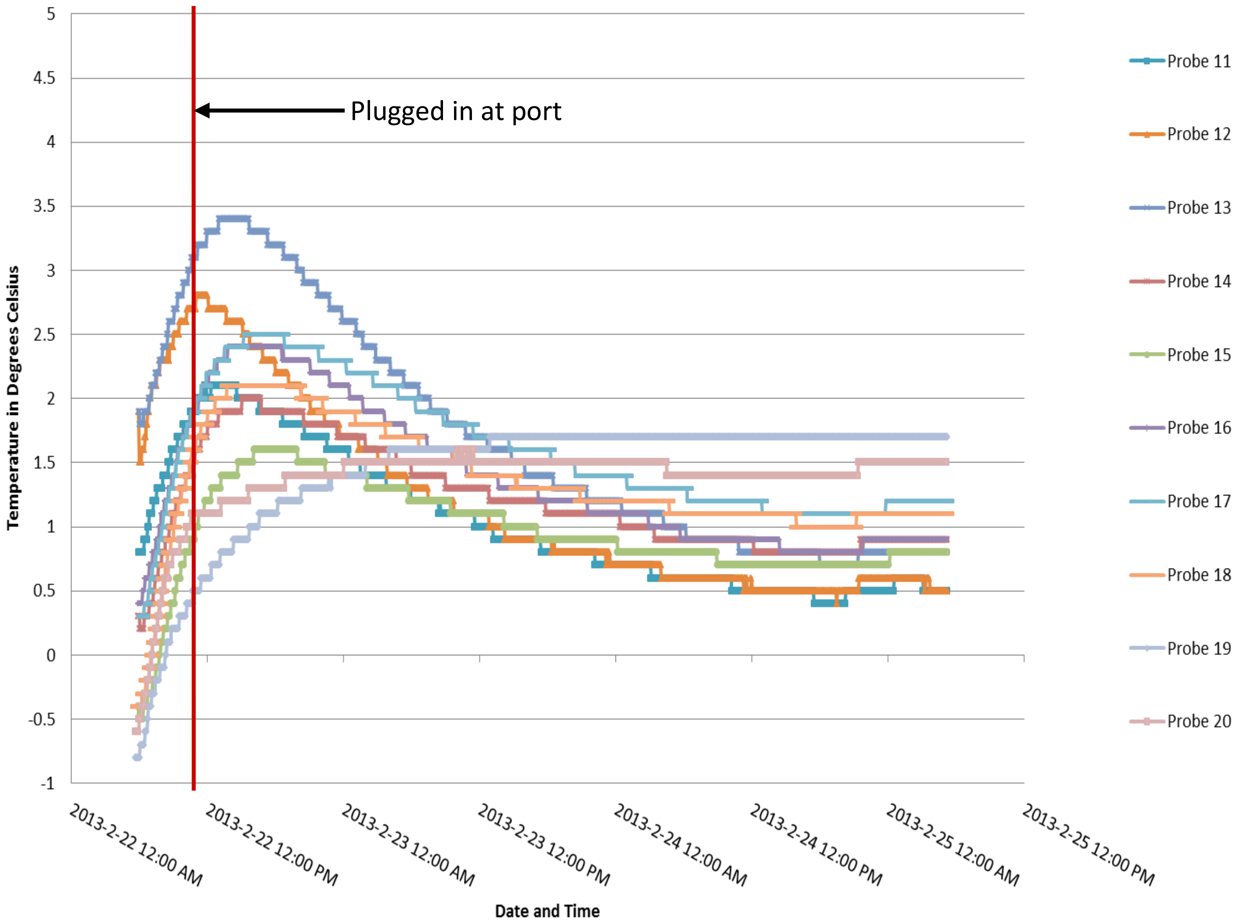

Figure 5.7 (B): Graph of pulp temperatures for last ten pallets loaded into the container (closest to the container door) from when the pallets were removed from the cold store until just before the vessel sailed

When Graph A is compared with Graph B, one clearly notes the difference in the shape of the curves. The temperatures of the fruit in the pallets shown in Graph B drop more slowly than those in Graph A and they mostly remain above 0.5°C, while in Graph A the majority of the pallets cooled down to below 0.5°C.

The temperatures measured in pallets 19 and 20, which are the two pallets against the door of the container, increased to approximately 1.5°C and remained at that temperature. Even though pallets 19 and 20 were below minus 0.5°C when they came out of the cold store, they were too warm during the rest of the journey.

Figure 5.7 (C) illustrates pulp temperatures for the whole voyage for the first ten pallets loaded.

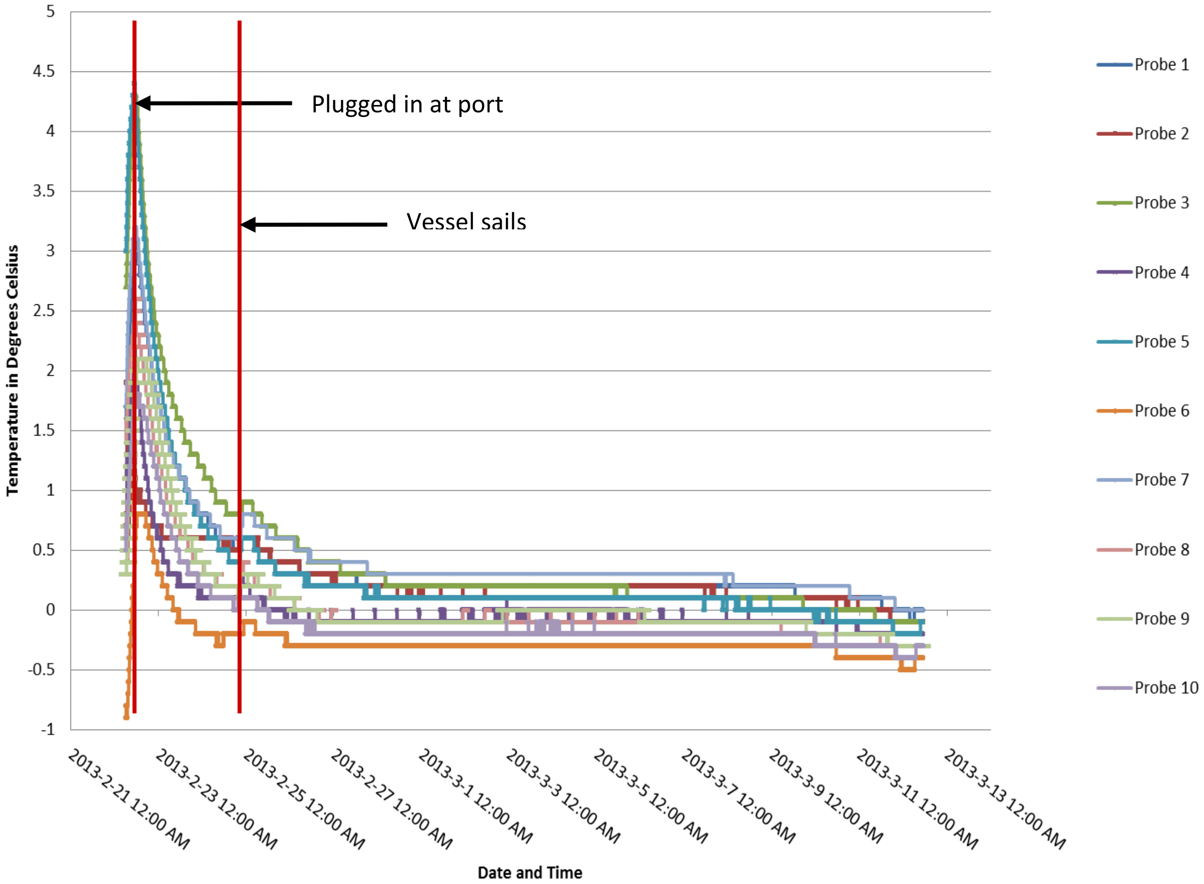

Figure 5.7 (C): Graph of pulp temperatures for first ten pallets loaded into the container (closest to the refrigeration unit) from when the pallets were removed from the cold store until arrival at the overseas destination

From Figure 5.7 (C) it can be concluded that during the sea voyage, the pallets closest to the refrigeration unit were fine. The pulp temperatures of the fruit ranged between minus 0.5°C and 0.5°C while on the vessel.

Figure 5.7 (D) illustrates pulp temperatures for the whole voyage for the last ten pallets loaded.

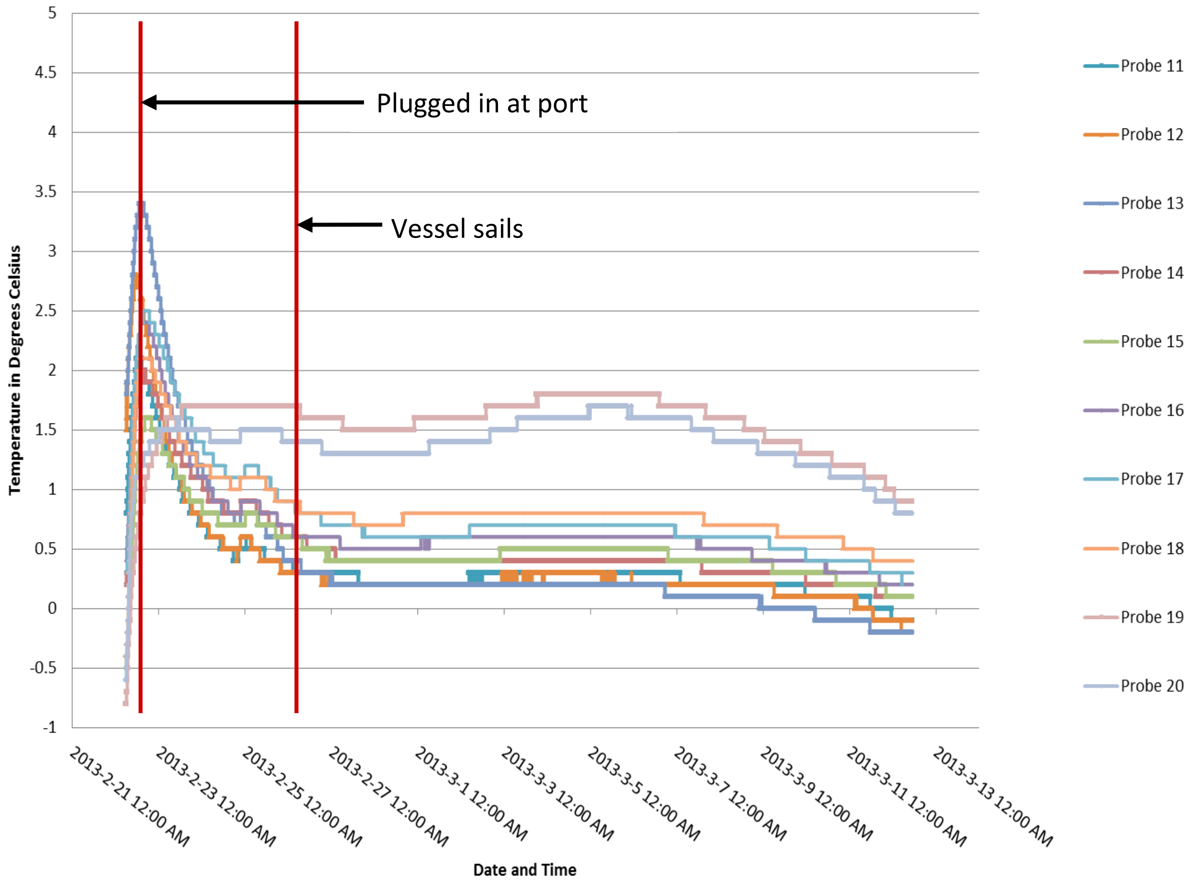

Figure 5.7 (D): Graph of pulp temperatures for last ten pallets loaded into the container (closest to the container door) from when the pallets were removed from the cold store until arrival at the overseas destination

When Graph D is considered it is clear that these pallets are all warmer than the first ten pallets (Graph C). The pulp temperatures for theses pallets ranged between 0°C and 1°C with pallets 19 and 20 ranging between 1°C and 2°C. This again confirms the fact that the container does not have the ability to re-cool the pallets closest to the door.

5.3 Analysis of data received from external companies

Apart from the temperature trials conducted, the main quantitative data used for the completion of this study was received from two external companies who export fruit from South Africa. These companies monitor the temperature of the fruit containers throughout their exporting journey from South Africa and kindly made their data available for this particular study. For the privacy of their data, the companies are identified as Exporters 1 and 2 throughout the study.

Temperature data was analysed for a total of 123 containers exported from South Africa. Data for approximately 170 containers was received from Exporter 1. Unfortunately, not even half of this data could be used as it was impossible to get hold of the tracking data for the majority of these containers. Therefore, the data for only 67 of these Exporter 1 containers could be analysed. These included 30 plum containers, 29 table grape containers and eight summer pear containers. The temperature data received from Exporter 2 included data for 56 fruit containers, including 29 table grape containers and 27 plum containers.

It should be noted that the data received from both exporters include only ambient temperature measures.

Table 5.2 is a frequency table which summarises the classification of the temperature data received from Exporters 1 and 2.

Table 5.2: Classification of temperature data

	Number of containers: Exporter 1	Number of containers: Exporter 2	Total number of containers
Table grapes	29	29	58
Summer Pears	8	0	8
Plums	30	27	57
Total number of containers	67	56	123

5.3.1 Analysis of the total number of breaks

Temperature data was analysed for a total of 123 containers exported from South Africa. These included 57 plum containers, 58 table grape containers and eight summer pear containers.

Figure 5.8 summarises the total number of table grape, summer pear and plum containers for which data was analysed.

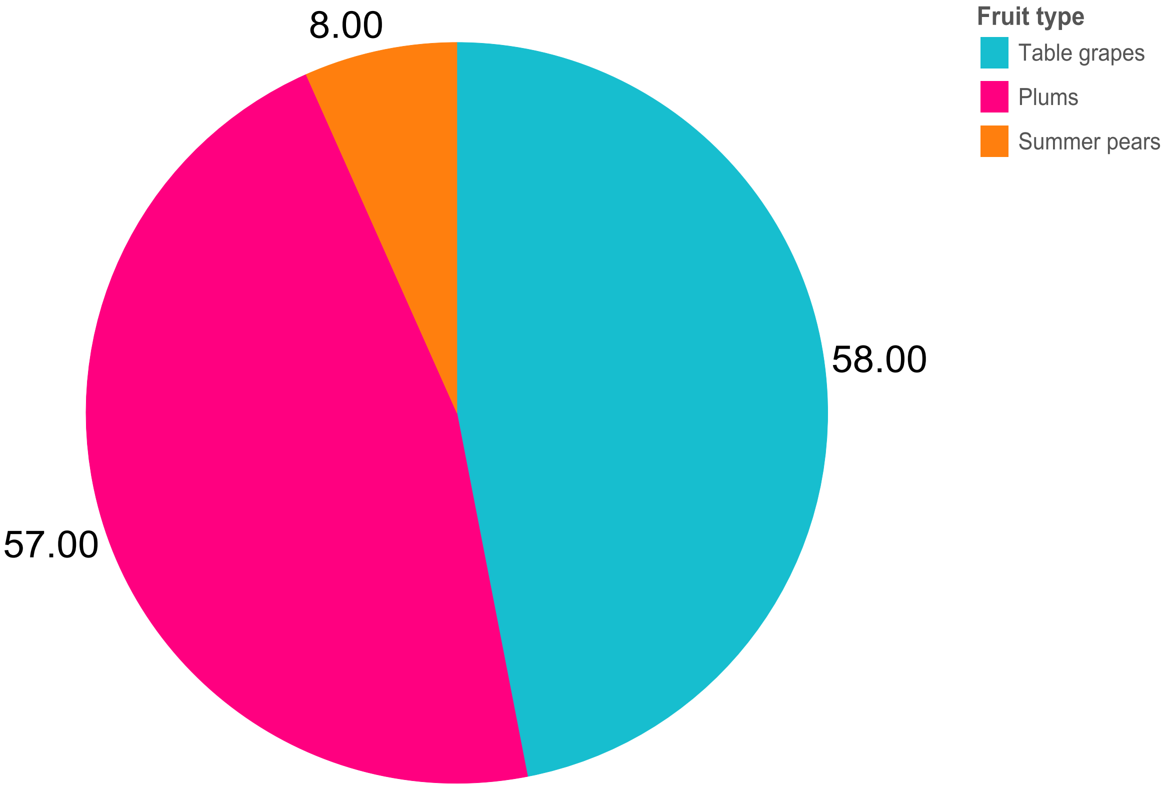

Figure 5.8: Graph of the number of containers per fruit type

The temperature data for the 123 containers was analysed in Excel. The data was analysed from the point where the data started (either the cold store or the truck) up to the point where the vessel sailed out of the South African port.

For the purposes of this study a break in the fruit cold chain was defined as any time in the data where the ambient temperature of the air measured within the fruit container rose above 2°C for longer than 90 minutes. A total of 183 breaks were identified for the data from the 123 containers. Only 13 of these containers had no breaks and two of the containers never went below 2°C throughout their datasets. Table 5.3 summarises this information.

Table 5.3: Summary of container information

Total number of containers	123
Total number of breaks	183
Number of containers with no breaks	13
Number of containers that never cooled down	2

Figure 5.9 illustrates the total number of breaks identified for the table grape, plum and summer pear containers.

When compared to Figure 5.8 it is clear that the relationship between the two graphs in terms of fruit type and number of breaks is quite similar when compared to the number of containers per fruit type. Forty-eight percent of the breaks occurred in table grape containers, 46% of them occurred in plum containers and 6% in summer pear containers, while 47% of the containers contained table grapes, 46% contained plums and 7% contained summer pears.

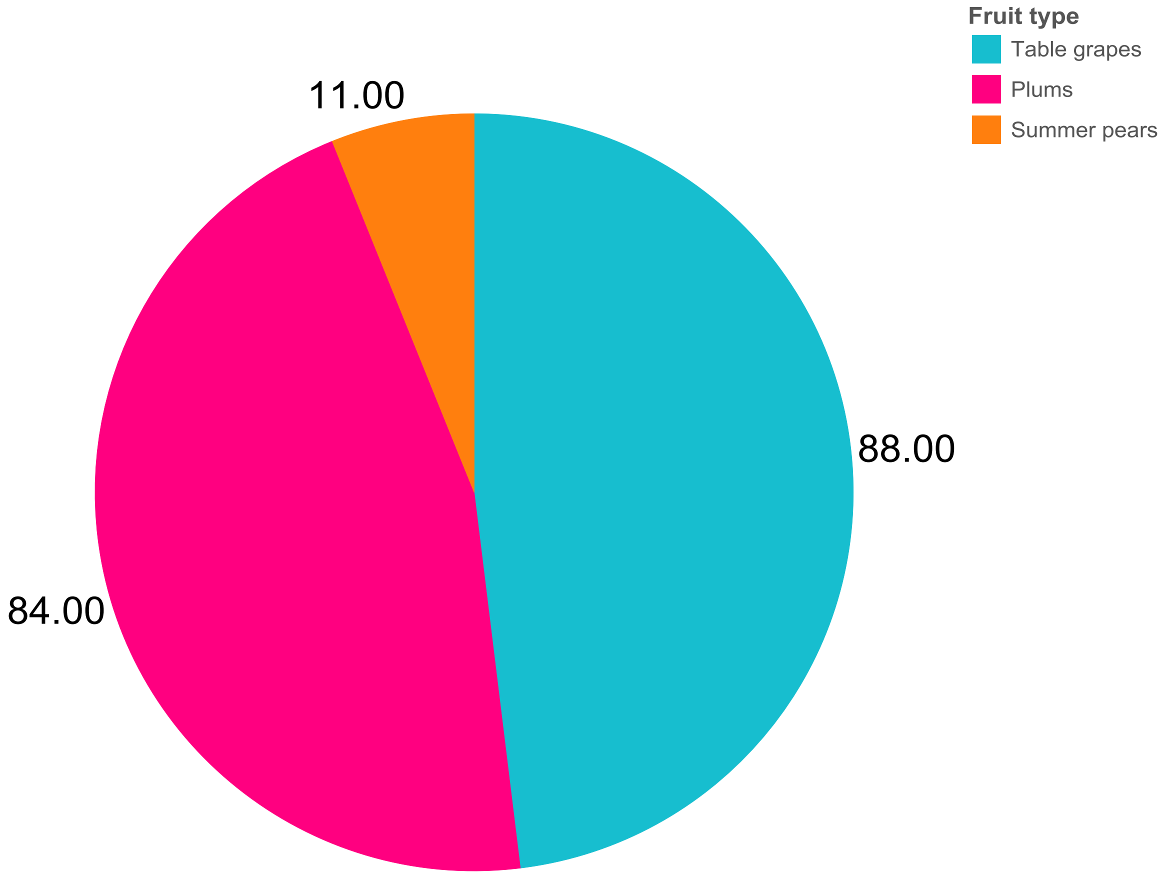

Figure 5.9: Graph of the number of breaks per fruit type

Figure 5.10 illustrates the number of breaks that occurred for each of the 123 containers. As mentioned before only 13 of the containers (that is 11%) had no breaks.

The majority of the containers (49%) had one break throughout their datasets. However, it should be noted that although a lot of the containers had only one break, many of these breaks continued for longer than a day.

A further 25% of the containers had two cold chain breaks throughout their datasets. The majority of these breaks occurred during the truck-to-port interface.

There were nine containers which had three cold chain breaks and eight containers with four breaks each. There were also two containers for which the ambient temperature of the container never dropped below 2°C throughout the whole datasets. This is concerning.

