‘COOL OR HOT’: A STUDY OF CONTAINER TEMPERATURES IN AUSTRALIAN WINE SHIPMENTS

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ABSTRACT: Wine production is an important component of Australia's regional economy and wine quality is essential for maintaining Australia's high levels of wine exports to more than 120 countries. Temperature conditions during shipment are highly important in ensuring that Australian wines reach the customer table, locally or overseas, in optimum condition. This paper presents the results of a study tracking the temperature fluctuations that wine is exposed to during international shipment. The results indicate that extreme temperature fluctuations are more prevalent in the land transport legs compared to the sea leg. The impact of other factors such as the date of transport and shipment destination is also analysed. With this knowledge of conditions during travel, the Australian wine industry can put in place guidelines and policies with the goal of minimising exposure to heat and other damage by using appropriate packaging, container insulation or refrigeration and giving attention to the entire distribution process.

KEY WORDS: wine logistics, container tracking, supply chain management, time series analysis, regional freight

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1. INTRODUCTION

Wine is a regionally based agricultural product. Australia's wine industry involves around 2000 wine companies, directly employs 60,000 people across 64 wine-producing regional communities and generates related employment by purchasing goods and services from regional and rural businesses (Supporting Australian Wine, 2011). On a national scale, there are 167,000 hectares under vine and the total grape crush in 2006 was 1.85 million tonnes (AWBC, 2009). Although winemakers are found in all states, vineyards in South Australia, Victoria and New South Wales account for over 90% of total production (ABS, 2012).

Australia is now the fourth largest wine exporting nation after France, Italy and Spain and Australian wines are enjoyed in more than 120 countries (Wine Australia, 2009). In 2007, wine exports reached a record 786 million litres worth A$3 billion (Wine Australia, 2011). Australia's largest wine export market in 2006–07 was the United Kingdom (269 million litres, worth $977 million), closely followed by the United States

(215 million litres, worth $856 million) (DFAT, 2009). Other leading destinations for Australian wines include Canada, Germany, China and New Zealand. Australian wine is also making inroads into Japan, Scandinavia, Europe, and Asia (Wine Australia, 2011).

Wine quality is essential for maintaining Australia's high levels of export and temperature plays a significant part in ensuring that wines reach the customer table in optimum condition. Numerous studies (Ough, 1985; Rankine, 1998; Marais, 1986) have shown that extreme temperatures and excessive temperature fluctuations have a damaging effect on the quality and appearance of bottled wine. These alterations in the chemical and sensory properties of wine often lead to the rejection of the product affected, which causes not only financial loss but also loss of consumer confidence in the winemaker. This research provides one piece in the complex challenge of continually providing optimum shipping conditions for wine exports under changing economic and climate conditions.

Temperature conditions during shipment are highly important since wine shipments from Australia to its major markets travel long distances, endure long travel periods over land and sea, and can be subjected to rapidly changing seasons by crossing the equator. It is of the utmost importance that the wine, produced with so much care, is packaged in such a way that it is contained, protected and identifiable until it is consumed (Meyer, 2002). It is therefore vital for winemakers and exporters to at least know the temperature fluctuations that wine is exposed to during shipments.

This paper presents the results of a study tracking international wine shipments to the USA from Australia. The temperature data collected for a sample of wine shipments originating from South Australia is charted and disaggregated. In addition the individual trip legs are analysed with respect to thresholds in temperature levels and fluctuations. This paper compares the temperature levels and fluctuations recorded at different legs of the journey in order to identify conditions where potential risk may exist to a wine shipment. With knowledge of conditions during travel, guidelines and policies can be put in place to ensure Australian wines reach their market with the same quality as when they left.

Temperature and Wine Quality

Several factors can influence the quality of wine, temperature being perhaps the most important (Hartley, 2008). In general, any storage place where the temperature exceeds 25°C for long periods and 40°C for short periods can affect wine quality (Ough, 1992). Temperatures in excess of 40°C will induce visual and sensory changes to a wine in only a matter of days (Ough, 1985). Table 1 summarises the typical defects that can result from exposure to high and low temperatures as well as temperature fluctuations.

Table 1. Impacts of temperature on wine quality

Physical defects	Organoleptic defects	Chemical defects
• Sediment • Cloudy • Protein haze formation - stabilisation process leads to solid waste generation • Browning • Leaking • Raised corks • Broken bottles • Reduced shelf life	• Maderised (baked taste) • Oxidised • Lack of CO_2 (flat) • Lack of fruit • Decrease in intensity of young wine bouquet • Increase in the intensity of the maturation bouquet • Ageing - change in aroma components • Decrease in overall wine quality • Subtle changes - leading to misjudgement of true nature and quality	• High volatile acidity • Re-fermentation • Oxygen uptake • Decline of free SO_2 in white wines • Tartrate stability - in cold weather • Faster release of monoterpene - giving the wine an older character • Changes in total acid - not significant in white wines • Acetate rapidly hydrolysed • Diminution of esters of volatile acids • Decrease in terpene alcohol

Source: Meyer (2002)

Wine is a complex mixture of water, sugars, organic acids and other chemical components. These individual components continually interact with one another. Numerous studies have investigated the impact of temperature on the individual components of wine using physical, chemical and sensory tests. Components which have been studied include various volatile compounds (Perez-Coello et al., 2003, Marais and Pool, 1980; Benitez et al., 2006), acetate levels (Marais, 1986; Marais and Pool, 1980), diethyl succinate levels (Marais and Pool, 1980), monoterpenes (Di Stefano and Castino, 1983; Rapp and Guntert, 1986), tartaric acid (Edwards et al., 1985), and the visible near infrared spectrum

(Cozzolino et al., 2007). A review of the effect of temperature on wine quality by Butzke (2001) reported that temperature fluctuations can have an impact not only on the aroma of wine, but also on more general chemical reactions, such as oxygen uptake, browning reactions in white wines, ethyl carbamate formation, and the decline of free SO_2 in white wines. The rates at which these reactions occur were found to be very sensitive to temperature such that a small temperature rise can produce a large increase in the reaction rate (Hartley, 2008).

