Title Air transport of horticultural products: A thermal analysis

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Abstract

Temperature is the most important factor in the postharvest life of horticultural products and temperature management is essential to reach the optimum postharvest quality. Preserving the quality of fresh fruits and vegetables requires a proper cold chain from the field to the consumers' home. Too often, transport operations are responsible for breaks in the cold chain, particularly in the case of air shipments.

Air transport plays a major role in the global food trade and, even during the recent worldwide economic slump the sector of air freight occupied by food products only experienced a small decline. Maintaining a proper cold chain during air transport operations is challenging since the cargo may spend extended periods of time on the tarmac, where they are exposed, with limited protection, to harsh environmental conditions.

Studies on in-flight environmental conditions and their impacts on the temperature distribution in loads of fresh fruits and vegetables transported by air have been limited in number. However, such studies are important to develop new handling methods as well as to predict and preserve quality. A thermal analysis was conducted on loads of horticultural products in single boxes and in an aircraft container exposed to detrimental temperatures in laboratory conditions. Different fruit sizes and packing arrangements were used for the tests on individual boxes. These tests showed small temperature differences between the pulp and air temperatures within the boxes. Relatively fast rates of change of the temperatures were observed even in the core region of the boxes. For the aircraft container, a similar thermal behavior was observed in the fruit near the outside surface of the load, particularly for the boxes located on the top row. Even after 8 h of exposure to detrimental conditions, the temperatures within the core of the aircraft container remained almost constant. With the exception of the bottom layer, a vertical stratification of the temperatures was observed in the boxes as well as in the container.

In addition to laboratory tests, temperatures were also monitored during several international flights using an instrumented aircraft container loaded with simulated horticultural products. Thermal behavior similar to that of the laboratory tests was observed during the air transport operations. The tests showed that the ramp transfers before and after flights were critical to maintaining a proper cold chain,

mainly because of the effect of solar radiation. For some shipments, the ramp transfer exceeded 8 h and temperatures above 60°C were also measured on the inside surfaces of the aircraft container walls. Even though temperatures were not always optimum within the aircraft cargo compartments, their effects were not as detrimental as those associated with ramp transfers.

Based on the experimental data collected through laboratory and air shipment tests, the validity of a heat transfer model based on an effective thermal conductivity was investigated. For individual boxes, simulations showed that an effective thermal conductivity approach provided acceptable results in the lower and lateral regions of the load but significantly underpredicted the temperatures in the core regions. Aircraft container simulations revealed that the temperatures were also underpredicted in the top of the boxes located on the bottom layer and at the bottom of the boxes located on the top layer. The model did not provide a good representation of the temperature distribution throughout the load of products, but did provide good results in the peripheral region. It appeared that the effect of natural convection must be included in the effective thermal conductivity via a variable dynamic component to improve the overall results of such a modeling approach. However, the results indicated that the modeling approach used could still be implemented as a useful tool for air shipments of horticultural products, since temperature abuses are generally observed in the peripheral region of the load, where the model provided useful results.