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# Implication of Temperature Changes During The Strawberry Supply Chain

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**Abstract:** The importance of the cool chain for strawberries from any destination is well known. Too high a temperature gives a high wastage. One of the main problems in the strawberry supply chain is temperature fluctuation, which causes condensation and increases disease infection, such as grey mould (caused by: *Botrytis cinerea*).

The objective of this work was to evaluate the changes that can occur from the retail outlet to the consumer's home refrigerator. The trials showed that the fluctuating temperatures could increase the level of infection; however there was little difference in total weight loss. The work also measured the actual flesh temperatures of the berries and also the temperature difference between the bottom and top of the berries. It was found that there was a temperature difference within the berry. Although the air temperature within the retail punnet would return to below 4$^{o}$C in less than an hour the berries could take over three hours to reach a similar temperature.

**Key words:** Cold store, temperature fluctuation, condensation, weight loss, strawberry, clamshell punnet

## INTRODUCTION

Strawberries have become an increasingly popular crop all year round and the total world production increased from 3.2MT in 2002 to approximately 3.6MT in the year 2006 (FAOSTAT, 2006). The strawberry (*Fragaria ananassa)* is much prized for its flavour and delicacy and is also a popular fruit with high visual appeal; However, strawberries are highly perishable, the structure of strawberries make them vulnerable to spoilage, because of a thin tender skin that is easily broken, making them vulnerable to crushing and bruising and susceptible to mechanical injury, water loss, decay and physical deterioration (Shin *et al.,* 2008)..

The eatable part of the fruit is the fleshy receptacle, which is bright red, juicy and covered with small achenes. Strawberry is non-climacteric (does not ripen after harvest) with little change in ethylene production during maturation (Thompson, 2003). Strawberries are among the fruits with the highest respiration rate, the ethylene production in a strawberry fruit decreases sharply when the fruit develops from green to white, but changes little with further development, with very low ethylene production 15- 18 nl/kgh in ripe strawberries (Dris *et al.,* 2001).

Temperature is the greatest determinant of fresh produce deterioration rate and potential market life. Produce temperature management must begin from the moment of harvest when postharvest deterioration begins (Thompson *et al.,* 1998). Both exposure temperature and duration are important to the amount of deterioration that will occur (Kader, 2002). Strawberries should be protected from warming while they remain in the field, shading can help to keep pulp temperatures of harvested berries below air temperature (Mitchell *et al,* 1996).

Water loss is one of the most critical parameters in terms of marketability. Physiologically, water loss results in reduced turgor pressure inside the cells, leading to symptoms such as wilting, flaccidity, limpness and loss of juiciness (Laurin *et al.,*2005). Wrapping strawberries with plastic semi-permeable film (or packaging in clamshell baskets immediately after harvest minimizes the weight loss of fruits (Paraskevopoulou-Paroussi *et al.,* 1995).

Temperature is one of the postharvest environmental characteristics that most influences the quality and storage life of strawberries, (Nunes and Emond, 1999). Tano *et al.* (2007) observed that, most of the physical, biochemical, microbiological and physiological reactions contributing to deterioration of produce are largely dependent to temperature. Jobling (2007) emphasised constant cold temperatre during storage and handling. Therefore, maintaining the correct temperature of the strawberries throughout the supply chain becomes primarily important. One of the main problems in the strawberry supply chain is temperature fluctuation, which causes condensation and increase disease infection, such as grey mould (caused by *Botrytis cinerea*). Snowdon (1990) mentioned that humidity is the most important factor regulating the occurrence of grey mould with the combination of high temperature (20-27°C).

Much research has been carried out on effects of temperature fluctuation on different horticultural crops focusing on quality. Ito and Nakamura (1984) observed that temperature fluctuation did not have a positive effect on the amelioration of chilling injury and in 1985 in another experiment they found that effects of fluctuating temperature on different crops showed different results. Nunes and Emond (1999) showed that fluctuating temperatures caused higher weight loss, PH, lower firmness and glucose content. They found that the concept of degree day cannot be applied to predict the effects of temperature on quality of strawberry since some quality parameters were dependent on the temperature pattern.