The phenomenon known as browning is notable among those that produce undesirable changes in the sensory characteristics of white wine. It is known that high temperatures (Berg and Akiyoshi, 1956) and exposure to light accelerate the browning process of wine (Benitez et al., 2006). Leakage of wine and/or movement of cork stoppers due to thermal expansion of wine may result following exposure to temperatures which are significantly greater than ambient temperature. Such physical damage does not necessarily imply that the quality of the wine has been affected, but will affect the appearance, and therefore the marketability, of the wine (AWRI, 2009).

In view of the effects described above, it is recommended that wine be stored under insulated and/or temperature-controlled storage conditions, which minimise fluctuations in both temperature and humidity. Amon and Simpson (1986) recommend that bottled wine be stored with the cork in contact with the wine in a cool (15–20°C), dry location. To help maintain optimal wine quality during transport, Ough (1985) concluded that:

1. Shipping temperatures should be minimised to maintain the wine in the best general condition.
2. Colour in wines will dramatically change with higher temperatures for even very short periods of time.
3. White colour will increase, red colour will decrease, and acetate esters will rapidly break down in reaction with water.
4. Samples of wine should be preserved at a controlled temperature for reference to assure vintner or shipper protection.

Container Temperature in Wine Shipments

Bottling wine at source and shipping in standard containers is the most common means of transporting wine (Hartley, 2008). Most wine bottles shipped in containers are first packed in boxes and then stacked on pallets. The number of bottles that can be transported in a container is usually determined by the internal container dimensions, rather than by the consignment's weight. Internationally there are three common standard lengths for containers - 20ft (6.25m), 40ft (12.5m) and 45ft (14m). The 20ft container is the most common format worldwide but the 40ft option is becoming increasingly popular as it is far more cost effective.

Bottled wines are subject to wide variations in temperature during transport by container, and quality can be adversely affected (Tremblay, 1984). The temperature inside a container is affected by both radiated and conducted energy. If the outside temperature reaches 40°C, as it can in Australia during the summer, the inside of an uninsulated container can rise as high as 60°C. Shipping wine in the harsh European winter is equally hazardous. At -5°C, wine will freeze, and at 0°C certain wines will throw an unsightly tartrate crystal deposit (Marsh, 2008).

Wine shipments can be protected against temperature fluctuations by using refrigerated containers (reefers), thermal blankets, polystyrene and any number of commercially-available reflective container liners. Unfortunately, insulation can add significant cost to a container shipment. For example, the cost of a reefer is almost three times the amount of a normal dry box container, a deterrent in a highly competitive sector (Marsh, 2008). As a result only a limited proportion of wine shipments, in general, use temperature controlled or insulated containers. The Province of Ontario's Liquor Control Board surveyed 21,500 containers of wines and spirits and found only 23% of the deliveries were made using temperature controlled containers (Hartley, 2008). In the United States, about 23% of shipments are in temperature-controlled containers, whereas in South Africa research indicates that the figure may be as low as 2% (Meyer, 2002).

2. MATERIALS AND METHODS

Two main studies exist on the variation of temperature during shipment and its effect on wine quality. Meyer (2002) of the Technology Exploitation Centre carried out a literature study for Winetech in South Africa and Christian Butzke (2001) of the University of California conducted a study on behalf of the American Vineyard Foundation. The typical defects caused by exposure to high and low temperatures as well as temperature fluctuations is summarised in Table 1.

Butzke (2001) showed that wine movements from California to the US East Coast during summer months in a non-refrigerated truck can be exposed to ambient temperatures as high as 43°C. As would be expected, the temperatures fluctuated depending on time of day and direction of sun. Exposure temperatures were regularly above 24°C. Winter wine movements across the US were reported to reach a low point of about -4°C, while wine not under an insulating quilt dropped to nearly minus 15°C, a temperature which could actually freeze the wine (Hartley, 2008). Expansion associated with freezing can result in the fracture of bottles (Hartley, 2008).

A study on temperature and humidity conducted by the Xerox Corporation (Leinberger, 2006) placed data loggers in containers of cardboard boxes for three different routes - two routes between Japan and the USA, and the third between Japan and the Netherlands. The study included 160 shipments between April 2004 and January 2006. The data loggers were placed on the outside of corrugated cardboard boxes and recorded temperature every 10 minutes. The results found that daily temperature cycles at sea were usually very minor or nonexistent and that direct sunlight can cause the upper part of the container to be more than 15°C warmer than the outside. Daily temperature differences can be extreme on land with the highest temperature 57°C recorded in July on the third stage of a shipment to Memphis while the lowest temperature of -21°C was recorded in January also on the third stage of a shipment to Memphis.