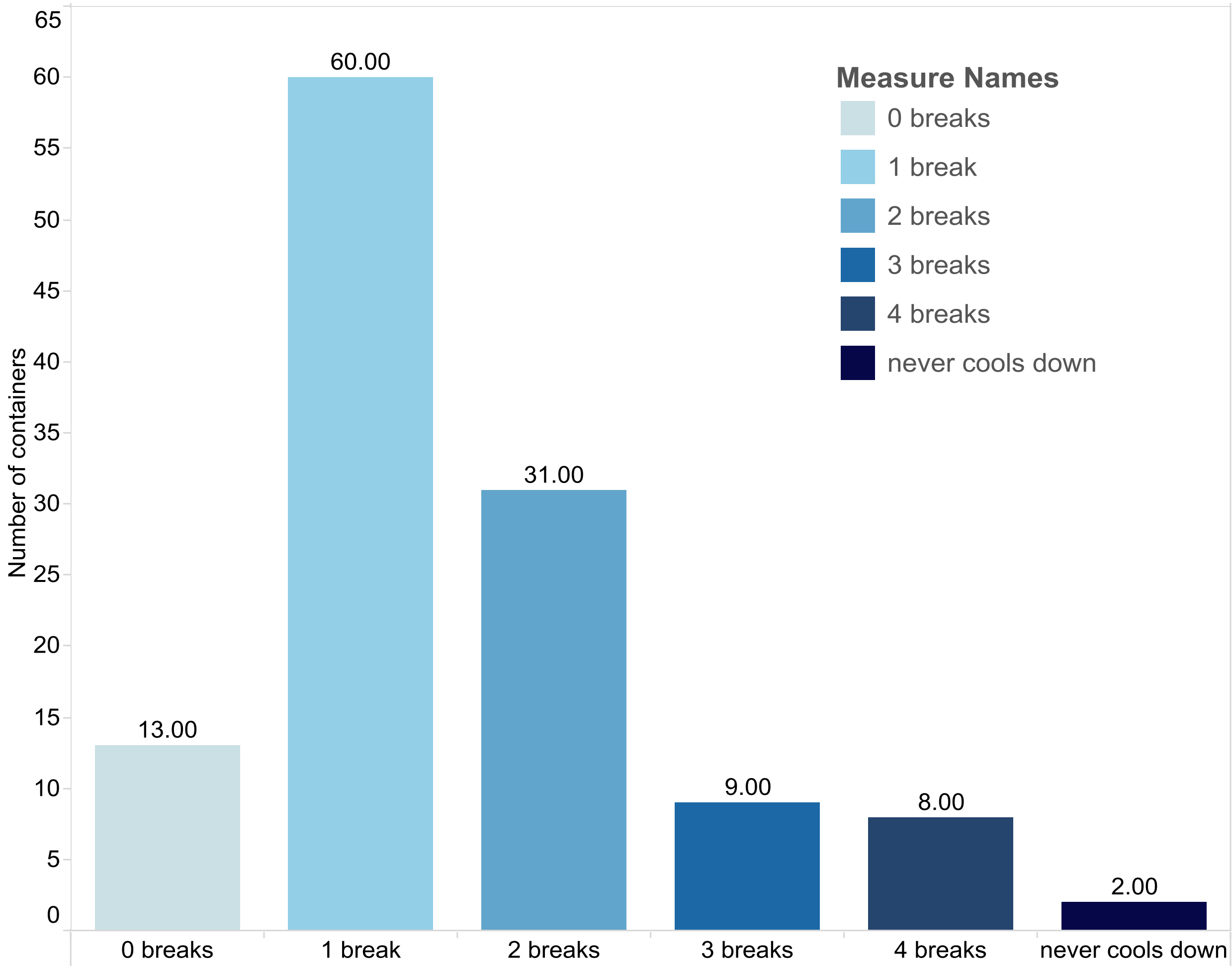

Figure 5.10: Graph illustrating the number of breaks

5.3.2 Analysis of the number of breaks per cold chain segment

It is important to investigate where in the cold chain these breaks originated. Figure 5.11 illustrates the number of breaks that originated in each of the cold chain segments.

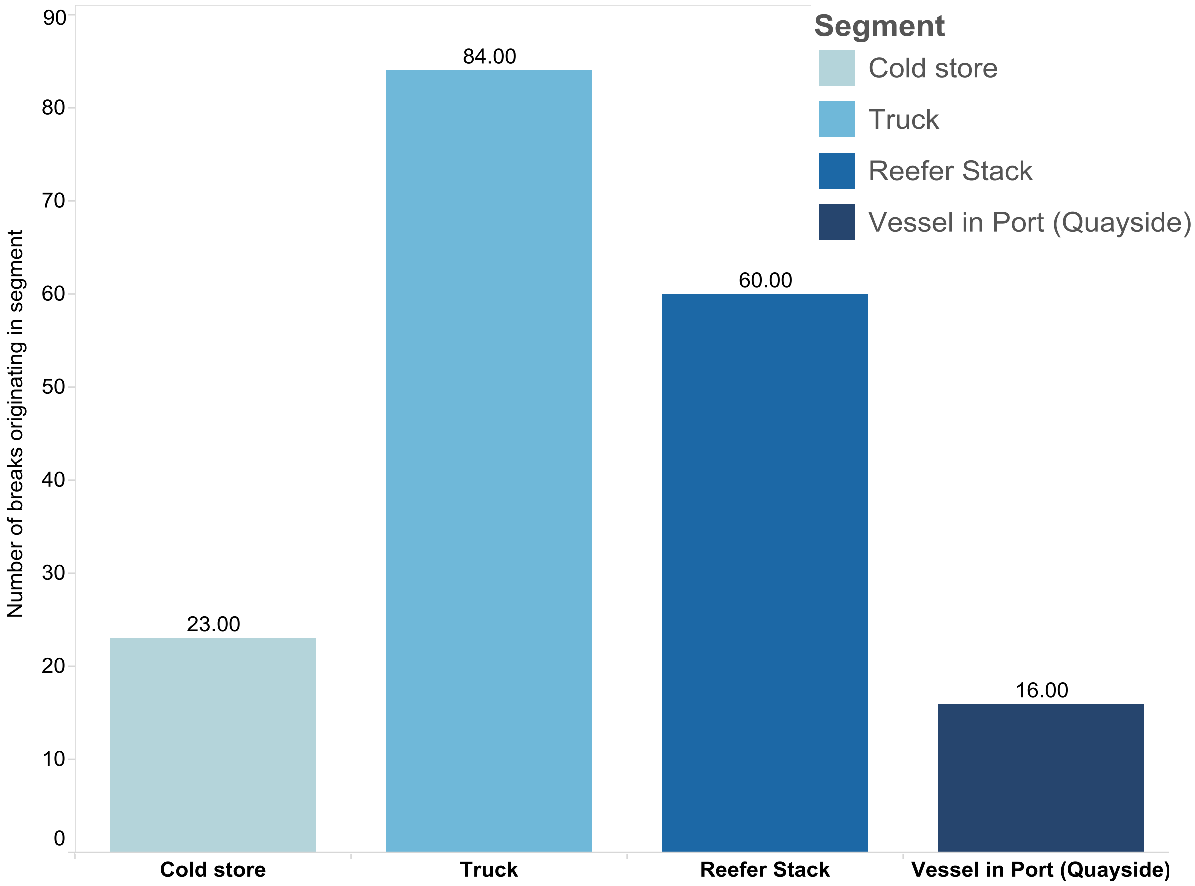

Figure 5.11: Graph of the number of breaks originating in respective cold chain segments

From Figure 5.11 it can be seen that most of the breaks in the cold chain data originated in the truck segment as it is responsible for 84 of the 183 breaks identified. The truck segment for the purpose of this study can be defined as the time from when the fruit pallets are loaded into the container up to the point where the truck enters the port gate. This means that 45.9% of the total breaks identified occurred just before the fruit is loaded into the container or during transit to the port. Almost every break identified in the truck segment occurred at the start of the truck data, which means that the biggest problem area is where the fruit pallets are removed from the cold store to be loaded into the container.

The reefer stack segment had the second highest number of breaks originating in the segment with 60 breaks. The reefer stack segment as defined for this study, includes the time from the moment the truck enters the port gate (gate entry time at port) up to the point where the reefer container is loaded onto the vessel (vessel loading time). It is therefore mainly the time that the container spends in the reefer stack. From Figure 5.11 it can be concluded that 32.8% of the breaks identified originated during this time.

The cold store and vessel segments together only accounted for the origin of 21.3% of the breaks identified. The cold store segment is defined as the time from the moment that the ambient logger is inserted into a fruit pallet at the cold store up to the moment just before the pallets are loaded into the reefer container for transport to the port. Although Figure 5.11 shows that only 23 of the 183 breaks (12.6%) originated in the cold store, this figure might be misleadingly low as only one dataset included temperature data for this segment. The other data only started at the truck segment. It is important to note that the breaks in the cold store segment and those in the truck segment actually indicate the same type of breaks, which are breaks originating when the fruit is removed from the cold store and comes into contact with the warmer outside temperature while waiting to be loaded into the truck. There are only a few cases where breaks actually occur while still inside the cold store.

For the purposes of this study the vessel segment only includes the time from the moment the container is loaded onto the vessel (vessel loading time) up to the point where the vessel sails out of the port (vessel departure time). Temperature data for the journey on the ocean is thus not included. For some containers, however, it was impossible to get hold of the vessel departure times. In these cases, the data was cut off 48 hours after the container had been loaded onto the ship. From Figure 5.11 it can be concluded that only 8.7% of the breaks originated during this time.

A factor which is also important to consider when analysing temperature data of fruit is the number of breaks that continued to the following segments after originating in a specific segment. Each cold chain segment was analysed separately in this regard, starting with the cold store segment in Figure 5.12.

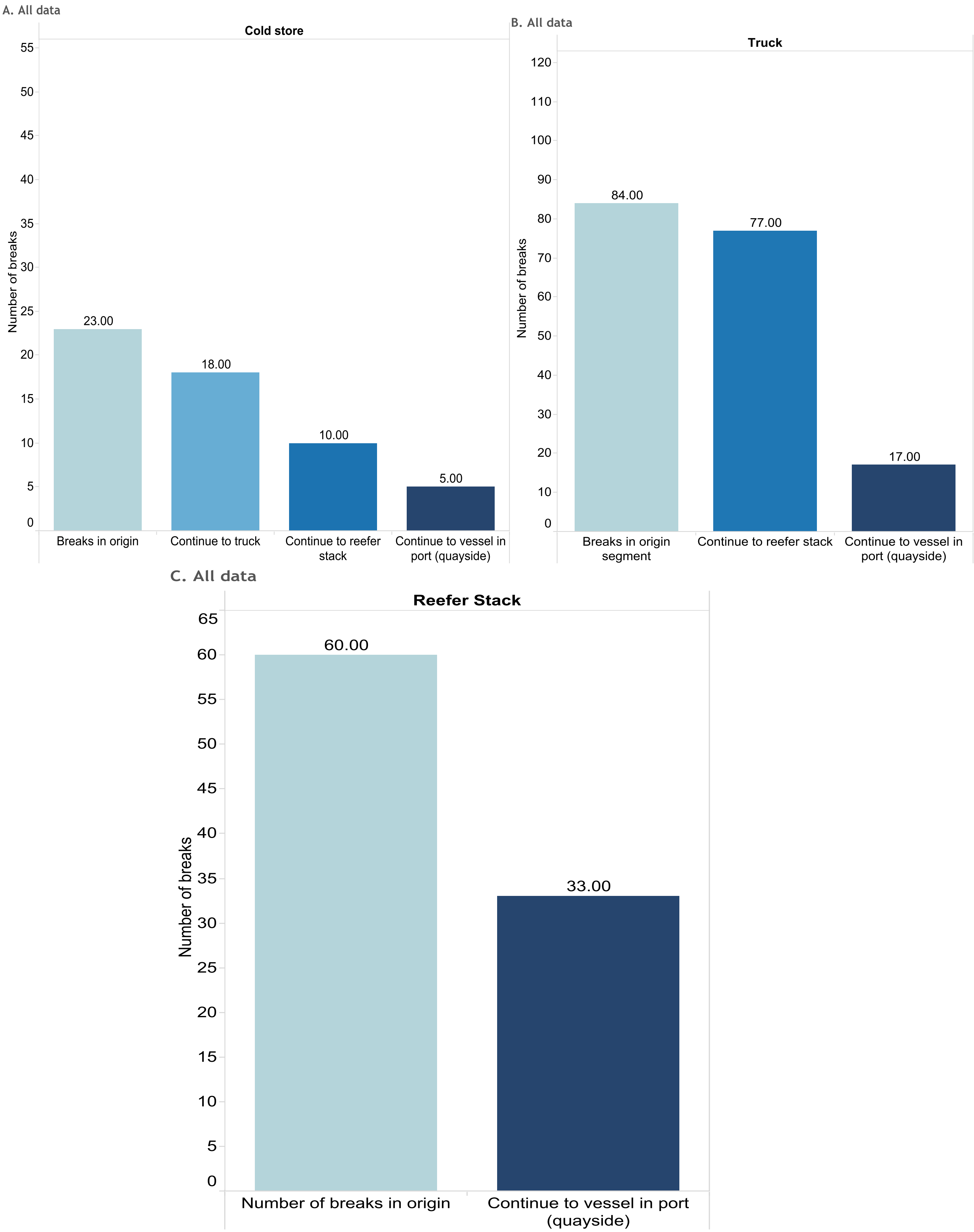

Figure 5.12: Graphs of the number of breaks originating in respective segments and continuing to other segments

Graph A in Figure 5.12 illustrates the breaks originating in the cold store and those continuing to the truck, reefer stack and vessel (quayside). The dataset which included the cold store segment contained 56 containers. For these containers, 23 breaks originated in the cold store segment. The graph illustrates that 78% of these breaks continued to the truck segment, 43% continued to the reefer stack segment and 22% continued to the vessel.

Graph B in Figure 5.12 illustrates the breaks originating in the truck segment. From the graph it can be seen that for the total 123 containers, 84 breaks originated in the truck segment. From these breaks, 92% continued to the reefer stack, while 20% continued all the way to the vessel.

Graph C in Figure 5.12 illustrates that for the total 123 containers, 60 breaks originated in the reefer stack and 55% of these breaks continued to the vessel.

It is clear that the majority of the breaks continued to segments other than the one they started in, further along the cold chain. This is especially true for the cold store and reefer stack segments. It is worrying to see that five out of the 23 breaks (22%) that originated in the cold store, continued all the way to the vessel segment. Almost just as concerning is the fact that 17 out of the 84 breaks (20%) that originated in the truck segment continued all the way to the vessel. In other words, about 20% of the breaks that originated during the stage when the pallets were loaded into a container, continued all the way to the vessel.

The more segments involved in a break, the longer the break tends to be and the more severe the impact of the break is expected to be. Figure 5.13 illustrates the number of cold chain segments involved in each of the 183 breaks identified in the temperature data for the total 123 containers.

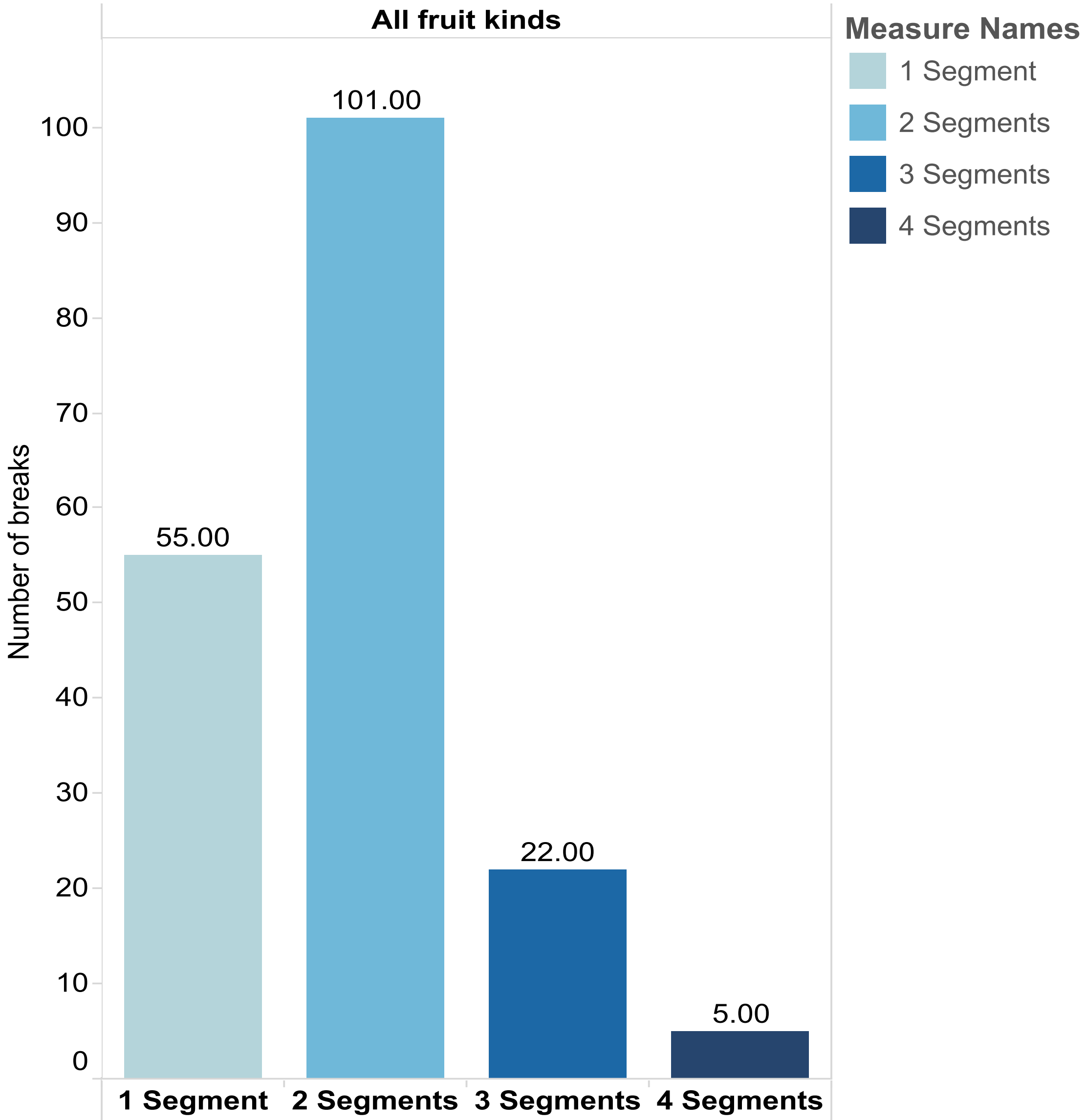

Figure 5.13: Graph of the number of segments involved in temperature breaks

The segments referred to in Figure 5.13 include the cold store, truck, reefer stack and vessel in port. From the graph it is clear that the majority of the breaks occur over two segments. Fifty-five percent of the 183 breaks identified continued over two segments in the cold chain. From the data it was identified that the truck-to-port interface was the biggest problem in terms of breaks continuing over two segments.

Thirty percent of the breaks ended in the same segment that they started in, 12% continued over three segments and 3% of the breaks continued from the cold store all the way to the vessel.

Figure 5.14 illustrates the specific segments involved in each of the 183 breaks.

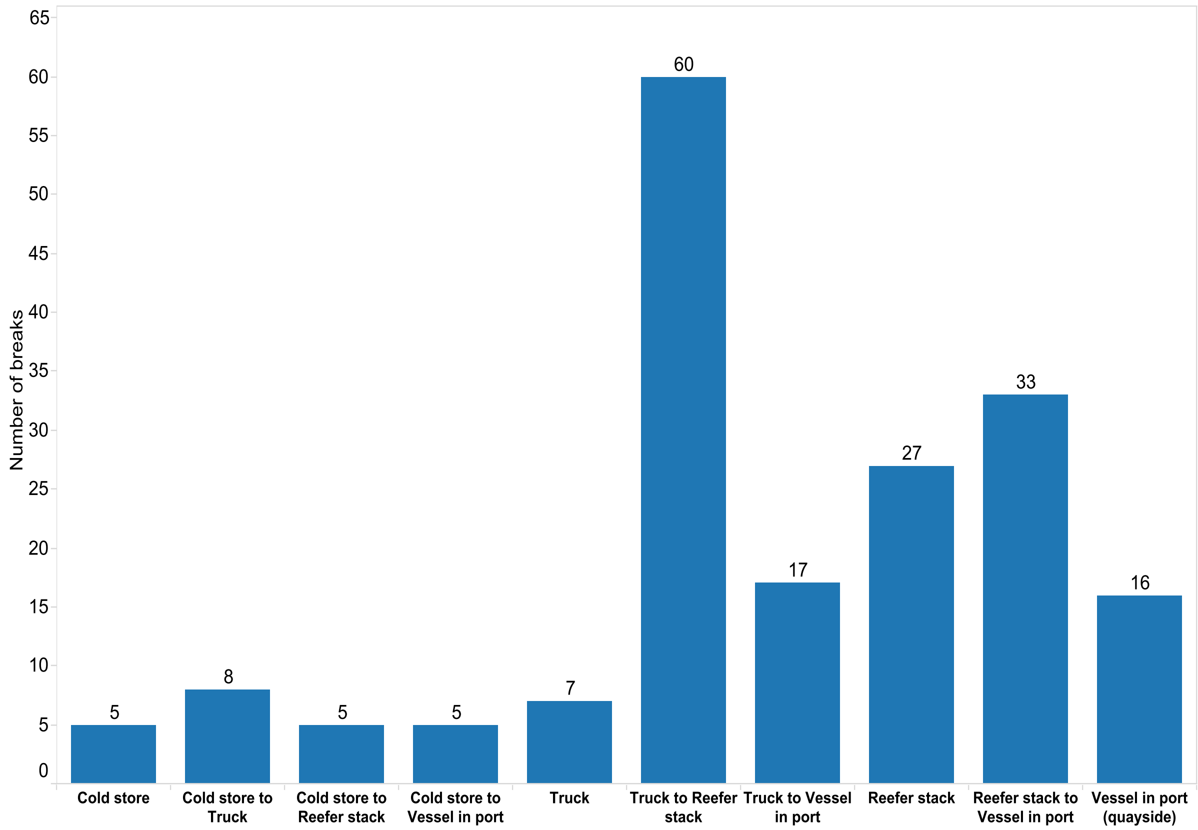

Figure 5.14: Graph of segment(s) involved in each break

From Figure 5.14 interesting conclusions can be drawn about where in the cold chain these breaks occurred. Firstly, the breaks that occurred in the truck segment and continued to the port segment were clearly the biggest culprit. This means that the majority of the breaks occurred from the moment fruit pallets are moved out of the cold store to be loaded into the container up to the point where the truck enters the port gate and the container is plugged into the reefer stack at the port. Because of the fact that the maximum temperatures for these breaks usually occurred within the first three data points of the truck data, it can be concluded that most of these breaks occurred during loading of the container. This accounted for 33% of the breaks.

The area where the second highest number of breaks occurred was the interface between the reefer stack and the vessel. Eighteen percent of the breaks occurred at this interface which includes the time from the moment when the container is unplugged from the stack at the port up to the point where the container is loaded onto the vessel and plugged in on the vessel. This confirms the results from Figure 5.13 which showed that most of the breaks continued over two segments.

When the breaks which occurred in one segment (a break that started and ended in the same segment) are considered, the reefer stack segment had the highest number. Fifteen percent of the 183 breaks started and ended in the port segment. In terms of one-segment breaks in the other segments, 9% of the breaks occurred in the vessel segment, 3% in the cold store segment and 4% in the truck segment. Sixteen one-segment breaks (9%) in the vessel are rather high and although five breaks in the cold store segment (3%) seem low, it must be remembered that only one dataset contained cold store data. The most likely explanation for the ambient temperature around the fruit rising to above 2°C for longer than 90 minutes while the fruit is inside the cold store, is that the fruit was moved from one cold room or cold store to another.

In terms of breaks continuing over three segments it can be seen from Figure 5.14 that the truck-to-vessel section produced the most breaks (17 breaks) while the cold store-to-port section produced five breaks. A total of five breaks, which is 3% of the breaks, continued all the way from the cold store to the vessel.