Much of the existing research mentioned previously considered the cool chain up to the retailer However it may be that the greatest problems for fruit occur in the “last mile”, therefore the objective of this work was focused on implication of temperature fluctuations at the last stage from retailer to consumer considering the temperature changes in the actual berries as opposed to the air within the punnet and the resulting implications.

## MATERIALS and METHODS

Strawberries (cultivars: Sabrosa and Elsanta) were used in three trials in the commercial clamshell punnets of supermarkets each one with approximately 400 g. Strawberries were free from defects, size of strawberries were different to compare different effects of different temperature regimes. To compare the typical temperature experienced the punnets were exposed to a temperature of approximately 30$^{o}$C, 80% RH for half an hour before being returned to a temperature of approximately 2$^{o}$C.

In all trials the same punnets (dimension: 168×148×57 mm, ventilation free area of 1.3%) were used. In each trial three punnets were selected and number of berries were counted, then the smallest and largest berries were weighed (before and after each trial). Small temperature loggers “Tinytalk” and “Tiny Tag” (Gemini dataloggers) were used to record temperature during each trial.

**Trial 1:** This trial was carried out to compare effects of temperature fluctuation on water loss and increasing disease infection in strawberries (Cultivar: Sabrosa). Two temperature regimes were used:

A) Constant temperature (2°C in cold store)

B) Fluctuating temperature (in cold store at 2°C, everyday 30 minutes at 30°C in hot box).

In this experiment loggers were set to record temperature every 3 minutes for 3 days. Sensors of loggers were put into the actual berries (small and large) as well as measuring air temperature.

In each punnet one berry was infected with Botrytis before starting the trial. The disease infection was measured after trial.

**Trial 2:** In this trial all treatments (Cultivar: Elsanta) were in fluctuating temperature. The punnets were selected, then berries were counted and weighed (before and after experiment), only in one punnet one berry was infected with Botrytis. In each punnet two temperature loggers were put; one sensor in a small berry and another in large berry. One logger (Tiny Tag) was used for recording air temperature outside the punnets.

In this experiment loggers were set to record temperature once per minute for two days. Four hours treatments were in cold store set at 2°C, and then they were put in hotbox at 30°C for 30 minutes (punnets side by side) and back in the cold store. Three punnets experienced the same temperature fluctuations but the punnets were stacked on top of one another rather than being placed side by side in the cold store

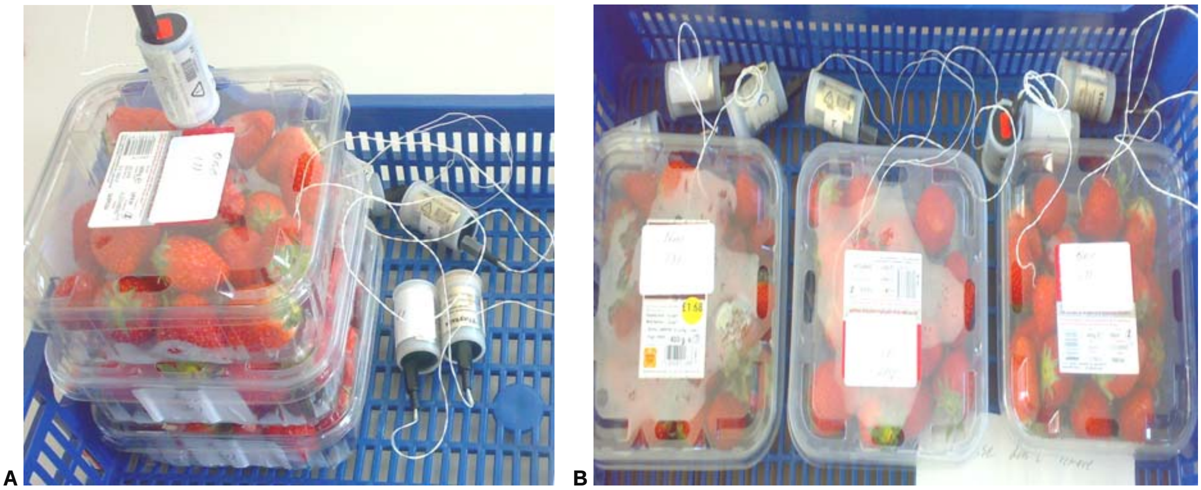


**Figure 1. Cylinders of loggers were put out of punnets. Note the condensation in punnets which were in bottom (A), there is no condensation in punnet which was on top (B).**

