



# Enhancing Snack Food Manufacturing Through Instrumental Spectrophotometric Color Measurement

## Introduction

Snack food manufacturing is a massive industry dominated by a handful of global companies. In this competitive landscape, consistent product quality is paramount – and color is often the first quality attribute consumers notice. Variations in color can signal differences in flavor, freshness, or even safety. Relying on human vision alone to judge product color is unreliable because perception is subjective and lighting conditions vary. Instrumental spectrophotometric color measurement provides an objective, quantifiable way to ensure each batch of snacks meets the desired color standards.

This technical white paper explores how spectrophotometers, particularly HunterLab's Aeros™, can enhance quality control in snack foods. We discuss the importance of color measurement, what product color reveals about quality, applications across various snack types, challenges in color quality control, and best practices for implementation. Real-world case studies (e.g. Lay's, Ore-Ida, Mondelez, Nestlé, Conagra) are included as evidence of improved quality, reduced waste, and enhanced ROI through spectrophotometric color control. We also highlight its advantages for at-line and lab use. Finally, we provide a summary table of key features and benefits of the Aeros for snack food color measurement – and consider the sustainability (ESG) benefits such as waste and energy reduction that these technologies offer.



## Importance of Color Measurement in Snack Foods

Color is a critical quality attribute for snack foods, directly influencing consumer perception and brand reputation. Consumers subconsciously associate the color of a snack with its freshness, flavor, and safety. If a product looks too dark or inconsistent, they may suspect it is burnt or stale, and an overly pale color might be seen as undercooked or bland. In fact, customers judge food heavily by appearance – any discoloration or inconsistency can make them think the food is unsafe or poor quality. Consistent color, on the other hand, builds trust. Leading snack brands establish a characteristic color for each product (for example, the warm golden hue of a potato chip or the vibrant orange of a cheese puff) and strive to reproduce it exactly in every batch. Spectrophotometric color measurement enables manufacturers to meet these customer expectations by providing objective data to maintain tight color tolerances.

Beyond consumer appeal, instrumental color measurement underpins consistency and quality in production. Many companies use defined color standards or indices as part of their quality specifications, indicating when a product has reached optimal quality. A spectrophotometer translates a snack's color into numerical values (such as CIE  $L^*$ ,  $a^*$ ,  $b^*$  coordinates) that can be tracked and compared to target values. This removes guesswork and human bias: a spectrophotometer's reading is the same regardless of who operates it or where it's located, ensuring objective, repeatable assessments of color. For example, a spectrophotometer can detect slight shifts in a cracker's browning that a person might not reliably discern under factory lighting. By catching these shifts early, adjustments can be made before products deviate outside acceptable color limits.

Another key benefit is early detection of quality issues or contamination through color changes. If a process anomaly occurs – say a seasoning mixer fails to add paprika to a batch of chips, or an oil used for frying starts to degrade – the product's color will often



drift from the norm. A spectrophotometer will flag this color inconsistency with quantitative data, alerting QA teams to investigate. In some cases, color can indicate contamination or adulteration (for instance, the presence of scorched particles or foreign material might darken a snack's color). Identifying such issues by instrumental color checks can prevent substandard or unsafe batches from reaching the market, averting costly recalls.

Instrumental color control is also crucial for supply chain and regulatory compliance in the food industry. Standardizing color measurements from ingredient intake (e.g. flour, oils) through processing and finished goods helps ensure each step meets specifications. For example, a snack manufacturer might measure the color of incoming potato flakes to ensure they meet a whiteness spec (affecting final chip color), then measure the color of chips after frying to ensure they hit the golden target.

By using the same spectrophotometric methods at the supplier, factory, and even warehouse stages, companies can track if products darken or fade over time, indicating potential issues in storage or distribution. Regulators and industry groups often define color-based quality grades (such as for frying oils or finished fried products), and spectrophotometers provide the data needed to adhere to these standards. In summary, color measurement in snack foods is essential not only to satisfy consumers' eyes but to verify that products meet quality, safety, and branding standards at every stage.

