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Maintaining cold chain integrity: Temperature breaks within fruit reefer containers in the Cape Town Container Terminal

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ABSTRACT

South Africa is among the top 10 fruit-exporting countries in the world. The South African fruit industry has identified temperature breaks along the fruit export cold chain that result in the deterioration of fruit quality, loss of market credibility, and financial losses. Seventy percent (70%) of South African fruit exports are shipped through the Cape Town Container Terminal (CTCT). This in-depth case study provides a better understanding of the significant challenges within the CTCT. This research revealed that 81% of the temperature breaks in fruit reefer containers carrying summer fruit originate within the CTCT. The average time for a reefer container to be plugged in from when it enters the port is 1 hour and 52 minutes; almost three times higher than the 40-minute goal time. Only one-fifth of containers experienced no temperature breaks, while almost a quarter never cooled down to the target temperature. Operational issues that need to be addressed have been identified, such as the increased use of gensets, improved scheduling for arrival at the CTCT, and training of port personnel as to the correct standards for cold chain management. There is, however, also a need for improved collaboration between the producers, fruit exporters, logistics service providers, the CTCT, and shipping lines to enable end-to-end integrity of the cold chain. The latter will be the subject of future research.

Key words: fruit exports; reefer containers; cold chain; Cape Town Container Terminal; temperature breaks

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Introduction

The South African fruit industry exports approximately 2.7 million tons of fresh produce annually to 87 countries on four continents, which places it among the top 10 fruit-exporting countries in the world (Department of Agriculture, Forestry and Fisheries 2015). In 2013, fruit exports accounted for 50% of South Africa's agricultural exports, with an export value of R19.8 billion (US$1.77 billion). It is a significant employment generator, employing roughly 460 000 people with approximately two million dependants (Kruger 2014; Transport World Africa 2015).

The global demand for fresh fruit has proven to be resilient with regard to economic fluctuations over time; however, the composition of that demand changes as markets mature (Uys 2016). Recent end-consumer demand shifts relate to, *inter alia*, a growing need for exotic fruits to meet demand for variety in both choice and nutrition, and increased requirements for high-quality organic produce. Fruit exporters also compete against expanding local supplies of fresh produce in export markets, especially the UK and Europe, driven by sustainability concerns (such as a lower carbon footprint and less complicated traceability-to-source processes) (CBI 2016; Uys 2016). Export opportunities to the Far East and Middle East are showing high medium-term growth, yet the most immediate opportunities for the expansion of South Africa's fresh fruit exports are still in the country's established destinations of Europe and the USA, with their stringent quality requirements (Uys 2016).

In this demanding market environment, meeting the significant logistical challenges required for maintaining high product quality when exporting large quantities of fresh fruit is imperative. In a global survey, the Nielsen Company (2015) reported that globally, following price, product quality is the second most important driver of consumer-switching behaviour between retailers. First and foremost, in order to ensure end-consumer access to quality fruit, the integrity of the cold chain must be maintained along the whole supply chain – from the point of production through to each of the supply chain phases, that is, loading, transport, unloading, handling, and storage (Salin & Nayga Jr 2003; Berry et al. 2015).

The cold chain is a temperature-controlled supply chain that allows for national and trans-national trade in perishable products, such as fresh fruit and vegetables. The objective of cold chain management is to maintain the integrity of the cold chain through adherence to globally agreed to, product-specific temperature ranges during storage and distribution activities (Rodrigue & Notteboom 2017). Maintaining these temperature standards within the cold chain is the most important factor in inhibiting fruit deterioration and achieving optimal shelf life as it reduces the rate of respiratory maturation as well as opportunities for microbial decay (Berry et al. 2015).

The refrigerated container (commonly known as a reefer container) is becoming the standard temperature-controlled transportation unit as it is fully compatible with the global intermodal transport system (road, rail, or waterways for the inland leg, and shipping for the transoceanic leg), and can accommodate a wide range of perishable products due to the availability of a range of temperature settings.

The move to reefer containers follows the shift to the containerisation of general freight as containers are designed to be moved with common handling equipment, which enables high-speed intermodal transfers in economically large units between ships, railcars, truck chassis, and barges using minimal labour and leaving the cargo intact. The environment in reefer containers is controlled electronically by plugging the container into a generator – commonly known as a genset, which can be attached to a reefer container during transit in order to deliver power to the container's own refrigeration system), into a power source on the ship or truck, or at the reefer stack in port container terminals (Rodrigue & Notteboom 2017). The reefer stack is the area in the port allocated specifically to reefer containers.

The Food and Agriculture Organization of the United Nations (FAO 2011) states that post-harvest losses range between 10% and 15% globally, pointing to challenges facing cold chain management. Recent studies have identified temperature breaks at multiple points along the South African fresh fruit export cold chain that compromise the quality of the fruit that the end-user receives and, ultimately, negatively impacting industry profitability (Freiboth, 2012; Haasbroek 2013; Stander 2014; Goedhals-Gerber et al. 2015).

Due to the proximity of South Africa's fruit production areas to the Port of Cape Town, 70% of summer fruit is exported through this port. The Cape Town Container Terminal (CTCT) therefore plays a crucial role in the handling of reefer containers used for the export of fresh fruit (Brooke 2015). The purpose of this research is to identify the incidence and length of temperature breaks that reefer containers experience within the CTCT leg of the fresh fruit export supply chain by analysing temperature data for reefer containers – from arrival at the CTCT to the point where the container is loaded onto the vessel. This information will inform remedial actions.

