Controls, instrumentation & measurement
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Replacing human muscle with machine power is the main point of automation, but it isn’t enough. Replication of human senses also is needed, and process analytics are the eyes, ears, nose and (light) touch of automation.

Food & beverage processors usually are dependent on laboratory tests to alert them when work in progress or finished goods are out of spec. As machine speed increases and automation advances, however, the time delay in learning about a quality issue magnifies the waste. Higher throughput means more waste with each minute of delay. Increasingly, manufacturers require real-time process feedback. Fortunately, a new generation of industrially hardened instruments that deliver reliable process feedback are answering the need.

Although nuclear magnetic resonance spectroscopy and other analytical technologies have been used in industry for decades, in-line quality measures are a relatively new phenomenon in food & beverage.

“Twelve years ago, there were near-infrared products that put gauges in line with a filter wheel and a hole for a quartz window, then placed a lab instrument next to it,” recalls Rick Cash, marketing technology manager with Thermo Fisher Scientific Inc. (www.thermofisher.com), Minneapolis. Those crude systems have given way to solutions that are better integrated into a line and are specifically designed to function in the production environment.

“The instrumentation and sensing technology today has been ruggedized and made more factory-floor usable,” seconds Derek Deubel, vice president at Techniblend Inc. (www.techniblend.com), Waukesha, Wis. It also is simpler to maintain and use without highly skilled technicians. The next step in in-line testing’s evolution is the multifunction sensor, preferably functioning without a dedicated controller, with feedback sent directly to a plant-floor controller for extrapolation.

Reflection and refraction of light, amplitude and frequency of waves, absorption of energy – the core technologies of in-line sensors vary, but relating the measurements they provide to the product characteristics of interest to the processor is the key to their utility. Sometimes, end-users and system integrators discover new applications for the technology.

An instrument based on visible near-infrared (NIR) spectroscopy that is primarily used in mining operations is being tested for pork grading, leading the device’s supplier to suggest NIR could be suitable for grading sides of beef. (That’s a stretch: NIR light only penetrates a few millimeters, so unless it is measuring a homogenous mass, readings won’t be representative.) A
recent buyer of the SM-35000 spectrometer from Spectral Evolution (www.spectralevolution.com), Lawrence, Mass., hopes to develop a model that relates the readings to the characteristics of tender ham.

“They’re trying to generate markers to guide the selection of which hams will make the best product,” explains Maurice Kashdamm, the firm’s marketing & sales director. “Every time I think the technology is mature, I get a call from someone looking at a new application.”

King of probes
High-volume breweries long have led the industry in their use of in-line sensors, and the King of Beers is acknowledged as the segment’s pacesetter. “Anheuser-Busch is the leader in in-line measurement,” proclaims Mettler Toledo’s Brian Vaillancourt, a judgment echoed by others.

Soft drink bottlers also have production volumes that are high enough to justify the investment, and “we’re seeing more and more measurement in dairy, particularly those selling product to pharmaceutical and nutraceutical firms,” adds Vaillancourt, aftermarket services & key accounts manager in the firm’s process analytics division (us.mt.com) in Bedford, Mass.

In years past, craft brewers never considered in-line instrumentation until they reached the 75,000-barrel threshold in annual production; today, even small-scale producers are installing in-line sensors to ensure consistent outcomes.

Turbidity, pH, color and dissolved carbon dioxide are some of the variables beer makers monitor. Trace amounts of oxygen can greatly reduce shelf life and produce off-flavors, and segment leaders have intensified efforts to control oxygen levels in recent years. “Twenty years ago, 300 parts per billion (ppb) of oxygen was OK,” says Vaillancourt. “Now, brewers want less than 10 ppb.”

To satisfy those demands, Mettler replaced its polarographic oxygen sensors with optical sensors that measure both dissolved
oxygen and CO2 levels. Digital signal accuracy, ease of use and solid-state electronics are additional enhancements.

Multifunction sensors have obvious appeal to industry, and mid-infrared instruments are the most likely to deliver it. Considerable interest surrounds VitalSensors Technologies, a Hudson, Mass., venture powered by MIT scientists working toward IP-ready units that don’t require a dedicated controller, which can account for half a system’s cost.