## What Color Reveals in Snack Foods

Color in a snack product is more than just an aesthetic trait - it is a barometer of many underlying qualities of the product and process. Food scientists and quality professionals can often correlate specific color values with critical attributes like flavor



development, texture, moisture content, and even the formation of undesirable compounds. Here are a few examples of what color can reveal in snack foods:

- **Degree of Cooking or Baking:** The color of a snack is often directly tied to Maillard browning or caramelization reactions during cooking. A darker brown on a baked biscuit or pretzel indicates longer or higher-temperature baking, which corresponds to a stronger toasted flavor (up to a point where it may become burnt and bitter). Conversely, a pale color might indicate an under-baked product that could taste raw or have excess moisture. In fried snacks like potato chips, a medium golden-yellow is usually the target – too light suggests under-frying (limp texture, underdeveloped flavor) and too brown suggests over-frying (bitter or burnt notes). By measuring color, manufacturers infer if a batch got the right heat treatment. For instance, in the production of chocolate-coated wafer bars (e.g. KitKat), the wafer's color after baking reveals whether it's properly cooked; a wafer that is too dark would have a charred taste. Hershey's found that by measuring the wafer color before chocolate coating, they could detect overcooked (burnt) wafers that would otherwise be hidden under chocolate – color data thus ensured only wafers baked to the correct light golden-brown were used, preserving the product's taste and quality.
- **Product Composition and Flavor Intensity:** Color can also indicate if the correct amount of flavoring or seasoning has been applied. Many snacks are coated with seasonings (cheese powder on cheese puffs, barbecue spice on chips, etc.). The intensity of the orange on a cheese puff or the red-orange on a BBQ chip correlates with seasoning level. Spectrophotometric measurement of that color can reveal if a batch is under-seasoned (too light, indicating potential under-coating) or over-seasoned (too dark or saturated, possibly over-coating). This helps ensure consistent flavor in every bite through color consistency. In addition, certain ingredients impart color that indicates their concentration – for



example, the inclusion of wholegrain in a cracker might make its color slightly darker or speckled. Consistent color readings batch to batch mean the ingredient mix was correct.

- **Moisture Content and Texture:** Some snack producers link color with final moisture content and crispness. A fully dried/crisped product often reaches a particular color. For example, puffed snacks or cereals usually achieve their target color at the point that moisture is low enough for crunchiness. If measured color is off, it may imply that drying was incomplete (risking staleness or microbial issues) or excessive (leading to breakage or scorch). Thus color provides a non-destructive estimate of texture-related parameters. In extruded and baked snacks, lighter color in the center might indicate retained moisture, whereas an evenly colored piece implies thorough baking. Quality teams sometimes develop empirical correlations where a spectrophotometer reading outside a certain range signals an out-of-spec moisture or texture.
- **Freshness and Oxidation:** Over time, fats and oils in snacks can oxidize, causing rancidity and often a darkening or yellowing of the product. A spectrophotometer can pick up gradual color changes in stored snacks (such as slight darkening of potato chips or nuts) that signal aging. This can be used in shelf-life studies or to monitor that distribution conditions are not adversely affecting product quality. Similarly, exposure to light might fade certain natural colors (like the green of an herb seasoning), so measuring color can reveal such degradation. Manufacturers of snack foods use these insights to adjust packaging or ingredients (e.g., adding antioxidants) to maintain color and freshness longer.
- **Safety Indicators (Acrylamide Formation):** Importantly, color can also correlate with the formation of compounds like acrylamide, which is a safety concern in fried and baked starchy foods. The browning that gives a potato chip its appealing color is part of the same chemistry (Maillard reaction) that can



