Measuring Produce Freshness: The Key to Preventing Waste

The Big Freshness Blind Spot*—The produce supply chain has a big problem—'freshness blindness' across the entire chain. Visual inspection is standard practice to assess freshness of produce as it travels from field to shelf. But visual inspection doesn't work very well. Visual freshness indicators are lagging indicators. Produce appearance only reflects visible deterioration, not remaining freshness, even when very few days remain to consume the product (see Figure 1).*

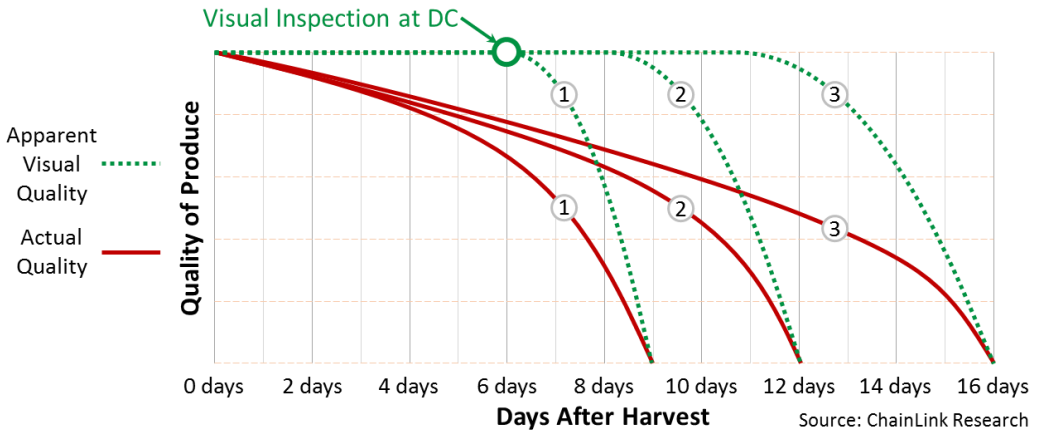

Figure 1 – Freshness Blindness—Divergence of Visual vs. Actual Quality

At the grower, everything looks fresh when loaded on the trailer. There is typically little or no visibility into how it has been handled up to that point. A grower may occasionally make a decision based on some known factor impacting freshness—for example, if they skimped on precooling some pallets, they may send that batch to the local market—but typically, growers are not using a consistent, product-condition measurement method to determine the actual remaining freshness when they make decisions about where to send the produce.

The retailer also relies on visual inspection, resulting in low rejection rates but high return, mark-down, and throw-away rates. They usually will not know about inadequate remaining freshness until it is too late, as the product will already be at the store. The retailer needs to accurately know remaining freshness at the point of receiving the product. If spoilage only becomes evident at the store, or shortly after the customer purchases, it is too late. Post-purchase spoilage is especially damaging to a grocer's brand and customer loyalty. Freshness of produce and other fresh food is the number one reason customers choose where to shop for their groceries. When produce goes bad shortly after being brought home, the shopper takes their business elsewhere.

What is needed is a consistent, condition-based metric to accurately determine remaining shelf life and systems that use that knowledge to make the smartest decisions at each step in the cold chain.

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Ensuring Delivered Freshness