Focussing on Australian wine shipments, a report prepared by E.J.C. Carr & Associates for BRL Hardy (Miclette and Martin, 2000) indicated that temperature levels and fluctuations on the ship were at acceptable levels irrespective of whether the containers were insulated or not. Such shipments usually come with instructions for the containers to be stored below deck although there is always the possibility that the container could be placed above deck or placed next to the ship's boiler (Dean and Paffard, 2002). However, temperature fluctuations were found to be unacceptable during the period following the discharge of the container from the ship, until the container was unpacked in Dallas. The tasting of the Australian samples confirmed the suspicion that the wines had been exposed to hot conditions that may have accelerated their ageing process and led to premature oxidation (Dean and Paffard, 2002).

In 2006, Food Science Australia simulated the temperature profiles of seven days of shipment, including one day at sea, for four container shipments from Adelaide to Cartagena, to test the performance of liners produced by Ospack Systems (Smale and Eddy, 2006). The simulation included outside temperature as well as solar radiation. The results showed that Ospack liners reduced the peak wine temperature (temperature inside the top row wine boxes) from 45°C to 35°C when compared to the container with no liners. In another trial, Ospack Systems and the Fosters Group filled six containers with wine and temperature loggers and sent these from Adelaide to the Napa Valley in California (Ospack, 2007). The data showed that solar radiation caused the roof temperature in unsheltered containers stored on land to reach 70°C. On the other hand, the temperature for the centre box of the exposed container with Ospack liner stayed below 30°C while the temperature above the liner exceeded 50°C.

Wine Supply Chain Council (WSCC) Temperature Study

As the aforementioned studies have shown, Australia's environment and distance from its major wine markets can have serious implications on the quality of Australian wine delivered to its customers. The Australian wine industry needs more comprehensive studies of temperature in wine shipments, which cover longer time periods and involve more wineries and distribution routes. One such study has been initiated by the Wine Supply Chain Council (WSCC, 2008), a new international initiative concerned with wine logistics and supply-chain issues. The founding participants of the WSCC are CSIR (South Africa), Catholic University Santiago (Chile), CSIRO (Australia) and Georgia Institute of Technology (The Logistics Institute, Atlanta, USA).

The WSCC wine temperature study commenced in September 2007. The study is gathering data on variations in temperature and transit times for international wine shipments. This is achieved by inserting temperature-recording devices, shown in Figure 1, in cases or containers of wine at wineries in Australia, Chile, and South Africa. The containers are then shipped to the US, where the WSCC team at Georgia Institute of Technology retrieve the temperature-recording devices. The measurements include time and temperature, recorded at 1 or 2-hour intervals. The devices are not much larger than a watch battery, are self-powered and are placed securely in an envelope inside each case.

The Australian portion of the study involves 3 of the 5 biggest wine exporters in Australia. The data from the returned loggers are being analysed in order to correlate time with location by interpolating scanning data collected along each supply chain. The shipping scans will be of value in themselves, independent of the temperature records, because these will be useful in understanding the distribution of transit and processing times.

Figure 1. Temperature logger button. Picture shows size of the WSCC logger relative to a golf ball. Source: the Authors

Trip legs and Reference Dates

This paper reports on the results of the Australian component of the WSCC wine temperature study. This component saw a total of 154 loggers sent out between June and Dec 2008 with 74 being retrieved. Each logger collected temperature readings at 2-hour intervals for the entire trip. The loggers were activated in Melbourne and synchronised with Melbourne date and time. Missing supporting information made many of the retrieved temperature records incomplete resulting in only 57 loggers being used in this analysis.

3. SUMMARY OF RESULTS

Figure 2 shows a chart of temperatures collected from 5 of the 57 loggers used. The chart illustrates two important characteristics of the temperatures collected. First, each curve displays the three stages of transport that each of the container shipments undertook. A container is initially transported, usually by truck, from its Australian winery to its port of origin, then travels by ship from the Australian port to a US port, and then is finally transported by land from the US port to its importer's location. These stages are indicated in a temperature curve by the presence of a wavy initial portion (corresponding to the Australian land transport stage), a stable middle portion (the ship voyage stage), and a fluctuating end portion (the US land transport stage). As the temperature curves in Figure 2 show, the prominence of the stages and size of the fluctuations can differ significantly between trips.