In theory, infrared devices can deliver hundreds of readings, though “the practical limitation for most of these instruments is three, and it’s usually two,” notes Thermo Fisher’s Cash. Nonetheless, quantifying fat and protein levels in milk or solids and oils in peanut butter with a single device is appealing.

“The simplicity of infrared and its ability to measure several things gives end users more bang for the buck,” says TechniBlend’s Deubel. The newer devices also are less obtrusive than instruments that rely on a slip stream of product to conduct evaluations. Pump failure and vibration-distortion problems are eliminated, and newer devices feature solid state construction and probes that barely dip into the product stream.

Deubel’s firm is working with one infrared supplier on development of an infrared sensor that could be used with diet soft drinks. Instruments that measure Brix are of little use in the absence of sugar, so developers are focusing on the titratable acidity of diet beverages. Currently, that is done off line. “We’re still involved in mapping the signature of a diet cola and making sure the results are repeatable and it doesn’t take a Ph.D. to set up the instrument,” he says.

Quantifying complex streams
While most sensor technology is best suited for a fluid stream, guided microwave spectroscopy (GMS) is finding a niche with ground beef. The technology excels at moisture analysis and first was applied 20 years ago at a grain milling operation. But it also can accurately measure both fat and lean constituents,
based on the amplitude and frequency of the waves transmitted between two points.

Thermo Fisher introduced its GMS solution nine years ago, though extensive refinements are reflected in the E scan analyzer. The instrument often is mounted at the end of grinders to ensure lean content is in spec. “If you can save 1 percent giveaway on a grinder, it’s worth a couple hundred dollars an hour, and the instrument provides a payback pretty quickly,” Cash points out. The unit also has been used to measure fat in milk, with results close to the Mojonnier lab method. Mojonnier calculates fat by weight to within 0.03 percent; the GMS analyzer has been demonstrated at 0.05 percent.

Recalibration is the limiting factor with all these devices and helps explain why in-line sensors are more common in other industries. Raw material variability is a fact of life in food production. “Unlike the ingredients in shampoo, food is not a chemical, and it’s not going to be the same every day,” says Cash. If an ingredient’s signature falls outside the fingerprint calibrated for the device, feedback data will not be reliable without recalibration.

Most lab technicians are unfamiliar with GMS, but the same can’t be said of infrared. Cognizant of that, PerkinElmer Inc. (www.perkinelmer.com) recently commercialized a mid-infrared at-line instrument for trans-fat analysis. Until now, gas chromatographic methods requiring transesterification in sample preparation were necessary.

Those lab analyses produce more comprehensive results on the types of fat in a product, allows Robert Packer, food solutions development leader in PerkinElmer’s Shelton, Conn., office, but partially hydrogenated fats are the focus of public health concerns. The new instrument – about the size of a laptop and “field deployable” – generates results in less than a minute, he says.

“It gives us the ability to put the instrument in the hands of nonscientists and get reliable results,” Packer adds. “Trans-fat is an issue everywhere, and just because your plant is in North America doesn’t mean your fats and oils aren’t coming from India or other markets where trans-fat levels are very high.”

Precise standardization of cheese milk can be done inline with Thermo Scientific’s ε scan analyzer, an instrument based on guided microwave spectroscopy. The analyzer has produced readings within 0.05 percent of actual milk fat.
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Meeting Today’s Fresh Food Challenges

By Infor

Fresh foods imply many things: healthier choices, higher-quality ingredients, and careful preparation. For food manufacturers, fresh foods present something far more challenging: a short shelf life. Worse yet is the highly volatile inventory with overages in some supplies, shortfalls in others, and a greater potential for selling unsafe food products.

Despite these challenges, producing fresh foods need not be impractical. The real challenge for the food and beverage industry is to produce fresher foods with shorter shelf lives, without incurring unnecessary or impractical costs. It can be done.

The freshness of today’s food products is as much an issue with consumers’ changing perceptions of fresh foods as it is with manufacturers’ ability to control shelf life. As consumers make healthier lifestyle choices, they want fresher and less-processed foods and beverages.

