ChainLink Research

Achieving Consistent Produce Quality

Applying Quality Management Methodologies to the Cold Chain

For decades, successful manufacturers have continually improved the quality of the goods they make. Using statistical process control and related process disciplines, they continually reduce process variation, thereby minimizing waste and reliably create consistent products conforming to precise specifications. In contrast, the produce industry does not have a tradition of strong process controls. This has created a major opportunity to substantially improve the consistency of produce quality and shelf life by adopting modern process disciplines and quality management techniques.

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Process Disciplines Reduce Variance and Increase Quality

Manufacturing industries have realized enormous improvements in quality over the past decades. In the late seventies, US automobiles averaged over 700 defects per 100 cars. By the late nineties, defect rates were down to about 100 defects per 100 cars[1] and have continued to decline since then to less than one tenth the level of defects in the seventies. In contrast, the US food industry has seen about a 50% *increase* in food waste[2] from the mid-seventies to now. While there are of course several major differences between these industries, there are key lessons and approaches the food industry can learn and adopt from manufacturing sectors to improve quality and reduce waste.

The achievement of these dramatic improvements in automotive manufacturing quality was largely a result of process disciplines such as statistical process control and kaizen (i.e. continuous improvement). Process control provides early detection and correction of problems by monitoring the process and making adjustments as needed. One of the goals is to reduce process variations to make product of a highly consistent quality. In the case of the produce supply chain, quality consistency[3] can be maintained end-to-end, so that the produce received at retail has a consistent, reliable shelf life, with much less waste at each stage across the chain. Ultimately this helps maximize the percent of harvest that makes it to consumers' tables in time and condition to be consumed fresh.

For a produce supply chain, continuous end-to-end time and temperature monitoring can drive better decisions in the various processes from cut-to-cool, to pre-cool, loading and unloading, transport, and distribution. For example, pallets being shipped from a farm are grouped into shipments without accounting for temperature exposure variations, resulting in shipments with widely varying remaining shelf life. Rather than assuming all pallets are equal, the time and temperature each pallet has been exposed to since harvest can be used to group together pallets with similar levels of freshness/remaining shelf life, thereby creating loads that have a relatively uniform remaining shelf life. A simple algorithm measuring time exposed to specific temperature ranges can be used to group products and decide where to send them, as illustrated in Table 1 below.

Group	Exposure Metric	'Send To' Rules
Group A: Longer Shelf Life	Pallets with less than three hours cut-to-cool exposure at 62°F	Send these to the furthest away and/or slowest consumption retailers
Group B: Medium Shelf Life	Pallets with three to five hours cut-to-cool exposure at 62F – 65°F	Send these to nearer and/or medium consumption retailers
Group C: Shorter Shelf Life	Pallets with greater than five hours cut-to-cool exposure OR more than two hours above 65°F	Send to fast-consuming buyers (e.g. food processors, restaurants, etc.) and/or retailers within same-day radius

Table 1 - Example of Rules for Grouping Pallets According to History of Temperature Exposure

Applying Process Disciplines in The Cold Chain

Mapping out perishable foods supply chain processes involves identifying and capturing various elements, including:

- *Key decision points*—Identify the key decision points in the end-to-end cold chain processes that impact freshness and/or shelf life the most; such as deciding how long to leave produce in field before taking it

[1] Source: *Improving Product Reliability: Strategies and Implementation.*

[2] This includes both pre- and post-consumer waste. For more, see *The Progressive Increase of Food Waste in America and Its Environmental Impact*.

[3] See *Why Quality Consistency Matters*.

to pre-cool, or deciding which pallets to put together to form a single shipment.

- *Environmental parameters*—Identify the input data and process metrics that have the most impact on key decisions; such as temperature exposure history.
- *Harvest conditions*—Identify key harvest parameters that help determine the total starting shelf life of the produce, such as: maturity level, harvest conditions, irrigation schedule, and so forth.
- *Product parameters*—Incorporate knowledge about different products' handling requirements and the impact of environmental conditions on shelf life.
- *Supply chain parameters*—Incorporate supply chain parameters, such as origin-to-destination pair transport times, storage conditions, different customers' freshness needs, and so forth.