This article is organised as follows: the next section reviews literature on the growth in the global reefer container trade and the concomitant challenges of cold chain maintenance, followed by a background to the operational challenges experienced in the CTCT, and aspects highlighted for future research that also impact on cold chain integrity. Thereafter, the problem statement is articulated and the research design and methodology are described. This is followed by a discussion of the research results, and culminates in the conclusion and recommendations.

Literature review

Growth in global reefer trade and cold chain challenges

The share of containerised refrigerated transport capacity as a percentage of the total global transport capacity in maritime shipping increased from 33% in 1980 to 72% in 2013. Traditional refrigerated ships have therefore been replaced by reefer containers using conventional container ships, the majority of which have power outlets able to accommodate reefer containers. This also brought about a shift from the need to handle refrigerated cargo at specialised ports or terminals with cold storage space, to being able to service reefer containers through standard container terminals (Rodrigue & Notteboom 2017). The global growth in the reefer container fleet is depicted in Figure 1.

Approximately 2.02 million 20-foot equivalent units (TEUs[1]) of reefer containers were in operation by 2011 (Rodrigue & Notteboom 2017). Dekker (2014) estimated that total global reefer cargo would increase from 92 million tons in 2014 to 107.5 million tons by 2017; with the growth linked to increased interest in healthy eating, population growth, and improved market access through trade agreements. This growth rate is expected to continue, with 120 million tons of reefer cargo predicted by 2020 (Hellenic Shipping News 2016).

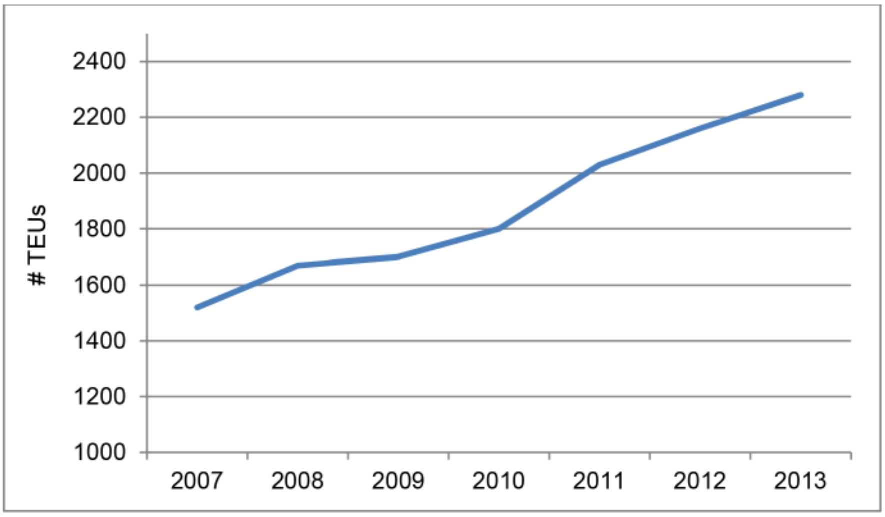

Figure 1: Global growth in the reefer container fleet (number of TEUs) (Dekker 2014)

The growth in reefer container transport increasingly requires port terminals to dedicate a portion of their storage yards to reefer containers, referred to as the reefer stack. Globally, this accounts for between 1% and 5% of total terminal capacity. The stacking requirements are basic – requiring only an adjacent power outlet – but the task is labour intensive as each container must be plugged in and unplugged manually and the maintenance of temperatures within pre-set ranges must be monitored (Rodrigue & Notteboom 2017). The latter issues require a motivated and trained workforce, which is often a challenge, and is one of the key interventions required, especially in developing countries, to improve cold chain management (Winkworth-Smith et al. 2015).

North of England P&I Association Ltd. (2016) identified a number of problems specific to cold chain management experienced in ports throughout the world. Firstly, the power supply to the reefer is not always connected in a timely manner upon arrival and after internal transfers. Secondly, container movements within the terminal are not properly documented. Thirdly, operational personnel do not always provide notification of any irregularities that they observe. Fourthly, containers are stowed at inappropriate locations and near heat sources. Fifthly, there is inadequate or inaccurate temperature monitoring of the reefer containers and/or subsequent recording. Finally, reefer containers can break down or malfunction.

In many developing countries, one of the main obstacles to the expansion of cold chains is the lack of the necessary infrastructure required to maintain cold chains; for example, insufficient plug-in points for reefer containers at port terminals (Miller 2016).

Emenike and Hoffmann (2014) summarised various studies on cold chain integrity that highlight the impact of these challenges on cold chain management, and reported that refrigerated shipments rise above the temperature standards in 30% of the trips from suppliers to distribution centres, and in 15% of the trips from distribution centres to retail stores. Temperature variations during transoceanic shipments were out of the specified range more than 30% of the time, with significant temperature variability both spatially across the width of the container as well as temporally along the trip.

As mentioned in the introduction, the South African fresh fruit export cold chain also experiences breaks at multiple points along the supply chain, which compromises fruit quality. The CTCT is a key node in this chain, facilitating the export of 70% of all summer fruits. A study on temperature breaks in the summer fruit export cold chain by Stellenbosch University and the Council for Scientific and Industrial Research (CSIR), conducted during 2012-2013 (Post-harvest Innovation Programme, 2012-2013), recommended more in-depth research into the role of the CTCT in these temperature breaks. This is the focus of this article. The next section summarises the current literature on operational challenges within the CTCT, which confirms the need to understand the magnitude of temperature breaks within the terminal.