Delivering Every Pallet at Full Value

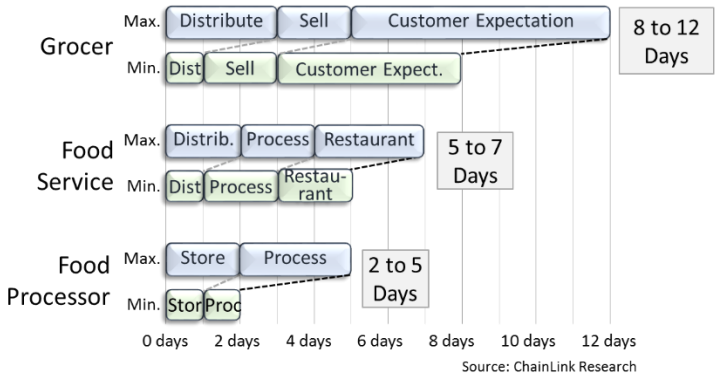
Freshness blindness in the produce supply chain results in many pallets being delivered at less than full value. Why is this? There are two primary contributors to this problem. First, a grower that has no visibility into actual remaining shelf life is shipping blind, resulting in a random distribution of freshness. Next, different customers have different '*delivered remaining shelf life*' requirements[1] (i.e. the customer's requirements for days of shelf life remaining at the point the produce is delivered to them), as well as different transit time from the grower to their facility:

- Group A—8-12 days freshness required: Regional and national Grocers
- Group B—5-7 days freshness required: Restaurants, Institutional Food Services, local Grocers
- Group C—2-5 days freshness required: Food processing plants, Bakers

When growers lack visibility into actual remaining freshness, some pallets with maximum remaining shelf life will be sent to B or C customers, whereas some pallets with inadequate shelf life will be sent to A customers. As a result, the value of the longer shelf life pallets sent to the B or C customers is wasted, since those customers do not need, or value, that extra shelf life as they will consume the product in a few days, whereas an A customer needs that extra shelf life. At the same time, the A customer ends up returning, marking down, or wasting product that had inadequate shelf life for them, which a B or C customer would have been perfectly happy to accept and use. Now instead those pallets end up discarded, donated, or sold for pennies on the dollar at a terminal market.

Deriving Freshness (Shelf Life) Requirements

The freshness requirements for each of groups A, B, and C are derived by adding up component requirements. For example, a grocer may require 1-3 days to distribute to the stores from their distribution centers (DC), another two days to sell the product, and their customers have an expectation of 5-7 days of remaining freshness when they buy, hence the grocer requires 8-12 days of remaining shelf life at delivery. Institutional Food Service companies (e.g. Sysco, US Foods) may have 1-2 days distribution from their DC, two days to process, and 2-3 days at the restaurant, thereby needing 5-7 days remaining freshness upon receiving the produce. A good freshness management system will do all this math for you, once the right information has been entered.



Every pallet has a 'home'… i.e. a place where it will have full value when delivered. This ideal can be realized if the grower has three things: 1) visibility into accurate actual remaining shelf life, 2) knowledge of the transit times to each customer, and 3) an understanding of each

[1] For example, requirements of Food 4 Less are not as strict as Whole Foods, but more stringent than a cafeteria or food processing plant.

customer's freshness requirements. With those three pieces of knowledge, all pallets can be sorted and delivered to the right customer for full value.