**Trial 3:** This trial was similar to trial 2. All temperature loggers recorded once per two minutes. In one punnet, two sensors were put in a large berry, one sensor on top and another in bottom of berry. Punnets were put in hotbox (30°C) for 30 minutes and again punnets stacked one on top of another (Figure 1).

## RESULTS

After the scheduled time for each trial, berries were weighed and the infection of Botrytis was observed, then loggers were offloaded and graphs of temperature changes were prepared from data obtained from loggers.

### Trial 1:

Water loss in both constant and fluctuating temperatures was low, strawberries stored in fluctuating temperatures lost more than 3% of their initial weight after 3 days while those stored in constant temperature lost less than 2%.

Botrytis infection in fluctuating temperature was about twice as high as constant temperature storage, 42.3% of berries in fluctuating temperature storage were infected while 24.3% of those stored in constant temperature were infected.

Data recorded by temperature loggers and temperature graph (Figure 2) showed that for 30 minutes of being in hot box and increasing air temperature from 2°C to 30°C, the temperature inside punnets was increased to about 17°C and in berries about 13°C, however air temperature returned to 2°C in less than 30 minutes after putting in cold store and after about four hours temperature inside the punnets returned to 2°C, while for berries, it took more than seven hours.

Maximum temperature in large berries was less than small berries; however it took more time in large berries to return the constant temperature (2°C).

### Trial 2:

Water loss was similar to trial 1 (about 2.5% after 2 days), however water loss in the punnet in which one berry was infected with Botrytis was more than others (about 3%).

Botrytis infection was observed only in the berry which was infected in one of the punnets, and did not spread to other berries after two days in fluctuating temperature conditions.

Both trail 1 and trial 2, showed higher maximum temperatures for smaller berries compared with larger berries and more time taken to return for large berries.

However in this trial when punnets were stacked one on top of another , the maximum temperatures in punnets which were located in the bottom were less than punnets on top, while the time taken for berries in punnets which were in the bottom to return to a constant temperature was more than berries in the top of the punnet (Figure 3).