Background to operational challenges experienced in the CTCT

The Port of Cape Town is the second busiest general freight port in South Africa, the first being the Port of Durban. The container terminal handles a wide variety of containerised cargo, including fruit, steel, paper, maize and wheat (Greve 2013).

The challenges surrounding cold chain management in the CTCT has been a recurring theme this century. The Commonwealth Secretariat (2008) compared logistics activities along the cold chain of South African fresh fruit exports with that of its major competitors – Chile and New Zealand. Table 1 presents a summary of the benchmarking analysis that was undertaken for South African ports, comparing them with the major terminals in Chile and New Zealand. Of specific reference to this article is the very poor score on gate access times and costs related to vessel and terminal access delays. Both of these delays have a detrimental impact on cold chain management.

Table 1: Efficiency of port container terminals for reefer exports: A comparison between South Africa, Chile and New Zealand against key criteria (rating 1-5; 5 = high and 1 = low)

Characteristic	**South Africa**	**Chile**	**New Zealand**
Available reefer capacity	4	5	5
Gate access time	2	4	4
Berth productivity	4	3	3
Crane productivity	4	5	3
Dwell time – in stack	4	4	4
Costs of handling (that the shipping line pays the stevedore)	2	3	4
Other costs – vessel and terminal access delays	1	4	5
Total ranking	**21**	**28**	**28**

Source: Commonwealth Secretariat (2008)

By analysing historical data sets for table grapes, apples and winter pears from the pack house to the port between 2009 and 2012, Freiboth (2012) identified that, on average, 65% of the breaks within the South African export cold chain take place within the CTCT. In addition, the study conducted a trial shipment of apples to observe the temperature variations between pallets at opposite ends of the same container during the transport segment from the cold store to the port. The average ambient temperature of the first pallet to be loaded (i.e. closest to the refrigeration unit) was more than 1 °C cooler than the pallet at the door, which could influence the quality and shelf life of fruit.

In a study on table grapes, summer pears and plums conducted between November 2012 and March 2013, Haasbroek (2013: 101) reported that temperature trials and temperature logs received from exporters showed that 46% of the temperature breaks occurred at the interface between the cold store and the truck (road transport leg), and 42% of the temperature breaks took place in the port. In addition, the study found a large number of problems within the CTCT, such as delays during offloading, faulty paperwork, and the unplugging of gensets.

Baetsen (2014) described congestion and inefficiencies in South Africa's ports as of serious concern. In the case of the CTCT, landside congestion is usually experienced both at entrances to the port and inside the port (Potgieter 2015). During peak season, trucks can experience long delays while waiting outside the port gate to enter. The city infrastructure, which developed around the existing port, limits the capacity and growth of the port and its terminals. In addition, rising volumes of commuter traffic into the metropolitan area have also contributed to higher levels of road congestion around the Port of Cape Town. Furthermore, there is a lack of coordination between the two entities responsible for port financing and decision-making, namely Transnet National Ports Authority (TNPA) and the City of Cape Town Metropolitan Municipality, which delays port improvements (De Wet 2014: 67).

Congestion also has a negative impact on transportation costs, which is already a major constraint to the fruit industry due to a reliance on road transport and high port tariffs. Almost all fruit exports are transported from the production regions to the ports by road transport. The fruit export industry spends R970 million on road transport costs annually (Pieterse et al. 2016). There is an opportunity for specialised reefer trains to serve segments of this market; lowering transport costs through consolidation, improved scheduling, and improved access to terminal facilities. Baetsen (2014) confirmed that the South African railway system has the potential to serve the fruit industry, provided that there is adequate investment in infrastructure and better management.

A collaborative effort between the South African fruit industry, Transnet Freight Rail (TFR), Transnet Port Terminals (TPT), and the TNPA is achieving good results in moving fruit transport from road to rail with the use of specialised reefer trains that transport fruit in refrigerated containers. TPT works closely with TFR to coordinate the timing of the arrival of the reefer trains in the Port of Cape Town, and they prioritise the allocation of sufficient resources to receive and offload the containers. The trains' siding in the Port of Cape Town is positioned close to the electrical plug-in stacks and the unloading process can be completed within a short turnaround time, which facilitates cold chain maintenance (Brooke 2015).

Congestion challenges are also compounded by the last-minute delivery of containers to the CTCT by road transporters, which put a strain on the container terminal resources and could mean that containers remain without power for long periods of time. If a container arrives within a few hours of having to be loaded onto the vessel, it is ineffective for the container terminal to offload the container in the reefer stack, plug it in, and unplug it again soon afterwards to be loaded onto the vessel. Containers arriving late are often placed in a stack closer to the vessel with the intention of loading them as soon as possible and they are thus not always plugged into a power source (Stander 2014).

In addition to these operational challenges, further offloading and loading delays occur when wind speeds are too high for the cranes to operate safely. The whole container terminal can essentially come to a halt as the majority of terminal operations are dependent on cranes. The windiest season in Cape Town is from December to February, which is also the peak summer fruit season (Van Marle 2013). Weather delays, according to TNPA (Birkenstock 2015), is defined as time delays (in hours) resulting from high wind speeds, thick fog, vessel ranging, strong underwater currents, and large ocean swells. Weather delays for the months of December to the end of February for the years 2011 to 2014 were recorded to have caused an average delay of 12.76 hours, that is, ocean carriers calling at the Port of Cape Town were delayed by an average of 12.76 hours between 2011 and 2014.