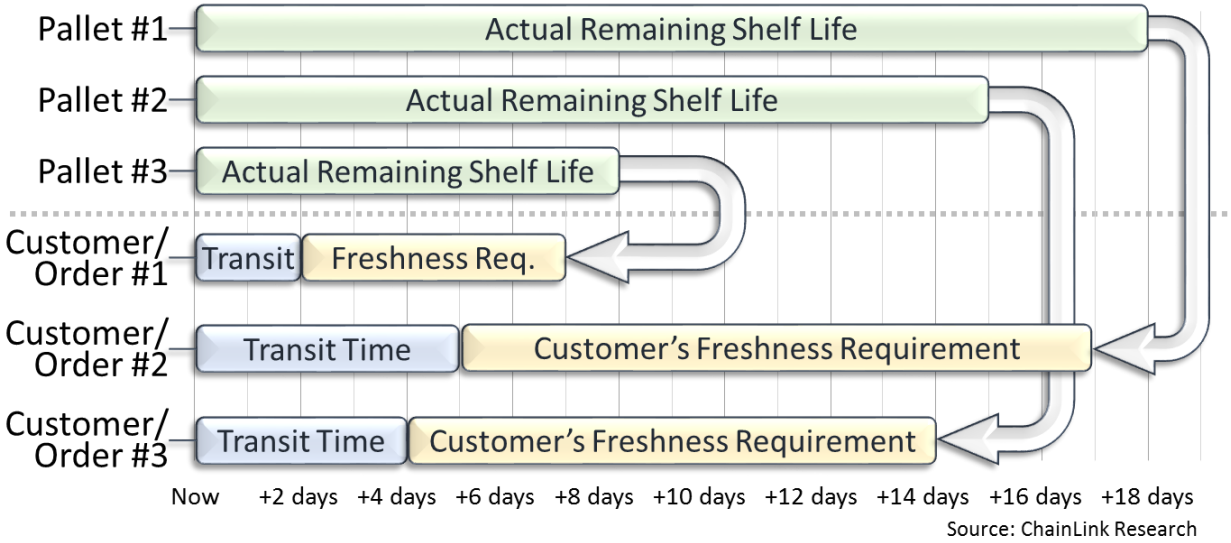


Figure 2 – Each Pallet Has a 'Home'—Matching Pallets to Customer Orders

Unfortunately, lacking visibility into actual remaining shelf life, the majority of growers do not match pallet freshness to customer requirements. How bad is the problem? Industry rejection rates are typically 1%-2%, but soft claims (product spoiled before it got to the store) are 7%-8%, representing a major revenue recovery opportunity for growers. Retailers typically cull over 10% of what they purchase, and markdowns represent another 7% inventory impact for retailers. Those numbers could be substantially reduced, while at the same time dramatically increasing reliable freshness for customers, resulting in decreased waste and more satisfied and loyal customers.

The Importance of Accurate Actual Remaining Shelf Life Measurement

As mentioned, one of the main reasons more growers do not adopt the kind of methodology described above is they lack a way to accurately predict remaining shelf life within the first 12 to 24 hours after harvest (key to making the proper distribution decisions), so they simply assume all pallets (of a particular variety of produce) have equal shelf life, based on the date of harvest. That assumption is wrong. As explained in *Pallet-level Monitoring: Maximizing Delivered Shelf-life in the End-to-End Fresh Food Supply Chain*, the varying amounts of time different pallets spend in the field can result in three or more days variation in shelf life between those pallets. Add to these differences in completeness of pre-cool and other handling varitations, and pallets of the same produce variety harvested from the same field on the same day, can have shelf lives that vary by as much as a week, even before they have left the pack house. The problem is compounded when pallets travel through a multi-echelon distribution system, as decisions are made at each node without knowledge of the actual remaining shelf life of each pallet.

Product-tailored Condition-based Expiration Date

What the industry sorely needs is a normalized freshness metric—more specifically, a *Pallet-level Condition-based Expiration Date*—one that is much more accurate than the traditional expiration date stamped on packages at the time of harvest. The traditional approach is a static date that ignores temperature exposure history and other conditions affecting shelf life. A Condition-based Expiration Date is dynamic, based on temperature exposure and other conditions such as location of harvest, condition at harvest (weather, ripeness), and time of season. Each time the Condition-based Expiration Date is referenced, it is re-calculated, based on the temperature exposure history up to that moment. It is also tailored to each product variety and field location, as each variety's response to these conditions differs.

Thankfully, there is an affordable system available that provides accurate estimates of the actual remaining shelf life of each pallet of produce. Zest Labs has developed a solution comprised of devices, software, methodologies, and algorithms that take into account the product type, variety, the specific location (field or lot number) of harvest, harvest conditions (weather, ripeness[2]/maturity level), time of season, and most importantly, temperature exposure history.