Fresh food (and with it healthy food) is glamorized by the theatrics of cooking as seen in television programs like Top Chef, on blogs and social media websites like Foodspotting and Pinterest, and in traditional food media, like magazines and cookbooks. But while consumers want fresh food, they don’t necessarily want to cook all their meals from scratch. They want their choices to be convenient.

Now, it is up to retailers and manufacturers to make the changes to meet this demand; but they also need to ensure that their business systems have the agility to plan daily production, look to long-term sourcing and forecasting needs, and manage the daily activities of warehouse and production facilities.

Ensuring transparency in food production

Producing a safer product is a greater challenge to food manufacturers than ever before. According to the Center for Disease Research and Policy (CIDRAP), food contamination costs the US $77 billion a year in total healthcare costs, making contamination a serious issue for government regulation. Since the FDA Food Safety Modernization Act (FSMA) in 2011, government regulations have become more focused on preventing food contamination rather than responding to it.

Food safety compliance can be assured by reducing labeling errors. Nearly 20% of recalls are due to labeling errors.

There are two key areas where label compliance can be an issue. The first is ensuring that the listed ingredients match what is actually in the product, in regards to completeness and...
correct order. Failure to disclose all ingredients, especially if there is potential for allergic reactions, can result in a recall.

Second, a product label’s nutritional and health claims must be accurate and comply with government standards. Due to changes in formulas, as well as raw material fluctuations, food manufacturers must make sure that the products they produce match the labels they are using.

**Sourcing ingredients: Think local, plan global**

Fresh food is about more than just food safety. It is also about cost-effectively sourcing the necessary ingredients for food production and manufacturing.

For the restaurant industry, sourcing hyper-local ingredients has become a key differentiator, with chefs preparing smaller plates that feature a variety of flavors and seasonal ingredients. Increasingly, the home cook shares this sensibility.

The pressure is on to satisfy an item’s shelf life—especially if its shelf life is less than a calendar quarter. Meanwhile, consumers want to feel that their foods are produced ethically, safely, and with freshness at the top of mind. Food manufacturers must have a clear understanding of their supply chain in order to plan and schedule the creation and shipment of a fresher product. To do so requires the agility of an ERP system to plan and re-plan on a daily or even hourly basis.

One tested and proven planning assumption is that for a particular product or product segment, the demand pattern is similar every week, assuming it is a normal week—one with no holidays or promotional events. If so, food manufacturers can anticipate the pattern with their ERP system, because consumer and retailer behaviors are repetitive and habitual.

Consumers, for example, resupply basics after the weekend or shop on Thursday for a weekend event. Retailers restock the shelves based on that pattern. Because they can’t keep stock, fresh-food manufacturers need to know the pattern and incorporate it into their planning. The more SKUs a manufacturer produces, though, the more complex this exercise becomes and simple Excel spreadsheets and manual calculations become overwhelming. With an ERP system, this data can be logged and analyzed to quickly understand customer and retailer behavior.

**Building a better warehouse**

The warehouse is at the core of the food manufacturing supply chain. The software technologies that drive today’s warehouse functions operate on one, unchanging, crucial concept—first expired, first out (FEFO), flawlessly moving older products out to make space for newer products.

Food manufacturers need their products to hit retailer shelves during the optimum delivery times on their freshness dates, while also reducing food waste and maintaining an efficient, cost-effective operation.

Internet-based tools are essential for viewing and operating an entire supply chain as a unified whole that encompasses participants inside and outside of an organization—including customers, contractors, and suppliers.

Due to the nature of fresh foods, typical distribution models often don’t work. The shelf life is so short that you need to go directly from manufacturer to retailer within a day or two of production making the adoption of direct store delivery (DSD) more common.

A poorly executed DSD program is worse than none at all. Complexity comes with the territory, however, and must be managed with systems that offer exceptional power, agility, and a specifically focused functionality. Some manufacturers have tried to execute DSD programs using their existing ERP and CRM systems, only to find that most of those systems lack the speed and functionality they need to meet retailers needs.

The usual response is to implement specialized software to support DSD operations outside of the main ERP installation. But if a specialized solution doesn’t interoperate smoothly with the ERP system of record, isolated silos of information emerge, which is a situation that tends to undermine a DSD program’s goals of rapid, flexible responsiveness throughout the delivery chain. Therefore having that last mile visibility integrated with your overall business systems is imperative in a short shelf life environment.