Figure 5.15 illustrates the total number of breaks which were present in each segment of the cold chain. The total number of breaks includes the breaks that originated in the specific segment as well as the breaks which originated in a previous segment but continued to the segment at hand. The total number of breaks for all segments combined will thus be more than the total of 183 breaks identified in the data as some of the breaks were double-counted in this graph. A break which for example originated in the truck segment and ended in the vessel segment will be counted as three breaks for the purpose of this graph, while in reality it was only one temperature break.

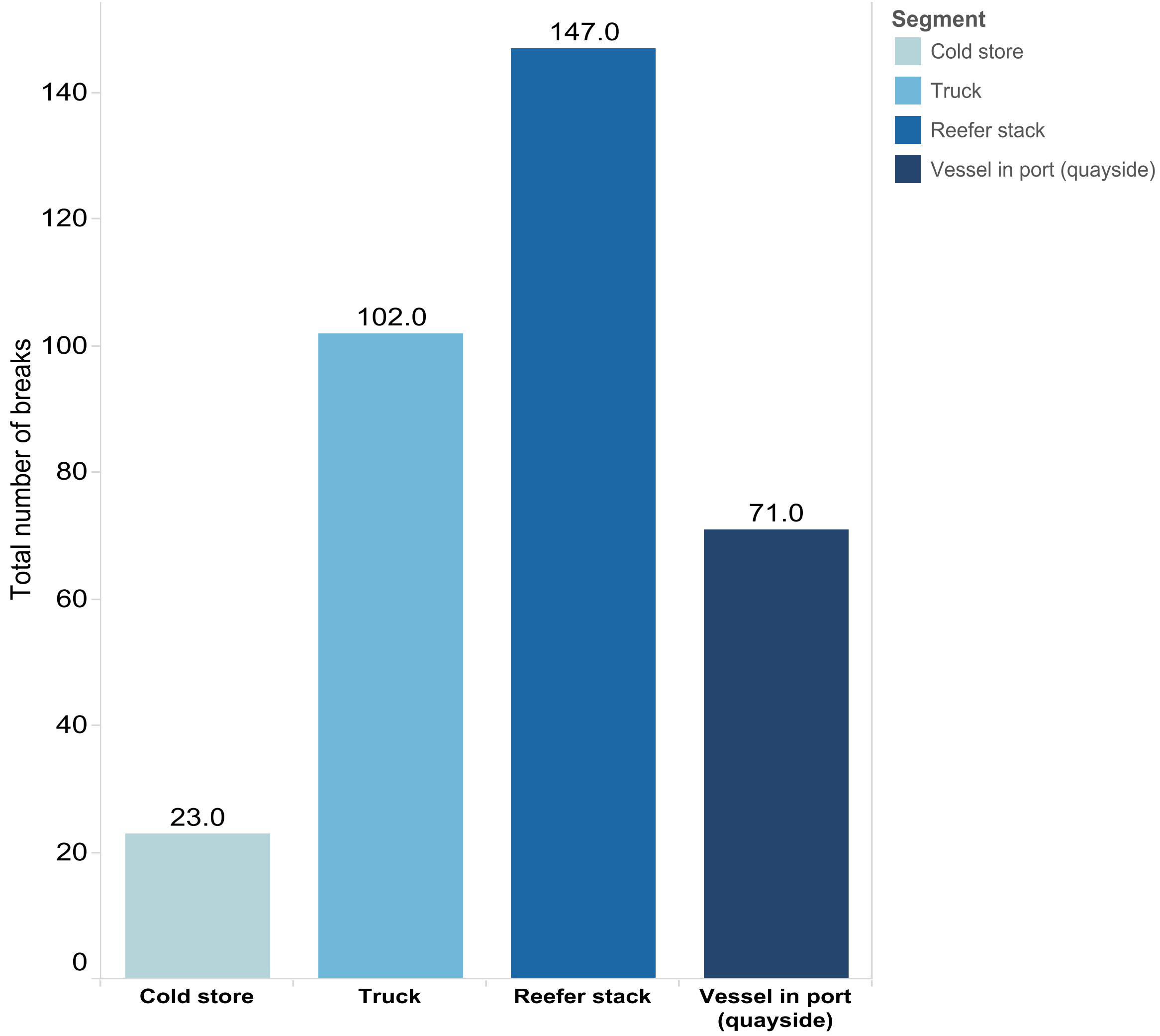

Figure 5.15: Graph of the total number of breaks present per cold chain segment

From Figure 5.15 it is clear that the majority of the breaks were present in the reefer stack segment, which had 147 breaks. The segment with second highest number of breaks is the truck with 102 breaks, followed by the vessel segment with 71 breaks in total. The cold store segment had a low total of only 23 breaks. However, only one dataset included the cold store segment.

Figure 5.16 is a combination of Figures 5.11 and 5.15 where the number of breaks originating in each segment (Figure 5.11) is compared with the total number of breaks present in each segment (Figure 5.15).

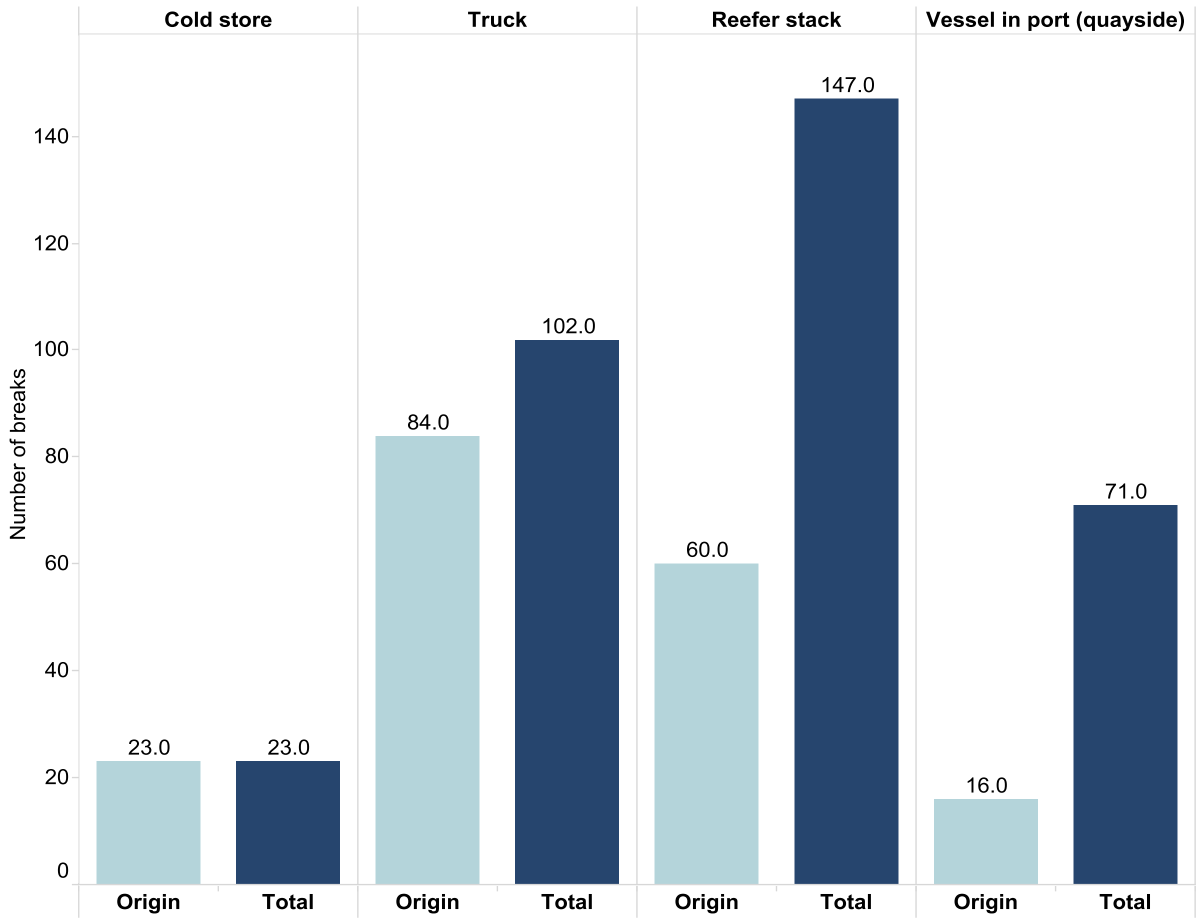

Figure 5.16: Graph of the number of breaks originating in each cold chain segment compared with the total number of breaks in each segment

The total number of breaks (dark blue bars) can be defined as the number of breaks that originated in the specific segment (light blue bars) plus those breaks continuing from previous segments.

In terms of the cold store segment, the number of breaks that originated in the segment and the total number of breaks in the segment were both equal to 23. The reason for these figures to be equal is because of the fact that the temperature data only begins in the cold store and, therefore, there is no data from segments occurring before the cold store, such as the pack house segment.

The smaller the difference between the total number of breaks present and the number of breaks that originated in the segment, the more troublesome the segment is. This is obviously not true for the cold store segment in this graph.

When the truck segment is considered, the graph shows that 84 breaks originated in this segment while the total number of breaks present was 102. This means that 82% of the total number of breaks in the truck originated in this segment. It can thus be concluded that the truck segment is a problem area when it comes to temperature breaks.

In terms of the reefer stack segment, there is a big difference between the number of breaks that originated in this segment and the total number of breaks present. Although the reefer stack is the segment with the highest number of breaks present, only 41% of these breaks actually originated in the reefer stack. This means that 59% of the breaks in the reefer stack continued from earlier segments such as the cold store or truck. The reefer stack might, therefore, not be as big a problem area as it seems when only the total number of breaks are considered.

The number of breaks which originated in the vessel segment was much lower than the total number of breaks for this segment. This means that the problem actually lies in segments earlier than the vessel (cold store, truck or reefer stack) where these breaks originated. Only 16 of the total number of 71 breaks (23%) in the vessel segment originated there.

5.3.3 Analysis of time of day and duration of breaks

Figure 5.17 illustrates at what time of the day the breaks originated.

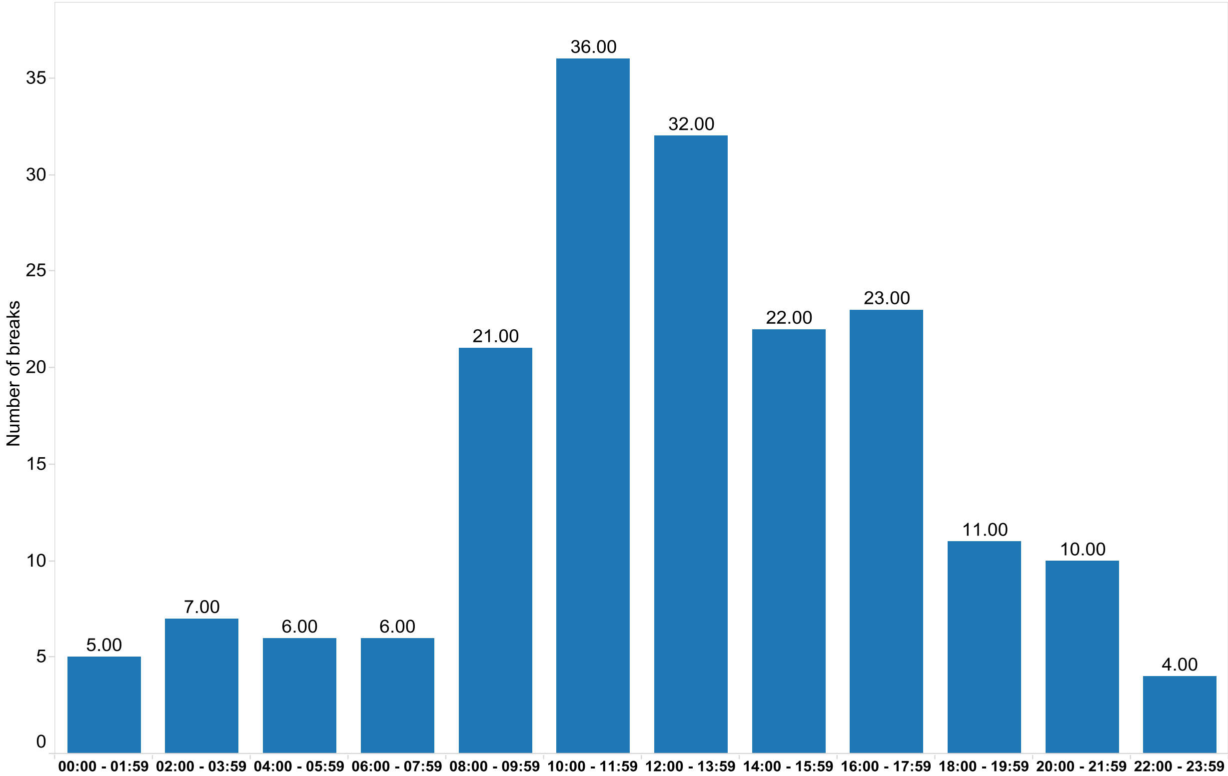

Figure 5.17: Graph illustrating at what time of the day breaks originated

From Figure 5.17 it is clear that most of the breaks occur between 08h00 in the morning and 18h00 in the afternoon, with the majority of these between 10h00 and 14h00. Seventy-three percent of the breaks identified occurred during 08h00 and 18h00, which means that the majority of the breaks occurred during daylight. Thirty percent of these breaks occurred between 12h00 and 16h00, which is the warmest part of the day.

Figure 5.18 illustrates the lengths of the breaks in intervals of two hours.

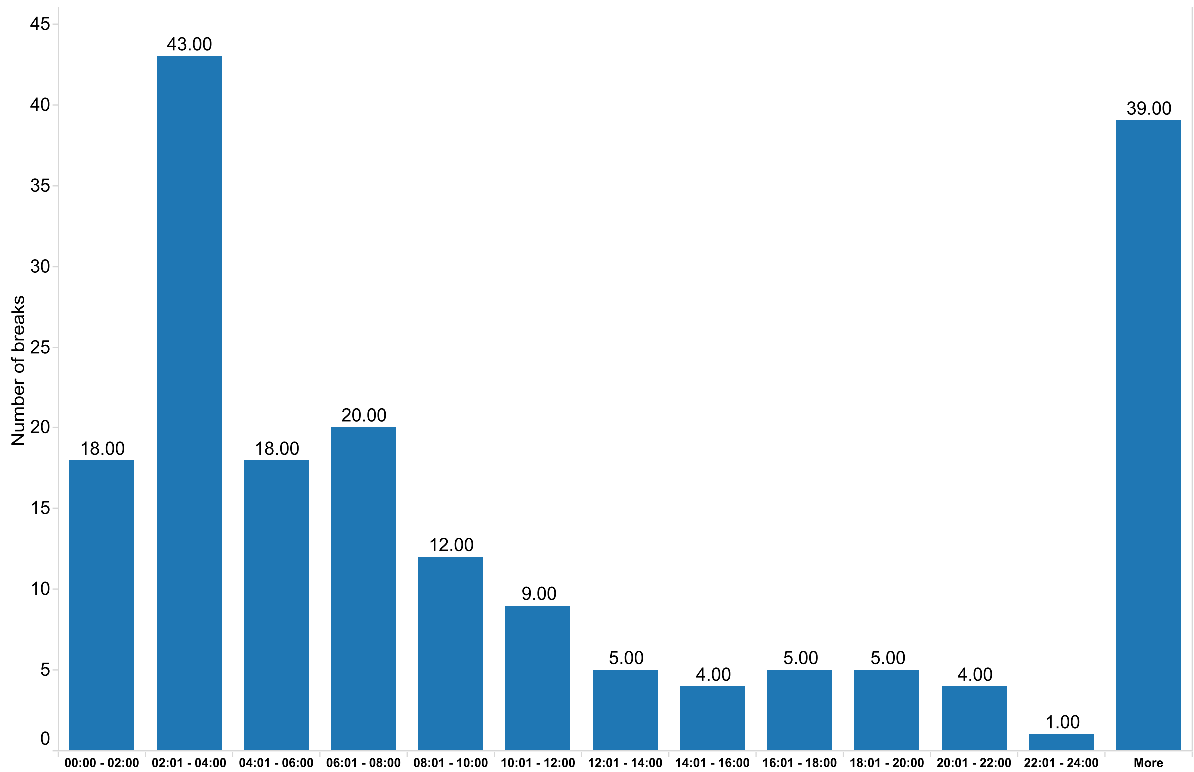

Figure 5.18: Graph illustrating the lengths of breaks in intervals of two hours

Figure 5.18 is a graph indicating the length of the cold chain breaks. The graph makes use of two hour intervals from zero hours up to one day. Any break which continued for longer than a day is counted in the “More” column.

From the total of 183 breaks identified, 144 of these breaks were shorter than one day, which calculates to 79% of the breaks. The other 21% of the breaks continued for longer than one day and are counted in the “More” column of the graph.

From Figure 5.18 it can be calculated that for breaks shorter than a day, 69% of the breaks continued for zero to eight hours. Eighteen of the breaks continued between zero to two hours, which is almost 10% of the 183 breaks. The interval with the most breaks which were shorter than one day is clearly the two to four hour interval with 43 breaks (23%). These are the only breaks that can be described as relatively acceptable. This means that only 61 out of the 183 breaks continued up to a maximum of four hours. Only 33% of the total number of breaks can thus be described as relatively acceptable.

Figure 5.19 illustrates the lengths of the breaks in intervals of two days.

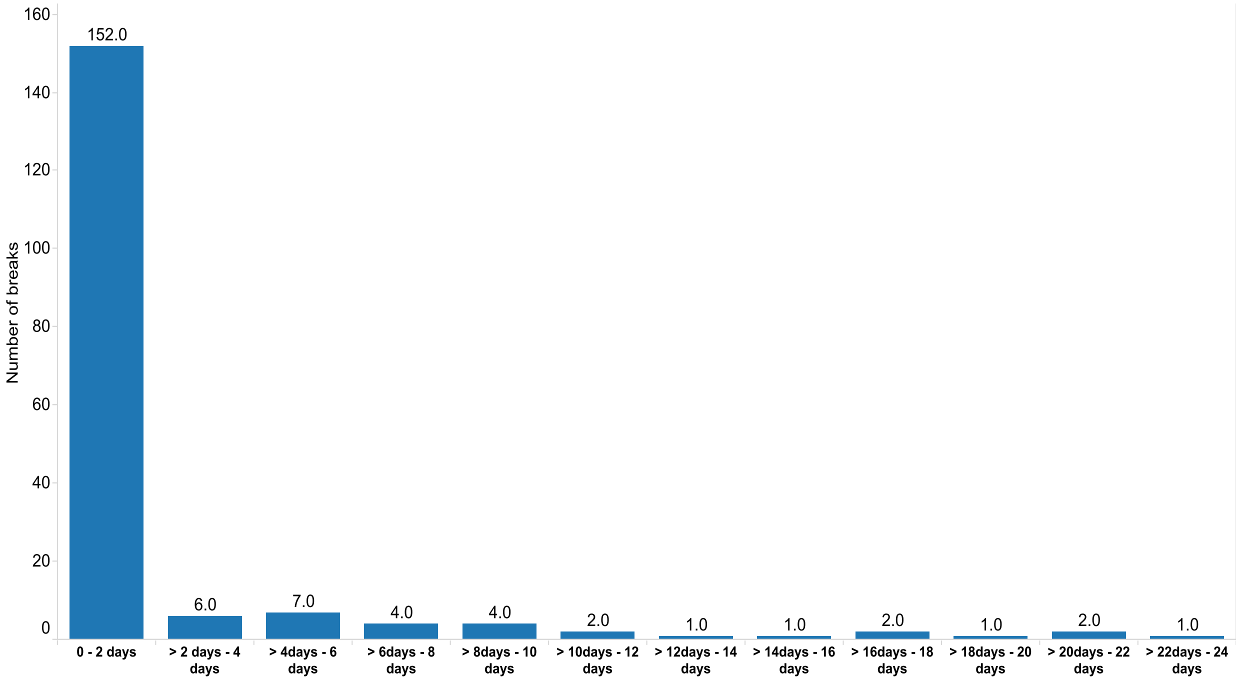

Figure 5.19: Graph illustrating the lengths of breaks in intervals of two days

Figure 5.19 shows the breaks that are longer than two days in more detail. The interval zero to two days accounts for 152 of the total of 183 cold chain breaks identified, which is 83% of the breaks. The remaining 17% of the breaks continued for time periods between two and 24 days. Of these remaining breaks, 68% continued for time periods between two and ten days. There are ten breaks that continued for more than ten days and three that continued longer than 20 days, which is extremely worrying.

5.3.4 Analysis of maximum temperatures reached during breaks

Figure 5.20 illustrates the number of maximum break temperatures which occurred in each cold chain segment. Knowing in which segments the cold chain breaks reached their maximum temperatures helps with identifying the most troublesome areas in the cold chain. When Figure 5.20 is considered, it is clear that the truck and reefer stack segments were the biggest problem areas in this dataset. From the total of 183 breaks, 37% of the breaks reached their maximum temperatures in the truck segment, 33% in the reefer stack, 21% in the vessel and only 9% in the cold store segment. The reader does, however, need to be reminded of the fact that only one dataset included cold store data.

It is interesting to note that only 16 breaks originated in the vessel segment (Figure 5.16), but 38 of the 183 breaks peaked or reached their maximum temperatures during the vessel segment.