A possible solution to weather-related delays would entail the upgrading of the terminal equipment to handle higher wind speeds. The coast of Kalimantan, home to various ports in Indonesia, also experiences demanding weather conditions similar to that of the Port of Cape Town. Three floating cranes were deployed for use around the coast of Kalimantan and the various ports in the vicinity. These cranes can operate at wind speeds of up to 86.4 km/h and maximum wave heights of 2.5 m (Yellow & Finch Publishers 2014), compared to the maximum wind speed of 72 km/h at which the rubber-tyred gantries employed in the CTCT can operate. Currently, the Port of Cape Town owns only one heavy-lift floating crane (Ports & Ships 2014).

The impact of delays on the cold chain is increased when the reefer containers are not connected to a genset, which powers the reefer container while on the truck, while delays are experienced en route to the reefer stack, or while waiting to be loaded onto the ship (Hancock 2011).

As part of the process of reefer container management, the CTCT implemented two IT systems. The NAVIS system – a web-based terminal operating system that allows real-time planning, scheduling, and tracking of cargo by TPT and their clients along land and terminal routes – was implemented at the CTCT in April 2012 and is currently operational in 21 marine and rail terminals in South Africa (Haasbroek 2013: 35). The Refcon system remotely monitors the state of reefer containers while they are stored in the container yard and while they are loaded onto a container ship. The Refcon system allows complete visibility of the status of reefer containers in the stack yard of the CTCT. There has been a reduction in the number of temperature breaks experienced in the CTCT following the implementation of the NAVIS and Refcon systems. Prior to the application of the systems, 47.2% of the breaks originated in the port, while 41.5% originated in the port post-application (32.8% in the reefer stack and 8.7% when the fruit is being loaded onto the vessel) (Goedhals-Gerber et al. 2015: 10).

This section highlighted the operational challenges experienced within the CTCT that could hamper cold chain management. In the next two sections, the problem statement and resulting research methodology applied in this article to quantify the incidence and length of temperature breaks within the CTCT are described. The ability to quantify the impact of these operational challenges on the ability to maintain the integrity of the cold chain can provide the impetus to address these challenges.

In closing, it is important to note that the literature survey also revealed challenges in other areas of the South African fresh fruit export supply chain that impact the ability of the CTCT to play its role in the maintenance of the cold chain. While not the focus of this research, it is important to note that collaboration along the whole supply chain is imperative for end-to-end cold chain management. Two examples are highlighted in the following sub-section. This is only indicative of the scope of challenges faced, and understanding and prioritising challenges to the end-to-end integrity of the cold chain will be the subject of future research.

Cold chain challenges prior to the CTCT leg

Haasbroek (2013) identified the fact that key post-harvest protocols to cool down fruit are frequently not followed, which results in fruit temperatures exceeding agreed norms when loaded into the reefer container. Neglecting this creates cold chain maintenance challenges from the outset and compounds the challenges encountered during subsequent supply chain links. Reefer containers are designed to maintain the temperature of their cargo in the specified range, not to lower it, and cargo must therefore be pre-cooled to the global standard carrying temperature (Rodrigue & Notteboom 2017).

Berry et al. (2015) found that 11 different types of ventilated corrugated carton designs were used in the export of pome fruit (i.e. apples and pears) from South

Africa, with the highest incidence of a single design occurring only 48% of the time in the case of apples and 57% of the time in the case of pears. In addition, each design is used in different dimensional formats to accommodate varying fruit sizes and market requirements, which demand different pallet stacking configurations. Improper vent positioning may result in non-alignment of ventilation in stacked pallets, which in turn may alter airflow patterns during forced-air cooling. The authors found no evidence of a move towards a standardised approach to optimise vent design.

Problem statement

Operational challenges experienced within the CTCT could impact the integrity of the cold chain. A lack of information regarding the magnitude of temperature breaks within the CTCT is hampering the ability and willingness of various stakeholders to address these operational challenges. This information will offer a better understanding of the problems faced and will provide impetus to address the challenges.

Research design and methodology

The purpose of this research is to identify the incidence and length of temperature breaks that reefer containers experience within the CTCT leg of the fresh fruit export supply chain by analysing temperature data for reefer containers from arrival at the CTCT to the point where the container is loaded onto the vessel.

This research utilised a case study approach, which involved the collection of both primary and secondary data. The secondary data were collected by conducting a desktop survey of similar studies undertaken in the past. In addition, information was collected on the procedures that fresh fruit undergo in the CTCT. Most of the secondary data consisted of qualitative information. Primary data were collected on the temperatures within fruit reefer containers exported through the CTCT. The primary data consisted of both qualitative and quantitative collected data.

The research instruments used for the qualitative portion of the primary research included personal interviews, observations (which involved 12 weeks spent at the CTCT), and e-mail correspondence, while the quantitative research element was fulfilled through temperature trials and the collection of Microsoft Excel data sheets from the participants that pertained to the temperatures within the fruit reefer containers exported through the CTCT. These data were analysed using graphical statistics such as line charts, pie charts, and bar charts.

For the purposes of this research, 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 reefer container rose above 2 °C for longer than 90 minutes"*. Globally there are five temperature standards for cold chains. The temperature standard of 2 °C comprises the standard refrigeration temperature and is commonly used to transport fruit, vegetables, and fresh meat as it provides optimal shelf life without freeze damage (Rodrigue & Notteboom 2017).

In order to identify temperature breaks of intra-Southern African fruit and vegetables exports, Emenike and Hoffmann (2014) also triggered temperature breaks below 0 °C and above 2 °C.