**Delivering fresher foods with software that won’t expire**

When it comes to successful fresh food planning, only a few hours exist between planning and execution. Like food products, software also shouldn’t expire. Yet, many companies are using outdated or “generic” software that doesn’t meet the needs of today’s food and beverage manufacturers.

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When it comes to monitoring inventory in bins, tanks and silos, one of the first questions often asked is “How accurate is it?” Unfortunately, that’s a loaded question that can’t be answered easily. Here we discuss why it’s a tough question and what you can and cannot expect from your level monitoring system.

Accuracy of a Single Point Inventory Measuring System

One consideration is the type of device you’re using to measure the material level. Bobs, guided wave radar, open air radar, and ultrasonic level sensors are commonly used devices. What they all have in common is they all measure a single point in the vessel. Although each device has its pros and cons (see our paper on Selecting Continuous Level Sensors), when installed properly they all perform well to their stated or printed measurement accuracy that appears in their literature.

But, what does printed measurement accuracy mean? For a single point measurement device the printed accuracy stated on a web site or in the literature is the distance measured from the sensor on the top of the tank to the material surface. This distance is often referred to as headroom, because it tells you how much space you have left in your bin. So, the printed accuracy is the accuracy of that distance in feet or meters. That one measurement is generally highly accurate within ± 0.25% of the total distance measured. However, this is not the accuracy of the volume or mass of material in the bin; it is simply the accuracy of that one measurement of distance.

Volume

Volume is very different than level. Volume is the amount of three-dimensional space the material takes up. When using the distance measured from the sensor to the material surface to estimate volume, the calculation is based on the internal vessel dimensions and the distance to that one point on the material surface. Therefore, it’s essential to have accurate vessel dimensions as mistakes in geometry will increase the overall error in the volume calculation. Material flow, buildup, or bridging can affect volume calculations. The placement of the sensor and the location of the filling and discharge points also have an impact on the overall accuracy of volume.

Mass

Accuracy can be further impacted when attempting to use a single point measurement device to estimate mass or weight. When converting volume to mass, the bulk density of the material – stated in pounds per cubic foot or lb./ft.³ – can have a significant impact on accuracy. Although there are resources available that provide general information about the bulk density of a particular material, the bulk density of the material that is actually in the bin could be quite different than what’s posted on the Internet.

Attributes such as particle shape, size and moisture content can profoundly impact bulk density. Compaction of material can also cause very different bulk densities of the same material in the top or the bottom of the bin. A cubic foot of material at the top of the bin could weigh less than that same material at the bottom of the bin, where the bulk density is greater due to compaction by the weight of the material above it.

When using bulk density to calculate mass in a bin for a particular material, it is very important to establish an average bulk
density based upon the actual material handled at the facility, and not the stated amount given to a material’s general name referenced on a table. One way to accomplish this is by taking a measurement before and after a “known-weight” load is put into the bin, and adjusting the bulk density in lb./ft.³ to reflect this weight.

What to Expect

When using a single point level measuring system, there will always be an increasing level of error associated as you progress through the conversion of distance to volume and then mass. The measured distance of most single point technologies is quite accurate and will be around ± 0.25% of the distance measured.

However, when level is used to estimate volume, accuracy will be dependent upon the correctness and completeness of the vessel dimensions, sensor placement, and the location and number of filling and discharge points. A vessel that is center fill, center discharge with material that flows freely and symmetrically will give you the best results when using a single point measuring device.

When converting volume to mass there will always be inherent inaccuracies due to variations in bulk density, regardless of whether you are using a single point or multiple point measuring device. The accuracy of the volume calculation will also impact the accuracy of the mass calculation.

Since there are so many variables, it is very challenging for any manufacturer of single point level measurement devices to pinpoint how accurate the calculated value of the mass will be. With accurate vessel geometry, strategic placement of the sensor, and a good average bulk density, the accuracy of the mass may be around 8% to 15%.