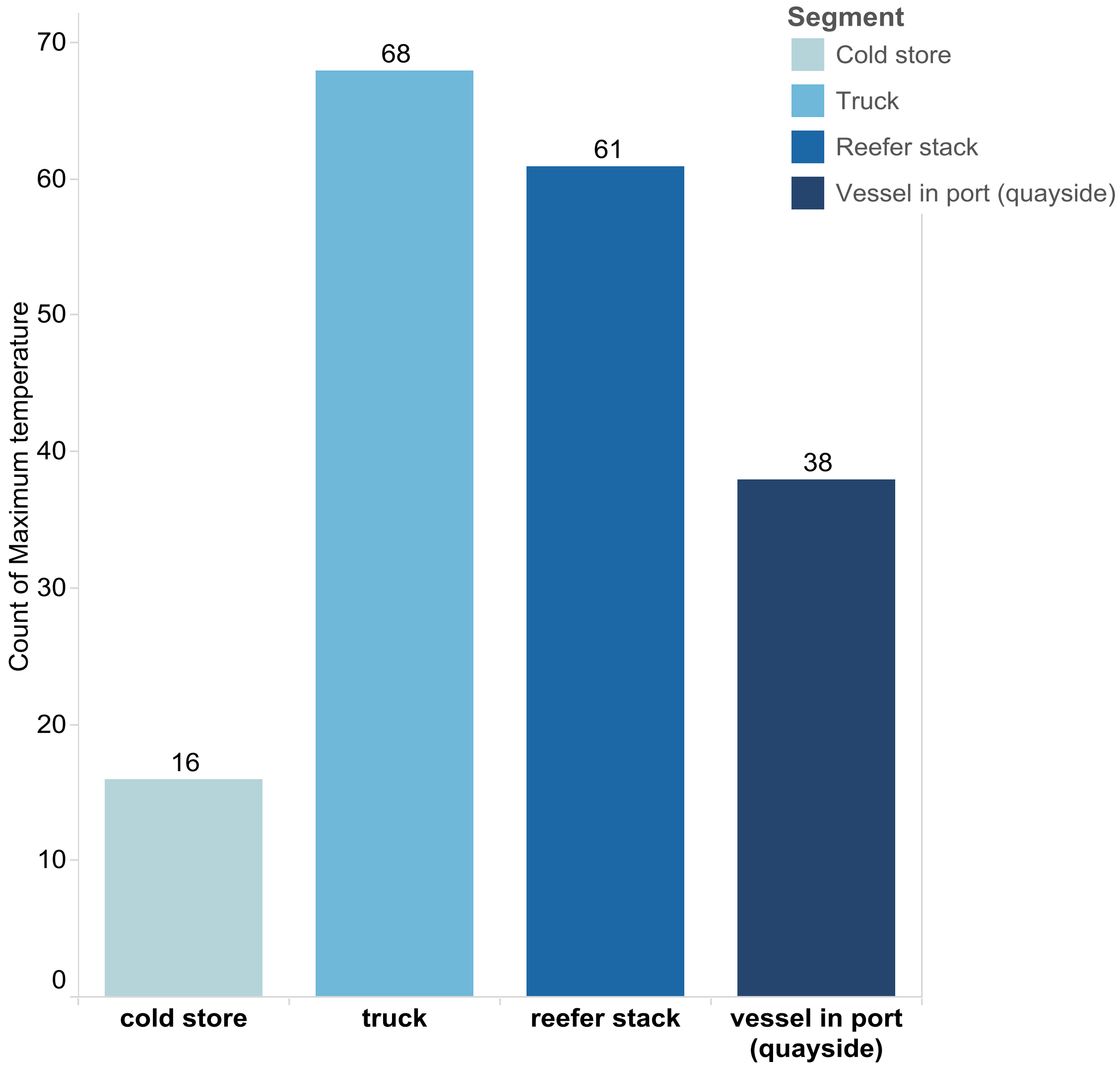

Figure 5.20: Graph of the number of maximum break temperatures which occurred in each cold chain segment

Figure 5.21 illustrates the range of maximum break temperatures in each cold chain segment.

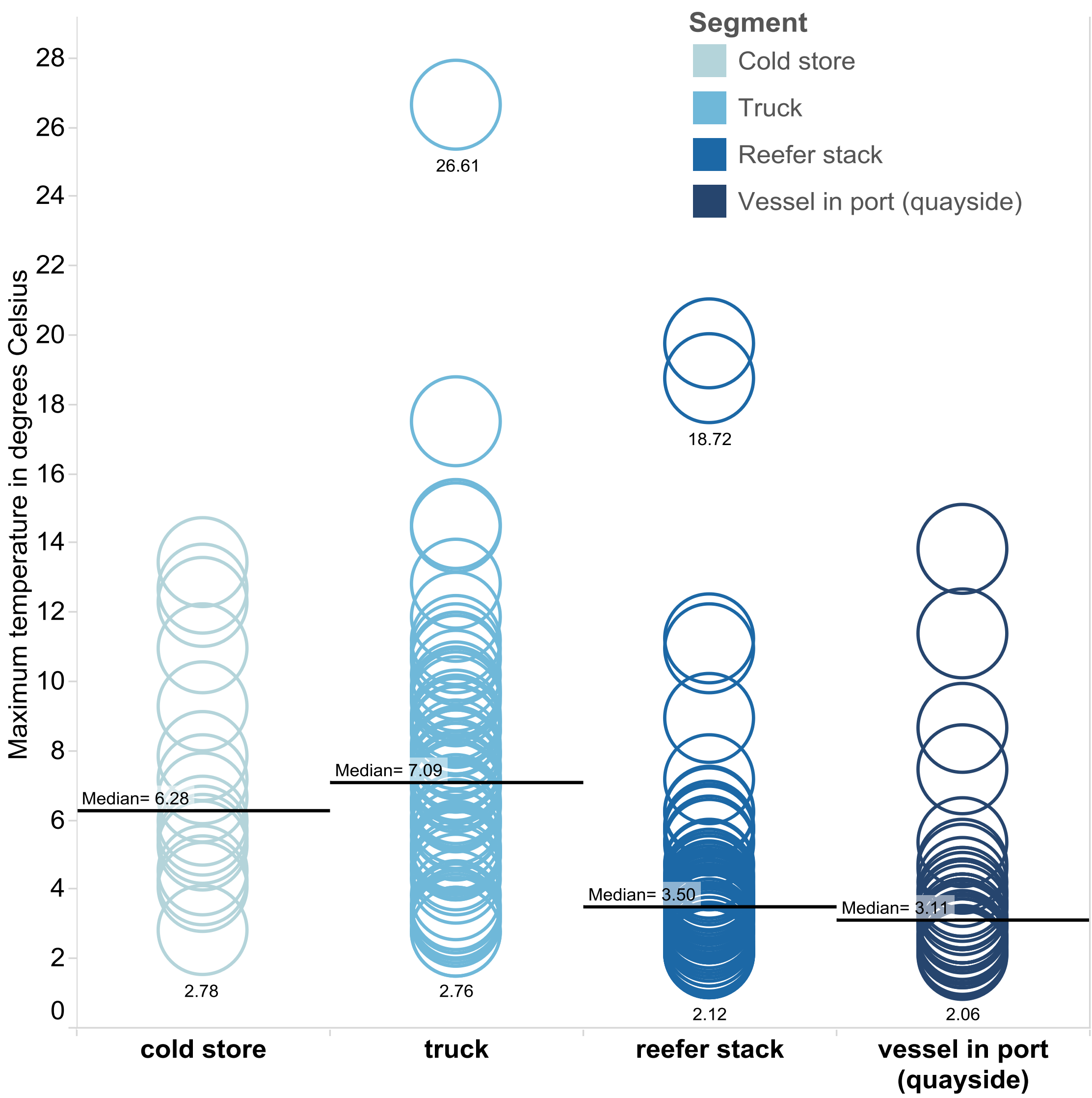

Figure 5.21: Graph of the range of maximum break temperatures in each cold chain segment

When considering the range of maximum temperatures for each break in the various segments it becomes easier to understand where in the cold chain the most severe breaks occur. The lowest maximum temperature for a break was 2.06°C which occurred on the vessel at the quayside, while the highest temperature reached during a break was 26.61°C, which occurred in the truck segment.

The maximum break temperatures reached in the cold store lie between 2.78°C and 13.44°C with the highest density of these between 4°C and 8°C.

In terms of the truck segment the maximum break temperatures reached are relatively densely grouped between 2.76°C and 14.5°C. There are two outliers with maximum break temperatures of 17.5°C and 26.61°C.

When the reefer stack segment is considered, the graph shows that the maximum break temperatures reached in this segment lie between 2.12°C and 19.72°C. There are two outliers that reached temperatures of 18.72°C and 19.72°C. The majority of the breaks, however, lie between 2.12°C and 11.22°C, with the highest density of these between 2.12°C and 6°C.

When considering the vessel segment, the graph shows that the maximum break temperatures reached range from 2.06°C to 13.81°C. The majority of these, however, lie between 2.06°C and 5.33°C.

Median temperatures are also indicated for each segment. The median temperature means that half of the maximum temperatures were higher than the median and the other half were lower. The median does not get skewed by outliers as would be the case for the average maximum temperature.

When the medians per segment are considered, it confirms the fact that the temperature breaks in the cold store and truck segments were clearly more severe than those in the reefer stack and vessel in the port segments. The median in the truck segment for the maximum break temperatures in this segment was a high 7.09°C. The cold store segment had the second highest median with a measurement of 6.28°C. The reefer stack and vessel segments had lower medians with measurements of 3.50°C and 3.11°C respectively.

It can be concluded that the breaks in the last two segments investigated in the cold chain, the reefer stack and especially the vessel, tend to be less severe in terms of the maximum temperatures they reach.

Figure 5.22 illustrates the range of maximum break temperatures reached in each cold chain segment per fruit type.

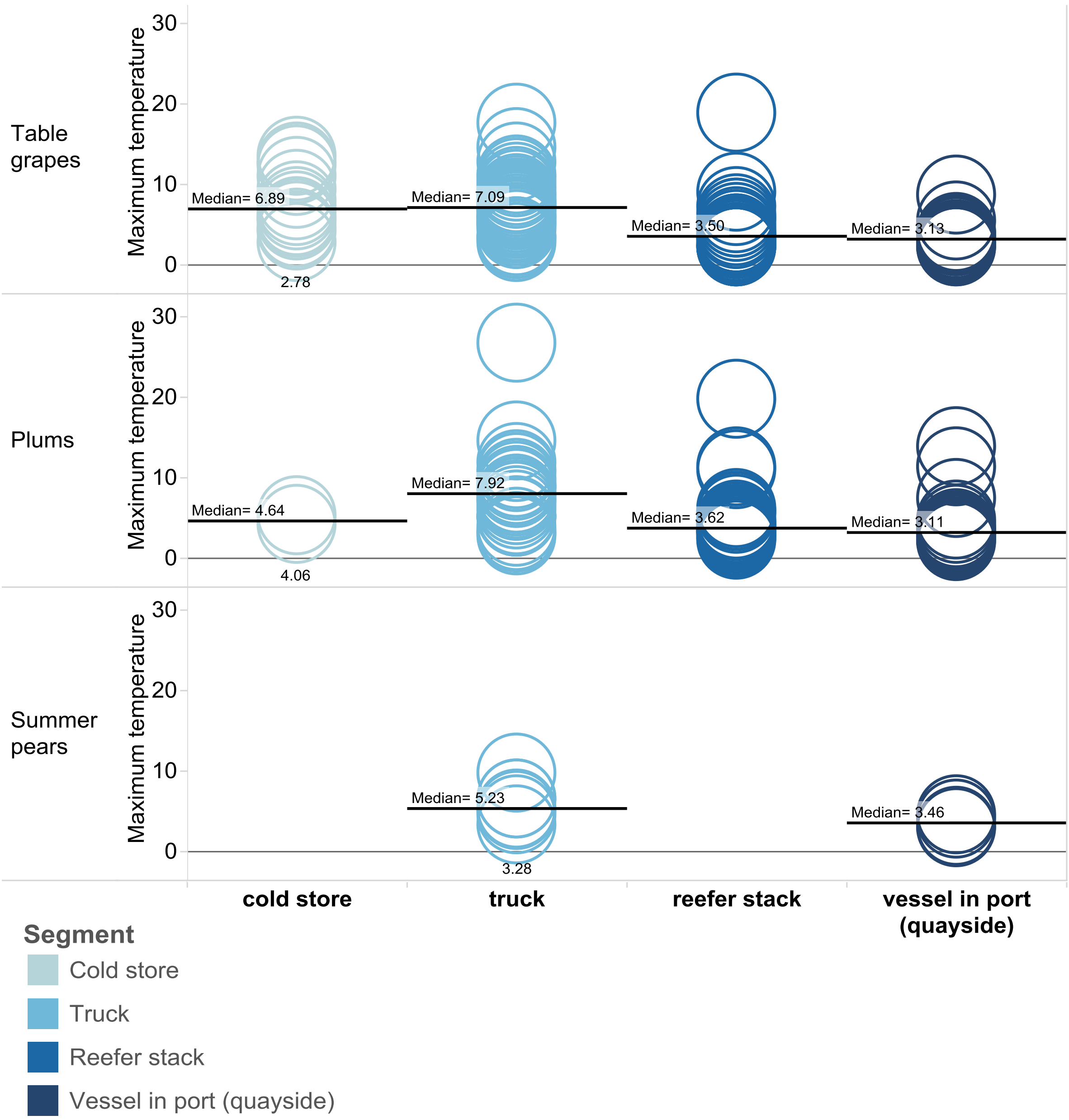

Figure 5.22: Graph of the maximum break temperatures reached in each cold chain segment and fruit type

From Figure 5.22 it is again clear that higher maximum temperatures were reached for those breaks originating in the cold store and truck segments than those that originated in the reefer stack and vessel segments. Figure 5.22 also shows that this is true for each fruit type.

Figure 5.23 indicates the break maximum temperatures reached for each fruit type.

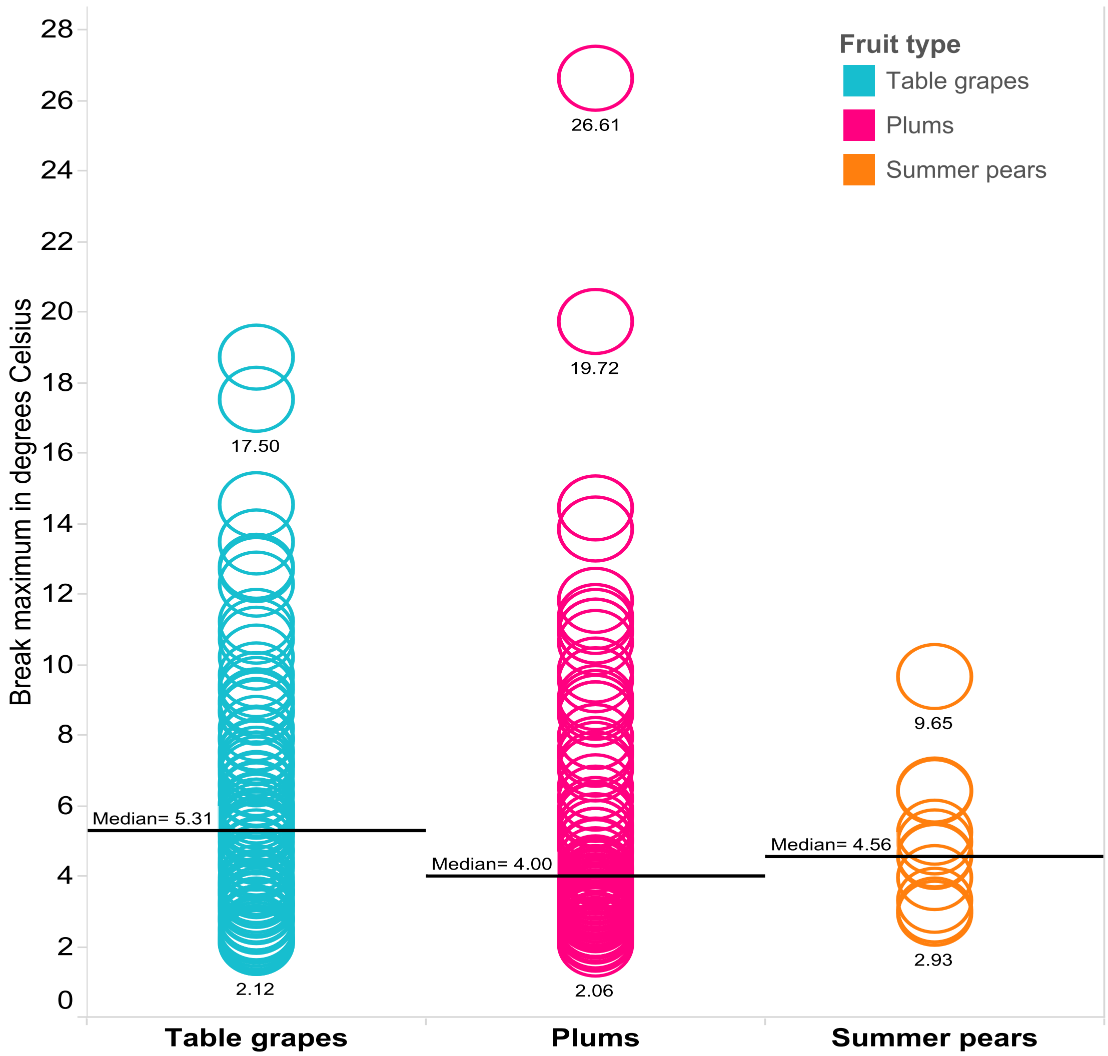

Figure 5.23: Graph of break maximum temperatures reached per fruit type

From Figure 5.23 it is clear that the maximum temperatures reached are relatively similar between the three fruit types as the median maximum temperatures reached vary between 4°C and 5.31°C. Table grapes reached slightly higher temperatures than plums and summer pears in general, with its median being the highest (5.31°C). Although the majority of the breaks reached maximum temperatures of between 4°C and 5.31°C, there are quite a few breaks reaching extremely high temperatures, especially for table grapes and plums. The two most severe outliers reached a maximum temperature of 26.61°C and 19.72°C, which were both measured in plum containers.

Figure 5.24 compares the break median temperatures with that of the maximum break temperatures for each fruit type.

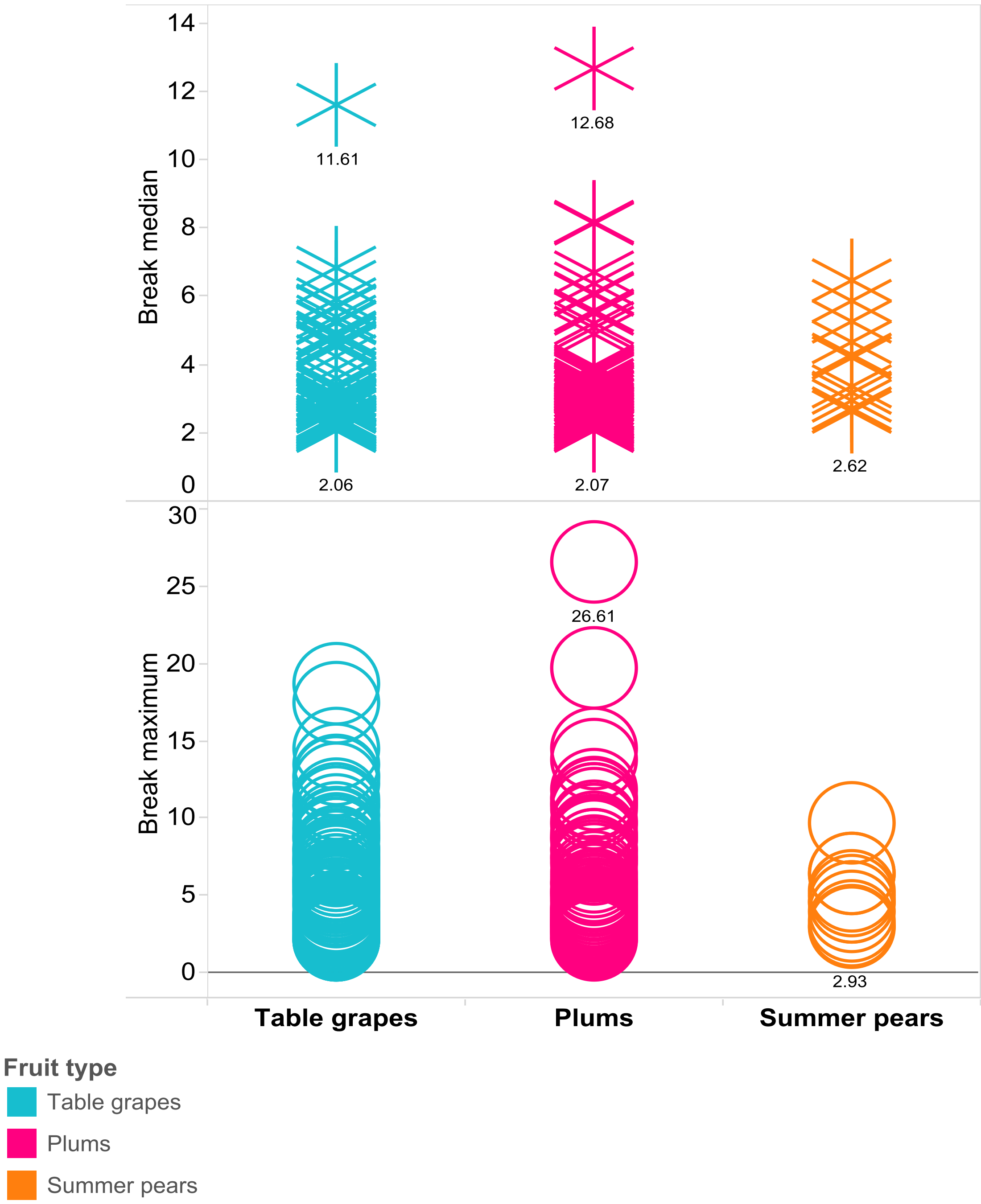

Figure 5.24: Graph of break median and maximum temperatures reached per fruit type

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Table 5.4 illustrates the ranges of both the maximum and median break temperatures reached for each of the fruit types.

Table 5.4: Ranges for break maximums and medians per fruit type

Fruit type	**Range of Maximum break temperatures**	**Range of Median break temperatures**
Table grapes	2.11°C – 18.72°C	2.05°C – 11.61°C
Plums	2.06°C – 26.61°C	2.04°C – 12.68°C
Summer Pears	2.93°C – 9.65°C	2.62°C – 6.45°C

When considering Figure 5.24 and Table 5.4, it is clear that the plum containers had the largest difference between the break maximums and medians. There were a few extreme outliers in terms of the break maximum temperatures reached. For table grapes there were also a few breaks reaching extreme maximum temperatures which are concerning. The summer pear containers had the smallest variety between the break maximums and break medians. It should be remembered, however, that there was only data for eight summer pear containers.

5.3.5 Analysis of severity of breaks

Figure 5.25 illustrates the severity of the breaks by comparing the maximum temperature of each break with the break length in days.