produce acrylamide – generally, the darker the chip, the higher the acrylamide level tends to be. The U.S. FDA has noted that sorting or assessing potato chips by color can serve as a useful indicator of acrylamide levels, especially if companies establish specific correlations for their products. In practice, snack manufacturers set color targets that achieve a balance: sufficiently cooked for good flavor and texture, but not so dark that acrylamide (or burnt flavors) become excessive. By measuring  $L^*$  (lightness) and perhaps  $a^*$  (redness) values of chips, quality control can roughly infer acrylamide risk – for example, an  $L^*$  value dropping below a certain threshold might trigger additional process control or testing. This data-driven approach, recommended by regulators, helps companies produce safer products. In one case, a manufacturer of fabricated potato chips (stackable crisps) used the HunterLab  $L,a,b$  color scale with target  $L=59-68$ ,  $a=3-6$  for their chips as part of acrylamide control. If chips fell outside that color range, it signaled potential overcooking and higher acrylamide, prompting adjustments.

- **Brand Identity and Consumer Experience:** Lastly, the color of a snack is integral to its brand identity and the expected consumer experience. For example, the bright reddish-orange of a Flamin’ Hot corn snack or the rich brown of a chocolate sandwich cookie (like an Oreo) are trademarked aspects of those products. These colors must be consistent not only for aesthetic brand recognition but because they set an expectation for taste (spicy in the former, chocolaty in the latter). Spectrophotometers allow manufacturers to maintain those signature colors across different production plants and lots. If a deviation in color is detected (say an Oreo cookie comes out lighter brown than normal due to a cocoa batch variation), the manufacturer can adjust the recipe or process (adding a bit more dark cocoa, or baking slightly longer) to correct it. In this way, color measurement serves as a feedback loop connecting directly to flavor and formula: it reveals if the product’s composition or process deviated



and thus helps ensure that every batch *looks* and therefore *tastes* the way it should, delivering the intended consumer experience.

In sum, instrumental color data in snack foods provides a window into the product's quality and production. By interpreting what slight shifts in color signify - whether it's cooking level, ingredient mix, moisture, or potential safety issues - manufacturers can take proactive steps to maintain high quality. Color measurement turns what used to be a purely visual assessment into a scientific control parameter tightly linked with critical quality attributes of snacks.

## Applications of Color Measurement Across Snack Food Types and Processes

Spectrophotometric color measurement can be applied at nearly every stage of snack food processing and for virtually every snack category. Below, we outline how various types of snack foods and processes benefit from instrumental color measurement:

- **Baked Snacks (Crackers, Pretzels, Cookies):** Oven-baked snacks require careful color control to ensure proper baking. Instruments measure the surface color of crackers, biscuits, or pretzels to judge if they achieved the target golden-brown. This helps detect baking variations across oven zones or between batches. For example, a major confectionery producer implemented in-line color monitoring for wafer biscuits (used in chocolate-coated bars) because the wafers' bake color was critical - a slight darkening meant a bitter, overbaked wafer that would be hidden under chocolate. By measuring the wafer color immediately as it exited the oven, they could automatically reject or adjust any wafers that were too dark or too light before those went on to be coated. Similarly, cookie manufacturers can use spectrophotometers to measure cookie color uniformly. Traditionally, large cookies that didn't fit in older instruments had to be



crumbled for measurement, but modern instruments like the Aeros can accommodate whole cookies, preserving the spatial color characteristics. This ensures the top and bottom bake color of the cookie is on target without destroying the sample. In high-volume bakeries, at-line color checks of a sample cookie or cracker every few minutes allow operators to fine-tune oven temperature or conveyor speed to keep color (hence bake level) consistent, reducing underbaked waste or burnt product.