Accuracy of a Multiple-Point Inventory Measuring System

Unlike traditional devices that measure one point and determine a single distance, a 3DLevelScanner takes measurements from multiple points within the silo. These points are used to determine the volume of material in the bin. Measurement points are not averaged to calculate bin volume. Instead, each point is given a “weight” or relevancy rating and a complex algorithm is used to calculate the true volume of material within the bin. This technology takes into account variations that can occur across the topography of the material surface by measuring and mapping the high and low points.

The 3DLevelScanner provides an accurate three-dimensional profile of the top surface within a storage vessel. This is beneficial when there are variations in the material surface due to multiple fill and discharge points, or with materials such as powders that do not fill/discharge symmetrically.

With the 3DLevelScanner as with a single point measurement sensor, volume accuracy is still dependent upon the accuracy of the vessel dimensions and sensor placement. When converting the volume to mass there will still be inherent inaccuracies due to bulk density variables. But, the improved accuracy of the volume calculation will improve the accuracy of mass calculation.

In the case of a 3DLevelScanner, “more is better” with multiple measurement points contributing to a higher degree of accuracy. Given correct vessel geometry and proper sensor placement, you can expect volume accuracy of 3% to 5%. When combined with a good average bulk density, the accuracy of the mass may be around 5-10%.
Instrumentation of course is essential in controlling production processes. But there is one more notable area in which instruments are having a large and positive impact on the plant: in the sanitation processes used in between production runs.

One example is the shift toward membrane technology to purify process water. Reverse osmosis and nanofiltration remove virtually all the total dissolved solids in municipal water. That opens the door for conductivity sensors in monitoring CIP water.

Conductivity sensors are among the most economical devices in the field, according to Derek Deubel, vice president at Techniblend Inc., Waukesha, Wis. But if there are too many different elements in the water, their reliability is compromised. When membranes purify the incoming water, “any chemical or ingredient in the water is more identifiable, and that makes conductivity sensors a better option,” he says.

Mettler Toledo effectively applied conductivity testing to CIP water at Anheuser-Busch’s Columbus, Ohio, brewery. Caustics in the rinse water needed to be under 40 ppb of dissolved solids per liter before discharge. Technicians determined that would translate to 300 micro Siemens of electric conductance. Sensors were installed at the front and end of each CIP loop to monitor caustic levels.

“We knocked (the standard) down to 50 micro Siemens before sending it to drain, just to be safe,” recalls Brian Vaillancourt, aftermarket services & key accounts manager in the process analytics division of Mettler Toledo (us.mt.com). Sensors also eliminated overdosing in the sanitation cycle. Ten control loops were needed, but the system helped shorten rinse time to 17 minutes from 45. The result was a three-month ROI.

Recovering and reusing chemicals can add to the payback with CIP, adds Rick Cash, marketing technology manager with Thermo Fisher Scientific Inc., Minneapolis. Still, the greatest value from field devices comes from improved product quality, and that can be difficult to express in financial terms.

On the other hand, “We’ve gotten past the ‘does this take accurate measurements?’ discussions to ‘how does this pay for itself in our plant?’ conversations,” he says. As more automation is added and production becomes more continuous and less batch oriented, the utility of plant floor instrumentation will increase.
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Temperature: Food Safety and Your Bottom Line
By Claudia Bentley of Tegam

Temperature measurement is your first line of defense against food borne pathogens. The control of temperature in all aspects of food production is of the utmost importance. The accuracy of your temperature measurements can mean the difference between a safe and an unsafe food, between freshness and spoilage of your products.

Secondary to the safety of the food, temperature also influences the food’s flavor and appearance, which can translate into consumer acceptance and repeat business or consumer disappointment. By understanding more about HACCP and critical control points, we can make rational selections on the safest, most accurate and expedient way to measure temperature for food safety and quality control.

According the Centers for Disease Control (CDC), food-borne illnesses cause about 300,000 hospitalizations and 5,000 deaths every year in the United States [Source: CDC]. Common causes are outbreaks of bacteria such as Salmonella and E. coli. These outbreaks not only take a toll on the victims’ health, but also the economy.