Data on the temperatures within fruit reefer containers exported through the CTCT were collected from three sources, namely fruit exporters, shipping lines, and the TPT.

The temperature data collected by fruit exporters are logged using temperature-monitoring devices such as iButtons®, which capture the ambient temperature in a container at pre-set intervals for the duration of the shipment. The monitors are inserted into a carton of fruit – usually in the pallet closest to the door – just before the container is sealed. Once the container is opened at the final destination, the temperature data are captured by manually downloading them from the device and sending them to the exporter. The temperature data are not available in real time, because the infrastructure required to support real-time data is too expensive, which makes the option unfeasible. The temperature is measured every 30 minutes. Temperatures from a total of 121 containers (or 17% of the total number of containers) passing through the Port of Cape Town between January 2014 and March 2014 for the identified fruits were monitored using iButton® devices; namely 53 grape containers, 52 plum containers, and 16 pome fruit containers.

The temperature data collected by shipping lines contain both supply- and return-air temperatures. The refrigeration unit pumps supply air into the container and then measure the return-air temperature at the end of the container closest to the refrigeration unit in order to regulate the air temperature within the container. The return-air temperature was used to analyse data received from shipping lines and is measured every hour.

It is important to note that the ambient temperature is measured by the exporters close to the door of the container (the end farthest away from the refrigeration unit), while the supply- and return-air temperatures are measured by the shipping lines at the end closest to the refrigeration unit. A sample of 42 containers was used to compare the temperature data collected by exporters and shipping lines.

The final set of data received from the TPT consisted of 493 containers carrying table grapes, plums, and summer pears that entered the Port of Cape Town from January 2014 to March 2014. These containers represented 70% of all the containers carrying the selected fruit types during the sample period. The remaining 30% of the containers were excluded from the analysis due to the fact that their data sets did not have all the information required for the data analysis. This data set was used to examine the container terminal performance by analysing a number of time measurements. By adding location information to the temperature time series, an analysis of the different phases within the port could be conducted to determine in which phases temperature breaks occurred. Four main phases within the CTCT were identified:

1. Firstly, when the truck entered the port: this phase was measured from the point when the truck entered the port until the reefer container was plugged into the power source in the reefer stack.
2. Secondly, when the container was plugged into the reefer stack: this phase measured how long the reefer container stayed in the reefer stack, as well as the temperature inside the reefer container while it was in the reefer stack.
3. Thirdly, when the container was unplugged from the reefer stack: this phase identified how long the reefer container was without a power source while it was being loaded onto the ship.
4. Finally, when the container was removed from the stack, loaded onto the vessel, and plugged into the vessel's power source: this phase determined the temperature inside the reefer container when it was plugged into the ship's power source.

All phases were examined to determine the average amount of time that a container spends inside the port. Most importantly, the temperature was examined to determine whether there are any considerable breaks in the cold chain during these four phases. The Port of Cape Town aims to connect a container within 40 minutes of delivery.

Results

The purpose of this research was to identify the incidence and length of temperature breaks that reefer containers experience during the CTCT leg of the fresh fruit export supply chain. This is done by analysing temperature data for reefer containers – from arrival at the CTCT to the point where the container is loaded onto the vessel.

The sample of 42 containers – used to compare data collected between exporters and shipping lines – had 17 breaks according to the data provided by shipping lines and 61 breaks according to the data received from exporters, as shown in table 2. These large discrepancies are the result of different measurement techniques as described in the methodology. Emenike and Hoffmann (2014) confirmed the variability of temperature measurements of sensors installed in different areas of the container.

Table 2: Number of breaks measured by return-air data and iButton® data (sample of 42 containers to compare data sources)

Number of breaks per container	Return-air data	iButton® data
0	30	3
1	9	24
2	2	11
3	0	2
4	1	1
5	0	1

Figure 2 shows the length of the temperature breaks recorded by the iButtons® and return-air data. Again, the discrepancies are visible. Due to the fact that iButtons® measured the actual ambient temperature inside a container at pre-set intervals and not the return-air temperature of the container, the iButton® data were deemed to be more reliable indicators of temperature inside the container and were used for the remainder of the analyses (Dodd 2015).

The maximum temperatures recorded for grapes, plums, and summer pears were 9.85 °C, 12.17 °C, and 10.85 °C respectively – significantly higher than the 2 °C defined as a temperature break for the purpose of this research.

Data from the iButton® container sample (data on 121 containers received from exporters) showed a total of 142 breaks for the 121 containers during the CTCT leg of the supply chain, of which only 27 temperature breaks (19%) started prior to entering the Port of Cape Town.

Nineteen percent (19%) of the containers experienced no breaks, while 36% experienced one break. Twenty-two percent (22%) never cooled down before leaving the container terminal, that is, these containers spent their entire time in the CTCT above *2 °C* (refer to Figure 3).