Each pallet has its own unique history of temperature exposure in its end-to-end journey from field to shelf. That is by far the single biggest determinant of freshness.[3] Therefore, to get an accurate measure of remaining shelf life, the temperature history of each pallet of produce must be monitored, from the time it is harvested in the field, until the end of its journey when it is delivered at the store.[4] However, temperature history data by itself is not enough. An algorithm is required to accurately calculate the actual remaining shelf life of each pallet, based on a combination of pre-harvest factors, harvest conditions, and its temperature exposure history to-date.

Zest Labs calls its Pallet-level Condition-based Expiration Date a ZIPR Code. It takes into account harvest location and conditions, and is adjusted[5] as a pallet of produce is exposed to various temperatures throughout its journey from field to shelf. Two pallets picked on the same day, from the same field, but which are then exposed to conditions that are different enough, will end up having different ZIPR Codes, accurately reflecting the actual remaining shelf life of each pallet.

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[2] For example, when harvested at peak ripeness under ideal conditions, strawberries may have 12 to 15 days (depending on the variety) of remaining shelf life. If they are harvested before or after peak ripeness (which can happen due to bad weather or timing of demand), it will reduce the actual remaining shelf life.

[3] Humidity, atmosphere content, and handling all impact the freshness of various types of produce to different degrees. However, for all types of produce, by far the number one factor impacting freshness is temperature exposure over time. According to the FAO, "*Temperature is the most important environmental factor that influences the deterioration of harvested commodities.*" (Source: *Post-harvest Management Procedures that are Critical to Maintaining the Quality and Safety of Horticultural Crops*)

[4] For more on this, see *Pallet-level Monitoring: Maximizing Delivered Shelf-life in the End-to-End Fresh Food Supply Chain*

[5] ZIPR Codes are based on typical handling and conditions. If the pallet is exposed to worse than typical conditions (such as inadequate precool) then the ZIPR Code is shortened to an earlier Condition-based Expiration Date to account for that exposure. Conversely, if the conditions and handling turn out to be nearly ideal, then the ZIPR Code may be extended to a later Condition-based Expiration Date.

The Role of Temperature Response Profiling

The Condition-based Expiration Date must be tailored to each produce variety if it is to have any validity and accuracy. Of the tens of thousands of varieties of fruits and vegetables grown in the U.S., about 500-1,000 varieties comprise the majority of what is sold in grocery stores and restaurants. In order to convert a temperature history of any one of those into an accurate remaining shelf life estimate, *someone* has to develop *temperature response profiles* for each of the various varieties. This requires testing and observing how each variety responds when exposed to different temperature histories. Zest Labs has done (and continues to do) the required testing and modeling of response to different temperatures for different varieties for each harvest location.

Temperature response profiling requires an objective measurement of what constitutes the end of shelf life for each variety. For grocers, this comes down to two moments of truth: 1) *buy decision*—when a shopper examines the produce and makes a decision whether it is fresh enough to buy, 2) *eat/throw decision*—later at home, does the produce stay fresh enough, long enough for the shopper to satisfyingly eat it (or if they have to throw it, has it been long enough that they don't expect it to still be fresh, so they don't blame the grocer). These subjective decisions, '*would I buy it*' and '*would I eat it,*' need to be converted into an objective measure[6] of freshness. This is done by building up a body of knowledge about specific objective measurements, such as number and size of spots, measured firmness, color changes, and other signs of deteriorating freshness that are specific to each variety. The system needs to be very specific about translating these measured freshness indicators into what is and isn't acceptable; i.e. what constitutes the end of useable shelf life. This also serves to capture and institutionalize this knowledge. Instead of relying on a few quality control experts, who can only be experts in a few dozen varieties anyway, knowledge of hundreds of varieties is encoded in the system.

A Methodical Approach to Temperature Response Profiling

Developing a temperature response profile for a variety of fruit or vegetable requires a methodical approach. Zest Labs takes samples of each specific variety right from the grower at the time of harvest over a period of time during the beginning, middle, and end of the season. These samples are brought to their lab to be stored at different temperatures. The samples are photographed and evaluated daily, using specific objective criteria. Different varieties spoil in different ways so the criteria are specific to the variety. The freshness criteria are developed through interviews with produce managers at the growers and quality control managers at the retailers, asking them what specific criteria they use. These criteria may vary by chain, region, and store. Through these interviews, a consensus criteria is reached.