In the United States, the economy suffers about $7 billion every year due to these outbreaks [source: Washington Times]. The recall costs, which include getting food off shelves, handling lawsuits, revamping plants and repairing public relations, are complex and massive for companies. And that’s not counting the tainted reputation and lost sales which can be difficult to quantify in dollars.
Hazard Analysis and Critical Control Points, or HACCP, is a preventative approach to food safety by controlling the biological, chemical and physical hazards in the production process. The Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) mandate HACCP programs for juice and meat which are effective for protecting the public health.

The meat industry is regulated by the USDA, the seafood and juice industry is regulated by the FDA and all other industries adopt HACCP voluntarily at this time. The implementation of HACCP is located at any step where hazards can be prevented, eliminated, or reduced to acceptable levels.

Critical Control Points (CCP) must be carefully developed and documented because they must be used only for purposes of product safety. A CCP is a point, step, or procedure in a food manufacturing process at which control can be applied. For example, a specified heat process, at a given time and temperature designed to destroy a specific microbiological pathogen is a standard CCP.

Each control measure has one or more associated critical limits. Critical limits may be based upon factors such as: temperature, time, physical dimensions, humidity, moisture level and numerous other variables. Critical limits are the maximum or minimum value to which a physical, biological or chemical hazard must be controlled.

For each CCP, there is at least one criterion for food safety that is to be met. Monitoring activities are necessary to ensure the process is under control at each CCP. According to the Food Safety and Inspection Service, the monitoring requirements and frequency of monitoring is to be listed in the HACCP plan. The final rule requires a plant’s HACCP plan to identify corrective actions to be taken if a critical limit is not met. Corrective actions are intended to ensure that no product is injurious to health.

Verification and record keeping are the final steps to a HACCP plan. The verification process should include a validation step ensuring that the HACCP plan is working as it is intended. Verification procedures may include verifying that equipment is working properly, review of HACCP plans, CCP records, critical limits, microbial sampling and analysis.

The HACCP regulations requires that all plants maintain hazard analysis, HACCP plan, records documenting the monitoring of critical points, critical limits, verification activities and handling the processing of deviations.

The right tools promote “safety first” and a quality end product. The wrong tools or inadequate calibration of your thermometers to verify and validate your temperature tool will compromise it all! Some questions that you should be asking:

- With all these safety precautions established and put in place, how accurate is your temperature measurement tool?
- Are you challenged to meet HACCP standards to successfully pass their audits?
- Can your temperature measurement tools register the information fast and efficiently to not slow down your production?
- When does your equipment need to be calibrated?

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In the food and beverage industry, color and appearance are key ingredients to a product’s success. When its color is off or doesn’t meet quality standards, customer satisfaction is compromised and rejects, processing time, and costs increase. Because of this, food and beverage manufacturers are adopting standardized processes to control the color and appearance of their products and packaging more effectively.

From research and development to production to quality control, a defined color process helps food manufacturers and processors establish and meet color quality standards with less waste, time, and effort. By standardizing this process, color consistency and accuracy can be maintained from batch to batch. Color measurement instrumentation, such as colorimeters and spectrophotometers, are vital components to this standardized process because they remove the subjectivity of human perception and express an object’s color in numerical terms.

**Color Measurement: Colorimeters vs. Spectrophotometers**

Color measurement instruments are effective tools in evaluating color and identifying inconsistencies to establish and meet color quality standards. Widely used in research and manufacturing environments, there are two main types of color measurement instruments – colorimeters and spectrophotometers. Both of these quantify the color of an object or sample; however, their capabilities and features are vastly different from each other.

Colorimeters evaluate the color of an object using a filter-based tristimulus method that measures three color components of light, red, green, and blue (RGB), corresponding to how the human eye perceives color. These instruments are ideal for quality control inspections and process control procedures.

Spectrophotometers evaluate the color and appearance of an object, generating the spectral reflectance curve of an object across the entire color spectrum. These instruments are ideal for formulation, research and development, quality control inspections, and process control procedures.

The ideal instrument depends on the sample being measured and the specifications required to accurately evaluate its color. In addition to instrument quality, the precision of the measurements depends on how the sample is prepared and presented for each measurement. A lack of standardization, as well as other factors, may result in noticeable inconsistencies between samples or batches. These errors often lead to increased waste or rejects, longer processing times, and increased costs within a company’s operations. With a standardized pro-
cess set in place, however, users can optimize energy, time, and money for peak efficiency.