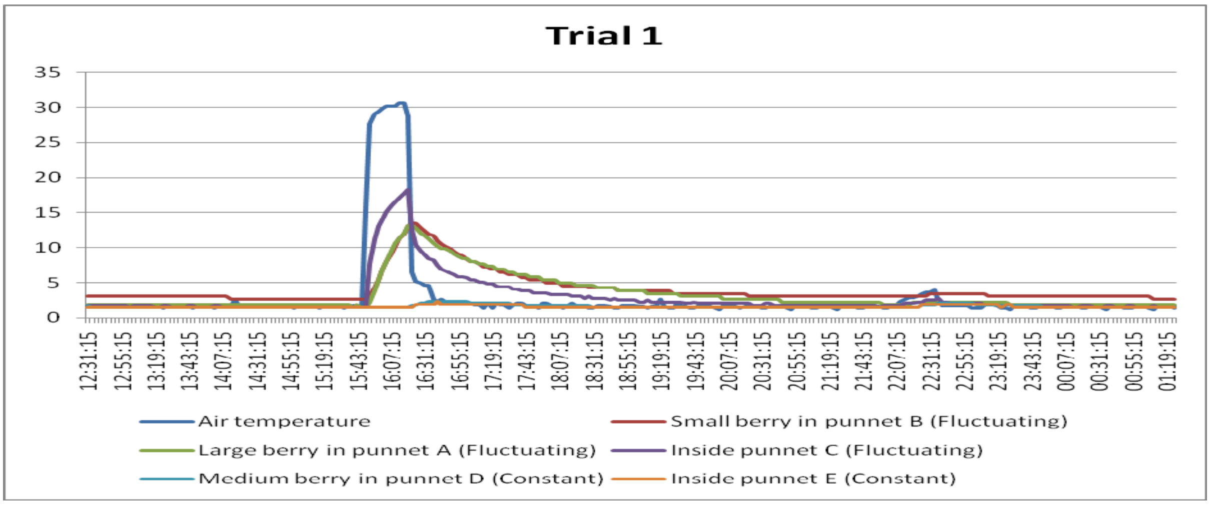


**Figure 2. Graph of temperature changes in trial 1.**

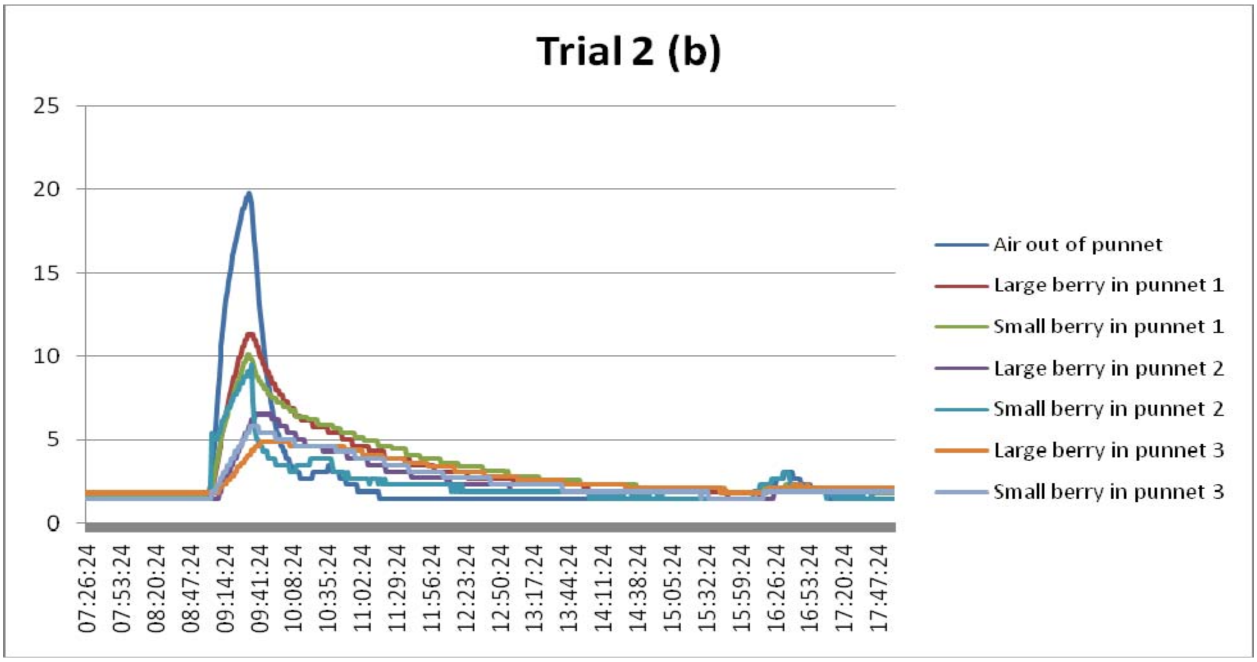


**Figure 3. Graph of temperature changes in trial 2 (second run in fluctuating temperature, punnets stacked one on top of another)**