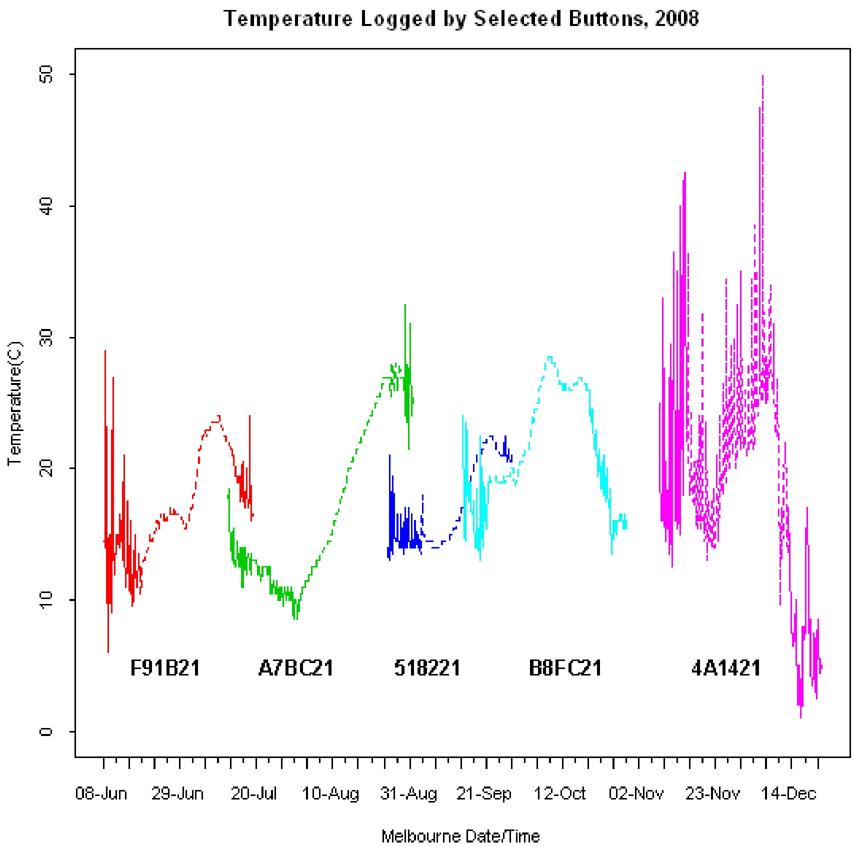

Figure 2. Plot of temperature data from 5 of the 57 loggers. The logger ID is indicated below the corresponding data. For each curve, note the existence of a wavy initial portion, stable middle portion (broken line) and wavy end denoting the Australian land transport portion, sea (voyage) portion and US land transport portion, respectively. On the left side of the chart, trips that start in June move from winter (Australia) to summer (US), while on the right, shipments in November move from summer (Australia) to winter (US). Source: the Authors.

The second important characteristic pertains to whether a general (increasing or decreasing) trend exists in the logged temperatures. Since each of the 57 trips involved crossing the equator, trips that started in June/July moved from winter (in Australia) to summer (in the US), while those that departed around November/December moved from summer (in Australia) to winter (in the US). Thus the June/July trips are expected to exhibit increasing temperatures while November/December trips would generally have decreasing temperatures.

Table 2 shows the averages calculated for the mean, minimum and maximum temperatures observed for the three legs. Since majority of the buttons (49 out of 57) started their trip before 1 August 2008, many of the OZ legs occurred in winter, resulting in lower mean temperatures, compared to the sea leg and US leg. Since the sea leg connects the OZ leg to the US leg, its minimum temperature mirrors that of the OZ leg while its maximum resembles that of the US leg.

Table 2. Summary characteristics of trip legs for 57 buttons. Table shows total hours and averages for the mean, maximum and minimum temperatures for each leg. Source: the Authors

Trip Leg	Total hours	Average (Leg Mean Temp) (°C)	Average (Leg Min Temp) (°C)	Average (Leg Max Temp) (°C)	Minimum (Leg Min Temp) (°C)	Maximum (Leg Max Temp) (°C)
OZ	15584	14.50	11.41	21.32	5.50	42.50
sea	32714	18.68	11.76	25.71	6.00	50.00
US	5082	22.04	19.87	25.15	1.00	38.50

Figure 3 shows a typical temperature chart for an Australian wine shipment constructed from logger data and supporting shipping information. For each chart, six dates of reference are estimated based on information provided by the importer/exporter/freight forwarder and from logger data as well. These include the date the logger is loaded into its container (pt. D), the date the container is loaded into the ship (pt. E), the date of ship departure from origin port (pt. A), the date of ship arrival in destination port (pt. B), the date container is unloaded from ship (pt. F), and the date the logger is unloaded from its container (pt. G). All dates of reference are then converted to Melbourne date and time in order to be directly comparable to the logger data. Only temperatures recorded between pts. D and G are included in the analysis.

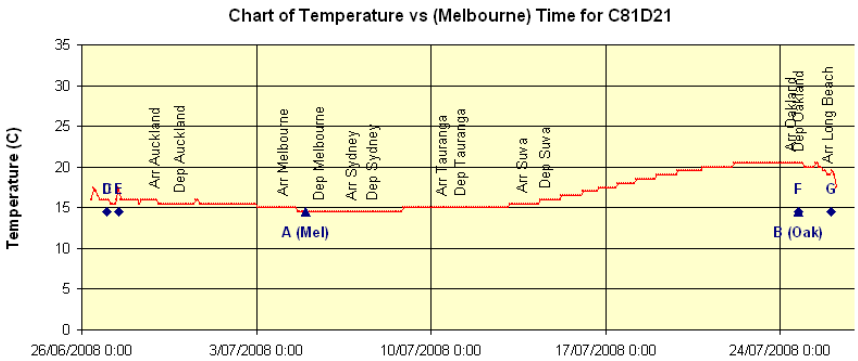

Figure 3. Sample temperature chart with dates of reference. Points indicate: D=date logger is loaded in container, E=date container is loaded onto ship, A=ship departure from origin port, B=ship arrival at destination port, F=date container is unloaded from ship, G=date logger is unloaded from container. The approximate ship location during voyage is also indicated, when possible.

