Issues and Innovations in Temperature Control

by H. Louis Cooperhouse

Temperature is the most important and most obvious criterion for maximizing the shelf life of fresh-cut produce products, and all refrigerated foods for that matter, yet it is frequently misunderstood and overlooked. The temperatures encountered at each link of the chain have a direct bearing on the shelf life, quality, and potential safety of fresh-cut products.

The Cold Chain

The cold chain for fresh-cut produce truly begins in the field, and does not conclude until the product has been consumed. The importance and dramatic benefits of utilizing rapid cooling techniques immediately after harvest to retard microbial growth and enzymatic activity have been well documented. These include hydrocooling, in which product is sprayed with chlorinated water at a temperature of around 33°F, and vacuum cooling, in which air is evacuated from an enclosed area to remove moisture and heat.

Other techniques include forced-air cooling, in which refrigerated air is moved rapidly over fruits and vegetables, and package icing, where an ice slurry is placed into vegetable containers. Following this first link in the chain, product temperature must be maintained in raw product storage, in the trim/core and washing operation, during packaging, in finished product storage and during the many points that occur during distribution.

Temperature Abuse

Distribution, including practices that occur at retail, has frequently been regarded as the Achilles' heel in cold chain management, and has been attributed by many to be a major impediment limiting the potential growth of the fresh-cut category. Despite the standards and information provided by federal, state, and county agencies, minimal education initiatives are in place and various surveys have shown that temperatures of foods in U.S. chilled food distribution channels are frequently in the range of 45°F–55°F. This is simply unacceptable.

Temperature abuse can, and does, occur too frequently during distribution and during the retail sale of fresh-cut produce products. Truckloads of perishable items are occasionally shipped above 50°F because of ignorance, negligence, or mechanical breakdowns en route. Abuse can also occur at the loading docks of the processor, during transportation to a regional distribution center, at the loading dock of a regional distribution center, in the cooler of the regional distribution center or warehouse, during transportation in refrigerated trucks to the retailer or foodservice operator, at the loading dock of the individual retail store or foodservice operator, etc. It is also becoming increasingly difficult to schedule supermarket delivery times, and, as a result, trucks may shut off their refrigeration units during the period prior to offloading. In addition, pallets of perishable goods occasionally may sit on the receiving floor of a supermarket for up to several hours during a mid-summer day until they are properly placed into refrigerated storage.

Store Level Temperature

Although a great deal of temperature abuse can occur at many points during distribution *prior* to the placement of

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product in the store's retail case, a significant amount of abuse occurs *after* product has been displayed for sale. Many fresh-cut products spend a great deal of their shelf life sitting in a display case at retail. The design and functionality of the retail case itself has a major impact on product shelf life. Most supermarkets and grocery stores have trouble keeping their produce cabinets below 45°F, and studies have shown that the refrigerated cabinets in the produce section of the store maintain some of the warmest temperatures in the entire supermarket—even though products sold there are among the most susceptible to spoilage.

By design, most retail cabinets, especially open cabinets, were developed for the merchandising of fast turnover products, not the effective long-term storage of products. Built into most systems are defrost cycles, lights, ballast, etc., that impair their effectiveness and air curtains that are easily disturbed during normal operation. Proper circulation of cooling air is essential if temperature control is to be maintained. Unfortunately, overstocking, promotional materials, etc., often impair this circulation. In addition to light-induced temperature changes that can occur, placement of products near lights and ballast can increase product temperature by as much as 10°F. Products located at the bottom of horizontal display cases or the back of vertical display cases are generally the coldest products in the case. This is due to the circulation of colder air, greater distance from store ambient temperatures and the near absence of radiant heat from lights.

Standard equipment in most refrigerated display cabinets is the display case thermometer, a potential source of both information and deception. These thermometers, usually required by local or state laws, have sensing elements that are frequently situated directly in front of incoming blower air and are, therefore, even if calibrated, more indicative of the blower temperature than the actual product temperature. Studies have shown that the average actual temperature of refrigerated product can be as much as 10 degrees warmer than the temperature indicated on a thermometer next to the blower. Similarly, defrost cycles in a refrigerated case have been shown to result in a short-term spike in which product internal temperature briefly reaches 60°F, and this may happen twice a day every day.

Temperature Abuse at Home

Temperature abuse certainly also occurs during the trip from the supermarket to home due to outside temperatures and/or lengthened times until products are properly stored. In addition, the home refrigerator is frequently a location for temperature abuse. An Audits International Home Food Safety Study found that lack of education and lack of motivation were typical reasons why refrigerator temperatures are set too high in many homes. Many consumers simply *do not know* at what temperature a refrigerator should hold product. In addition, many refrigerators are set too warm simply because many refrigerators lack a thermometer.

Superchilling Solutions

"Superchilling," also called "sub-zero degree chill," "deep chilling," and "supercooling," is generally agreed to be the temperature just above the freezing point of the product or raw material. For fresh-cut produce, this would equate to a holding temperature in the range of 33-35°F for most products. It has been determined that at these deep chill temperatures most microbiological activities are kept at a minimum. It has also been determined that *shelf life is 1.5 to 4 times greater* for products stored at these temperatures versus those stored at conventional refrigeration temperatures of 40–45°F. Superchill temperatures make chemical and biochemical processes go slower and provide opportunities for improved product quality in almost all cases.