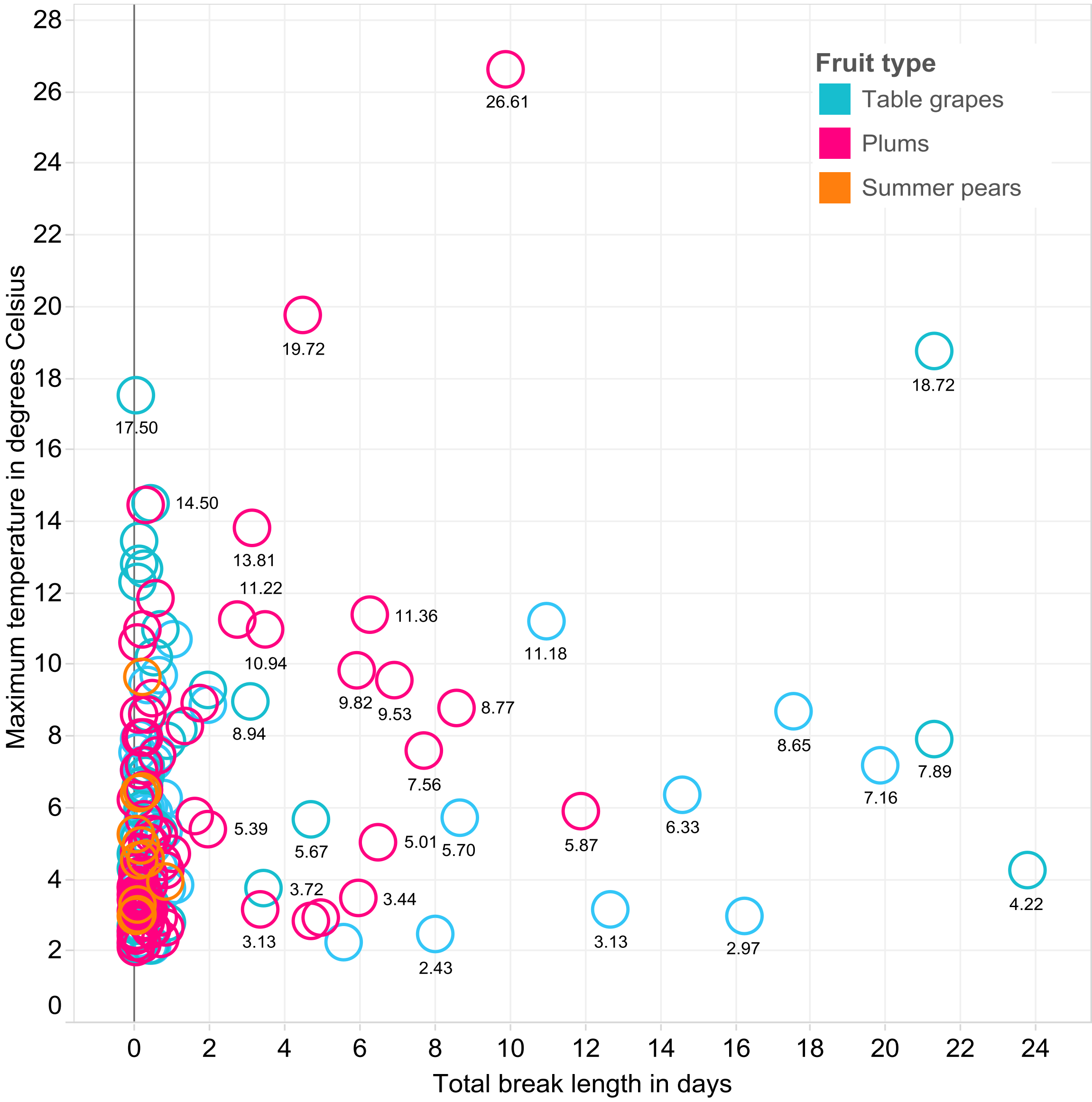

Figure 5.25: Graph of severity of the breaks in days

When considering Figure 5.25 it appears that the majority of the breaks are medium in severity in terms of their break lengths and maximum temperatures reached, because of the fact that most of the breaks are plotted in the bottom left corner of the graph. The further a break is plotted away from the bottom left corner of the graph, the more severe the break becomes. It is clear that the majority of the breaks continue for time periods shorter than a day, reaching maximum temperatures of less than 6°C.

There are, however a large number of breaks reaching maximum temperatures higher than 6°C and continuing for time periods longer than a day. A few extreme situations occurred which can be identified as outliers. The most severe of these include a break reaching a maximum temperature of 26.61°C and continuing for almost ten days as well as a break reaching a maximum temperature of 18.72°C and continuing for just more than 21 days.

Figure 5.26 looks at the bottom left corner of Figure 5.25 in more detail, by focussing on the breaks that have a duration of two days or shorter. Although the majority of these breaks reached a maximum temperature of 2°C to 5°C and continued for periods of between zero to five hours, there are a large number of breaks with higher maximum temperatures and which continued for longer than five hours.

Figure 5.26: Graph of severity of all breaks continuing up to 48 hours

5.4 Conclusion

From the data analysis, it is clear that a large number of breaks occur during the export cold chain of fruit. The number of breaks tends to be more during the early stages of the cold chain, especially during the loading of the container. The severity of the breaks also seems to be higher during the early stages of the chain. A large percentage of the breaks continued over more than one cold chain segment and one break even continued for 24 days.

Chapter 6: Interpretation of results

6.1 Introduction

In this chapter the data illustrated by the graphs in chapter 5 are interpreted. Possible reasons for the outcome of the data are also suggested.

6.2 Main findings from the analysis of breaks

Temperature data was analysed for a total of 123 containers exported from South Africa. A total of 183 breaks were identified and only 13 containers did not have any breaks. For the purposes of this study a break in the fruit cold chain was defined as "any time in the data where the ambient temperature of the air measured within the fruit container rose above 2°C for longer than 90 minutes".

Although 60 containers only had one break, 39 of the 183 breaks lasted for more than 24 hours.

The majority of the breaks originated in the truck and reefer stack segments. The data indicates that 46% of the 183 breaks originated in the truck segment and 33% in the reefer stack segment (Figure 5.11). The truck segment was thus the biggest culprit in terms of number of break origins. The majority of the breaks in the truck segment originated right at the beginning of the truck data, which means that the breaks occurred when the fruit pallets were removed from the cold store to be loaded into the container. These breaks typically continued up to the point where the container was plugged in at the reefer stack.

Due to the fact that only one of the exporters' data included the cold store segment, the number of breaks occurring in this segment seems low. The majority of the breaks that originated in the cold store segment, occurred during the time when the fruit was removed from the cold store and loaded into the container. These breaks are therefore identical in nature to the ones at the beginning of the truck segment. This means that almost 60% of the breaks can be attributed to the interface between the cold store and the container truck.

Only 9% of the breaks occurred at the port after the container had been unplugged in the reefer stack up to the point where it was again plugged in on the vessel (Figure 5.11).

There was a tendency under breaks originating in one segment to continue to the following cold chain segment(s) (Figure 5.12). This means that once a break occurred in the cold chain, it often took a long time for the temperature to drop below 2°C again, if it ever did.

Fifty-five percent of the breaks continued over two segments, meaning that it started in one segment and continued to the following segment where the temperature eventually dropped below 2°C again (Figure 5.13). Sixty of the 183 breaks originated in the truck segment and continued to the reefer stack (Figure 5.14). This explains why the number of breaks continuing over two segments was so high.

The majority of the breaks originated during the day. Seventy-three percent of the breaks identified occurred between 08h00 and 18h00, while 30% of the breaks occurred between 12h00 and 16h00, which is the warmest part of the day (Figure 5.17). These results are expected as the majority of the activities such as loading of the container occur during day time. There are, however, some cold stores that load the containers during the night to prevent or reduce the impact of the breaks.

In terms of the length of the breaks in the dataset, 33% of the breaks continued between zero and four hours, which is acceptable. On the other hand, 21% of the breaks (39 breaks) continued for longer than 1 day and 5.5% (10 breaks) continued for longer than ten days, with the longest break continuing for 24 days (Figures 5.18 and 5.19).

It was interesting to note that the maximum temperatures reached during these cold chain breaks were more severe in the earlier stages of the cold chain. The temperatures reached in the cold store and truck segments were generally much higher than those reached in the reefer stack and vessel, except for a few outliers (Figure 5.21).

Table 6.1 summarises the main findings from the analysis of the breaks

Table 6.1: Main findings from the analysis of the breaks

	Finding
1.	33% of the containers had one break, but the fact that a lot of these breaks continued for days should not be overlooked.
2.	Almost 60% of the cold chain breaks originated at the interface between the cold store and the container truck.
3.	30% of the breaks occurred during the warmest part of the day (12:00 – 16:00).
4.	The maximum temperatures reached were generally higher in the cold store and truck segments than in that of the reefer stack and vessel.
5.	55 % of the breaks continued over two cold chain segments.

6.	33% of the breaks were shorter than 4 hours
7.	21% of the 183 breaks continued for longer than a day.
8.	5.5% of the 183 breaks continued for longer than 10 days.

6.3 Possible reasons for breaks originating in the truck and reefer stack segments

As mentioned before the truck segment includes the time from when the fruit pallets are moved out of the cold store to be loaded into the container up to the point where the truck enters the port gate. The question as to why the break occurrence was high during this segment may be answered by the observations made in the cold chain. Sections 6.3.1 to 6.3.4 suggest four possible reasons for the high number of breaks in the truck segment.

6.3.1 Loading areas situated outside

It was observed that fruit pallets may stand in the loading area for a long time while waiting to be loaded into the container. Most of the loading areas in South Africa are outside and are only covered by a roof. These roofs do not always supply sufficient shade. The problem arises when the fruit comes out of the cold store with pulp temperatures of minus 0.5°C and comes into contact with the outside temperature, which could easily be above 30°C during peak summer. When the pallets stand in the loading area during these warm conditions for longer than 30 minutes (loading time was regularly observed to take longer than 30 minutes) a break in the cold chain is inevitable.

6.3.2 Fruit loaded into a container with pulp temperatures higher than the optimum

Fruit pallets are sometimes loaded into the container with pulp temperatures warmer than required by protocols. When removed from the cold store, the fruit should be at its optimum storage temperature, which is minus 0.5°C for table grapes and plums, and minus 1.5°C for summer pears. A pulp temperature measurement should be taken from each pallet before it is loaded into the container. When the fruit pulp temperature of a pallet is higher than these optimum temperatures, the pallet should technically be placed back into the cold store, but by doing this the container will be delayed. If the pallet is replaced with another one from the cold store, the consignment note will be wrong. Ideally the pallet should go back into the tunnel for a short period of time, but the tunnel will not be efficient unless it is full.

This becomes highly problematic when no genset is used, which means that the container is not refrigerated during transit. When the fruit enters the container too warm and is not cooled en route to the port, a break in the cold chain is to be expected.

6.3.3 Containers not sealed properly

A problem identified during the loading of the fruit pallets into a container is that the container door is not always sealed properly after the pallets have been loaded and the door is closed. This can be explained by the fact that 21 pallets are occasionally being squeezed into a container instead of the optimal 20 pallets. Proper sealing of the door is extremely important to prevent warm air entering from the outside during transit as this will definitely lead to a rise in the fruit temperature.

6.3.4 Reefer trucks transporting fruit to the port without gensets

It was observed that even when the cold store is further than two hours away from the port, gensets are not always being used. This is not good practice as the quality of the fruit inside the container is at risk. However, producers often find it too expensive to have the genset operating for the whole journey to the port.

There are even speculation that some truck drivers purposefully turn off the genset during long journeys. The drivers sell the diesel received for the operation of the genset en route to the port. When asked about this, truck drivers often blame the operation of the genset.

Sections 6.3.5 to 6.3.8 suggest four possible reasons for breaks originating in the reefer stack segment.

6.3.5 Delays at the port entrance

The reefer stack segment had the second highest number of breaks originating in the segment. This segment includes the time from when the truck enters the port gate up to the point where the container is plugged out of the stack at the port and is loaded onto the vessel.

The main reason observed for breaks originating at the reefer stack is because of delays resulting from congestion at the port. After entering through the port gate, trucks enter a queue to offload their fruit containers. During peak season these queues can be very long. When a truck is not equipped with a genset, the container has no source of power and can thus not be cooled. In addition, it was observed that although some of these trucks are equipped with gensets, the truck driver switches the genset off during these delays in order to save diesel. When the truck stands in the sun for hours during the middle of summer without an operating genset, the container literally becomes a hot box and the temperature of the fruit will rise.

6.3.6 Direct sunlight in the stack

Breaks in the port can result when a container stands in the reefer stack for days where it is exposed to direct sunlight in the middle of summer. Even though the containers are plugged-in while in the stack, most of them will be exposed to direct sunlight on one side at least.

6.3.7 Ineffective utilization of the REFCON container monitoring system

Both reefer stacks in the Cape Town Container Terminal have been fitted with the REFCON container monitoring system. Although REFCON is a powerful system, it seems that it is not being utilized optimally. The system should be used to monitor the condition of each container on a computer screen, 24 hours a day. Alerts should be sent out automatically when containers are not operating properly. Unfortunately, Maersk no longer supports REFCON and a large percentage of the reefer containers coming into the port are not fitted with the necessary modems for REFCON to work. This means that the containers have to be monitored manually and the whole purpose for the implementation of the REFCON system at the port is defeated.

6.3.8 Containers that bypass the reefer stack

When a vessel arrives at the Port of Cape Town, the port opens an area in the reefer stack for the number of reefer containers booked on that vessel. The stack is opened for incoming reefer containers for three days before the vessel sails and closes eight to 12 hours before the vessel arrives at the port. Once the stack is closed, the layout of the containers on the ship is planned. However, a number of reefer containers only enter the port once the stack has closed. These exceptions are made for exporters whose fruit, for example, was not on temperature on time. These exceptions are only made at the Port of Cape Town as it is the last stop before the European destination. These reefer containers are sent to another reefer stack where in theory they are plugged in at a specific area in the reefer stack. It was, however, observed that these containers are not always immediately plugged in and sometimes are never plugged in. When there is no space in the reefer stack, the containers are sometimes placed in the dry stack where there are no reefer points. The main problem comes in when the vessel does not depart as scheduled, which happens regularly during the peak season, as this is the time of the South Eastern wind in Cape Town. Containers cannot be loaded onto a vessel when the wind is too strong. This means that the containers that might have been neglected to be plugged in or are in the dry stack are now forced to stand in the sun for days waiting to be loaded onto the vessel. The risk of a cold chain break occurring, therefore, becomes higher for those containers entering the port once the stack is closed (Bosman, 2013).

6.4 Why the majority of the breaks occurred during the warmest part of the day

The warmer it is outside, the faster a break (ambient temperature rising above 2°C) will occur when the fruit is left without cooling. This holds true for when the fruit is loaded into a container, during the truck journey to the port if there is no genset, when the container waits to be plugged into the reefer stack and when the container is loaded onto the vessel. In addition, fruit is mainly handled during the daytime.

6.5 Lack of responsibility for cold chain preservation

Throughout the chain it seems that responsibility is one of the major issues. It appears that very few parties involved in the cold chain are willing to take responsibility for preserving the quality of the fruit and actually follow given protocols. There sometimes are, however, reasons for these protocols being neglected.

On the farms it was observed that the fruit is being picked during the warmest part of the day. The quality of the fruit is neglected here as farmers are keen to pick and remove fruit from the orchards/vineyards as quickly as possible irrespective of what the outside temperature is. Farmers should realise that by picking their fruit during the early morning or even at night, the quality of their fruit will be better and they are likely to receive higher prices for their produce. It should be noted, however, that farmers are under pressure to pick fruit as quickly as possible for several reasons. Firstly, if the fruit is left on the trees/vines for an extra day or two, it might miss the export vessel. Secondly, if the fruit is left on the trees/vines it may over ripen. Thirdly, if the market is saturated by the time the fruit arrives, farmers will not be able to receive a good price for their fruit even if the quality is high. On the other hand, if the market needs fruit, the fruit will be accepted even if the quality is not perfect.

Fruit is regularly left in the orchards/vineyards for up to several hours after being picked. It is clear that the workers on the farm do not always understand the importance of keeping the fruit temperature as low as possible from the moment the fruit is picked and, therefore, no responsibility is taken in this regard.

When the fruit arrives at the pack house, again little responsibility is taken to prevent breaks in the cold chain. Fruit is not always pre-cooled properly before being packed and many pack houses are too warm. Again it should be noted that the farmers are under a lot of pressure to get their fruit to the market as quickly as possible.

In terms of the cold store fruit is sometimes loaded while it has not been cooled down to the optimum pulp temperature. Fruit regularly comes into contact with the outside temperature for way too long when waiting to be loaded into a container. The container is also not always sealed well after the fruit has been loaded. It seems that workers at the cold stores are adamant to ensure that the fruit leaves the cold store as quickly as possible. Unfortunately by having only speed in mind, the quality of the fruit is often being neglected.

During the peak season there is usually a shortage of tunnel capacity. Labourers, therefore, want to remove the fruit as quickly as possible from the tunnels to be able to take in new fruit, which will also deteriorate the longer it waits to be cooled. In the end none of the fruit receives perfect treatment.

En route to the port, farmers save money by choosing to transport their produce without gensets. Again, the quality of the fruit is being neglected. In the event where gensets are actually used, truck drivers do not always take responsibility for the fragile produce they are transporting. It was observed that gensets are switched off by truck drivers and the diesel for the genset is sold en route to the port. It is important to use reputable trucking companies with reliable drivers who are properly trained about the cold chain.

After entering the port, again little care is taken to monitor the temperature of the container.

There is a lack of understanding throughout the chain of the impact of temperature breaks on the quality of the fruit. Theoretically, temperature breaks can have a negative impact on the pathological and physiological aspects of fruit. The higher the temperature of the fruit, the more likely it is for pathogens to be present (Fourie, 2013). Lately, there has been a shift towards a lot of old pathogens emerging again in fruit and these are enticed to grow faster than before, especially fungi. These are all pathogens that could actually be suppressed by maintaining fruit at its optimum storage temperatures. Once a temperature break has occurred and pathogens have been established, the damage is done, even when the temperature of the fruit does cool down again later in the cold chain (Fourie, 2013).

It is clear that not all role-players in the cold chain understand the importance of their responsibility in preserving the quality of the fruit they handle. Because of this lack of understanding, large numbers of cold chain breaks do occur. There are various trade-offs which result in the cold chain not being managed properly. There is a lot of pressure to do things quickly due to the volumes that need to be handled, for example the loading of containers. As a result some good cold chain practices fall by the wayside in the process.

6.6 Conclusion

It is clear from this chapter that too many cold chain breaks occur in the fruit industry, especially during the early stages of the chain. The majority of the breaks originate during the loading process and these breaks tend to continue at least to the reefer stack. The positive side is the fact that there are solutions to the causes of these breaks and some of these are discussed in the good cold chain practice guide developed in the following chapter. Each role-player in the fruit industry should understand their role in the maintenance of the cold chain and take the necessary responsibility.

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Chapter 7: Good Cold Chain Practice Guide

7.1. Introduction

In this chapter the knowledge gained during the study is used to develop a best practice guide for exporting fruit from South Africa in order to minimize the breaks occurring in the cold chain. Best practices are suggested in a practical, easy-to-follow format. The practice guide discussed is specifically customized for the table grape industry.

A workshop was held on 3 October 2013 during which the practice guide was presented in the form of a Power Point presentation. The aim of the workshop was to test the credibility of the guide with people who are actively involved in the industry. The audience included owners of fruit pack houses, representatives from various cold stores, exporters, and researchers within the relevant field of study. During the presentation there was opportunity for any criticism and suggestions for the guide. The guide was sent electronically to each of the attendees, as well as those who were invited, but could not attend the workshop due to other obligations, after the workshop and a period of two weeks was given for any further feedback and suggestions. All of the suggestions received were incorporated into the guide. The general feeling under those present at the workshop was positive and they felt that the guide will be of great value to all the role-players in the industry. It was clear that there is a definite need for greater knowledge and understanding of what good cold chain practices entail.

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7.2 Good Cold Chain Practice Guide for table grapes

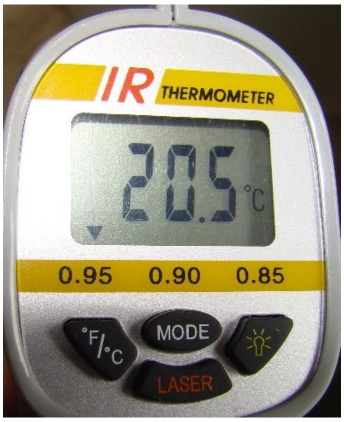
7.2.1 Harvesting on the farm

Do not harvest fruit in ambient temperatures above 30°C.

Do not harvest fruit for the rest of the day once the ambient temperature exceeds 30°C.

Do not leave fruit standing in the vineyard after it has been picked.

Harvest fruit in ambient temperatures below 30°C. The pulp temperature of the fruit should be below 25°C.



Harvest fruit during early morning when the outside temperature is cool (Orange River: 04:00 – 10:00, Western Cape: before 11:00).

Move fruit in covered transport to pre-coolers directly after it has been harvested.

7.2.2 The pre-cooling unit

Do not offload fruit in a place where the fruit is exposed to direct sunlight.

Do not delay the offloading process at the pack house, it will lead to dry stems in grapes.

Variance in temperature within the pre-cooling unit is a problem (Fans only on one side of the room).

Fruit should be offloaded in a shaded, cool area.

Fruit should be offloaded and put into a pre-cooler within 30 minutes after arrival at the pack house.

Consistency in temperature within pre-cooler is essential (Fans should be on each end of the room).

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The pre-cooler should not be warmer than 18°C.

Humidity levels should not be too low as it will result in shrivelled fruit.

The temperature of the pre-cooler should be above dew point (normally between 15°C and 18°C). A permanent thermometer is essential.

Maintain humidity levels between 85% and 95% through the use of either wet walls or fogging systems.

Wet walls

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7.2.3 The pack house

Pack houses should not be warmer than 25°C.

Humidity levels should not be too low as it will result in shrivelled fruit.

Pack houses with roofs that are not insulated cause high room temperatures.

Pack houses should be maintained between 18° and 25°C according to protocol. A permanent thermometer is essential.

Maintain humidity levels between 85% and 95% through the use of either wet walls or fogging systems.

Pack houses with insulated roofs help keep the room temperatures low.

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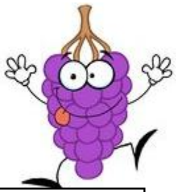


The lighting inside a pack house can cause a rise in fruit temperatures when it is too bright or situated low (very near fruit working stations).

Fruit coming from the pack house should not have high pulp temperatures.

Temperature monitors should not be inserted just before the fruit is loaded into the container.

Lighting should be sufficient, but should not have a substantial effect on the fruit temperature.

Fruit arriving from the pack house should be at a temperature inside protocol.

Insert temperature monitors in the centre of pallets while the pallets are being built inside the pack house.

i-button

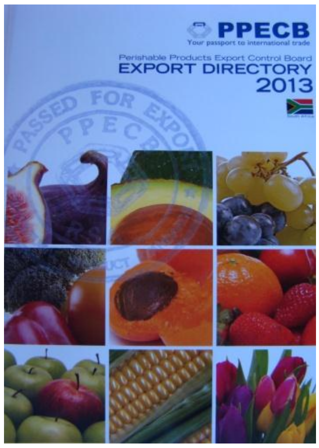
Temptale

Logtag

7.2.4 The cold store

There should be no uncertainty about each fruit type's optimum temperature that it needs to be cooled down to.

The optimum fruit pulp temperature for table grapes are minus 0.5°C.



Cold store doors should not left be open for longer than necessary.

Cold store doors should only be opened when absolutely necessary.

Open doors without strip curtains let warm air in.

Make use of strip curtains in cold store doors to prevent warm air from entering when the door is opened.