The subjective criteria ('this one has too many spots,' 'the color is not quite right') are then translated into specific measurable objective criteria in a normalized rating from one to five (for example, 10-15 spots might be a two rating for a specific variety of fruit). From this, Zest Labs is building up a database of intelligence

[6] Typically, freshness assessment is done at various points in the supply chain by farm hands, supervisors, quality control experts, buyers, and chefs who make these judgement calls. This is fraught with difficulties. Variety-specific knowledge is needed to know freshness and when the product is bad (i.e. decay, spotting, bruising, what is and isn't acceptable). Nobody can be an expert in hundreds of varieties. A consistent, normalized metric is needed.

about how long different varieties stay fresh (according to the specific freshness criteria used in the industry) under varying temperature conditions. This approach also discovers how each variety's temperature response profile changes when it is grown in different locations and/or harvested at a different level of maturity or time of the growing season. Zest Labs' knowledgebase is continually expanding as new varieties are tested, and deepening as the same varieties are tested in different seasons, locations, and conditions. There is no other solution provider that we are aware of making anything close to that kind of investment and building up that knowledgebase.

For the highest volume varieties (the 20% of produce that comprises 80% of the volume), Zest Labs also has its retail customer's quality control (QC) expert conduct testing at the retailer's DC. The QC person takes pictures every day, using the same mobile application used in Zest Labs' lab. In this case they are observing the condition of the produce in real world scenarios, having tracked the temperature exposure of each of those pallets from the point of harvest. Zest Labs correlates observations of these 'retention samples' back to what it is seeing in its labs from the growers' samples. This includes observing which symptoms prevail first (e.g. decay, spotting, wilting).

Zest Labs may also have the produce manager in some of the retailers' stores use the same application to check the produce again at the store. This helps the retailer dispel the common myth that the real problem is in the handling of produce at the store. People tend to blame the workers at the place where the item spoils, but the data shows that often it was going to spoil anyway, no matter what the store did. This knowledge directs attention to where the real problem is—*delivered freshness*. The point is not to blame the grower, but diagnose the problem and give both the grower and the retailer the tools to fix it.

Meeting Customer Requirements

Understanding the Customer's Minimum Required Expiration Date

As illustrated in Figure 2 above, an accurate actual remaining shelf life is only one piece of the puzzle. Transit time and freshness requirements for each customer order are also needed, in order to match each pallet to its optimal 'home.' Zest Fresh reflects how a system should calculate each customer's freshness requirements. When a retailer places a purchase order (PO) with the grower, the Zest Fresh system will embed ZIPR Codes[7] specifying the *Minimum Required Expiration Date* for items delivered for that order. The system calculates the Minimum Required Expiration Date for each order by adding the number of days of freshness required by that customer to the required delivery date. For example, if Grocer A (Order #123) requires 10 days of freshness for an order of lettuce to be delivered on July 10, then the Minimum Required Expiration Date for that order is July 20 or later. Suppose Food Service company B (Order #456), a customer of the same grower, requires six days of freshness and places an order for lettuce to arrive on July 8, then the Minimum Required Expiration Date for that order is July 14 (see Figure 3, illustrating this hypothetical example).

[7] Unlike the ZIPR Code attached to a pallet of produce, the one attached to a PO is not dynamic. It does not change over time, but is fixed, based on the customer's requirements for that order.