- **Fried Snacks (Potato Chips, Corn Chips, Extruded Snacks):** Frying is another process where color is a critical quality indicator. Potato chips, for instance, are typically monitored against color standards to ensure a uniform golden appearance. Spectrophotometers can be used in the quality lab to measure composite samples of chips from a batch. Some manufacturers historically used visual comparators or single-point color meters, but these struggled with the translucent, oily nature of chips. Frito-Lay (PepsiCo) experienced this issue: their chips are translucent, curved, and have some natural color variation, which made readings from a small-aperture instrument inconsistent. The solution was to use an instrument with a very large area of view and averaging – initially by physically crushing chips to fill a sample cup for consistency, and ultimately by adopting a non-contact rotating platform that could measure multiple whole chips’ color at once. By doing so, Frito-Lay achieved much more precise color control. They measure chip color at regular intervals (e.g. every 30 minutes on each line) and use the data to ensure each batch of Lay’s or Doritos meets the color spec for optimal flavor. Fry color monitoring also ties into acrylamide control as discussed – for instance, one common practice in french fry and chip plants is to measure the product’s Hunter L-value or a reflectance score (like Agron value) to verify it’s not too low (dark). Companies like Ore-Ida (Kraft Heinz) have implemented in-line color sensors at the fryer exit for products like fries and tater tots, enabling immediate feedback to adjust fryer settings if the



color drifts. This at-line data helps maintain a consistent fry color even when raw potato sugar content or other factors vary. It also reduces waste: if one fryer starts over-browning, operators catch it within minutes rather than discovering a pile of overcooked product later. In summary, for fried snacks, spectrophotometric color measurement ensures the product cooks to just the right degree – preserving the intended flavor/texture and meeting any regulatory color guidelines.

- **Frozen Snacks and Par-Fried Products:** Many frozen snacks (e.g. frozen french fries, breaded appetizers) undergo a partial fry or bake at the factory and are then frozen for consumers to finish heating. Measuring the color after the factory cook step is crucial because it correlates with how the product will look after final preparation by the consumer. Ore-Ida, for example, faced the challenge of multiple potato products (fries, wedges, etc.) each with different shapes and surface coatings, all needing consistent color after par-frying/baking. By using in-line spectrophotometers (such as HunterLab's SpectraTrend HT) to continuously monitor color on the production line, they gained immediate feedback on product color. If a particular product was coming out too light (perhaps due to lower sugar content in potatoes or a temperature drop), the system would signal operators or automatically tweak the process (e.g. slightly increase oven temperature or conveyor time) to reach the target color. This rapid control loop is especially valuable for frozen foods, because any color deviation at the factory can be amplified or result in an unappealing look when the consumer finally cooks it. The in-line system coupled with at-line verification using a lab spectrophotometer (the Aeros) gave Ore-Ida confidence that every bag of frozen fries would bake up golden and uniform for the customer. Beyond potatoes, consider breaded mozzarella sticks or chicken tenders: these are par-fried to set the breading. A spectrophotometer can measure the breading color to ensure it's a light golden



(so it won't over-brown when the consumer ovens it). Thus, color measurement in frozen snacks helps maintain product appearance and quality through the final preparation, and it also cuts down on factory waste by catching any off-color batches before they are packaged and shipped.

- **Confectionery and Candy Snacks:** In the realm of candies, chocolates, and other confections, color consistency is tied to both visual appeal and indicating correct formulation. Chocolate products, for example, have subtle color variations depending on cocoa content and processing. A milk chocolate bar should have the same light brown color every time - if it's too dark, it might indicate too much cocoa or over-roasting; if too light, perhaps too much milk powder. Companies like Hershey's and Mondelez (Cadbury) use color measurement to ensure chocolate coatings and candies stay within a tight color range for each product. The Hershey's Reese's peanut butter cup is a case in point: the chocolate shell and the peanut butter filling each have defined color standards measured with spectrophotometers. Any deviation could hint at an ingredient issue (such as peanut roasting variance affecting filling color). Similarly, brightly colored sugar-coated candies (think of candy-coated chocolates or gummies) are measured to maintain their distinct hues. Spectrophotometers are employed in confectionery factories to measure color during batch mixing of candy shells or jellies - this ensures that, say, each batch of "red" gummy bears is the same shade, so the consumer can't tell a difference between lots. For multi-part products, color measurement can be used at different steps: e.g., Mondelēz produces cookie sandwiches like Oreo, where the cocoa biscuit and the white cream each have target colors. Instruments can verify the darkness of the cocoa cookie (as a proxy for proper cocoa and bake) and the brightness of the vanilla creme (ensuring it's not contaminated or off-color) during production. By applying spectrophotometers, confectionery makers reduce batch-to-batch color variation, which in turn means consistent



flavor and brand appearance. Moreover, because many confections are globally distributed, color data helps ensure that products made in different factories (across different countries) look the same – a crucial aspect of global brand management.