Using the dates of reference, each trip is divided into three legs that correspond to the three stages of transport. The first leg, referred to as the OZ leg, covers the Australian transport period when the wine shipment travelled from the Australian winery to the container ship. The OZ leg includes; waiting time the loaded container spends in the winery warehouse, land transport from winery to port, and waiting times spent by the container at the port of origin (on the docks and in the ship). The OZ leg is denoted in the logger chart by the period between points D and A.

For the second stage, the sea leg denoted the period of the voyage from the port of origin (pt. A) to the port where the container was unloaded from the ship (pt. B). For the 57 buttons, the port of origin was either Adelaide, SA or Melbourne, VIC whereas the ports of destination included Oakland, CA and Philadelphia, PA. Finally, similar to the OZ leg, the US leg covers the container's movement in the United States from the port of destination (pt. B) to the importer's warehouse (pt. G).

Figure 4 shows a representative temperature log for a complete trip. The OZ leg portion of the temperature log is denoted by the solid thin line in the initial stage of the trip, while the US leg portion is the solid thin line at the end of the trip. In between the OZ and US legs, the sea leg is denoted by the dotted thin line.

4. ANALYSIS AND DISCUSSION

Temperature Deviations and Seasonal Component

In order to understand the variability in daily temperatures, the temperature curve is fitted with a smooth curve representing a general trend line and denoted by the dotted black line in Figure 4. The smoothed temperatures are obtained from the recorded temperatures by applying a double exponential weighted moving average function from the R package with a lambda of 0.1. Deviations from the observed temperature to the corresponding point in the smooth curve are then calculated and the absolute values averaged for each of the trip legs.

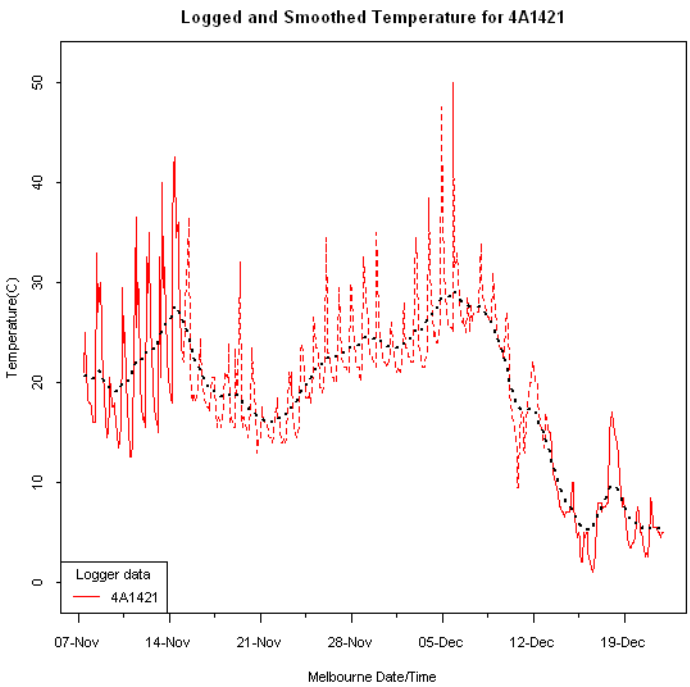

Figure 4. Chart of logged (red thin line) and smoothed (dotted black line) temperatures for a given button. The logged OZ land transport temperatures are denoted by the solid portion at the beginning, sea temperatures are denoted by the dotted line in the middle, and the US land portion is the solid line at the end.

Table 3 summarises the daily variation in temperature recorded for the trip legs. The land legs, particularly the OZ leg, exhibit significantly higher deviations when compared with the sea leg. This can be attributed to many of the containers being exposed to the daily exchange between the day sun and night cold of Australian winter.

Table 3. Summary of temperature fluctuations for 57 buttons. Table shows averages for the mean, maximum and minimum temperatures for each leg, as well as the deviations from the smoothed fit. '25C+ hours' indicate the number of hours that temperatures of 25°C or more were recorded. Similarly, '40C+ hours' indicate the number of hours that temperatures of 40°C or more were recorded. Source: the Authors

Trip Leg	Total hours	Average (Leg Mean Deviation) (°C)	Average (Leg Max Deviation) (°C)	Seasonal Daily Range (°C)	25C+ hours	40C+ hours
OZ	15584	0.92	4.83	17.39	180	6
sea	32714	0.33	2.11	5.95	4326	8
US	5082	0.67	2.70	10.67	1104	0

Figure 5 shows the distribution of the average (absolute) deviations calculated for each of the trip legs in all 57 trips, plotted against the corresponding start date of the trip leg. The chart shows that most of the large deviations of 2°C or more occurred in the OZ and US legs. The sea leg exhibited barely any deviation from the smooth curve since majority of its deviations were close to zero.