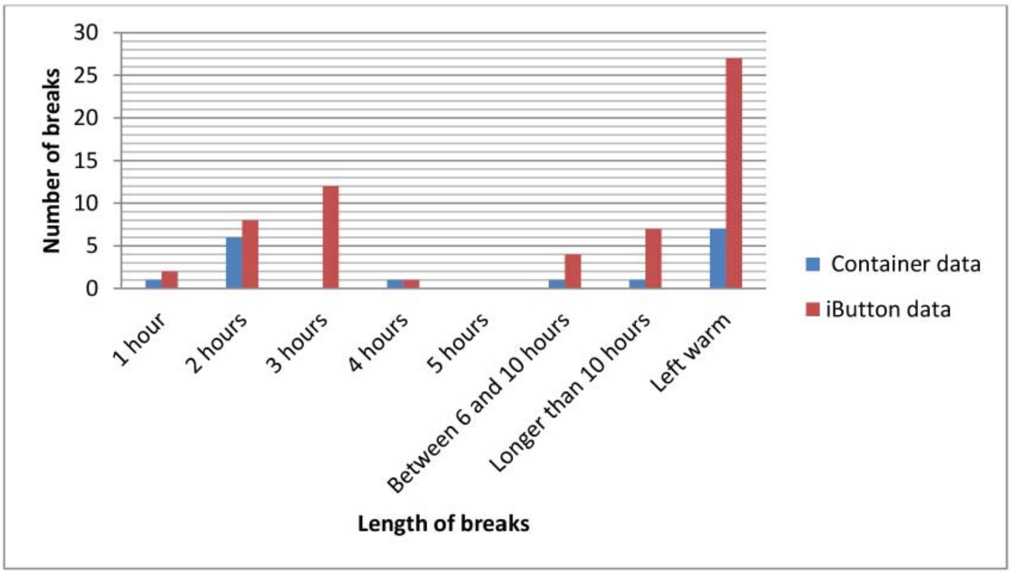

Figure 2: Length of temperature breaks measured by iButton® data and container data (return-air data) (sample of 42 containers to compare data sources)

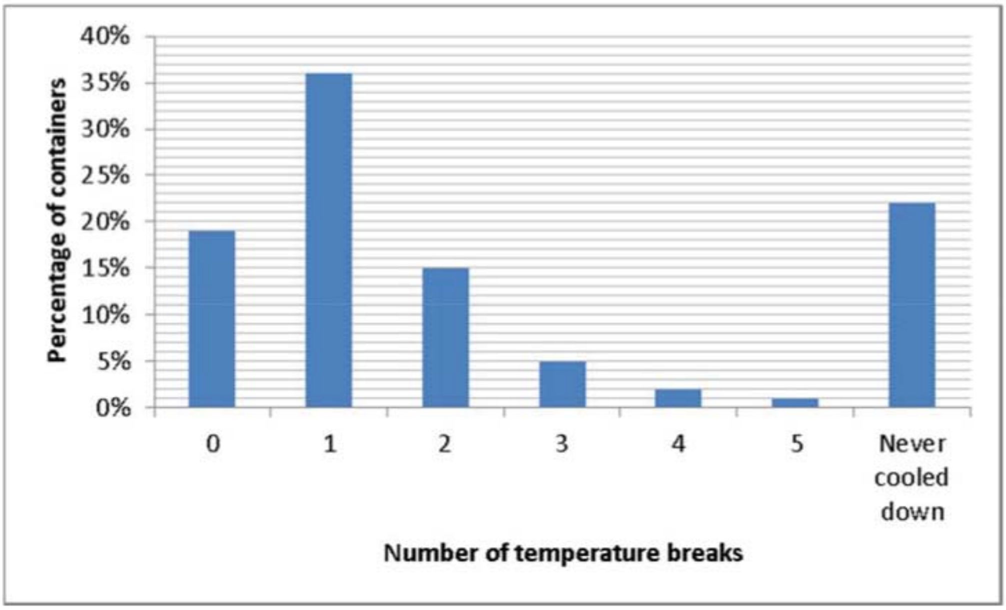

Figure 3: Total percentage of containers experiencing a certain number of breaks in the CTCT (sample of 121 containers using iButton® data)

The sample of 493 reefer containers supplied by the TPT that entered the Port of Cape Town from January 2014 to March 2014 showed that the majority of the containers (76%) were not connected to the terminal's power source within 40 minutes of entering the port gate. The average time from entering the port gate to plug-in was 1 hour and 52 minutes. Fifteen percent (15%) of the containers were only plugged in after a period of at least three hours (refer to Figure 4).

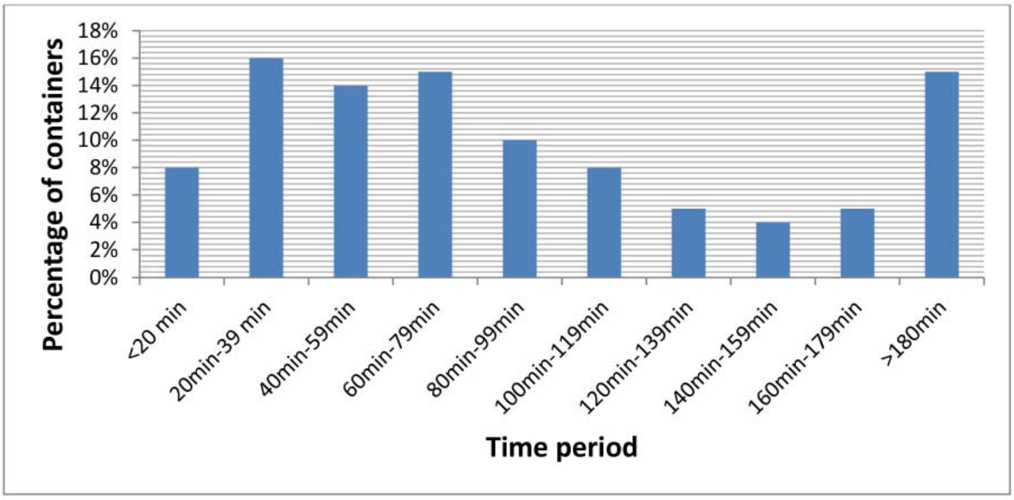

Figure 4: Percentage of containers that were plugged in within a specific time period after entering the port gate (in 20-minute intervals) (sample of 493 containers using TPT data)

The sample of 493 containers that was received from TPT showed that the largest percentage of containers (41%) arrived between 12:00 and 14:59 in the afternoon. The second and third busiest time periods were 09:00-11:59 and 15:00–17:59, with 26% and 18% of traffic arriving within these time periods (refer to Figure 5).