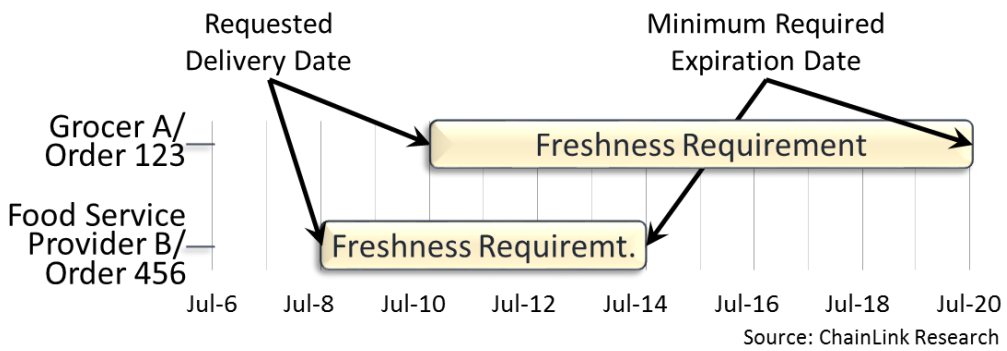

Figure 3 – Hypothetical Example of Differing Freshness Requirements

Process Mapping Key to Accurate Per-Location Freshness Requirement Calculation

To get an accurate forecast of requirements for each customer by location, realistic conditions on the ground need to be understood. Zest Fresh implements process mapping to assess each customer's full supply chain, all the way to the store shelf display, to determine actual handling and conditions, which often vary from ideal conditions. For instance, most shelf displays are 40 - 45°F, not the ideal 32 - 34°F. This is why process mapping[8] is so important. In the Zest Fresh system, each process has a forecasted value (based on actual conditions) and duration, for each grower and customer location, from the field, through to processing, distribution, customer DC storage, DC-to-store distribution, store backroom storage, and store display. The whole supply chain is mapped out.

Reducing Retailer's DC Inventory

Retailers never want a shortage at the store, which can result from late or short deliveries that happen all the time. Therefore, the retailer maintains some buffer inventory in the DC as safety stock. Because of the perishable nature of produce, most retailers would like to keep that buffer inventory to under one day of supply. But most end up with two to three days of supply, due to errors in replenishment, store inventory counts, and off-schedule deliveries. That also translates into 2-3 days of time (on average) that produce spends in the DC before going to the store. That time is added into the freshness requirement by Zest Fresh as part of the process mapping. Use of the Zest Fresh solution will improve quality consistency over time. As that happens, buffer inventory can be reduced, in part because there will be less culling required at the store and more reliable deliveries by suppliers.

Different location will have different process maps and forecasted freshness requirement values. A single PO may contain an order destined for a single DC, but that DC aggregates orders for multiple stores. Therefore, a single PO could have different ZIPR Codes based on the different freshness requirements of the different stores. Other factors that impact the freshness requirement include the velocity of the item and the store. A slow-moving item or a low-velocity store might require an additional day or two, on average, for sell-through.

Accounting for Transit Times

The system also needs to know the transit time to each customer's site, as well as the required delivery date (specified in the PO). Transit time information is calculated in the Zest Fresh system based on the requested

[8] For more on process mapping for produce supply chains, see *Preemptive Freshness Management: Empowering Workers to Improve Delivered Freshness*

delivery date in each PO. In the previous example, suppose Grocer A's DC is four days away and Food Service Provider B's DC is two days away from the grower's DC. On July 6, the grower is shipping lettuce out of their DC for both of these customers and for many others. The system looks at the Condition-Adjusted Expiration Date (aka ZIPR Code) for all lettuce available to ship and ensures that only pallets with a July 20 or later date are sent to Grocer A, whereas pallets with at least a July 14 date are sent to Food Service Provider B (shown in Figure 4).