This knowledge can then be combined and mapped onto the various end-to-end cold chain processes, from harvest through final delivery, using algorithms to guide each key decision point in the process (such as which pallets to group together in a shipment and where to send each shipment). Knowledge-based rules can also be used to create alerts, measure performance, and drive potential corrective actions.

A Freshness Metric to Drive Key Decisions

In the vast majority of produce supply chains, there is currently no 'freshness metric' that can reliably estimate remaining shelf life. Temperature exposure monitoring is typically only done piecemeal during transportation on a leg-by-leg basis. Several different process parameters impact freshness (e.g. product maturity at harvest, harvest climate conditions, temperature exposure over time, and humidity over time) each to a varying degree, with varying impacts on different types of produce. By tracking the appropriate combination of parameters throughout the end-to-end life of a pallet, a reliable remaining freshness metric can be calculated for each pallet. This enables managing and optimizing the end-to-end process and accommodating variations in freshness through intelligent routing.[4] An example of such an approach is the ZIPR code used by the Zest Fresh solution.

Identifying Key Decision Points

When mapping out the processes, key decision points are identified. These are where actions are taken that will have a material impact on freshness and/or decisions are made that should take into account the remaining freshness of the product. Examples of key decision points include:

- *Harvest-to-pre-cool:* In a typical operation, the trucks transporting produce from the field are filled to capacity before being sent to pre-cool. In warmer weather, this creates significant loss of freshness for those pallets that have sat in the warm temperatures the longest. Instead, data should be used to optimize the best time to send harvested produce to the pre-cooler, balancing shelf life vs. the cost of extra trips to the field. Input parameters for this key decision point include temperature exposure over time (cut-to-cool exposure), previous night temperature, and humidity.
- *Grower pack house:* Shipments from the farm are typically assembled into loads based on the sequence they happen to be put in the pre-cool unit. Instead, this critical decision should take into account remaining freshness of each pallet so that uniform freshness loads can be created (as outlined in Table 1 above). This ideally occurs prior to pre-cooling, but uniform loads can also be constituted just prior to shipment, in cold storage staging.
- *DC load building:* Similarly, at the distribution center, total temperature exposure history and other parameters can be used to calculate remaining freshness to select and sort cases destined to the store into uniform freshness loads. Customer destination parameters such as total transport time, velocity of consumption, and freshness requirements, can be used to determine which freshness group should go to which destination. This decision-making approach to load-building can be used at the grower's, wholesaler's, and retailer's DCs.

[4] For more on intelligent routing (a.k.a. intelligent distribution), see page four of *Pallet-level Monitoring: Maximizing Delivered Shelf-life in the End-to-End Fresh Food Supply Chain*