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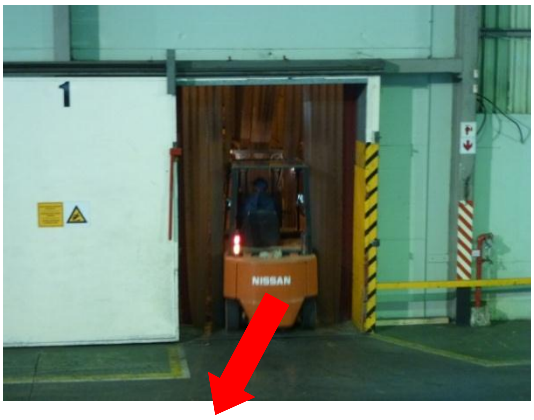
Cold stores neglecting to monitor humidity levels results in shrivelled fruit.

Maintain humidity levels between 85% and 95% through the use of either wet walls or fogging systems.

7.2.5 Loading of pallets into a container

Loading of containers should not be delayed because of misplaced pallets.



Forklift delaying loading of container while searching for missing pallets!

Do not neglect PPECB protocols in terms of fruit pulp temperature requirements when loading pallets into a container.

Loading of pallets mostly happens outside in warm temperatures.

Make use of staging rooms for the loading process to be completed as quickly as possible.

Fruit should remain in cold stores until the fruit pulp temperature meets PPECB protocols which is minus 0.5°C for table grapes.

Making use of airlock loading bays is the ideal.

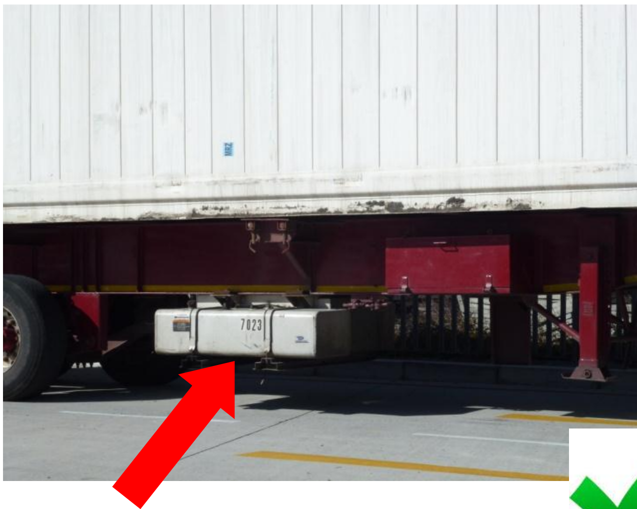
7.2.6 Cold store to stack

Trucks regularly wait in long queues at the port gate without gensets or gensets are switched off in order to save diesel.

No Genset!

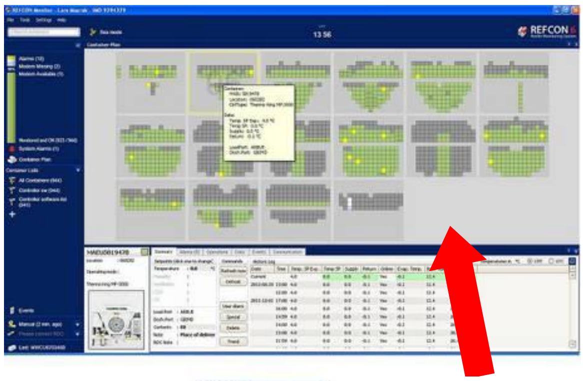
All containers are not fitted with the necessary modems for Refcon to function and monitor the container temperature in the stack. Reefers now have to be monitored manually which is not done regularly enough.

All trucks standing in queues at the port gate should ensure that containers are plugged into a genset and that the genset is operating.

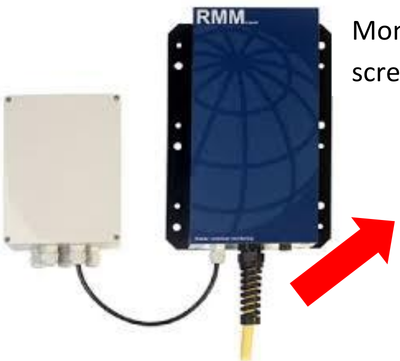


Genset!

For a container's temperature to be monitored 24 hours of the day, while in the stack, it must be fitted with the necessary monitored by an automated monitoring system.



Monitoring on computer screen



Modem installed into container

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7.2.7 Stack to vessel in port (Quayside)

Avoid entering the port once the stack has been closed.

Risk of container not being plugged in!

Containers should enter the port during the time when the stack is open to ensure a place in the reefer stack.

7.3 Conclusion

Temperature is the greatest determinant of cold chain effectiveness and therefore the guide focussed on practices of maintaining an optimum temperature in each step of the chain. By implementation of the practices suggested in the guide, the industry can start to move into the direction of a more effectively managed cold chain which will result in less cold chain breaks and ultimately less wasted fruit.

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Chapter 8: Conclusions and Recommendations

8.1 Conclusion to the study

The concern of the South African fruit industry about the amount of fruit and money lost each season due to temperature breaks in the export cold chain was the catalyst for this study. The aim of the research was to identify how often cold chain breaks occur, where in the cold chain they occur and how severe they are. For the purposes of this study a cold chain break was identified as any rise in ambient temperature above 2°C for longer than 90 minutes. The outcome of the study was then to develop a good cold chain practice guide to assist the industry in minimizing the occurrence of these breaks.

Secondary research was conducted to complete the literature review for the study. The literature review started with a background on the South African fruit industry as a whole. General information regarding the specific fruit types (table grapes, summer pears and plums) focussed on during this study was also discussed. Information was gathered on why effective maintenance of the cold chain is so important and the importance of temperature and relative humidity was emphasized. Each step of the fruit export cold chain was described from the farm to the Cape Town Container Terminal. The role of the PPECB in the export fruit cold chain was also explained. The literature review ended off with a discussion on international best practices which should be considered in the South African fruit industry such as the implementation of airlock loading bays at cold stores, which will eliminate cold chain breaks during the loading of the container.

Between November 2012 and March 2013 qualitative primary research was done by making observations in several segments of the fruit export cold chain; namely on farms, in pack houses, in cold stores as well as at the Container Terminal of the Port of Cape Town. The specific fruit focussed on during this study included table grapes, summer pears and plums. Every step in the export cold chains for each of these fruit types was documented. It was clear from the observations that protocols are not always followed and that not all role-players in the fruit industry understand the important roles they play in maintaining the cold chain.

During this period of time, quantitative primary research was also done in the form of temperature trials that were conducted on these fruit types. Temperature monitors, known as Temptales, were placed into specific fruit cartons just after the pallets left the cold store to be

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loaded into the container. These monitors measured the fruit pulp temperatures and/or the ambient temperature and humidity throughout the journey up to the point where the fruit arrived at the overseas destination. The temperature data was then electronically mailed back to the researcher for analysis. Unfortunately, only 57% of the monitors for the temperature trials were retrieved in spite of extensive communication about the trials between the exporters and the overseas receivers. Nevertheless, valuable information was gathered from the temperature data that was retrieved. The most important lesson learnt from the trials was that a container does not have the ability to re-cool the fruit pallets closest to the container door (furthest away from the refrigeration unit) once the temperature had risen too high.

The majority of the temperature data analysed during this study was received from two exporting companies who monitor the temperature of the fruit containers they export from South Africa. Temperature data was received for a total of 123 containers that were all exported through the Port of Cape Town to either Europe or the United Kingdom. The data was analysed from the cold store segment up to the point where the vessel sailed out of the Port of Cape Town. Interesting, and in some cases worrying conclusions were made from the data. For the 123 containers a total of 183 cold chain breaks were identified. Seventy-three percent of the breaks identified occurred between 08h00 and 18h00, while 30% of the breaks occurred between 12h00 and 16h00, which is the warmest part of the day. These results are expected as the majority of the activities, such as loading of the container occur during day time. Almost 60% of the cold chain breaks originated at the interface between the cold store and the truck when the pallets are loaded into the container. A further 33% of the breaks occurred between the times when the trucks enter the port gate and when the containers are plugged in at the reefer stack. The breaks had the tendency to continue to the segment/s following the segment they originated in. Fifty-five percent of the breaks continued over two segments. It was interesting to note that the maximum temperatures reached during the breaks were generally much higher in the cold store and truck segments than those reached in the reefer stack and vessel segments. Although 33% of the breaks were shorter than four hours, it was worrying to notice that 21% of the breaks continued for longer than a day and 5.5% of these breaks continued for longer than ten days, with the longest break continuing for 24 days. From this information it was thus clear that there is great opportunity for improvement in terms of cold chain maintenance in the fruit industry.

As the final outcome of the study, a good cold chain practice guide was developed on the basis of the results obtained from the data and observations made. The aim of the guide is to supply the fruit industry with easy-to-follow practices which will assist them in minimizing these cold chain breaks. It is, however, imperative that role-players should first be educated on why temperature protocols play such an important part in maintaining the cold chain.

8.2 Recommendations

The Good Cold Chain Best Practice Guide developed as an outcome for this study includes recommendations on how to minimize the occurrence of cold chain breaks during each step in the cold chain from the farm to the quayside. The next section includes a discussion of the recommendations from the practice guide in Chapter 7. Each step in the cold chain is discussed separately.

8.2.1 Harvesting on the farm

It is important for the cold chain to be maintained from the moment the fruit is harvested, as the quality starts to decrease from this point. Fruit should be harvested during the cool hours of the day, once the fruit pulp temperature has had sufficient time to cool down after the heat of the day. This includes early mornings and in some cases even during the night. One of the most common quality issues developing in table grapes when they are harvested during high temperatures are brown stems.

Once the fruit has been picked it is important to remove the fruit from the vineyards/orchards as quickly as possible. Because the seasons of table grapes, summer pears and plums all peak during the middle of summer, leaving the fruit in the vineyards/orchards after being picked will definitely have a negative impact on the quality of the fruit further along the cold chain. Fruit should be placed into pre-cooling immediately. In the case where there are no pre-cooling facilities on the farm itself, fruit should be placed in the shade and pome and stone fruit could be covered with wet blankets while waiting to be transported to the pack house.

8.2.2 The pre-cooling unit

On arrival at the pack house, fruit should be removed from the truck as quickly as possible and placed into the pre-cooler. Most of the receiving bays at pack houses visited are outside and only covered by a roof. These roofs do not always provide sufficient shade, depending on the time of the day and the position of the sun, and therefore the fruit should be moved into the pre-cooling room quickly. A maximum time of thirty minutes should be allowed for the fruit to be offloaded from the truck and placed into the pre-cooler. Pack houses should preferably ensure that their facilities are of such a standard that fruit is received in a cool, constantly shaded area at all times. The development of dry stems in table grapes is significantly increased by a delay in time between harvesting and cooling.

Pack houses and farms should ensure that their pre-cooling units are effectively and evenly cooled throughout the room. This can be achieved through the installation of fans on opposite ends of the pre-cooling unit. The temperature of the pre-cooling room should be set at between 15°C and 18°C for the field heat to be effectively removed from the fruit.

It is extremely important for the correct humidity levels to be maintained in the pre-cooling room. This can be done through installing so-called “wet walls” in the pre-cooling room. This entails water flowing down the walls of the pre-cooling room which is continuously circulated by a pump, in order to maintain the humidity inside the room as well as keep the temperature low. Humidity levels should be kept between 85% and 95% at all times inside the pre-cooler. It is important to have at least one humidity metre inside the room to enable continuous monitoring of the humidity level inside the pre-cooling room.

8.2.3 The pack house

Pack houses in South Africa tend to be too warm. Protocols state that the ambient temperature inside a pack house should be maintained at below 25°C. Most of the pack houses observed during this study had temperatures closer to 30°C. It is critical for the fruit pulp temperature to stay cool once pre-cooled. Pack houses should thus be equipped with effective air cooling systems and permanent thermometers should be in place to monitor the temperature continuously. By insulating the roof of a pack house, it will be much easier to maintain the temperature below 25°C.

Aside from the temperature, the humidity also needs to be maintained inside the pack house. Humidity levels should be between 85% and 95% and permanent humidity meters should be placed inside the pack house. Humidity levels that are too low will result in fruit with dry stems or shrivelled fruit.

The lighting inside a pack house should be well balanced; there should be sufficient light for labourers to see well, but the lighting should not lead to an increase in the pulp temperature of the fruit.

It is important for exporters to monitor the temperature of their fruit from the moment it is packed up to the point where it arrives at its international destination. Temperature monitors should already be inserted inside the pack house once the fruit pallet involved has been built. Currently, the majority of temperature monitors are only inserted just before loading of the container which means that little temperature data for the time period inside the cold store is available. It will be of high value to have access to temperature data earlier in the cold chain.

8.2.4 The cold store

Cold store operators should know the exact optimum storage temperature that each fruit type needs to be cooled down to during cold storage. Temperature protocols of the PPECB should be followed strictly. The optimum storage temperature for table grapes and plums are minus 0.5°C and summer pears are either cooled down to minus 1.5°C or minus 0.5°C depending on the demands of the market. It is extremely important that the cooling process of the fruit is not rushed, but that the fruit is stabilized at its optimum temperature before being removed from the cold store.

In order for the fruit to be cooled down to their specific optimum temperatures as quickly as possible and for the temperature to be maintained within the cold store, the doors of the cold store should be kept closed as far as possible. Strip-curtains should be in place to prevent warm air from flowing into the cold store when the doors have to be opened.

Maintaining the humidity levels between 85% and 95% inside the cold store is just as important as with the pre-cooling room. One way of maintaining high levels of humidity inside a cold store is to make use of a hydraulic cooling system. Keeping the floor wet at all times is another method regularly used. Cold stores should be fitted with humidity meters in order for the humidity levels to be monitored continuously.

8.2.5 Loading of pallets into a container

The data revealed that the time between when the fruit is removed from the cold store and when it is loaded into the container truck is the area where the biggest number of breaks and most severe breaks occurred. The following recommendations could help to minimize these breaks.

Firstly, it is important that the fruit is properly cooled to its specific optimum temperature before being loaded into the container. If the fruit is not cooled properly at the beginning of the cold chain, the chances are that it will never reach its optimum temperature throughout the rest of the journey. When fruit is too warm when removed from the cold store, it should be placed back into the cold store and replaced with other pallets that are at optimum temperature.

In order to prevent delays resulting from forklifts searching for pallets inside the cold store, staging of the pallets beforehand is recommended. A staging room entails a room where the temperature is set at approximately 0°C and the pallets are staged per container in the order that they have to be loaded into the container. Making use of a staging area will drastically decrease the time that pallets stand outside waiting to be loaded into the container. This means that the fruit pallets will be in contact with the warmer outside temperature for a shorter time period and the severity of the breaks occurring will be decreased.

A critical step that cold stores in South Africa will have to consider to eliminate the cold chain breaks during loading of containers is the installation of air-locks at loading bays. This enables pallets to be moved directly out of the cold store into the container without making contact with the warm outside air temperature.

8.2.6 Transport from cold store to the port

Gensets are fitted onto container trucks to act as a power source for the container to be plugged in and refrigerated during transit from the cold store to the port. For journeys shorter than two hours from cold stores to the port, gensets are not required by the PPECB and therefore not normally used because of the high costs involved. However, trucks are often delayed at weighbridges for hours and again at the port gate. This means that although the distance from the cold store to the port was relatively short, the time between loading and being plugged-in at the reefer stack could be longer than the allowed PPECB Time Temperature Tolerance of six hours. This often leads to severe breaks in the cold chain. It is thus highly recommended that gensets should be used for containers loaded during daytime no matter how short the distance to the port is. Another option is that the containers should be loaded at night.

8.2.7 Port gate to stack

It was observed that some truck drivers are instructed to save diesel by switching off the genset once they have joined the queue at the port, waiting to offload their containers. This is unacceptable as the cold chain of the fruit inside the container will be broken. Containers standing in the sun for up to several hours without being refrigerated will become a hot box. Gensets should thus remain switched on during delays at the port.

It is recommended for exporters to ensure that their containers enter the port while the stack is still open. The risk of cold chain breaks is higher with containers entering the port once the stack has been closed. The higher risk can be attributed to factors including the failure of the container to be plugged in as the focus of the labourers at the port will be on those containers which entered the port on time and the container being placed into the dry stack because of the reefer stack being full.

It is, therefore, preferred that containers enter the port early enough when the reefer stack is still open and the container is plugged-in until loaded onto the vessel.

Table 8.1 summarises the recommendations made in this section.

Table 8.1: Cold chain recommendations

Cold chain activity	Recommended actions
1. Harvesting on the farm	1.1 Fruit should be harvested during cool temperatures (early morning). 1.2 Once harvested, fruit should be removed from the vineyards/orchards immediately. 1.3 Wet blankets should be placed over stone and pome fruit during journey to the pre-cooling facility / pack house.
2. Pre-cooling	2.1 On arrival at the pack house, offload fruit within 30 minutes. 2.2 Fruit should be offloaded in a cool, shaded area. 2.3 Ensure the pre-cooler is effectively and evenly cooled. 2.4 Maintain an ambient temperature of between 15°C and 18°C. 2.5 Maintain humidity levels between 85% and 95%.
3. The pack house	3.1 Temperature inside pack house should always be below 25°C 3.2 A pack house should have an insulated roof to keep the temperature low. 3.3 Maintain humidity levels of between 85% and 95%. 3.4 Lighting in the pack house should be sufficient, but should be far away enough from the fruit so that it does not increase the pulp temperature of the fruit. 3.5 Insert fruit monitors during this stage.
4. The cold store	4.1 Ensure that each fruit type is cooled down to its specific optimum storage temperature. 4.2 Ensure that fruit is cooled for long enough to stabilize at its optimum temperature before being removed from the cold store. 4.3 Doors of the cold store should remain closed as far as possible. 4.4 Strip curtains should be in place when the doors are open.

	4.5 Maintain humidity levels between 85% and 95%.
5. Loading of pallets into a container	5.1 Ensure that each fruit type is cooled down to its specific optimum storage temperature before loading. 5.2 The use of staging areas will minimize delays and thus also the occurrence of cold chain breaks during loading. 5.3 The installation of air-locks at loading bays has the ability to eliminate cold chain breaks during loading.
6. Transport from the cold store to the port	6.1 The use of gensets during transport can eliminate cold chain breaks during transit to the port. Loading containers at night and travelling at night can also eliminate this problem.
7. Port gate to stack	7.1 Gensets should remain switched on during delays at the port. 7.2 A truck should enter the port before the stack is closed to ensure that the container is plugged-in until vessel is loaded. Thus do not make use of the direct-to-vessel option.

8.3 Challenges faced during the study

8.3.1 Financial losses confidential or difficult to quantify

Although it is now known that a large number of cold chain breaks do occur during the exports of fruit from South Africa, it is extremely difficult to quantify exactly how much money is lost through the occurrence of these breaks. There are various reasons for this. The price paid for fruit depends on the market demand. If the market is saturated, the receiver will offer a lower price for fruit if there is the slightest quality defect. On the other hand, if there is a shortage of fruit in the market, a good price will be offered in spite of some defects. Temperature breaks could result in the growth of fungi, but only if the fungi were present on the fruit before it was cooled to its optimum temperature. The quality defects might therefore not be visible but the remaining shelf life would have been compromised. In addition, the data about claims and losses is normally confidential.

Post-harvest losses are said to be approximately 10%-20% worldwide. Estimates for developing countries, such as South Africa, are considerably higher. It has been argued that post-harvest losses in developing countries range between 20% to 50%, and as much as one third of all fruit and vegetables produced is lost before it reaches the end consumer. These are all general estimates and there is a definite lack of information regarding post-harvest losses in the South African Fruit Industry.

The following scenarios presented in Table 8.2 give an indication of the magnitude of bad cold chain practices.

Table 8.2: Estimate of monetary losses due to breaks in the cold chain

Fruit type	Average Net export price per ton	% loss because of bad cold chain practices	Resulting financial loss per ton
Plums	R10 384	5%	R519
		10%	R1038
		15%	R1558
		20%	R2077
Pears	R6 760	5%	R338
		10%	R676
		15%	R1014
		20%	R1352
Table Grapes	R12 505	5%	R625
		10%	R1250
		15%	R1876
		20%	R2501

(HORTGRO, 2012), (SATI, 2012)

8.3.2 Difficult to retrieve data loggers

During the temperature trials conducted for this study, only 42 out of the 74 loggers (57%) were retrieved. The exporters communicated with the receiving depots several times to alert them about the temperature trials in advance and to inform them about the number and locations of the monitors to be retrieved. The cartons containing monitors were also clearly marked with large green stickers with "quality control" printed on them. Nevertheless, the depots claimed that they could not find the monitors.

8.3.3 Some shipping lines do not publish loading times of containers

Temperature data for approximately 200 containers were received from the exporting companies. Data for only 123 of these containers could be analysed because the tracking data for the rest of the containers were not available. In order to analyse the data it is necessary to know the segment in the cold chain where each temperature measure was taken. However, some of the shipping lines do not keep record of the specific times the containers are loaded onto their vessel. Record is only kept of the vessel loading date. This meant that the data for these shipping lines could not be segmented between the reefer stack and when the vessel was loaded, indicated as "vessel in port (quayside)" on the graphs.

8.3.4 NAVIS system unstable since upgrade

The NAVIS system has been unstable since April 2013 because of upgrading, which meant that no queries could be run to determine the vessel loading times for the data of the shipping lines that do not publish these times.

8.3.5 Detailed history of pallets / container not readily available

In some cases it was difficult to understand the temperature data without knowing the detailed history for the specific fruit pallets or containers at hand. One pallet, for example, was in the cold store for approximately two weeks and had two long cold chain breaks during the time in the cold store. This is very difficult to interpret when there is no detailed information available. One can only assume that the vessel had been delayed and that the fruit was moved to another cold store.

8.4 Future studies

8.4.1 Measure temperature from an earlier stage in the cold chain

The data received for this study started in the cold store or truck segments. In most cases the data started at the point where the fruit is removed from the cold store and placed in the loading area and the majority of these containers' data started with temperature measures already above 2°C.

It is recommended that the temperature monitors should be inserted into the cartons while the pallet is built in the pack house. It would be easier to insert the monitors at this point and would have the added advantage of starting to collect temperature data from last stage of the pack house segment. The data would then show whether the fruit was cooled sufficiently in the cold store. Data would also be available from the moment the fruit is removed from the cold store to be loaded into the container so it would be possible to analyse the data from the onset of the break, rather than from a random point after the break has started.

8.4.2 Place focus on the port segment

Since approximately 60% of the temperature breaks occurred before the container arrived at the port, the limited funding and manpower available for the study was used to focus on the initial segment of the cold chain. It is, however, necessary to also analyse the operational procedures inside the port in order to reduce the occurrence of breaks there.

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Appendix A: Plum Cold chain from farm to cold store

1. Picking of plums

The cold chain of the plum supply chain begins directly after the fruit has been picked from the tree. Before plums are picked, maturity of the fruit is monitored from three to four weeks before it is expected to be mature (Fruit South Africa, 2004). The maturity of plums is determined by internal as well as external factors. Internal factors include pressure levels, stone quality as well as sugar levels, while external factors include fruit size, skin colour and firmness of the fruit.

