Summary of Prior Experiments Regarding Temperature in Sea Containers

A Literature Review by the Wine Supply Chain Council

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Abstract
In the following document, we summarize the results of studies into the temperatures occurring inside sea containers during transport. Most of the studies we looked at focus on the situation for the wine industry. But we also look at one study concerned with the export of electronic goods. Our goal is to give an overview of the current state of published knowledge on the temperature development inside containers that involve transport on ocean going vessels.

1 Introduction
To guarantee optimal quality of wine, it should be stored in a constantly cool environment. For wine at 40°C, it is only a matter of days until visual and sensory changes occur and exposing wine to temperatures over 25 degrees for long durations and over 40°C for short duration affects wine quality [5]. Therefore, wine exporters are interested in the temperatures that their product is exposed to while in transit to an overseas destination.

This overview looks at six studies where the temperature inside transport containers during sea transit was measured. The first study was executed by the Xerox Corporation and is not primarily concerned with wine [2]. The study by Food Science Australia dealt specifically with containers filled with wine and tested the performance of OsPack liners for the inside walls of the containers [7]. The third study was executed by OsPack together with Fosters and compared two different liner systems as well as containers with no liners [4]. The study executed by Orlando Wyndham put temperature loggers into wine boxes in order to observe the temperature development in domestic road transport as well as in overseas shipments [1]. Meyer [3] relied on information collected

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from the South African wine industry as well as experts to study the impact of
temperature changes during transport on shipments of wine. Finally, Dean
and Paffard [6] present the experiences and experiments executed by McPherson
Wines in Australia.

2 The Xerox Temperature and Humidity Study

In the Xerox study, temperature and humidity data loggers were placed in con-
tainers for three different routes between Japan and two destinations in the USA
as well as one destination in the Netherlands.

2.1 Experimental Setup

The three routes studied were:

- Nagoya, Japan → Pacific → Portland, Oregon, USA
- Yokohama, Japan → Pacific → Memphis, Tennessee, USA
- Nagoya, Japan → Pacific → Indian Ocean → Suez Canal → Mediterranean
  → Atlantic ocean → Oostrum, Netherlands

The study included 160 shipments between April 2004 to January 2006. The data loggers were placed on the outside of corrugated cardboard boxes and measured the temperature every 10 minutes. Most of the loggers were placed in the top row of boxes on the outside of the central box at the door end of the container.

There was also one container where seven loggers in different positions were installed to observe the temperature variations between different regions in the container. The contents of the boxes in the containers were presumably electronic products like copiers.

A shipment consists of three phases:

1. Closing of container, land transport, storage at harbour, until loading on ship
2. Time aboard ship
3. Ship unloading, customs, road transport, storage until opening of container

Stage 2 was not always the longest stage, even for containers from Japan to Europe.

2.2 Results

- Daily temperature cycles at sea were usually very minor or non-existent
- Temperature changes at sea are usually very gradual occurring over days rather than hours
- Daily temperature differences can be extreme on land
• Highest temperature recorded was in July on the third stage of a shipment to Memphis (57°C)

• Lowest temperature recorded was in January on the same stage of a shipment to Memphis (-21°C)

• Temperatures in containers on the same ship are usually identical unless one of them is above deck. But even for above deck containers, the temperature variations are smaller than on land.

• Direct sunlight can cause the upper part of the container to be more than 15°C warmer than the outside

• The bottom row of boxes in a container can be up to 20°C cooler than the top row of boxes

3 The Food Sciences Container Liner Study

OsPack Systems asked Food Science Australia to test the performance of its container liners for wine export [7]. These liners are installed inside the shipping containers and reduce the ingress of heat.

3.1 Experimental Setup

Four 20-foot-containers were loaded with 960 cases of wine. Temperature sensors were distributed in a grid inside the containers. One of the containers had no liner while three had different liner combinations including the combination actually sold by OsPack.