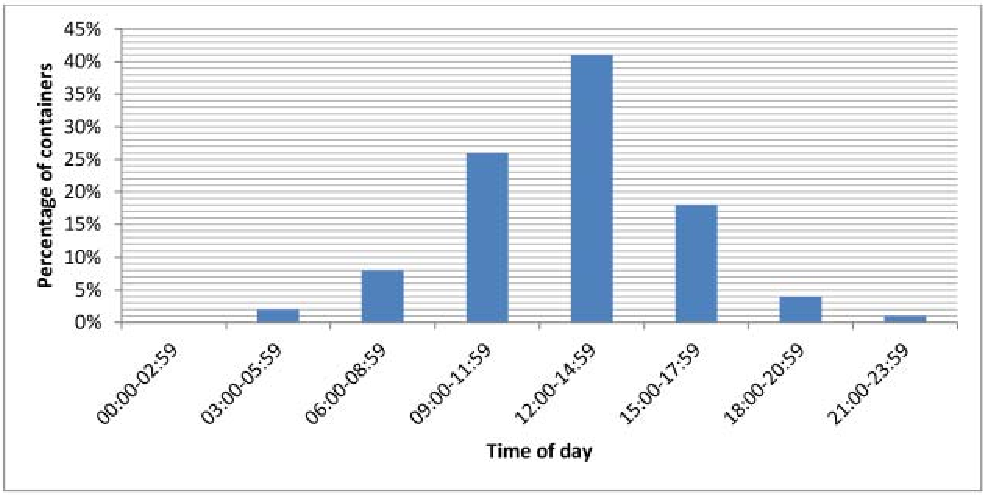

Figure 5: Number of containers arriving at a certain time of day (sample of 493 containers using TPT data)

A subset of 167 containers from TPT data set was used to ascertain the time from when the container was disconnected in the reefer stack to when it was loaded onto the vessel. (The data of the remaining 326 containers in the sample could not be used as a large number of the variables had been omitted from the data). Only 13% of the containers were loaded in less than 30 minutes. A total of 39% of containers were loaded in under an hour, while 29% of the containers took between 60 and 89 minutes to be loaded onto the vessel (refer to Figure 6).

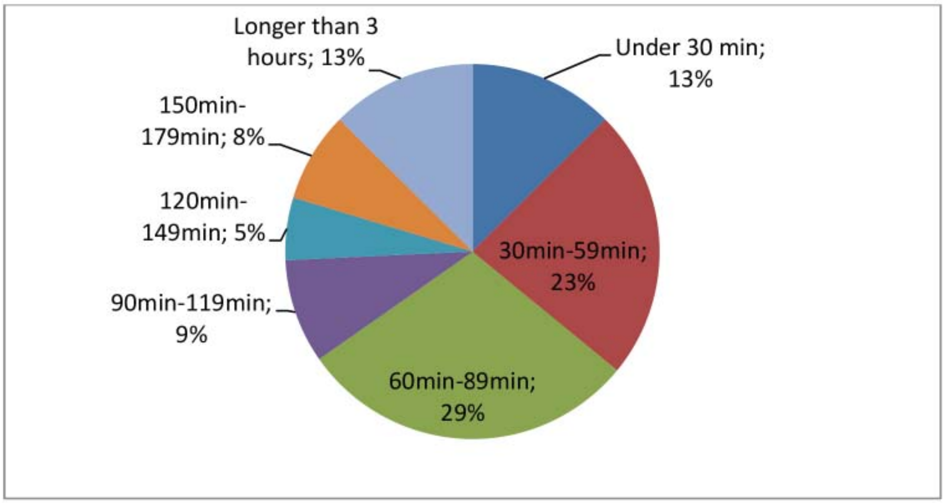

Figure 6: Percentage of containers loaded onto vessel within a certain time period (30-minute intervals) (167 containers, subset of the sample of 493 containers using TPT data)

Table 3 (based on the sample of 493 containers) tabulates the percentage of containers arriving at a certain time of the day versus the time it took from the moment the container entered the container terminal to the moment the container was connected to the container terminal's power source. Eighty-five percent (85%) of the containers arrived during typical working hours (09:00-18:00), and within each of the three time slots, as per Table 3, three-quarters of the containers that arrived during that time slot took longer than 40 minutes to be connected to a power source. In the 06:00-08:59 time slot almost all the containers took longer than 40 minutes to be connected. It is therefore not clear whether smoothing out arrivals during the course of the day will have any impact, as delays seem to occur irrespective of the number of containers involved. These results are post port entry and therefore confirm the challenges within the CTCT as described in the literature survey.