There are six main plum cultivars grown in South Africa and these cultivars mature at different times. Therefore it is important to strictly monitor the maturity of these fruits.

Plums grow on trees and the picking process is assisted with ladders in order to reach the fruit at the top of trees. Lightweight ladders are preferred to prevent trees from being damaged (Fruit South Africa, 2004). The picking team is split into two groups; namely, ground pickers and top pickers. The ground pickers pick the fruit growing in the lower part of the tree while the top pickers pick the fruit from the higher parts of the tree, while standing on ladders.

Plums are picked one at a time, using the palm of the hand, by twisting and pulling the fruit downwards (Colors, 2012). The fruit should be carefully placed into picking buckets, bags or baskets. Once a picking bag or basket has been filled, the fruit is deposited into a fruit bin. These bins are either made of wood or a synthetic material like plastic and should be lined with liners (Colors, 2012). They are placed in a strategic place in the orchard, usually at the end of a row of trees. Once a bin is filled, it is moved by a forklift to the nearby trailer. It is essential that the trailer is positioned somewhere in the shade to prevent the plums from heating after being picked (Fruit South Africa, 2004).

Once the trailer is full, the tractor either transports the fruit to the pack house on the farm or in the event where a farm does not have its own packing facilities, the tractor moves it to a place of shade on the farm where a truck will pick up the bins and transport them to a nearby pack house. The bins are moved to an undercover area in the orchard, where they are stacked in the shade. Wet blankets are thrown over each bin to prevent sunburn, rub marks and exposure to dust while waiting for a truck to transport it to a nearby pack house. Instead of blankets, wet hessian bags can also be used.

Because plums develop severe rub marks when picked at high temperatures, they should not be picked in conditions warmer than 30°C and normally no later than 11:00am. However, it was observed that farms do not always follow these protocols. A farm in the Paarl region was visited at 12:00 where the picking process was still under way in temperatures of 35°C. Filled bins were moved to a shaded place in the orchards and left there until late afternoon (around 16:00) when the truck arrived. This is not ideal as it is protocol that the fruit should be moved from the orchards as quickly as possible and field heat should be removed within two hours of picking by reducing the pulp temperature of the fruit to between 15°C and 20°C. The protocol is unfortunately not always adhered to.

2. Transport from farm to pack house

It is protocol that fruit should not be stored on the farm for longer than six hours when the pack house is situated within 40km of the farm. In areas more than 40km from the pack house, the fruit should be delivered within eight to ten hours from the time of picking (Colors, 2012).

Fruit bins should be loaded onto a truck while standing in the shade. Sponges should be placed on the bed of the truck underneath the bins as well as between bins to minimize fruit damage during transportation.

A curtain truck is the preferred option when transporting the fruit from the farm to the pack house. As the truck is not refrigerated it is protocol that if the farm is further than 40km from the pack house, the fruit should be transported in the early morning in order to reach the pack house before 09:00 (Fruit South Africa, 2004). In the event of using a flatbed truck, sand-free canvases should cover the bins. The canvas should be tightly secured to prevent fluttering and damaging of the fruit. It was observed that very little of the fruit is transported to the pack house in the early morning as the protocol states. Fruit is often picked during the morning and transported to the pack house in the afternoon. This creates a problem as the fruit is transported in unrefrigerated trucks during warm conditions.

3. Receive fruit at pack house

Once the truck arrives at the pack house, it is critical that the truck is parked in a shaded area. It is important to offload the fruit from the truck as soon as possible. Protocol states that plums should be offloaded within 30 minutes after arrival at the pack house. A sample is drawn of ±200 plums from different orchards of which the pressure, sugar levels and pulp temperatures are tested.

The fruit bins are then transported by forklifts to the cold room where the field heat is removed from the fruit. In the cold room the bins are stacked with enough space around each pallet to ensure effective cooling. The humidity in the cold room should be kept between 90% and 95%. Humidity levels that are too high (near 100%) may lead to condensation.

4. The packing process

The temperature inside the pack house should be kept below 25°C. This is, however, very often neglected and most pack houses visited were observed to be at temperatures of around 30°C. This is a definite break in the cold chain which needs to be addressed. Pack houses should be equipped with a sufficient air conditioning system inside the packing area.

The packing process begins with forklifts transporting the plums from the cold room into the pack house. It is ideal for the bins to be brought in one by one as this ensures that the plums are kept in the cold room as long as possible before being packed. Once inside the pack house, the bin is put onto a machine which slowly tips the bin to roll the plums onto a conveyer belt. The conveyer belt feeds the fruit to a station where the fruit is sorted by labourers into local and export fruit. The one side of a pack house is dedicated to export packing stations while the other is for local packing. Usually the amount of fruit packed for the export market is far more than that of the local market and therefore there are fewer local packing stations than those dedicated for export markets.

All the damaged and sub-standard fruit is placed on a separate conveyer belt which ends up falling into a bin. These fruits are either thrown away or sold to hawkers at a low price.

Once the local and export fruit have been separated from each other, the local fruit moves along its own conveyer belt to be packed at one end of the pack house, while the export fruit moves along another conveyer belt to the other end of the pack house. On these conveyer belts, each plum is weighed, counted, checked for the right colour under infra-red lights as well as sorted according to size. Plums with similar characteristics move on the same route to the same packing stations. Each packing station is dedicated to a specific market and packed into the correct packaging as required by that specific market.

5. Palletisation

Once a carton of plums arrives at the end of the conveyer belt it is weighed, labelled and stacked onto a wooden pallet by labourers. Each labourer is typically responsible for the pallets of a specific market. Cardboard boxes for the same market are stacked onto the same pallet. The number of cartons stacked onto a pallet depends on the size and depth of the cartons used. Plastic or cardboard corner pieces (angle boards) are placed over the fully stacked pallet which is secured with securing strips (Fruit South Africa, 2004). A ventilated top sheet or pallet cap is placed over the top of the pallet. Finally, a pallet identity sticker is placed on all four sides of the pallet. This sticker contains all the relevant details about the plums being transported (Fruit South Africa, 2004). On each pallet a thermocouple is inserted into a plum in a carton at the centre of the pallet to enable the monitoring of pulp temperatures in the cold store (Fruit South Africa, 2004).

6. Movement of pallets from pack house to holding room

The completed pallets are now moved by forklifts into the holding room. The temperature of the holding room is normally set at between 8°C and 12°C. A holding room typically has two main functions. The first function of a holding room is to accumulate enough pallets before moving them into the cold store. Cold stores mostly operate through forced-air cooling tunnels which entails that pallets are placed into tunnels where the pulp temperature of the fruit is reduced to minus 0.5°C. The tunnel has to be filed with pallets in order to work effectively. If a tunnel is only half full, the cooling process will not be effective. Therefore, the holding room is used to store pallets until there are enough to fill a tunnel. The pallets are statically cooled inside the holding room waiting to be inspected and approved by a PPECB member before moved into the tunnels.

Once the pallets have been cooled in the cold store and the fruit pulp temperature has been reduced to minus 0.5°C, the pallets are moved back into the holding room where the pulp temperature of the fruit is monitored to stay at minus 0.5°C. This is the second main function of a holding room.

It is important to note though, that not all pack houses make use of holding rooms. During these circumstances pallets are moved straight from the pack house into the cold store and straight out of the cold store into the staging area or container.

7. Moving pallets into the cold store

Once the pallets have been approved and there are enough pallets to fill a forced air cooling tunnel, the pallets are moved by forklifts from the holding room to the cold store. The pallets are stacked into the forced-air cooling tunnels where the temperature of the tunnel is set at a specific temperature, which is minus 0.5°C for plums.

Forced-air cooling tunnels have large fans in the ceiling of the tunnel pulling the warm air out of the tunnel as quickly as possible, while at the same time cool air is circulated through the pallets inside the tunnel. It is important to stack the pallets in a manner which supports effective airflow through the tunnel in order for the fruit to cool down as quickly as possible. The fruit will not cool down to the ideal temperature when a tunnel is only half full.

8. Holding room

Once the pulp temperature has been reduced to minus 0.5°C, the pallets are ready to be moved into the holding room where they will stay until a loading instruction is received. In the holding room, the pulp temperature of the fruit is monitored to stay at minus 0.5°C.

9. Staging area

Once the loading instruction has been received, the fruit pallets are moved by forklifts into the staging area. A staging area is a room where pallets are staged per container the day before those pallets are loaded. The pallets for each container are stacked according to the specific location indicated in the staging area. Figure 1 illustrates the marked floor of a staging area where the "1" indicates the specified area for the 20 pallets to be loaded into the first container scheduled to arrive at the cold store the next day. The 20 pallets are stacked in a row behind each other. In the same way, all the other pallets to be loaded the next day are stacked per container. The temperature of the staging area is also set at minus 0.5°C. By making use of a staging area, the loading process is simplified and time is saved.

Figure 1: Pallets stored in staging area ready for transportation

10. Loading of a container

Once the truck arrives at the pack house, the container should be inspected to determine whether it is clean, undamaged and whether the temperature of the container is set at minus 0.5°C. Only when the container has been approved, can the loading process proceed.

Forklifts transport the pallets from the staging area into the container. It is extremely important that the pallets are loaded correctly into the container to achieve maximum airflow through the container. A maximum of 20 pallets should be loaded into a 40 foot container.

The cold chain of plums described above is illustrated step-by-step in Figure 4.2.

Figure 2:Step-by-step illustration of plum cold chain from farm to cold store

1: Picking and placing of plums into picking buckets assisted with ladders

2: Tractor standing in the shade while bins are filled with plums as they are being picked

3: Bin filled with plums on a tractor standing in the shade

4: Filled bins are transported by tractor to a place of shade on the farm where a truck will collect the bins for transport to pack house

5: Receiving area at pack house where trucks arriving with plums are offloaded

6: Inspection of fruit arriving at pack house. Stone quality, pressure and sugar levels are measured

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7: Fruit bins are placed inside the pre-cooling room

8: Fruit bins being transported to the packing line after being pre-cooled

9: Plum bin tipped onto conveyer belt to proceed on packing line

10: Plums being sorted into local and export fruit

11: Plums being weighed and colour checked before dropping into the correct packing lane

12: Fruit arriving at packing stations

13: Plums being packed as specified by specific markets

14: Packed plum cartons proceeding to the palletisation area

15: Labeling being done

16: Plum cartons being palletised

17: Forklift transporting a pallet to the cold store

18: fruit pallets being put into cold storage

19: Forced air cooling tunnels inside cold store

20: Monitoring of plum temperature inside holding room

21: Pallets stored in staging area ready for loading

22: Forklift lifting pallets into container

Appendix B: Summer pear cold chain from farm to cold store

Summer pears are extremely susceptible to loss of firmness when the cold chain of the fruit is not maintained from the moment it is picked. Warm temperatures result in water loss and fast ripening which again leads to a short shelf life. It is, therefore, critical that the cold chain of summer pears is maintained effectively.

1. Picking of summer pears

The cold chain of the summer pear supply chain begins directly after the fruit has been picked from the tree. Before pears are picked, orchards should be monitored regularly for maturity by taking large enough samples to be representative of the block (Fruit South Africa, 2004). The maturity of pears is determined by internal as well as external factors. Internal factors include pressure levels, stone quality as well as sugar levels to a lesser extent. External factors include fruit size, skin colour and firmness of the fruit. Firmness of the fruit is the main indicator of maturity in summer pears.

There are seven main summer pear cultivars grown in South Africa and these cultivars mature at different times. Therefore it is important to strictly monitor the maturity of these fruits.

Just as with plums, pears grow on trees and the picking process is assisted with ladders in order to reach the fruit positioned high in the trees. Lightweight ladders are preferred to prevent trees from being damaged (Fruit South Africa, 2004). The picking team is split into two groups; namely, ground pickers and top pickers. The ground pickers pick the fruit growing in the lower part of the tree while the top pickers pick the fruit from the higher parts of the tree while standing on ladders.

Pears are picked one at a time, using the palm of the hand, by twisting and pulling the fruit downwards (Colors, 2012). The fruit is placed into picking buckets, bags or baskets. Once a picking bag or basket has been filled, the fruit is deposited into a fruit bin. These bins are either made of wood or a synthetic material like plastic and should be lined with liners (Colors, 2012). They are placed in a strategic place in the orchard, usually at the end of a row of trees. Once a bin is filled, it is moved by forklifts to the nearby trailer. It is essential that the trailer is positioned somewhere in the shade to prevent the pears from heating after being picked (Fruit South Africa, 2004).

Once the trailer is full, the tractor either transports the fruit to the pack house on the farm or in the event where a farm does not have its own packing facilities, the tractor moves it to a place of shade on the farm where a truck will pick up the bins and transport them to a nearby pack house. The bins are moved to an undercover area in the orchard, where they are stacked in the shade. Wet blankets are thrown over each bin to prevent sunburn, water loss and exposure to dust while waiting for a truck to transport it to a nearby pack house. Instead of blankets, wet hessian bags can also be used.

The ideal time to pick summer pears is in the early morning when the outside temperature is relatively low. Summer pears are extremely sensitive to warm temperatures and should never be picked in conditions higher than 30°C.

2. Transportation of summer pears from farm to pack house

In the event where a farm does not have its own pack house facilities, the fruit must be transported by truck directly from the orchards to a nearby pack house. It is critical that the summer pears are removed from the orchards as quickly as possible after being harvested. Summer pears are sensitive to warm temperatures and standing in the orchard for long periods of time during the summer will have a negative effect on the quality of the fruit.

It is protocol that fruit should not be stored on the farm for longer than six hours when the pack house is situated within 40km of the farm. In areas further than 40km from the pack house, the fruit should be delivered within eight to ten hours from the time of picking (Colors, 2012).

Fruit bins should be loaded onto a truck while standing in the shade. Sponges should be placed on the base of the truck underneath the bins as well as between bins to minimize fruit damage during transportation. Just as with plums, a curtain truck is the preferred option of transportation for this link of the supply chain.

3. Receiving of pears at pack house

Trucks arriving at the pack house should be parked in a shaded area to prevent decaying of the fruit. The receiving areas of pack houses in South Africa tend to be an open area outside the pack house covered with a roof. Shaded outside parking is not sufficient during the warm summer months. Figure 1 illustrates the receiving area of pack house where it is clear that the roof covering the receiving area does not always ensure a sufficiently large shaded area, depending on the time of the day.

Figure 1: Receiving area at Pack House

Trucks should be offloaded quickly after arrival to ensure that the pears are cooled as soon as possible after being picked. Summer pears should be offloaded within 30 minutes after arrival at the pack house. During peak times a lot of trucks could arrive at the pack house at the same time, which inevitably causes delays.

While the pear bins are being offloaded from the truck into the pack house, samples are drawn from the fruit to inspect the pressure and sugar levels of the fruit. Sugar levels are not as important with pears as they are with plums and grapes. Only a few markets specify what sugar levels pears should have. The pressure level, however, should be between seven and ten on a fruit pressure gauge. Once the fruit has been approved, the pear bins are ready to be stacked into the pre-cooling room.

4. Stacking of bins into pre-cooling room

The pear bins are moved by forklifts into the pre-cooling room. The function of the pre-cooler is to remove the field heat from the fruit and to cool down the fruit as quickly as possible after being picked. The temperature of the pre-cooling room is set above dew point, usually between 15°C and 18°C. The room temperature will rise slightly after the pears have been placed inside the pre-cooler as the pulp temperature of the fruit coming in, is normally much higher than the room temperature because of the field heat in the fruit. The pulp temperature of the pears coming into the pre-cooling room depends on the conditions the fruit was picked in, the type of truck it was transported on to the pack house, as well as the time it took for the pears to be offloaded at the pack house.

As the density of pears are relatively high when compared to other fruit types such as plums and grapes, pears take longer to cool down when placed into the pre-cooling room. Because of this, some pack houses stack the incoming pears in the pre-cooling room only along the sides of the room close to the cooling unit. This ensures that the field heat is removed from the fruit as soon as possible. Other fruit types with lower densities can be stacked towards the middle of the pre-cooling room. Figure 2 is a picture taken of a pre-cooling room to illustrate this.

Open area where cool air is less effective than along the sides of the room. Pear bins are only stacked along the sides of the room because of the high density of the fruit.

Figure 2: Pre-cooling unit stacked with pears

5. Packing of pears

Once the field heat has been removed from the fruit, the bins are moved by forklifts from the pre-cooling room to the pack house. In some cases where the pre-cooling room and the pack house are not situated next to each other, the bins are transported with large tractors to enable moving more bins at a time. The fact that the bins are moved by a tractor means that the fruit will have to wait longer than those that are moved by forklifts. In the event where the pre-cooler and the packing line are situated within the same building, summer pears can now stay inside the pre-cooling room for longer. The bins are transported by forklifts from the pre-cooling room into the pack house as needed on the packing line. Figure 3 is a picture illustrating this.

Figure 3: Bins being transported into the pack house shortly before packing

It is interesting to note the difference in the pulp temperatures of summer pears just before being packed. Pulp temperatures measured included temperatures of 4.2°C, 6.8°C, 7.2°C as well as 17.1°C. The reason for this difference in pulp temperatures could be the fact that some pears are taken out of the cold store while others come from the pre-cooling room before they are packed. Fruit coming out of the cold store will be cooler than those coming from the pre-cooling room.

Once a pear bin reaches the start of the packing line, a machine mechanically picks up the bin and slowly tips it to roll the pears into a waterline. The water pumped into the waterline is not chilled before the pears are placed into the line; the cooled pears coming from the pre-cooling room results in a drop in the temperature of the water. The pears are washed by moving through the chlorified waterline. The waterline vibrates to ensure that the fruit is washed clean from sand and dust. Figure 4 is a picture taken to illustrate the vibration within the waterline.

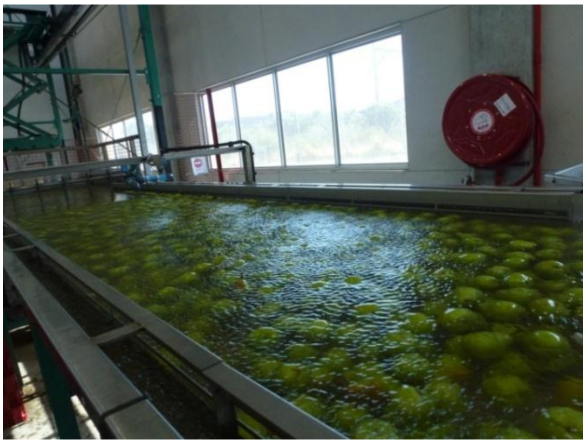

Figure 4: Waterline vibrating to clean pears

After being washed, the pears are dried by a unit blowing cold air. Cold air is used to ensure that the fruit stays cool. The reason for drying the pears is to prevent fungal growth and in the event where post-harvest treatments are applied, the fruit should be dry (Fruit South Africa, 2004).

Once the pears have been dried they move along the line to be pre-sorted into class 1, 2 and 3 categories, class 1 being the highest quality. The pears are sorted by labourers in the pack house who check the fruit for sunburn and bruises. The class 1 pears are packed for either export or local markets, the class 2 pears are sold to hawkers, and the class 3 pears are used for the production of juice.

After being sorted, only the class 1 pears move along to the packing stations. The class 2 and 3 pears move along other conveyer lines to appropriate areas. The class 1 pears move over scales positioned within the conveyer belt. The pears are weighed and moved to the correct packing stations accordingly. For some pear cultivars, the fruit is also checked for colour by an infra-red lighting system.

Once the pears arrive at the packing stations, labourers begin the process of packing the pears into the respective packaging as required by each market. The fruit is graded at each packing station on a number of factors including blemishes, colour, rub marks and size. Buyers order specific volumes of small, medium and large fruit units (Fruit South Africa, 2004). The majority of the packing stations are allocated for export markets as the number of pears being exported are much larger than those sold locally. It seems that the cardboard boxes used as packaging tend to have very few holes to support the cool airflow through the fruit during its voyage. Figure 5 is an example of a carton with only a few holes.

Figure 5: Carton used as pear packaging

Once the cardboard box is filled with pears, the labourer places a label onto the carton which contains important information such as the cultivar, the class category, the count number, the farm of origin and the name of the pack house.

Some pack houses have separate rooms where all the cartons are stacked and stored. The cartons are hung onto an air-conveyer which follows a route into the pack house. The cartons are taken down by labourers and filled with fruit. The carton store is usually unbearably hot. This means that the temperature of the cartons used as packaging can be unnecessarily warm. This is not ideal when the goal is to keep the pears as cool as possible throughout the supply chain. The cooling time of the fruit could be shorter if the cartons used are already cool at the start of the packing process.

6. Palletisation

Once the cardboard boxes have been filled and labelled, they are either put back onto the conveyer belt to proceed to the place of palletisation or, when each packing station has its own place of palletisation next to the station, the labourer stacking the pallet collects the box from the station and stacks it onto the pallet.

Each labourer is typically responsible for the pallets of a specific market. Cardboard boxes for the same market are stacked onto the same pallet. The number of cartons stacked onto a pallet depends on the size and depth of the cartons used. Plastic or cardboard corner pieces (angle boards) are placed over the fully stacked pallet which is secured with securing strips. (Fruit South Africa, 2004). As the boxes are stacked higher and higher, a labourer straps the pallet to ensure stability during the voyage. A ventilated top sheet or pallet cap is placed over the top of the pallet. Finally, a pallet identity sticker is placed on all four sides of the pallet. This sticker contains all the relevant details about the pears being transported (Fruit South Africa, 2004). On each pallet a thermocouple is inserted into a pear in a carton at the centre of the pallet to enable the monitoring of pulp temperatures in the cold store (Fruit South Africa, 2004).

A problem noticed in some pack houses was the worryingly high temperature of the fruit after being palletized. The temperature inside a pack house should never exceed 25°C. One specific pack house claimed to follow a protocol that the pulp temperature of the pears should not rise above 12°C during the packing process, and should therefore not leave the pack house with pulp temperatures higher than this temperature. Observations made, however, tell a different story. Pulp temperatures of four pears from four different pallets arriving at the cold store were measured and showed respective temperatures of 15.5°C, 17°C, 29.2°C and 29.5°C. Pulp temperatures measured in the same pack house just before the fruit was placed onto the packing line showed temperatures of 6.8°C, 7.2°C and 17.1°C respectively. These differences in temperatures between measurements taken just before packing and just after packing illustrates the large impact that the room temperature of the pack house has on the pulp temperature of the fruit. Figure 6 is a picture of one of the measurements being taken just after the packing process. This indicates that the temperature of the pack house is much too high and protocols are not being followed leading to breaks in the cold chain.