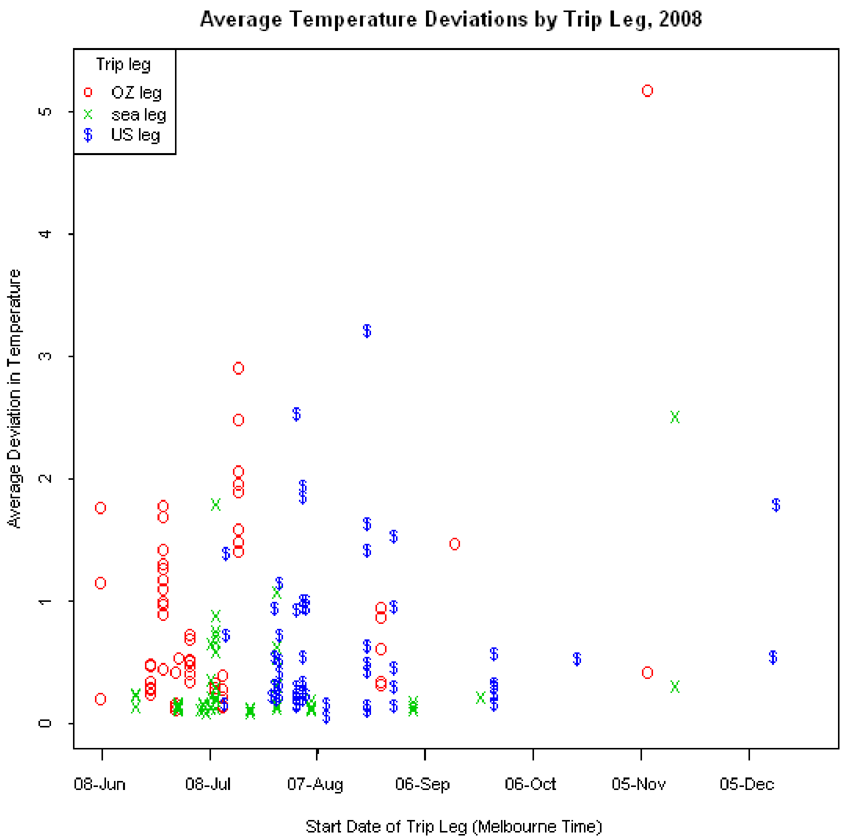

Figure 5. Average deviation by trip leg plotted against start date. The large deviations occurred in the OZ leg and US leg. Majority of the deviations in the sea leg were close to zero. Source: the Authors.

Figure 6 shows the average deviations from the sea legs ranked from highest to lowest and compared against the rankings from the OZ and US legs. The graph again shows the deviations from the land legs clearly exceeding those from the sea leg for all rankings. Between the land legs, the graph shows the deviations from the OZ leg clearly exceeding or equalling those from the US leg.

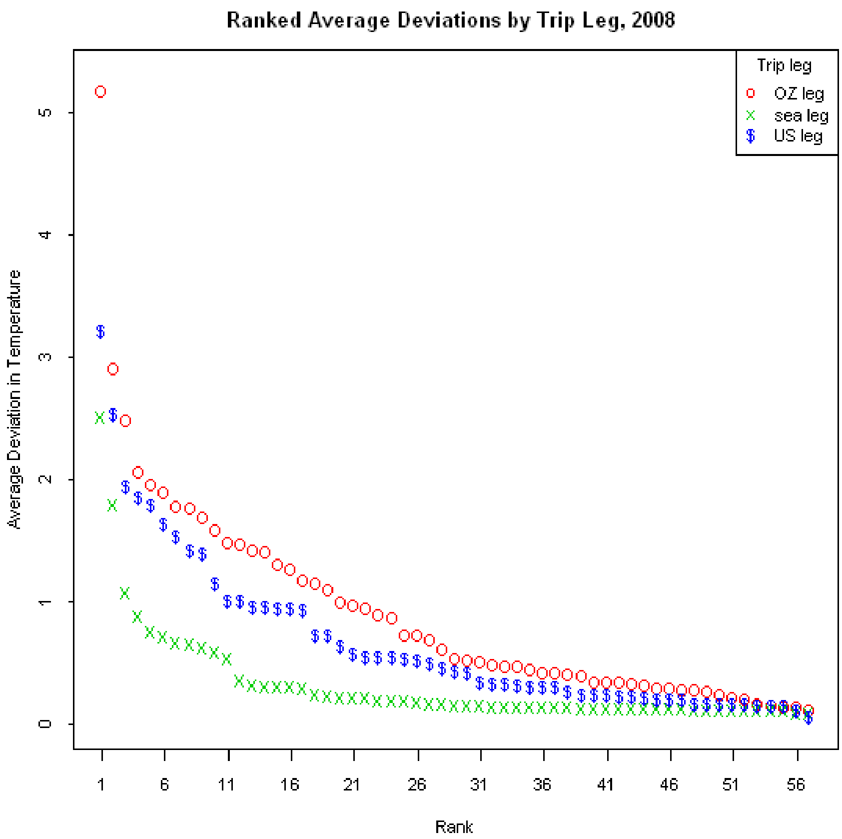

Figure 6. Average temperature deviations ranked by trip leg. The deviations from the OZ leg exceed those from the US leg and sea leg. Source: the Authors.

In order to estimate the daily range of temperature fluctuations, a seasonal decomposition of the temperature time series by Loess (STL in the R package) is applied to the data from each logger. The daily range is taken as the absolute difference between the maximum and minimum values of the periodic deviations in the seasonal component. Since each period is two hours, twelve periods are covered in each cycle. The seasonal daily range is calculated for the entire trip and for each of the three legs.