Each container was placed in an environmental chamber at the Food Science facility simulating the temperature profiles of a shipment from Adelaide to Cartagena. Seven days of the trip were simulated, including one day at sea. The simulation included outside temperature as well as solar radiation.

3.2 Results

• Liners reduced the peak wine temperature (temperature inside the top row wine boxes) from 45 to 35°C compared to the container with no liners

• Liners for single Palettes do not make a significant difference, even if the container has no liner itself.

• The differences between the different liner combinations were marginal.

4 The OsPack/Fosters Liner Trial

Ospack and Fosters executed a trial including six containers filled with wine and temperature loggers send from Adelaide to the Napa Valley in California [4].
4.1 Experimental Setup

Six containers filled with boxes of wine were used in the study. Two had no liners, two had OsPack liners and two had liners of a competing company. Containers without liners contained four loggers, containers with liners contained seven loggers:

- Three in the top row of boxes: One at the door, one in the middle and one at the closed end. These were programmed incorrectly by Fosters and did not work for the whole journey. No data was used to obtain the results of the study.
- One in a box in the center of the container
- Containers with liners additionally had three loggers between the container walls and the liners (one at the ceiling and one on each side)
- Loggers recorded every half hour

All six containers left Adelaide on the same train to Melbourne and travelled on the same ship from Melbourne to Oakland, California. Then they were trucked to the Napa Valley.

4.2 Results

- In general, wine temperatures fluctuate much more while on land than at sea
- Containers placed on deck of the ship in full sunlight show the same temperature differences as on land. This results is different than in the Xerox study but it could be explained by the Xerox container being not as exposed on deck as the OsPack container.
- The center box of the exposed container with the OsPack liner did not exceed 30°C while the temperature above the liner exceeded 50°C.
- While stored on land, the roof temperature of containers sheltered by other containers stays at or below ambient temperatures while it goes up to 70°C for unsheltered containers due to solar radiation.
- Wine temperature on land for the exposed containers peaked 10 to 15°C lower for the OsPack lined containers than for the competition and the unlined containers.
- In the OsPack lined container exposed on the ship, the roof temperature regularly peaked at 50°C while the wine temperature stayed below 30°C.
- If a container is not exposed to direct sunlight at sea, the wine temperature with or without liners is similar and acceptable.
- Direct sun exposure leads to rapid temperature increase in containers even at moderate ambient temperatures. The temperature can rise up to 30°C above ambient on the metal and 10°C above ambient in the wine.
5 The Orlando Wyndham Transport Study

The Orlando Wyndham Study provides a view of the wine transport issues from the perspective of a wine producer. It looks at the behavior of wine temperature when the bottle is exposed to heat as well as at the temperature development in wine boxes during overseas transport.

5.1 Experimental Setup

“Tiny Tag” data loggers were placed in boxes containing wine bottles, that in turn were placed on pallets and wrapped with stretch film. The pallets were then placed into containers, but no further information about the position of the data loggers in the containers is given.

One of the containers was left in the open in Adelaide in February 2004 for four weeks to simulate a container transported above deck through the tropics or left on a dock in Asia. Data loggers were also placed into boxes travelling in containers from Adelaide to the UK, to Singapore, the USA and Japan.

To observe the behavior of wine temperature in a hot environment, a bottle of “Jacob’s Creek Semillon Chardonnay” was placed in an oven at a constant 30°C with a temperature sensor inside the wine.

5.2 Results

The temperature on the skin of the container left in the open peaked at just below 50°C while the temperature inside the container peaked at 35°C. The wine box started with a temperature of 18°C. The temperature increased slowly to 30°C by day 13 and then went down to a level of about 25°C due to cooler weather. The average temperature in the box was 25°C.

All loggers travelling overseas showed gradual changes over days with daily variations barely perceptible. There was a great variation in temperature profiles, even for the same destination. On an August trip to the UK, the temperature peaked midway through the journey at 28°C while it peaked sitting on the wharf in the UK for a June trip at 25°C. This could be explained by different container placement on the ship.