Table 3: The percentage split between the time intervals per arrival time slot for connecting the container to the reefer stack power source

Time	**0–0 minutes**	**20–9 minutes**	**40–59 minutes**	**1–2 hours**	**2–3 hours**	**Longer than 3 hours**		**Longer than 40 minutes**
00:00–02:59								
03:00–05:59	0%	27%	9%	27%	9%	27%		73%
06:00–08:59	0%	6%	17%	44%	17%	17%		94%
09:00–11:59	7%	18%	13%	33%	12%	17%		75%
12:00–14:59	6%	15%	14%	30%	16%	19%		78%
15:00–17:59	12%	16%	19%	28%	17%	8%		72%
18:00–20:59	23%	23%	9%	41%	5%	0%		55%
21:00–23:59	75%	25%	0%	0%	0%	0%		0%

It is clear that there are significant challenges regarding the handling of reefer containers within the CTCT. The literature survey provided context regarding the possible reasons for the temperature breaks in the cold chain identified in this research. These reasons form the core of the recommendations presented in the last section. It is, however, important to note that the scope of the project was not a detailed analysis of procedures within the CTCT and further research is required.

Conclusions

The purpose of this research was to identify the incidence and length of temperature breaks within the CTCT leg of the fresh fruit export supply chain in order to inform remedial actions.

The data analysis indicated that 81% of the temperature breaks originated within the CTCT. This was significantly higher than previous studies conducted by Freiboth (2012), Haasbroek (2013), and Goedhals-Gerber et al. (2015), which respectively showed that 65%, 42%, and 41.5% of the temperature breaks originated in the CTCT. These studies were conducted during different time periods, which can contribute to the discrepancies due to, *inter alia*, variability in weather delays, ambient external temperatures, and service providers. These discrepancies, however, confirm the importance of working towards a universal method of measuring temperature across the fruit export supply chain. The reduction in uncertainty enabled by accurate measurement of the cold chain will release resources to focus on accurately prioritising and addressing challenges that compromise the integrity of the cold chain.

The sample of 42 containers had 17 breaks according to the data provided by shipping lines and 61 breaks according to the data received from exporters. This confirms that by monitoring the delivery and return-air temperatures of the container (as measured by shipping lines), there is no guarantee that the ambient temperature in the back of the container (near the door, as measured by exporters) is in accordance with the temperature standard.

Within the CTCT, 80% of reefer containers experienced temperature breaks, while almost a fifth never cooled down before being loaded onto the ship. In addition, 76% of the containers were not connected to the terminal's power source within 40 minutes of entering the port gate. The average time from entering the port gate to plug-in at the reefer stack was 1 hour and 52 minutes. Forty percent (40%) of containers arrived between midday and 15:00. However, congestion does not seem to be the main reason for these delays as three-quarters of the containers that arrived during the course of the working day (between 09:00 and 18:00) took longer than 40 minutes to be connected to a power source.

The high incidence and length of temperature breaks that reefer containers experience within the CTCT leg of the fresh fruit export supply chain impact the integrity of the cold chain and the quality of the fresh fruit exported. In order to address these temperature breaks, the following remedial actions are recommended. Cognisance needs to be taken, however, that the implementation of these recommendations should take place within the context of the end-to-end cold chain, for which future research is recommended.

Recommendations

Exporters

Exporters should consider using gensets even if the distance between the cold store and the port is short. This reduces the risk of delays due to congestion or other interruptions when entering the terminal. The gensets should be kept running until just prior to offloading. Exporters should also avoid last-minute delivery of containers as containers arriving late are often placed in a stack closer to the vessel with the intention of loading them as soon as possible and they are therefore not always plugged into a power source.

The use of specialised reefer trains to reduce congestion, fast-track reefer stack access, and reduced transport costs should also be investigated proactively.

CTCT

Port workers should be trained on the importance of good cold chain practices and the proper sequence of work to maintain the cold chain. The CTCT should also consider more efficient work methods with regard to connecting and disconnecting containers from the terminal's power source. Port workers have to walk long distances in large groups. Equipping port workers with golf carts as a means of transport and a mobile NAVIS device could improve efficiency.

The feasibility of a dedicated lane for reefer containers to eliminate delays behind non-perishable cargo should be investigated (as recommended by the Federal Maritime Commission Bureau of Trade Analysis 2015).

A possible solution to weather-related delays would entail the upgrading of terminal equipment to handle higher wind speeds.

Increased collaboration

More than a decade ago, Van Dyk and Maspero (2004) investigated the shortage of fruit-exporting infrastructure during peak seasons. The main conclusion of the study was that although logistics infrastructure provides some challenges to South Africa's fruit exports, information sharing, collaborative planning, and improved productivity would be the deciding factors in ensuring quality fresh fruit exports. This recommendation still holds true today. Collaboration between the key parties involved in the cold chain – namely the fruit exporters, logistics service providers, the CTCT, and the shipping lines – is imperative to ensure the end-to-end integrity of the cold chain.

This also incorporates the issues mentioned in the section on future research. Cold chain challenges prior to the CTCT leg, such as insufficient pre-cooling and heterogeneous packaging which influence ventilation, impact the ability of the CTCT to play its role in the maintenance of the cold chain. While not the focus of this research, it is important to note that collaboration along the whole supply chain is imperative for end-to-end cold chain management.

Increased collaboration is also required to implement a universal method of measuring temperature across the fruit export supply chain in order to assist with the accuracy of detecting temperature breaks along the cold chain.

Endnote

1. The two most common international standardised container types are twenty and forty foot in length. In order to express the capacity of a container ship in a uniform manner, the number of containers that the ship can load is converted into a number of containers of the smallest size, i.e. those that are twenty feet in length, or twenty-foot equivalent units (TEUs). TEUs are therefore used to indicate the nominal capacity of container ships or container terminals, as well as the fleet size of reefer containers (Logistics Glossary, n.d.).

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