- **Dairy-Based Snacks and Ingredients:** Snacks involving dairy products – such as cheese-flavored snacks, yogurt-covered treats, or dairy-based dips – also leverage color measurement. One example is cheese powders and coatings. Snacks like cheese puffs or cheddar popcorn get a bright orange coating from cheese powder formulations. The color intensity of these powders can vary with cheese aging or supplier, so snack manufacturers use spectrophotometers to qualify each lot of cheese powder (ensuring the powder’s color, and thus strength, is as expected) and to monitor the coated snack. The goal is that each cheese puff in a bag has a uniform neon-orange appearance, indicating it’s properly coated for flavor. Instruments like the ColorFlex or Aeros are used to measure ground samples of the coated puff, or a collection of intact pieces, to quantify that orange color in terms of colorimetric values. If the color deviates (say a batch looks more yellow than orange), it might mean the cheese ingredient mix is off or needs adjustment. Similarly, yogurt or chocolate-coated snacks (like yogurt-covered pretzels, or chocolate-coated nuts) are checked for color to ensure that the coating thickness and formulation are correct – a thin yogurt coating might let the brown pretzel show through, dulling the white color, which a spectrophotometer would detect. Even in dairy-based products like ice cream or dairy snacks, color measurement is used for quality (for instance, vanilla ice cream color is measured to maintain a consistent white-to-cream shade across productions, as consumers associate color with flavor purity). While not a “snack” per se, milk powders used in snack formulations are often color-graded as a quality check (pure white indicates proper processing, whereas a scorched light-brown tint could indicate overheating in drying). In all



these cases, spectrophotometers help ensure that dairy-derived ingredients and coatings impart the right color cues for quality and flavor.

- **Cereals and Grain-Based Snacks:** Breakfast cereals (which double as snacks in many cases) and cereal-based snack foods present unique color measurement challenges. They come in varied shapes (O's, flakes, puffs) and often have complex surfaces. Consistency in cereal color is important for both brand and perceived flavor - for example, Honey Nut Cheerios are a toasted brown color that must remain consistent to signify the correct toast and sweetness level. General Mills encountered difficulty measuring the color of small toroidal (ring-shaped) cereal pieces with traditional colorimeters, as the donut-like hole and small size led to light loss and inconsistent readings. Their solution was twofold: off-line averaging using a non-contact spectrophotometer (the Aeros) which can measure a larger quantity of cereal pieces together for a stable average color, and in-line monitoring using a SpectraTrend HT sensor right after the toaster oven. This allowed continuous tracking of the cereal's color as it is being toasted. If the cereal started coming out too light (under-toasted) or too dark (over-toasted), the system could alert operators to adjust the process. For flaked cereals, color measurement can indicate if the coating syrup was applied correctly (e.g., frosted corn flakes have a baseline golden flake color plus white frosting - both aspects can be measured). In puffed or extruded grain snacks (like rice cakes or corn puffs), color tells you about the raw grain quality and the evenness of toasting. Non-contact spectrophotometers are especially useful for these irregular shapes because they can capture an aggregate color without needing to crush the product (which was the old method). Furthermore, cereal makers often multi-source grains; spectrophotometers ensure that if one lot of oats is slightly different in color, the final toasted O's color can be adjusted (by toasting a bit more or less) to hit the standard target. This yields a consistent bowl of cereal for the consumer every time.