Figure 6: Pulp temperature measured on arrival at the cold store after being packed

The same procedure was followed at another pack house where pulp temperatures of fruit were measured just before and just after the packing process. The pulp temperature of a pear just before being placed on the packing line measured 4.2°C whereas the measure taken just after the packing process was 14.4°C. Figure 7 illustrates the measuring of the pulp temperature of pears.

Figure 7: Measuring the pulp temperatures of pears just before being packed

7. Moving pallets into the holding room

Once enough pallets have been filled, they are transported by forklifts into the holding room. The pallets are statically cooled waiting to be inspected and approved by a PPECB member.

The holding room has two specific functions. The first function of the holding room is to accumulate enough pallets to fill one of the forced-air cooling tunnels used to cool down the fruit in the cold store. A forced-air cooling tunnel does not cool fruit effectively when the tunnel is only half full and therefore pallets are stored in the holding room until there are enough pallets to fill one of these tunnels. Typically 60 pallets fill one of these forced-air cooling tunnels.

A second function of the holding room is to store pallets after being cooled down to the specified temperatures in the forced-air cooling tunnels. Once the pallets have reached the ideal temperatures in the cold store, the tunnels are opened and the pallets are moved straight to the holding room where the pulp temperature of the fruit is monitored to stay at these specified temperatures. The pulp temperature of summer pears should be reduced to minus 1.5°C. By moving these pallets back into the holding room, the space in the tunnels can be used more efficiently.

It is important to note though, that not all pack houses make use of holding rooms. During these circumstances pallets are moved straight from the pack house into the cold store and straight out of the cold store into the staging area or container.

8. Moving pallets from the holding room to the cold store

Once the pallets have been approved and there are enough pallets to fill a forced-air cooling tunnel, the pallets are moved by forklifts from the holding room to the cold store. The pallets are stacked into the forced-air cooling tunnels where the temperature of the tunnel is set at the required temperature.

Forced-air cooling tunnels have large fans in the ceiling of the tunnel pulling the warm air out of the tunnel as quickly as possible while at the same time cool air is circulated through the pallets inside the tunnel. It is important to stack the pallets in a manner which supports effective airflow through the tunnel for the fruit to cool down as quickly as possible. Figure 8 is a picture taken of an empty tunnel to illustrate the fans in the ceiling of the tunnel indicated by red arrows.

Figure 8: Empty forced-air cooling tunnel

The tunnel must be completely filled with pallets as the fruit will not be cooled effectively when the tunnel is only half full.

Different pack houses set their forced air cooling tunnels at different temperatures. One pack house claimed to set the temperature of the tunnel at minus 1°C whereas another pack house set their pear tunnels at a temperature of minus 4°C. The time the fruit stays in a tunnel also differs from pack house to pack house. The first pack house stated that the pulp temperature of their pears are reduced to a temperature of between 0°C and 1°C within two days, while the other pack house stated that their summer pears take at least five days in the tunnel to be cooled down to pulp temperatures of between minus 1.5°C and minus 2°C. The reason for this difference in time to bring down the temperature of the summer pears could be explained by the fact that the fruit of the second pack house are moved directly from the pack house into the forced air cooling tunnels, while the other pack house's fruit is first put into a holding room where fruit is already cooled. The pulp temperature of the fruit entering the first pack house's tunnels are thus expected to be lower than those entering the second pack house's tunnels. Another possibility could also simply be that the cooling facilities of the first pack house are more powerful as it is a newer facility than the second pack house.

Figure 9 indicates a forced-air cooling tunnel in action while Figure 10 illustrates a forced-air cooling tunnel opened after the fruit has reached the ideal temperature and is ready to be moved to either the holding room or into a container.

Figure 9: Forced-air cooling tunnel in action

Figure 10: Tunnels opened after cooling

The more tunnels there are inside the same cold store, the longer it takes for the fruit inside the tunnels to cool down. The reason for this is the fact that the incoming fruit raises the temperature of the cold store and the more fruit stored in the cold store, the more the temperature of the cold store rises and the longer it takes for the temperature to drop. In newer facilities the rooms will be smaller, containing only one tunnel or a few tunnels to minimize this problem. Figure 11 illustrates the effect that entering fruit has on the temperature of the cold store. The temperature of this particular cold store was set at minus 4°C, but the warmer fruit entering the cold store caused the room temperature to rise as high as 0.74°C.

Figure 11: Room temperature of cold store illustrating effect of warm fruit entering the cold store

Interestingly the forced-air cooling tunnels in some pack houses do not completely cover the fruit pallets as illustrated in Figure 12.

Figure 12: Forced-air cooling tunnels only covered at the top of the tunnel

It is protocol that summer pears should be cooled to a pulp temperature of minus 1.5°C before the tunnels are switched off and opened.

9. Moving cooled pallets from cold store back to the holding room

Some pack houses make use of holding rooms where pallets are stacked once the pulp temperature of the pears have been reduced to its optimal storage temperature. The use of a holding room enables better space management inside the cold store. Instead of the cooled fruit standing in an opened tunnel in the cold store after being cooled, the pallets are moved to a holding room. Through this process, the tunnels in the cold store are available for incoming fruit.

10. Loading of container

When a truck arrives to load pears, the specific pallets are moved out of the holding room by forklifts to the loading area. The pallets are inspected by a PPECB member. Once the pallets have been approved they are ready for loading into the container. The container is also checked by the PPECB member to ensure that it is clean, undamaged and can be cooled sufficiently.

Forklifts transport the pallets from the loading area into the container. It is extremely important that the pallets are loaded correctly into the container to achieve maximum airflow through the container. Not more than 20 pallets should be loaded into a 40 foot container to ensure sufficient air flow.

It was observed that this activity leads to breaks in the cold chain of pears. The loading areas of most cold stores are not cooled or even covered by a roof. This means that the pears coming out of the holding room or cold store with a pulp temperature of approximately minus 1.5°C are placed in conditions which are much warmer while waiting to be loaded. As the season for summer pears is during summer time, the temperature of the loading areas are sometimes well above 30°C. This leads to condensation and moisture inside the pear cartons which again results in faster decaying of the fruit. Figure 13 illustrates a loading area only covered by a sink roof with no cooling system.

Figure 13: Loading area covered only by a sink roof

The cold chain of summer pears as described above is illustrated step-by-step in Figure 14.

Figure 14: Step-by-step illustration of the pear cold chain from farm to cold store

1: Truck arriving at receiving area.

2: Field heat removed from pears in pre-cooler.

3: Pear bins in pre-cooler.

4: Pear bin lifted onto packing line.

5: Pear bin tipped into chlorified water to proceed to packing line.

6: Sorting of pears into class 1, 2 and 3 categories.

7: Class 1 pears being moved along waterline before being packed.

8: Pears being dried, weighed and checked for the right colour.

9: Receiving, packing and labelling of pears at packing station according to specific market specifications.

10: Packing of labelled pears into cardboard box.

11: Palletisation of filled and labelled cardboard boxes.

12: Palletisation of filled and labelled cardboard boxes.

13: Thermocouples placed in a carton to enable temperature monitoring inside cold store.

14: Completed pallets waiting to be transported to the cold store.

15: Cold store entrance.

16: Pallets packed into tunnels inside cold store.

17: Forced air cooling tunnels in action.

18: Pallets being loaded into container truck to be transported to the port.

Appendix C: Table grape cold chain from farm to cold store

The monitoring of the cold chain of table grapes is extremely important as an effective chain results in fresh fruit for much longer. The export cold chain of table grapes begins once the grapes have been harvested and continues right up to where the consumer buys the grapes at an international retailer. The cooling process should begin from the moment the grapes are cut from the vines. The cold chain of table grapes is now discussed step by step.

1. Picking of table grapes

Maturity indexing is the process followed to determine when grapes are ready to be picked. There are internal and external factors determining fruit maturity (Fruit South Africa, 2004). With table grapes external maturity indicators include grape size, firmness as well as the colour of the grapes. Sugar levels are an internal factor indicating the maturity of table grapes.

Different table grape cultivars reach the right level of maturity or ripeness at different times and, therefore, it is necessary to monitor the ripeness of the fruit regularly. Vineyards are divided into blocks and a certain number of fruit units are selected per block for sampling (Fruit South Africa, 2004). The first samples are taken three to four weeks before the grapes are expected to be mature and continues until it has been determined that the fruit is ready to be harvested (Fruit South Africa, 2004).

Table grapes are harvested with trimming shears which have rounded tips to minimize the amount of fruit damaged during the picking process (Fruit South Africa, 2004). Each labourer is provided with a trimming shear and bunches are grasped by the stem and clipped free from the vine. Before picking the grapes, it should be determined whether the sugar level of the particular bunch has developed enough. This is determined by either the labourer tasting a grape from each bunch before it is picked or by testing the sugar level with a refractometer. A measure of 15 and higher on the refractometer indicates a high enough sugar level. Table grapes are non-climacteric fruit, which means that the ripening process stops as soon as the fruit has been picked (Fruit South Africa, 2004). This is the reason for grapes to be picked at the preferred sugar level – the sugar level does not change after being harvested.

It is important for the fruit producer to accurately determine the number of pickers that will be needed. The reason for this is that the longer the table grapes are kept on the vine after being fully matured internally, the shorter its shelf life will be (Fruit South Africa, 2004). Fruit quality should not be neglected because of a lack of pickers.

Table grapes should not be picked when outside ambient temperatures are high. The reason for this is that 85% to 95% of the pulp content of grapes consists of water and after being picked the fruit loses its ability to replenish the water lost due to high temperatures and low humidity. Most farms follow the protocol to not pick grapes when the outside temperature rises above 30°C. Grapes in the Orange River region, where extreme temperatures prevail, are therefore either picked during the night (with headlights) or early mornings when temperatures are cooler. This ensures that the fruit enters the cold chain with relatively low pulp temperatures, which is critical when considering lasting quality and freshness. It was, however, observed in the Orange River that farms do not always follow their own protocols in terms of picking the grapes at low temperatures. When asked about this, a typical answer is that the grapes have to be harvested when they have reached maturity and need to be removed from the vine even when the outside temperature is not ideal.

Plastic crates (Lugs) are used for the picking of table grapes. Because of the fragile nature of grapes, bunches are put into crates with much care. The crates are placed in the vineyards the evening before picking and on some farms a layer of bubble wrap is put on the base of each crate to protect the fruit from being bruised. When a crate has been filled, it is left in the shade of the vineyards to be collected by a tractor as quickly as possible. As the grape season is during peak summer, it is critical to remove the grapes from the heat of the sun shortly after being picked. It was observed that although farms intend to remove the grapes from the heat as soon as possible, this is not always the case. Crates with harvested grapes were observed in the vineyards at 12h30 during peak summer in the Orange River region, while the outside temperature was around 40°C. Neglecting the cold chain protocols as illustrated in the example above can have major impacts on the shelf life of the grapes as the quality and freshness of the grapes will be reduced.

Due to increasingly stringent market requirements vineyards can no longer be stripped of all the fruit in one visit. This results in pickers returning to the same vineyard two or three times as not all of the grapes from the same vineyard mature at the same time (Fruit South Africa, 2004).

2. Moving the grapes into the pre-cooling room

The filled crates are loaded onto the trailer of a tractor, which is preferably covered with rubber mats on the base to ensure that the crates are kept as stable as possible in order to minimize fruit damage. The tractor slowly moves the crates filled with grapes to the pack house. This can be a problem in areas where high temperatures prevail as the fruit pulp can heat up en route to the pack house, which will increase the loss of moisture from the fruit (Fruit South Africa, 2004).

Crates should be handled with care from the tractor to the storage room where they are placed onto wooden pallets. A standard of 60 crates are packed onto a pallet. The pallets are weighed to know the net weight of grapes picked.

These pallets are then moved to the pre-cooling room. The pre-cooler is a room with a monitored temperature above dew point, usually between 15°C and 18°C. The aim of the pre-cooling room is to remove the field heat out of the fruit by reducing the pulp temperature of the grapes. The humidity level should be maintained between 85% and 95% inside the pre-cooling room to prevent the grape stems from drying out. This can be achieved through the implementation of “wet walls” or the use of a fogging system.

In the Orange River region it was observed that the temperature inside pre-cooling rooms tend to differ depending on the distance from the fans. Room temperatures varied from 16°C in the area closest to the fans to 21°C in the area furthest from the fans. This leads to a difference in the pulp temperature of grapes coming out of the pre-cooler, which is not ideal.

It was further observed that the pulp temperature of the grapes entering the pre-cooler was higher than it should be. Pulp temperatures of up to 29.4°C were measured, while the ideal temperature of grapes leaving the field is said to be between 17°C and 18°C. This is the reason why table grapes should be picked during the cooler hours of a day (at night or in the early morning).

3. Packing the grapes

Once the field heat has been successfully removed from the grapes, the fruit is ready for the packing process. Crates are mostly moved on a conveyer belt from the pre-cooler straight into the pack house. One of the farms in the Orange River region follows a protocol which allows the fruit to be inside the pre-cooler for a maximum of eight hours.

This protocol also states that the temperature in the pre-cooling room should be 1°C to 3°C (maximum) above the temperature of the pack house, and normally not higher than 18°C. An observation made in most of the pack houses in the Orange River region is that the temperature of the pack house tends to be higher than desired. This indicates a definite break in the cold chain as grapes are cooled in the pre-cooler and then moved into the pack house, which is supposed to have a room temperature similar to that of the pre-cooler, but as observed, tends to be around 30°C. When asked about this, pack house managers seem to be aware of the fact that the room temperature of their pack houses are higher than ideal, but there were no plans in the pipeline to address the problem.

Crates entering the pack house are removed from the conveyer belt. The first step of the packing process inside the pack house is to cut the bruised, blemished and malformed grapes off each bunch. This is achieved with the same trimming shears used in the vineyards. Hereafter the grapes are sorted and graded on the basis of quality, appearance and size (Fruit South Africa, 2004). Each cultivar has different specifications regarding berry diameters based on export markets' requirements. Berries are generally categorized into sizes ranging from regular (R) to large (L), extra-large (XL) and double extra-large (XXL) (Hall, 2012). The colour of the plastic crate identifies the size category of the grapes it contains, for example, grapes of regular size (R) are placed into blue crates.

After being trimmed and categorised, the crates are put back onto the conveyer belt to proceed to the packing stations. There are several packing stations with labourers packing grapes for various markets. Each market has its own specifications in terms of grape quality, size and packaging. Grape bunches are either packed into carton boxes or punnets depending on the market requirements. Once a box or punnet has been filled with grapes, it is closed and a sticker, as prescribed by the market, is placed onto the packaging.

Once the carton box arrives at the end of the conveyer belt, it is weighed and stacked onto a wooden pallet. Cartons for the same market are placed onto the same pallet. The number of cartons stacked onto a pallet depends on the size and depth of the cartons used. Plastic or cardboard corner pieces (angle boards) are placed over the fully stacked pallet, which is secured with securing strips. On each pallet a thermocouple is inserted into a grape in a carton at the centre of the pallet to enable the monitoring of pulp temperatures in the cold store (Fruit South Africa, 2004). A ventilated top sheet or pallet cap is placed over the top of the pallet. Finally, a pallet identity sticker is placed on all four sides of the pallet. This sticker contains all the relevant details about the grapes being transported (Fruit South Africa, 2004).

4. Pallets moved from pack house to the holding room

The pallets are now moved from the pack house into a refrigerated holding room. The temperature of the holding room is monitored to be between 8°C and 12°C. The holding room prevents temperature shock, which occurs when the grapes are put straight into the cold store with a room temperature of 0°C. By first being put into the holding room, the fruit is cooled down systematically.

The holding room has two main functions. Firstly, the cold store normally uses a forced-air tunnel cooling system, which means that the tunnel should be filled with pallets for the cooling to be effective. Therefore, pallets are kept in the holding room until there are enough pallets to fill a tunnel. When pallets are put into the tunnels one by one as they come out of the pack house, the cooling tempo will not be constant.

A second function of the holding room is to store pallets that have already been cooled down in the cold store. This is done to ease space management in the cold store. A holding room can thus be used directly before or after pallets have been placed in the cold store.

In the case where a pack house does not have its own cold store, the holding room comes in handy to keep pallets at a temperature of around 8°C. When the holding room is filled with pallets, the pallets are transported by refrigerated trucks to a nearby cold store.

The holding room also serves as a place of inspection. Pallets are kept in the holding room until the PPECB inspector has approved each pallet.

It is important to note though, that not all pack houses make use of holding rooms. During these circumstances pallets are moved straight from the pack house into the cold store and straight out of the cold store into the staging area or container.

5. Pallets moved from the holding room to the cold store

Once the number of pallets is sufficient to fill a tunnel and have been approved in the holding room, they are ready to be moved into full refrigeration in the cold store. The temperature of the cold store is set between minus 1°C and 0°C (Hall, 2012). The humidity of the cold store should be maintained between 85% and 95% which is achieved by the implementation of "wet walls" or fogging systems (Hall, 2012).

Pallets should be lined up in the direction of the airflow within the room, not across it (Hall, 2012). It is also important to realise the importance of keeping the door of a cold store closed and opening it only when absolutely necessary.

In most cases forced-air cooling is used in cold stores. Pallets are stacked inside tunnels which need to be completely filled before the cooling process is effective. The pallets are stacked tightly against each other to prevent the air from taking shortcuts around the pallets. By stacking them tightly, the air is forced to go through the fruit cartons. Once filled with pallets the tunnel is closed and the temperature of the grapes is reduced to 0.5°C. Once the desired temperature has been reached, the refrigeration of the tunnel is switched off.

6. Pallets moved from the cold store to the loading area

Once the pallets have been cooled down to a temperature between minus 0.5°C, they are moved to the loading area. In the event where the cold store is too full and there are no scheduled loading times in the near future, pallets that have reached the right temperature are moved back into the holding room where their temperature needs to be monitored at minus 0.5°C until they can be loaded into a container.

In the Orange River region it was observed that the ambient temperature of some of the loading areas were very high. Pallets are moved straight out of the cold store into the loading area where they wait to be loaded into the container. This is a definite break in the cold chain as the pulp temperatures of the fruit rise before being loaded into the container. The time that the pallets stand outside in the loading area, where no cooling is available, depends on the time it takes for the paperwork to be done and the container to be approved by the PPECB. The loading of a container should not exceed 30 minutes.

7. Pallets moved from the loading area into the container

Before a container can be loaded, the container should be inspected to determine whether it is clean, undamaged and whether the refrigerated unit is in good working condition. The pulp temperature of the fruit is also measured by a PPECB member. Once the container and fruit have been approved, the loading process can proceed.

Forklifts transport the pallets from the loading area into the container. It is extremely important that the pallets are loaded correctly into the container to achieve maximum airflow through the container. A maximum of 20 pallets should be loaded into a container.

It was observed that the time spent to load a container varies considerably. Some loadings took only 15 minutes, while other loadings took as long as 45 minutes. Because most of the loading points are not temperature controlled, it is safe to assume the shelf life of grapes being loaded into a container within 15 minutes will be longer than those waiting in the loading area for up to 45 minutes.

The cold chain of table grapes described above is illustrated step-by-step in Figure 4.17.

Figure 8: Step-by-step illustration of the table grape cold chain from farm to cold store

1: Grapes ready to be picked from vineyard

2: Mature fruit being picked

3: Picked grapes standing in the shade in plastic crates ready to be cooled

4: Grapes are placed in a pre-cooling unit after being picked

5: Grapes entering the pack house via a conveyer belt from the pre-cooling unit

6: Grapes cut into bunches of the right size and bad fruit is removed

7: Grapes being packed into cartons

8: Temperature sensor placed into fruit for management of the temperature in the cold store

9: Cartons stacked onto pallets

10: Pallets are moved into a cold store to be cooled

11: Cooled pallets are moved into a holding room or a staging area where they are stacked according to container loads

12: Pallets are brought from the cold store or holding room into the loading area once the truck arrives

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13: Pallets are loaded into a truck with forklifts

Appendix D: Cold chain of Summer Pears, Plums and Table Grapes from cold store to the port

Since the part of the cold chain of summer pears, plums and table grapes is similar from the moment the pallets have been loaded into a container at a cold store until the container is loaded onto a vessel, this part of the chain is described only once representing all three fruit types.

The final part of the cold chain of summer pears, plums and table grapes observed and investigated during this study is from the moment the filled truck leaves the cold store up to the point where the vessel sails. This part of the cold chains are discussed in the following section.

Once the fruit pallets have been loaded onto the truck, the truck leaves the cold store embarking on a journey to the port. In situations where this journey takes less than two hours, a generator set (genset) is not required. A genset supplies the refrigeration unit of the container with power and thus enables the container to cool down during the journey on the truck. During short journeys this is, however, not necessary. The doors of the truck are closed tightly and the fruit should stay cool inside the container for these short periods of time. The container will only be plugged in at the port.

For journeys longer than two hours, however, a genset is required. This increases the transport costs considerably. Under these circumstances, the container is set to 0°C once the fruit pallets have been loaded and the doors of the container have been closed.

Arriving at the port gate, the truck joins the queue waiting to offload cargo. This queue can sometimes mean delays for hours. When a truck without a genset is delayed at the port gate for several hours, unable to plug in the container, the temperature inside the container will rise and the quality of the fruit will be negatively impacted.

Figure 1 illustrates delays at the port gate because of a long queue of trucks waiting to offload cargo.

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Figure 1: Trucks queuing to offload cargo at port

Once the truck finally reaches the first position in the queue and enters the container terminal, the container is removed from the truck by a straddle carrier and placed onto a truck-like vehicle, known as a Mafi, which is only used to transport containers within the port. The Mafi transports the container to the reefer stack where a rubber-tyred gantry crane places the container in a specific location indicated for that container. The container is then plugged in and monitored by the Refcon system and port operators. (The Refcon system was discussed in the Literature Review of this study).

The next step in the cold chain is for the reefer containers to be loaded onto the vessel. The reefer is lifted out of the stack by a rubber-tyred gantry crane and is once again placed onto a Mafi which transports the container to the quay. A large quay crane lifts the container off the Mafi and places it onto the vessel. The container is finally plugged in on the vessel. Once all the containers have been loaded onto the vessel, the long ocean journey begins.

Wind is often a cause of delays at the Port of Cape Town. Rubber-tyred gantry cranes and quay cranes cannot operate in strong windy conditions which results in regular delays. The negative impact of wind at the Port of Cape Town was discussed in the Literature Review of this study.

Figure 2 illustrates the process just discussed.

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Figure 2: Cold chain of summer pears, plums and table grapes from cold store to port

1: Once the pallets have been loaded into the truck, the truck leaves for the port

2: A genset is required for journeys of more than 2 hours to the port

3: On arrival at the port gate, trucks wait in line for offloading

4: The container is removed from the truck

5: The container is loaded onto a Mafi

6: Reefer containers are stacked into the reefer yard and reefers are plugged in and monitored by Refcon

7: Rubber-tyred-gantry crane removing a container from a stack and loading it onto a Mafi

8: The Mafi transports the reefer from the stack to the quay

9: Containers are being loaded onto a vessel and are plugged in