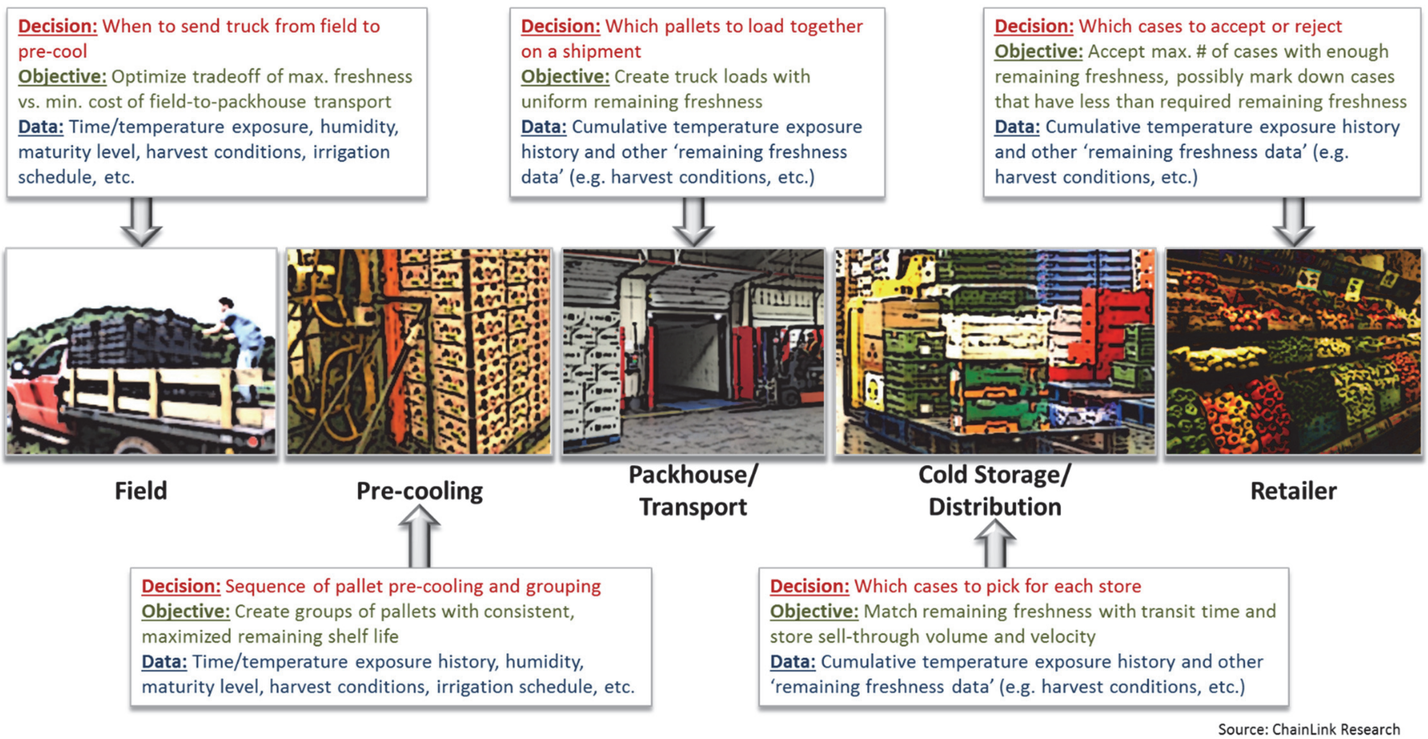

Figure 1 - Example Key Decision Points and Data for Improving Cold Chain Process Control

Kaizen/Continuous Improvement in the Produce Cold Chain

Applying PDCA to Improve Cold Chain Processes

Kaizen (Japanese for 'improvement') is an approach to continuous improvement. It may incorporate PDCA and other methods. PDCA (plan, do, check, act) is an iterative approach to continuously refining processes and improving performance and quality. Popularized by W. Edwards Deming,[5] PDCA has been applied broadly over the decades as part of Total Quality Management (TQM) initiatives. The four ever-repeating steps are:

1) *Plan*—Specify updated process steps and their expected outputs (i.e. the parameters by which to measure the results). For example, you may change your cut-to-cool process by imposing a time-limit on how long the product can stay out in the field, rather than always waiting until the truck is full. This time-limit might be different for different types of produce. The expected results might be an improvement in freshness, as measured by a metric designed specifically to calculate the expected remaining shelf life.[6]
2) *Do*—This is where the actual work happens; harvesting the produce, building the pallets, transporting them to pre-cool, building and loading shipments, and so forth. With an intelligent system in control, these steps are now guided by the system for optimal results.

[5] Deming was a highly influential pioneer and promoter of modern scientific quality control methods.
[6] Some software systems have built-in knowledge of how exposure to different environmental conditions over time will impact the remaining shelf life and can thereby calculate remaining freshness metrics.

3) *Check*—This involves studying the actual results vs. the expected outputs. For example, looking at what the actual remaining freshness is after imposing cut-to-cool time-limits and comparing it to the expected results. Advanced solutions (such as Zest Fresh) can provide real-time alerts and prioritization that automate the "check" process, and enable management-by-exception.
4) *Act*—If the new method results in an improvement in performance and reduction in variability, then this method becomes the new standard for the process; how to *act* going forward.

The process is repeated continuously as new process improvement ideas are tried out. For example, once a cut-to-cool time-limit has been implemented and shown to improve freshness and is working well, the formula for cut-to-cool time might be improved from a static time-limit to a variable time-limit based on the temperature in the field. The expected output may be a narrowing in the variability of remaining freshness for product going into the pre-cool, longer average freshness, and a reduction in field-to-pack house transport costs (because on cooler days, the time-limit is relaxed, allowing fuller truckloads to be taken). These calculations can be sophisticated, because they are executed by the intelligent computer system controlling the operation which simply alerts the field crew when the optimal time to send the truck to the pre-cooler has been reached.