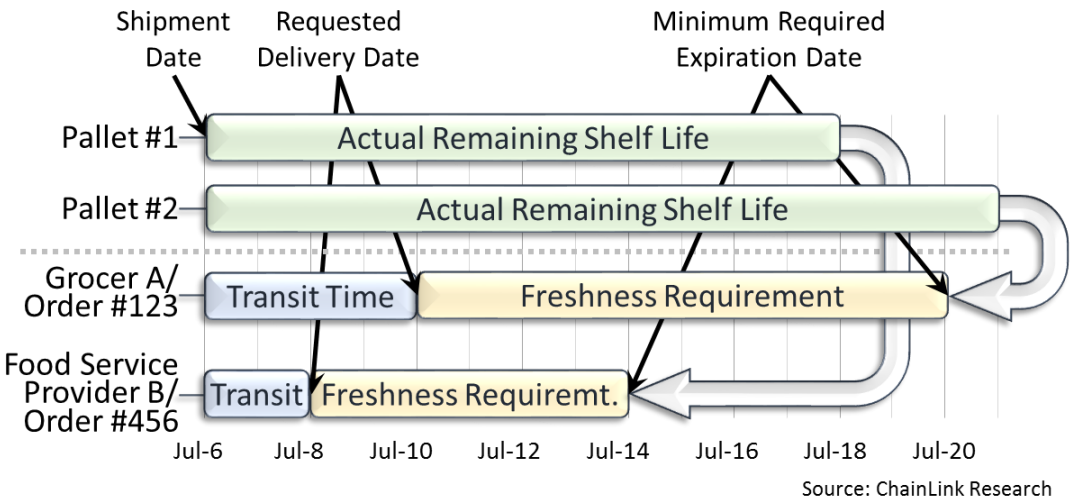

Figure 4 – Hypothetical Example—Matching Pallet's Remaining Shelf Life With Customer Need (Transit + Freshness)

Prescriptive System Required

It is critical that the system is prescriptive—that is, workers, supervisors, and managers at the grower shouldn't have to do any calculations or searching around the system to find a pallet whose Condition-based Expiration Date matches some customer's required expiration date. Instead, the Zest Fresh system looks across all available pallets and all outstanding customer orders, and then matches them up, to ensure all customers are receiving at least their minimum required freshness. It then simply instructs the workers: '*send these pallets here and those pallets there.*'

The only time a manager or supervisor needs to make a decision is when there is no feasible solution to meeting all customer requirements, which happens in supply constrained times such as early and late season. Then the Zest Fresh system presents alternatives for the manager to choose from, showing what the tradeoffs are in terms of missed deadlines or less-than-required freshness. Armed with this information, the grower may decide to call one or more customers to see who might have some flexibility (in exchange for some value, such as a discount). This kind of transparent process, with full insight into the remaining shelf life of orders being sent, builds trust and confidence. It is much better than the old way of blindly sending pallets that will be rejected or spoil at the store.

Similar prescriptive actions are provided by Zest Fresh to locations and participants throughout the supply chain:

- *Receiving/Quality control*—The system can advise the retailer (or other customer) on whether or not to accept each pallet, based on whether the pallet's current Condition-based Expiration Date (ZIPR Code) still meets the requirements on the order. A pallet may have been within spec when shipped, but was exposed to high temperatures in transit, so now does not meet the freshness requirements. This may not be visually evident, but the temperature exposure history tells the story.
- *Consolidation/Multi-level distribution*—Growers, Distributors, and Retailers may all operate within a multi-level distribution paradigm. They operate DCs that are continuously receiving pallets from various growers and locations. The pallets are cross-docked to outbound trucks. Now, the system can orchestrate these consolidation centers, to ensure each pallet meets the requirements for the destination. Normally these consolidation centers are not performing quality checks. Now the system can ensure that all pallets meet freshness requirements and can reject (or reroute) pallets that don't.
- *Retail distribution*—Stores vary both in distance from the DC and sell-through rates. Using ZIPR Code data (Condition-based Expiration Dates), retail WMS systems can employ FEFO inventory management, matching pallets to store transit and freshness requirements and automatically advise workers which pallets to send where.
- *Store freshness management*—Zest Fresh advises store managers which pallet to sell first, which ones they might want to put on special to sell quickly, and which ones will last until later.