For two trips to the USA in December, a June shipment to Singapore and February shipment to Japan, the temperature also peaked at unloading at about 25°C except for Singapore where the temperature reached 30°C.

In the test where the wine bottle was placed in the oven, the wine had an initial temperature of 16°C. After five hours, it reached just under 28°C, rising about 2.4°C per hour.

5.3 Judgments from the Paper

- Quality reductions in wine due to excessive temperature are mainly caused in transport, not in storage at the retailer.

- About 90% of quality faults in wine are caused by excessive heat at some stage between producer and consumer.

- Assessments of tasters are a better tool for measuring faults than chemical analysis.
- Location of the container in the vessel has a big impact on temperature development.
- “Warehousing” on a dock is a significant cause of quality loss.
- Use of reefers (cooled containers) might be an opportunity for avoiding heat problems, albeit with greater cost and a 30% capacity penalty.

6 The Wine Impact Study by Danie Meyer

In “A Study of the Impact of Shipping/Transportation Conditions and Practices on Wine” [3], Meyer collected information by conducting internet and library searches, extracting information from the local wine industry, shipping agencies and main suppliers of packaging material, as well as liaising with experts abroad.

The study distinguishes three different kind of effects that exposure to high or low temperatures can have on wine:

1. **Organoleptic defects**: These defects affect sensory properties of the wine like taste, colour and odour and include oxidation, lack of fruit and change in aroma components.

2. **Chemical defects**: These are measurable chemical changes in the wine like re-fermentation, oxygen uptake and changes in total acid content.

3. **Physical defects** include obvious defects like pushed cork, sediment, clouding and leaking.

Another problem mentioned is the over-stabilization of wine in order to prepare it for extreme temperatures. This is expensive, creates a waste problem (of the bentonite used in the process) and makes damage in the wine harder to spot optically even though the taste is still affected.

The author also looks at quality standards imposed by Canada and far east countries in order to improve transport standards. The paper finishes with a list of recommendations that include the use of data loggers in all shipments, supply of storage guidelines to the user chain, and the optimization of packaging and shipping configurations for each type of product.

7 The McPherson Wine Transport Study

The McPherson Wine transport study [6] discusses the problems experienced by McPherson Wines and the actions they have taken to address the causes. The study was initiated when McPherson Wine experienced quality issues with wine shipments from Australia to Florida and Texas. These were initially believed to be closure related but because bottles from the same badges exported to other states of the US had no defects, this explanation could be discarded. Instead, the kind of damage pointed to expansion and contraction of the wine at high temperatures.

Data loggers have been used to trace the temperatures during transport of the wine from Australia to the US. The data retrieved indicated that the temperature increase during the sea voyage was slow and steady while large and potentially damaging fluctuations occurred after arrival on US soil.
The authors recommend the regular use of temperature loggers not only to identify potential problems in the transport chain but also to enforce quality standards on the shipping companies.

8 Conclusions and Open Questions

The main cause for temperature variations inside shipping containers seems to be direct solar radiation because it can heat the inside of the container to temperatures of up to 30°C above ambient. Therefore, protection of the container from direct sun light is crucial. If the container is stored below deck during the sea voyage, the temperature stays inside a benign range even without any additional protection. But extensive exposure to solar radiation is almost unavoidable during the land part of container transport. Liners can make a significant difference for containers exposed to direct sun.

The main challenge of the experiments with real transports (as opposed to simulated transport in the Food Science facility) is that the exposure of the container to sun light could not be directly observed but only inferred from the temperatures. Open questions include:

- What is the impact of container colour? Does a light colored container skin reduce solar heating significantly compared to a dark colour?
- What is the impact of the position of the container relative to other containers on the ship? Is there a significant difference between one container on top and two containers on top? Is “below deck” much better than under another container? What about containers on the sides?
- How much of the temperature increase is caused by solar radiation on the sides of the containers compared to the top? If the top is the main problem, counter measures could be concentrated in that area.

References