**Trial 3:**

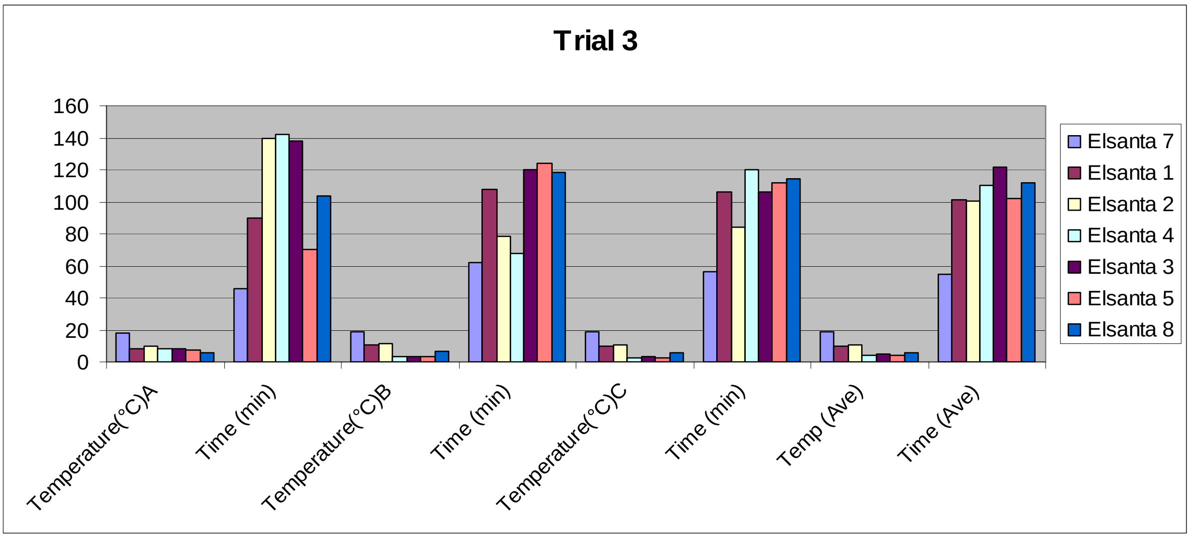
Water loss in trial 3 was less than others (about 1.5% after 2 days), again water loss in punnet which was infected with Botrytis was more than others (about 2% after 2 days).

As with trial 2, there was no infection in punnets which were not innoculated, however in punnets which one berry was innoculated in this trial, the infection had spread to about 18% of berries.

The loggers showed that increasing temperature in small berries was faster than for large berries. In punnet 1, two sensors were inserted in the top and bottom of a large berry, which showed more than 2°C difference. As was expected the maximum temperature in the bottom of the berry was less than the top, however in cooling the top cooled quicker, so the time that bottom remained warmer was more than top (Figures 4 & 5 and table 1).

**Table 1. Time taken for returning to 4°C**

| Trial 3 | Temp(°C) Run(A) | Time (min) | Temp(°C) Run(B) | Time (min) | Temp(°C) Run(C) | Time (min) | Temp (°C) Mean of 3 Runs | Time (min) Mean of 3 Runs |
|---|---|---|---|---|---|---|---|---|
| **Air** | 17.7 | 46 | 18.8 | 62 | 18.8 | 56 | 18.4 | 54.6 |
| **Large top 1** | 8.1 | 90 | 10.6 | 108 | 9.6 | 106 | 9.4 | 101.3 |
| **Small pun1** | 9.9 | 140 | 11.4 | 78 | 10.3 | 84 | 10.5 | 100.6 |
| **Small pun2** | 8.1 | 142 | 3 | 68 | 2.3 | 120 | 4.4 | 110 |
| **Large pun2** | 7.8 | 138 | 3.4 | 120 | 3.4 | 106 | 4.8 | 121.3 |
| **Large pun3** | 7.3 | 70 | 3.3 | 124 | 2.8 | 112 | 4.4 | 102 |
| **Large bottom 1** | 5.6 | 104 | 6.7 | 118 | 6.1 | 114 | 6.1 | 112 |



| | | | |
|---|---|---|---|
| Elsanta 1: Top large berry (punnet 1) | | Elsanta 5: Large berry (punnet 3) | |
| Elsanta 2: Small berry (punnet 1) | | Elsanta 7: Air temperature | |
| Elsanta 3: Large berry (punnet 2) | | Elsanta 8: Bottom large berry (punnet 1) | |
| *Elsanta 4: Small berry (punnet 2)* | | | |

