Proc. Fla. State Hort. Soc. 127:145–146. 2014.

New Clamshells to Decrease Moisture Loss and Extend Storage Life of Small Fruits

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Additional index words. relative humidity, firmness, decay

A humidity efficient one-pound clamshell was designed for small fruit packaging. Quality attributes and shelf-life of lychee, sweet cherry, strawberry, blueberry, Chinese bayberry, and loquat fruits packaged in the new clamshells and commercial clamshells were compared during storage at 0 °C, 5 °C, 10 °C, and/or 20 °C. Water loss of fruit in the new clamshells decreased by at least 62%, in comparison to commercial clamshells at all storage temperatures. As a result, fruit in the new clamshells had less surface shriveling and flesh softening (cherry, strawberry, and blueberry), stem (cherry) and calyx (strawberry) browning and drying, and pericarp browning (lychee).

Growers and packers of small fruits are often surprised at how their fruit in a grocery store can sometimes look so poor (having brown stems, shriveled fruit surface and a soft texture). They are perplexed because the temperature, a critical factor for quality, was strictly controlled throughout postharvest storage and marketing. We analyzed the postharvest handling systems of these fruits, and found that water loss played a major role in the deterioration of fruit. We also found that the unattractive appearance is only a part of the quality deterioration. Nutritional and taste deterioration due to water loss usually precedes or occurs concomitantly with the appearance of visible symptoms. This is why we initiated the idea of "humidity efficient packaging."

Small fruits, such as sweet cherries, strawberries, blueberries, cranberries, raspberries, gooseberries, blackberries, and table grapes comprise a fresh market industry of four billion pounds valued at 6.366 billion dollars in the United States alone. The demand is steadily increasing because of their functional nutrition value as a source of healthy foods. Humidity efficient packaging will decrease postharvest loss and promote consumption of small fruits, and ultimately benefit the health of consumers.

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(Some of the material discussed in this abstract and associated manuscript comprises the subject matter of a patent application currently pending with the U.S. Patent and Trademark Office. If you are interested in licensing the technology described herein, please contact Jinhe Bai or Liz Baldwin. Dr. Bai or Dr. Baldwin can direct you to the appropriate USDA, Agricultural Research Service (ARS) personnel who can answer your questions and provide you with further information regarding licensing opportunities. In the event that either Dr. Bai or Dr. Baldwin is not immediately available, please contact the Technology Transfer Coordinator for the USDA–ARS Southeast Area Office in Stoneville, MS).

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Humidity maintenance practices, such as polyliner and polyethylene pallet covers, along with low temperature environment, are commercially used to decrease water loss and slow the quality deterioration of stem and fruit in the packing house. However, when fruit arrives at the retail market, the polyethylene pallet cover and polyliner in the box often are removed, leaving the fruit exposed to the ambient air. At the retail store, fruit on the shelf in bulk, in loose perforated polyethylene bags, or in clamshells with large open spaces, will lose water rapidly. A non-refrigerated display will make this situation worse.

We have developed a new clamshell, which has smaller openings. The opening ratio to total surface area of the new clamshell is 0.05% to 0.5%, in comparison with the commercial ones with ratios of 3% to 10% (Fig. 1). Lychee, sweet cherry, strawberry, blueberry, Chinese bayberry, and loquat fruits were washed immediately after harvest, drained and packaged in both the new and commercial clamshells, and then were stored at 0 °C, 5 °C, 10 °C, and/or 20 °C for various time periods. Relative humidity (RH) and gas (oxygen and carbon dioxide) in the clamshells, and water loss of fruit were monitored, and quality attributes were measured during storage.

The results showed that RH inside the new clamshell was 5% to 6% higher than in the commercial clamshell. Oxygen and CO_2 concentration were similar in both clamshells and there was no anaerobic metabolism in the packaged fruits. Water loss of fruit in the new clamshells was at least 62% less, compared to fruit in commercial clamshells at all storage temperatures. As a result, fruit in the new clamshells had less surface shriveling and flesh softening (cherry, strawberry, and blueberry), stem (cherry), and calyx (strawberry) browning and drying, and pericarp browning (lychee). Blueberries inoculated with a fruit decay organism, *Colletotrichum acutatum* Corda, or non-inoculated, were packaged in the clamshells and stored at 1 °C and 20 °C, and there was no difference in decay incidence despite the higher internal humidity caused by the reduced open areas. The new clamshell extended

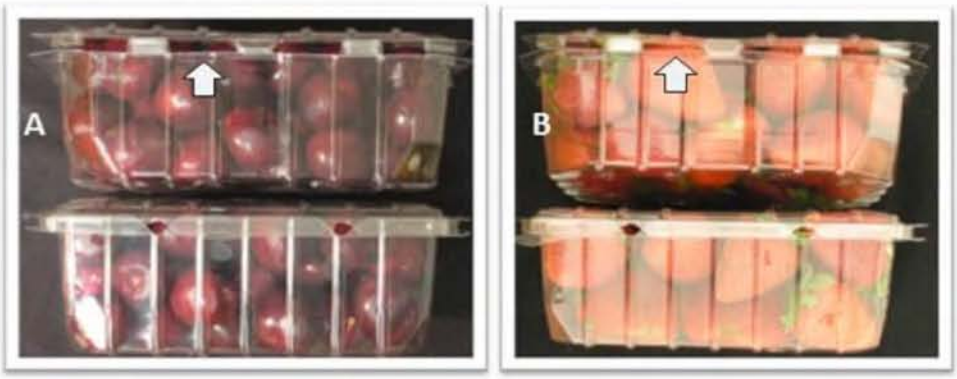

Fig. 1. Sweet cherries (**A**) and strawberries (**B**) packed in commercial clamshells (upper) with a ratio of opening 3.3% and experimental clamshells (bottom) with a ratio of opening 0.5%.

shelf-life of fruits by an average of 178% in comparison to fruit in commercial clamshells.

The rate of water loss is dependent primarily on the external vapor pressure deficit. Water loss is a major cause of postharvest deterioration because it results not only in direct quantitative losses (loss of saleable weight), but also losses in appearance (wilting and shriveling) and textural quality (softening, flaccidity, and loss of crispness) (Burg, 2004). Bai et al. (1990) reported that 'Hassaku' orange packed in low perforation (0.16%) polyethylene bags had less weight loss, decay and physiological disorder as compared to high perforation (1%) bags. In addition the resulting water stress, hormonal changes are induced such as enhanced ethylene production and increased abscissic acid (ABA) levels, which hasten senescence, membrane disintegration, and the leakage of cellular contents (Ben-Yehoshua and Rodov, 2003). While the influences of temperature and gaseous atmosphere on postharvest quality have been studied in depth, research on relative humidity, the simplest and easiest way of delaying produce deterioration after harvest, is infrequent (Paull, 1999).

This research provided solid evidence that a humidity modification without substantially influencing gas concentrations in the packaging can markedly improve quality of small fruits and extend shelf-life

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