Figure 7 shows the cumulative frequency distribution of buttons with respect to the seasonal daily range of temperature fluctuations. As the chart shows, there were 8 buttons with daily fluctuations exceeding 5°C and only two (35E521 and 4A1421) exceeding 10°C. Among the trip legs, there were 6 OZ legs, 1 sea leg and 4 US legs that had daily fluctuations of 5°C or more. One OZ leg and one US leg had daily fluctuations of 10°C or more. The OZ and US legs had significantly higher daily fluctuations than the sea leg. In fact, only eight of the 57 buttons had sea legs exceeding 1°C of daily fluctuations.

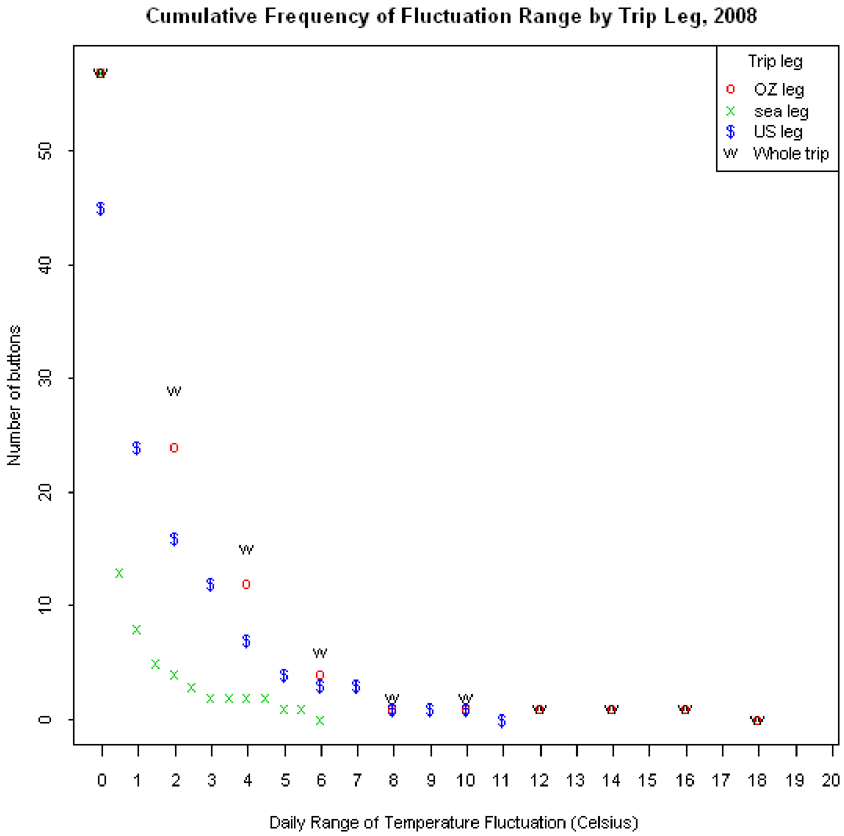

Figure 7. Cumulative frequency distribution of buttons with respect to daily range of temperature fluctuation in degrees Celsius. The daily range is obtained from the seasonal component of time series. Chart shows that fluctuations of 7°C or more only occurred in the OZ and US legs. Source: the Authors.

Hours of 25°C/40°C and Over

As Ough (1992) noted, exposure to temperatures exceeding 25°C for long periods and 40°C for short periods can affect wine quality. Figure 8 shows a graph of the number of buttons and the number of hours when temperatures of at least 25°C (denoted by '25C+') were recorded. For the entire trip, there were 31 buttons with at least 10 hours of temperatures of 25°C or more. Among the trip legs, only 1 button had at least 10 hours of 25°C temperatures during the OZ leg while the number was 14 for the US leg and 27 for the sea leg.

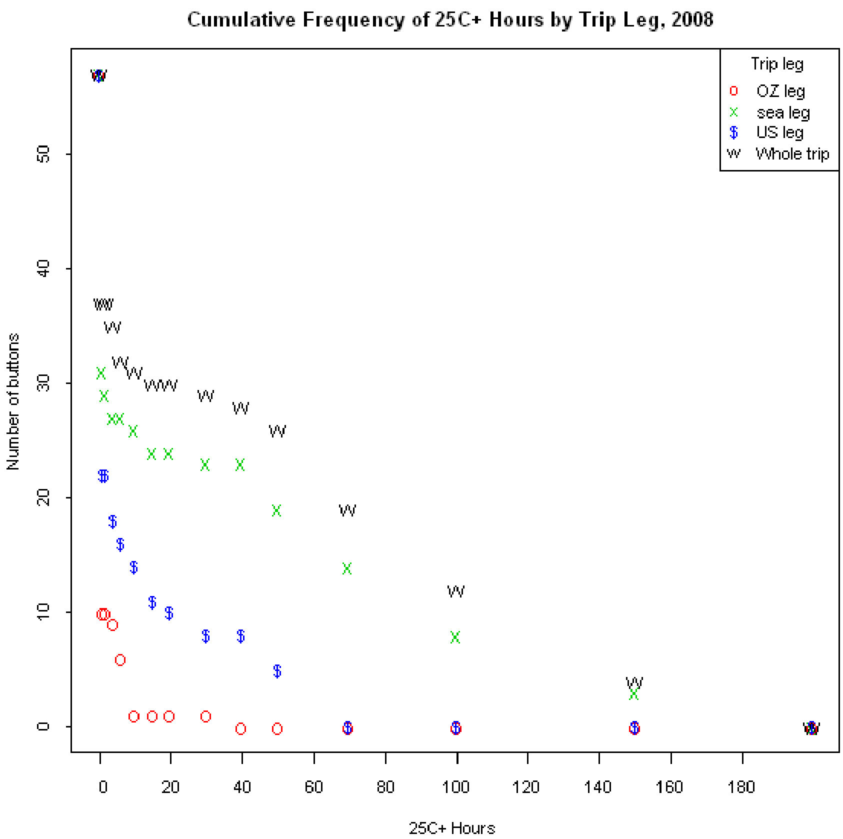

Figure 8. Cumulative frequency distribution of buttons with total hours of temperature readings of at least 25°C. There were 31 buttons with at least 10 hours of temperatures of 25°C or more. Source: the Authors.