Cultural Changes and Metrics Required to Achieve Continuous Improvement

Kaizen requires a cultural change where all members of the operations, especially the workers actually doing the work, are empowered and encouraged to look for small continual improvements to the flow of product and each process step. By encouraging and incentivizing suggestions for improvements, a continual flow of new ideas can be generated. By constantly measuring process throughput and freshness metrics, positive improvements can be directly recognized and incorporated into the process. As well, this helps workers take pride and ownership of the work and the process.

This also requires that workers and management have immediate and ongoing visibility to the metrics defining success. In the case of a farm, an overriding metrics might be something like average remaining shelf life for pallets shipped from the farm. A system that can accurately calculate remaining freshness, and makes those metrics easily and continually visible to workers and management alike, is thereby critical. There may be other metrics for specific operations on the farm. For example, for the field crew, the metrics might include the average remaining shelf life for pallets arriving at pre-cool as well as the average throughput of the operation (cases or pallets per hour). The key is to make these metrics and current performance continuously and prominently visible to workers and managers.

Knowledge-based Systems

Situational Awareness/Total View of Operations

It is important that the system running the operations incorporates situational awareness, so its algorithms encompass a total view of the operation. For example, the "cut-to-cool" time-limit calculation may need to factor in available pre-cool capacity, as well as knowledge of the queue of other product waiting for pre-cool. Ideally, by knowing the capacity of the pre-cool unit, the expected shipments and rate of loading the trucks, availability of trucks, expected rates of harvest—in other words, a total picture of the operation—the system makes smarter decisions, rather than blindly implementing simple threshold algorithms.

Intelligent Handling at Peak Operating Capacity

If operating capacity is not properly accounted for, the process and feedback loop breaks down during peak operating times. It may not be possible to precool every pallet to the optimal temperature, in which case workers are forced to start making their own judgments on when and how to keep things moving, which pallets to cut short at which steps, to avoid ever-increasing backups and congestion. Real-time feedback and situational awareness can be used to identify when the operation is nearing full operating capacity, enabling the system to 'shift gears,' modifying its decisions to accommodate the higher product flows in the most intelligent way—maximizing freshness, matched with different customers' requirements, within the constraints of the operation's capacity vs. the volume of product being processed. The ability to intelligently handle surges at peak operating capacity is a critical component to successful adoption and utilization.

Incorporating Product, Customer, Supply Chain Knowledge

The system should also incorporate knowledge of the product, the customer's requirements, and the supply chain. For example, different product have different handling requirements and impacts on shelf life. Different customers have different remaining freshness requirements. Different locations have different transport times. All this needs to be put together considering the current demand, i.e. shipments scheduled for the current day, available inventory, fields ready to harvest, pre-cool capacity and so forth. The system can then recommend which fields to harvest and prioritize pre-cooling sequences to match current day's shipment requirements. Similar knowledge can be used in determining the sequence of shipments and which pallets to send where, as in the 'intelligent distribution' approach discussed above.

Getting Started

Produce supply chains have not employed nearly the level of process discipline seen in the manufacturing sector. As a result, there are enormous opportunities for process improvements in produce. Improvements from implementing these process disciplines in the cold chain have been proven to *cut losses in half* for both growers and retailers.

Though these systems are relatively sophisticated, *getting started does not have to be difficult*. There are cloud-based systems available (such as Zest Fresh) that do not require deploying any computer systems and that already have much of the built-in knowledge and algorithms we have been discussing. You do not have to reinvent the wheel!

Furthermore, you don't have to start with overly complex process controls. Experimentation on process improvements can start small and simple, for example with one harvest at one operation with one process. Once the team starts seeing results, they will be encouraged to do more. Change management is critical here—helping supervisors and workers understand why things are being done in a new way, making them part of the planning team for the new approach, giving them ownership and responsibilities for improvements, setting up incentives for offering improvement suggestions, and a culture of rewarding feedback. The results are well worth the effort. Not only will your operation continually improve, but your workers will feel more engaged and take pride in the operations they are helping to improve. Process disciplines can be a win-win for your workers, your firm, your customers, and ultimately the end consumer.

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