Components to a Standardized Color Process

Implementing a color process streamlines how food manufacturers and processors communicate, evaluate, and control the color and appearance of products and packaging to maintain consistency and meet color quality standards. The methods for evaluating the color and appearance of a sample are unique to each application.

1. Visual Assessments: Visual assessments are conducted to identify noticeable inconsistencies between a sample’s color and the standard, as well as to correlate human visual perception of a color with the numerical values of that color. These should be performed within a controlled environment, such as a light booth, to ensure conditions are consistent for each assessment. A food sample, for example, could appear darker under incandescent light than under natural daylight. To maintain accuracy, the following conditions must be defined and standardized:
   - Light sources
   - Viewing angles
   - Sample preparation and presentation conditions

2. Instrumental Measurements: Colorimeters and spectrophotometers are color measurement instruments designed to evaluate and quantify the color and appearance of food and packaging products. By accurately expressing color in numerical terms, users can communicate, share, and coordinate product color more seamlessly internally and throughout the supply chain. Identifying inconsistencies in a sample or batch before a bulk production run is important to avoid rework and waste.

   To maintain accurate and consistent results for each measurement, the following instrumental specifications must be defined and standardized:
   - Instrument model and type
   - Aperture size
   - Color space
   - Color difference formula
   - Color tolerances
   - Instrument geometry
   - Standard observer
   - Illuminants

   If multiple instruments are needed, ideally, the same instrument model should be used internally and throughout the supply chain. In addition, how the sample is prepared and presented for each measurement and other conditions must be consistent. This includes grinding, mixing, or slicing samples the same,
placing the sample in the same container or at the same angle, and using the same quantity (e.g., when measuring powders or pastes) for each measurement.

3. Color Analysis Software: Color analysis software is often used in conjunction with a colorimeter or spectrophotometer to provide a comprehensive analysis of a sample's color. Depending on which type of software needed, these innovative programs are integrated into the color process for formulation and color correction, comprehensive quality control inspections, and to record color measurement results, standard color values, and target color values. This comprehensive data helps users make smarter, more informed decisions and perform more effectively throughout research and development and the production process.

4. Defined Color Standards: Color quality standards specify the color requirements for the final product and should be defined internally or between supplier and customer. Once defined, the color values should be recorded in software to reproduce in future samples or batches.

5. Quality Control and Process Control Procedures: Quality control and process control procedures are required to ensure a product meets the defined color quality standard through an efficient process. An outline of these procedures should define:
   • Visual and instrumental specifications
   • Sample preparation and presentation conditions for measurements
   • Number and location of measurement readings on sample
   • Ambient temperature and humidity conditions
   • When and how often samples or batches are to be inspected
   * Steps to be taken for troubleshooting color inconsistencies

Establishing tolerances within the color process is an effective way to ensure color consistency and accuracy throughout the supply chain and from one sample batch to the next. Tolerance values should correlate to the human eye so that color is both visually and numerically acceptable. Color that falls within the defined tolerance range is considered acceptable, while color that falls outside of this tolerance range is rejected.

Using instrumentation and a color tolerance system, users can effectively evaluate the color of a sample against the standard and detect any deviations or inconsistencies immediately. The resulting data should be used to correct inefficiencies and refine the process to meet color quality standards in future batches.

6. Documentation of Specifications and Procedures: The standardized specifications and procedures within the color process should be documented and shared internally and throughout the supply chain. This ensures the same guidelines and specifications are adhered to for color consistency, accuracy, and improved efficiency within an organization's operations.

7. On-Going Training and Education: Continuous training and education are vital components to an effective color process. A solid understanding of color evaluation techniques and technology for each application are necessary to effectively control the color quality of a product and continuously improve efficiency.

The process to communicating, evaluating, and controlling the color and appearance of food and packaging samples should be tested and refined, if needed, to identify the ideal method for each unique application. With the proper tools and color processes set in place, food manufacturers and processors are able to establish and meet color quality standards with less waste, time, and effort - a key ingredient to operational and retail success.

The technological leader in color and light measurement solutions, Konica Minolta Sensing Americas helps organizations formulate, evaluate, and control color to meet product quality and operational goals more efficiently.