The inhibition of growth of a majority of pathogenic and food spoilage microorganisms is an extremely important advantage with superchilling. The effect of low temperatures on different microorganisms is well documented. The growth of bacteria and their ability to produce toxins are strongly temperature dependent. At temperatures just above the freezing point of a food, most pathogenic bacteria have lost their ability to form toxins and their growth rates are significantly reduced. In addition, some bacteria are very sensitive to a sudden drop from their normal growth temperature to a temperature near the freezing point. This "cold shock" is most commonly associated with gram-negative bacteria, such as *Escherichia coli*, in which bacterial counts drop dramatically. However, it should be noted that pathogens such as *Listeria monocytogenes, Yersinia enterocolitica*, and *Aeromonas hydrophila* have shown growth in foods at these superchill temperatures, although their potential has been lessened.

Temperatures must, of course, be precisely monitored. Fruits and some vegetables are very sensitive to ice crystal formation because the cell walls are easily damaged. As fruits and vegetables are physiologically active after harvesting, each plant has its own optimum temperature at which it should be stored. Most fruits and vegetables have water content between 80 and 95 percent. If the temperatures of fruits and vegetables are reduced towards the freezing point, respiration and transpiration rates are also reduced. Although low temperatures in most cases have a favorable effect by reducing reaction rates, care must be taken against ice crystal formation.

What Can We Do Now?

As a measurement to reduce the risk of foodborne disease outbreaks, improve product quality and increase shelf life, fresh-cut processors can *immediately* begin using superchill temperatures as a replacement for standard chill temperatures within their internal operations. This includes storage of raw materials, work-in-process products, finished products, and shipments to distribution depots. Food manufacturers can also actively promote superchill distribution of fresh food via cooperation and joint ventures with equipment manufacturers, wholesalers, transportation companies, and major consumer outlets.

Temperature recording devices are valuable tools, and should be incorporated in each stage of the cold chain as part of an overall HACCP plan. Many such indicators exist. New systems are now available for distribution that utilize wireless sensors and sophisticated web-based tracking capabilities, and provide a quicker ability for monitoring and alerting should a problem occur.

Other options now available include "Intelligent packaging" systems, which consist of sensors that provide information about the product to the consumer, foodservice operator, or other user. The most widely known intelligent packaging system is the time temperature indicator (TTIs). These indicators track the relationship between time and temperature and their impact on spoilage or some other end-point to product acceptability. They must be individually developed for specific products. The degree of color change will reflect any temperature abuse encountered, integrating time and temperature in an exponential, irrevers-

ible relationship.

Time-temperature indicators have been available for well over a decade, but have been only sporadically utilized in industry. Unfortunately, a major reason that their use in industry has been minimal to date is because these indicators do in fact provide "real" information on abuse that occurs during the cold chain. Food manufacturers and retailers, for example, feel that recognition of these facts will result in increased "finger pointing" between these buyer and seller parties. If TTIs were to be utilized, for example, a dramatically increased rate of spoils and credits for product may result due to realistic information concerning product spoilage. Cost has also been a concern to the industry, especially when the indicator is used for consumer shelf life communication purposes rather than for manufacturer quality assurance purposes. In a consumer application, for example, indicators are typically added to every primary package; in a less costly application, indicators are statistically applied to cases or pallets of product instead. It should also be pointed out that TTIs do not reflect the microbiological quality or safety of a product. If a few organisms of *E. coli O157:H7* are present on a cut fruit or vegetable, for example, then regardless of what happens to the population of spoilage organisms and the pathogen's ability to compete with them, the product is compromised from the start. Nevertheless, manufacturers and retailers can use TTIs, and the information they provide, to instill *refrigeration discipline* during product distribution.

New Standards Needed

The current industry "standard" for refrigerated holding conditions is 40°F. Health departments, federal and state agencies and safety education programs are in place to educate the public that a refrigerator set at 40°F or below will protect most foods. Although federal and state agencies use the temperature of 40°F as the "standard" for refrigeration, both the safety and quality of refrigerated foods would benefit greatly if recommended temperatures are *less than* 40°F. Certain pathogenic microorganisms, which can grow at temperatures below 40°F, would be less likely to cause foodborne disease if products were in fact kept at colder temperatures. Product quality has been shown to be *demonstrably* enhanced and extended at temperatures that *approach the actual freezing point* of foods.

The optimum temperature for holding refrigerated foods should be in the superchill range. It is recommended that the setpoint and standard for refrigerated foods holding temperatures be established as 33°F (1°C). It is also recommended that a national awareness program be developed to encourage manufacturers, distributors, retailers, foodservice operators, consumers and all those involved in the cold chain to keep refrigerated foods at a setpoint of 33°F and not 40°F. Perhaps a refrigerated icon (such as a thermometer or refrigerator symbol) should be developed and a nationwide awareness program implemented to communicate that product must be kept cold at this new setpoint. It is believed that food safety nationwide would be dramatically improved if a national awareness program was created to inform consumers, and others involved in the cold chain, about this new standard. ■

***Editor's Note**: Lou Cooperhouse is director of the Food Innovation Research & Extension Center of Cook College and the New Jersey Agricultural Experiment Station at Rutgers University. He has also recently published a comprehensive study entitled **Retail Prepared Refrigerated Foods: The Market and Technologies**. For further information, please contact Lou Cooperhouse at 732-537-1901 or at cooperhouse @aesop.rutgers.edu.*