**Figure 4. Comparison of time taken to return 4°C in 3 different treatments.**

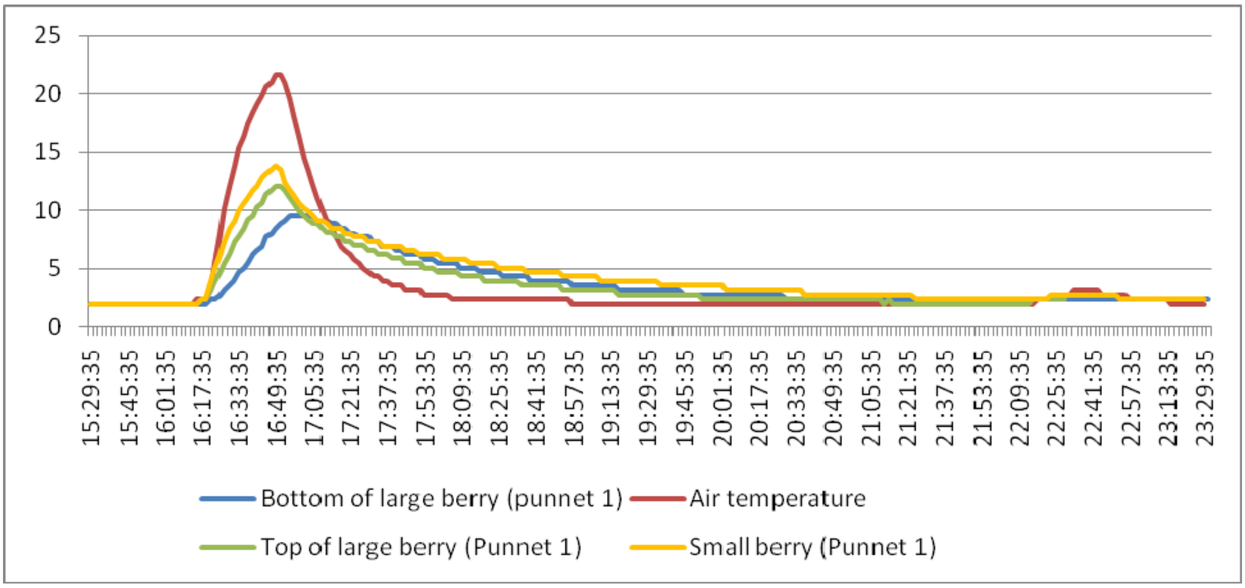


**Figure 5. Graph of temperature change in first fluctuating temperature and differences of changes in top and bottom of berry (punnets placed next to each other).**

## DISCUSSION

These trials would appear to be the first work where the temperature of the berry, as opposed to the air temperature within the punnet, has been monitored and showed not only a lower temperature gain while exposed to high temperatures but also a much slower cooling rate of the berries.

The results showed that water loss in fluctuating temperature was higher than in constant temperature, however because the period of each trial was short (2-3 days) the difference was small. This showed the same results which were obtained by Nunes and Emond (1999). During handling and storage, consistant temperature helps to prevent water loss as well as preventing the occurrence of condensation.

From time delay photography carried out at Writtle College (not reported in this paper), it was observed that the Botrytis infection started to develop from the bottom of punnet. The reason for this may well be highlighted in the third trial where it was shown that the temperature change was slower in the bottom than the top of the berry so putting the base of the fruit at risk for longer. To prevent this, better ventilation and the use of absorbing pads at the bottom of the punnet may be a benefit although unfortunately there was not enough time to investigate this further. It was noticed however that some of the supermarket punnets which at first glance looked similar had vents in the base.

When the punnets were stacked rather than placed side by side the temperature changes were slower and this would suggest that, with the limited percentage free area, and air movement within a domestic refrigerator, that consumers should be advised to place punnets side by side rather than stacked if space allows, and always ensure that the punnets are side by side during the “final mile”.

## CONCLUSIONS

Since there can be many serious implications for strawberries in the supply chain occur during the “last mile”, and preventing fluctuation in temperature especially between retailer and consumer’s refrigerator seems very difficult to avoid, the results of this work showed that better ventilation and proper arrangement of punnets can help to reduce condensation and possible diseases infections.

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