Benefits of a Freshness-Aware Intelligent Cold Chain

Operational realities in produce supply chains result in significant variations in freshness between different pallets, even when they were harvested from the same field on the same day. Recognizing and managing that variance is the key to maximizing value and minimizing waste. This is best accomplished via intelligent routing of pallets, matching measured remaining freshness with accurately assessed customer requirements. This approach creates a number of benefits:

- *Improved quality consistency*—Produce is delivered with freshness and quality consistently meeting the end customer needs.[9]
- *Brand value*—The value of both the grower's and the retailer's brand is significantly enhanced by delivering more consistently fresh produce.
- *Higher 'delivered yield'*—A higher percentage of delivered product is accepted, sold, and ultimately consumed. Rejections and soft claims are reduced. Waste is avoided.
- *Significantly higher delivered yield to distant customers*—In particular, deliveries that have to travel long distances, such as berries going from Mexico to Canada, will see an even more dramatic increase in delivered yield, as they previously had the highest rejection rates, but now can be reliably served.
- *Reduced waste*—Mapping of actual remaining freshness to each customers' need reduces waste across the supply chain.
- *Reduced inventory buffers*—Extra inventory buffers are built in to compensate for waste. By providing more accurate visibility into freshness and product quality, both remotely (when the trailer is loaded) and locally (when the trailer unloaded), greater confidence is achieved, waste is reduced, and hence safety stocks can be reduced. For retailers, this significantly reduces the cash burden of inventory.

[9] For more on this see *Why Quality Consistency Matters: Reducing Waste and Maintaining Shelf Life in Our Fresh Food Supply*

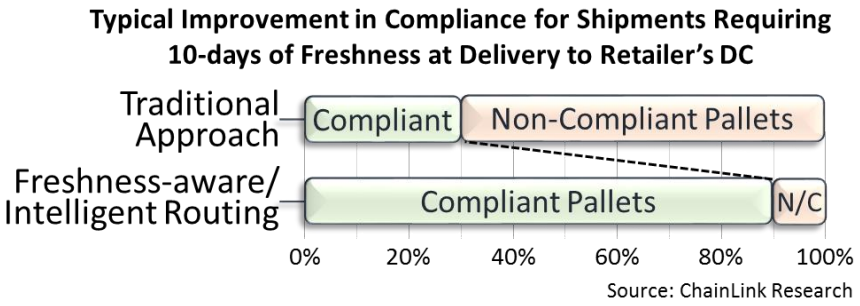

Figure 5 – Compliance Improvements[10] with Freshness-aware Intelligent Cold Chain

To realize these benefits, temperature tracking alone is not enough. What is needed is a system bringing together the end-to-end temperature history of each pallet from harvest to shelf, knowledge of the temperature response of different varieties grown in different locations under different conditions, knowledge of variety-specific criteria for freshness, capabilities to match each pallet's Condition-based Expiration Date with different customers' requirements, and finally, prescribing simple actions to workers and supervisors, based on all of that knowledge to ensure the best match between remaining shelf life and customer need. Zest Labs provides the only solution we know of that brings together all these required elements.

Growers and retailers alike have a huge stake in maximizing consistent reliable freshness and minimizing waste. Using the approaches and system described in this paper, they can create freshness-aware intelligent cold chain that achieves these substantial benefits to help achieve their strategic goals.

[10] With traditional visual inspection, most of the ~70% of non-compliant pallets of produce are accepted by the retailer anyway. Some will be returned, some will be discarded, some will be sold at markdown, and some will be sold at full price, but not meet the customers' expectations of freshness.

321 Walnut Street, Suite 442

Newton, MA 02460-1927

617-762-4040

Email: info@CLResearch.com

Web: www.ChainLinkResearch.com