Referring back to Table 3, there were a total of 15,584 hours logged in the OZ legs, 5,082 hours in the US legs and 32,714 hours in the sea legs. The total hours logged with a temperature of 25°C or above was 180 for the OZ legs, 1,104 for the US legs and 4,326 for the sea legs. This means that the proportion of 25°C+ hours was highest for the US leg (22%), followed by the sea leg (13%) and OZ leg (1%).

With respect to the 40°C threshold (Ough, 1985; 1992), only two buttons (4A1421 and 47B721) logged temperatures of 40°C or more (denoted by '40°C+'). The 40°C+ temperatures logged for 4A1421, as shown in Figure 4, show 6 hours in the OZ leg and 4 hours in the US leg. Button 47B721 logged 4 hours of 40°C+ in its sea leg.

Aside from having 40°C+ hours, button 4A1421 raises a lot of interest in other ways. As shown in Table 4, the trip had average temperatures of 22°C for the OZ and sea legs, and exceeded acceptable limits for wine storage with maximum temperatures of 50°C and 42°C for the sea and OZ legs, respectively, and a minimum of 1°C for the US leg. The seasonal fluctuation during the OZ leg had a range of 17.4°C, almost four times those of the sea and US legs. In addition, this shipment had 64 hours of 25°C+ temperatures in the OZ leg and 196 hours in the sea leg. In view of these measures, there should be concerns regarding the quality of wine delivered from this shipment.

Table 4. Summary characteristics of temperatures from button 4A1421. '25C+ hours' indicate the number of hours that temperatures of 25°C or more were recorded. Similarly, '40C+ hours' indicate the number of hours that temperatures of 40°C or more were recorded. Source: the Authors

Trip Leg	Ave Temp (°C)	Min Temp (°C)	Max Temp (°C)	Ave Deviation (°C)	Max Deviation (°C)	Seasonal Daily Range (°C)	25C+ hours	40C+ hours	Total Hours
OZ	22.53	12.50	42.50	5.19	14.89	17.39	64	6	182
sea	21.97	9.50	50.00	2.51	20.90	4.84	196	4	676
US	7.08	1.00	17.00	1.79	7.26	3.50	0	0	212

5. CONCLUSION

The WSCC wine temperature study continues to collect data on temperature and transit times of international wine shipments. Results from the Australian component of the study show that there are areas where Australian wine exporters should allocate more consideration and planning. The data collected will assist the Australian wine industry to identify and understand the causes of temperature variations and implement policies and measures aimed at minimising exposure to heat and other damage of wine shipments by using appropriate packaging, insulated containers and appropriate storage facilities.

For example, the results showed that the great majority of the daily temperature fluctuations considered unacceptable occurred during the land transport stages, with the OZ leg exceeding or at least equalling the US leg. As the distance between source winery and departure port, or between arrival port and final destination, increases, so does the risk that extreme daily summer or winter temperatures will impact the wine shipment. Many Australian wine shipments arrive at the port of Oakland in California destined for the East Coast, such as Baltimore or Philadelphia. Some of the points in this route are known to produce daily temperatures of 43°C in summer and minus 4°C during winter (Butzke, 2001).

Temperature levels and fluctuations during the sea stage were found to be mostly at acceptable levels, irrespective of whether the containers were insulated or not. The minimal or nonexistent temperature fluctuations and the low proportion of 25°C+ or 40°C+ hours during the sea legs is most likely the result of standard instructions that wine containers be stored below deck. However, irrespective of what directives the captain of the ship may have been given, there is always the possibility that the container could be placed above deck or placed next to a ship’s boiler (Dean and Paffard, 2002).

In response, some Australian wine companies have already taken a number of actions to reduce the risk of spoilage as a result of exposure to high temperatures. These include (Dean and Paffard, 2002):

- Trials on the use of inverted cases.
- Use of synthetic corks to minimize exposure to cork taint and random oxidation.
- Use of container liners in every shipment.
- Use of at least one data logger in each container.
- Identification of status (temperature controlled or not) of destination warehouses, and
- Establishing guidelines for distributors regarding the use of quilted containers, the operation of data loggers and the thresholds of warehouse temperature limitations.

Data collected by the WSCC wine temperature study indicate that the issues surrounding extreme temperatures in wine shipments continue to go unresolved. There is sufficient evidence that the Australian wine industry should review policies and guidelines on current shipping conditions with the goal of raising awareness among wine producers, exporters, freight companies, distributors, wholesalers and retailers about the mutual goal of minimising exposure to heat and other damage by using appropriate packaging, insulated containers and appropriate storage facilities. Attention should also be given to truck routes and shipping schedules and to the whole shipping process (Meyer, 2002).

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