- **Plant-Based and Alternative Snacks:** The surge in plant-based snacks (such as vegetable chips, lentil puffs, soy jerky, etc.) comes with a need to control color for consumer acceptance. Many of these products are designed to mimic the experience of traditional snacks (for example, a plant-based “jerky” made from soy or mushroom should have the deep reddish-brown appearance of beef jerky). Spectrophotometers are used to fine-tune the color of these products - from adjusting natural color ingredients (like beet juice or caramel color in a vegan jerky) to monitoring drying processes. In vegetable chips (such as beet chips, kale chips, sweet potato chips), color is a major indicator of nutrient retention and proper dehydration. A kale chip that turns too brownish-olive might have been overcooked, losing its appeal and nutritional value; a spectrophotometer can quantify that green color to help optimize the drying temperature. Companies like Blue Diamond Growers, known for almond snacks, use color measurement to classify roast levels of nuts (almonds have roast color standards to ensure the flavor development is correct without reaching a burnt taste) - almonds are plant-based snacks, and their color consistency is crucial for quality. Similarly, Conagra Brands, which produces snacks like popcorn (Orville Redenbacher) and seeds (David’s Sunflower Seeds), likely monitors color during roasting and popping. For popcorn, an ideal pale yellow-white with slight browning in spots indicates a proper pop; too brown suggests scorching. Sunflower seeds are often oil-roasted - the seeds’ surface color (and the color of their seasoning coat, if any) is checked to ensure even roasting and flavor. Plant-based extruded snacks made from pea protein or lentil flour also benefit from color checks: these often have added spices or vegetable powders (spinach powder for green veggie straws, tomato powder for orange ones) - measuring the color ensures the right mix of those powders and that the extrusion cooking didn’t darken the product beyond the fun veggie colors expected. In summary, as snack portfolios diversify into new



plant-based offerings, spectrophotometers provide the quality control needed to hit color (and thus quality and marketing) targets consistently, whether the product is an almond, a kale chip, or a pea-protein puff.

Across all these categories, the common theme is that instrumental color measurement brings consistency and confidence. It allows producers to manage a wide variety of snack products – baked, fried, frozen, confectionery, cereal, or plant-based – with data-driven color standards. These applications illustrate that virtually any snack product’s appearance can be quantified and controlled, leading to improved quality and reduced waste from off-color rejects.

## Challenges in Color Quality Control of Snack Foods

Implementing color quality control in the snack food industry is not without its challenges. Snacks are often complex in shape, texture, and composition, and environmental factors in production can complicate color measurement. Additionally, there are inherent limitations to relying on human vision. Below, we detail some key challenges and limitations when controlling snack food color, highlighting why specialized instruments and methods are needed:

- **Human Visual Limitations:** Historically, color quality was judged by operators comparing products to visual standards (like color cards or their own experience). This is highly subjective – different people perceive color differently, and even the same person’s perception can change due to fatigue or lighting. Ambient lighting on the factory floor may be uneven or not color-neutral, causing a snack to look different under factory lights versus daylight. An operator might accept a slightly over-browned batch at night under warm lighting that would look obviously too dark in daylight. Moreover, the eye is less able to detect gradual drifts in color over time; a slow shift might go unnoticed



until it's quite large. This subjectivity and variability make human color inspections inconsistent. Even with trained experts, visual grading can result in disagreements and is hard to standardize across shifts or plants. Instrumental measurement addresses this by providing objective numeric values, but even deploying instruments comes with challenges, as described next.

- **Product Irregularities (Shape, Size, Texture):** Snack foods are rarely uniform flat samples. They come as chips with curved surfaces, cereals with holes, powders on surfaces, etc. This irregularity poses a challenge for getting representative color measurements. Traditional colorimeters with small measurement ports can be thrown off by these shapes. For example, a standard tristimulus colorimeter might measure a single spot on a potato chip – if that spot happens to be an area with a burnt edge or a folded part (doubling the thickness), the reading might not represent the overall chip color. Small or oddly shaped products can also allow light to escape around them or reflect unpredictably. The General Mills Cheerios case illustrates this: the small toroidal cereal pieces caused inconsistent readings because light would pass through the center hole or multiple pieces weren't fully covering the port. Likewise, translucent or glossy snacks (like a thin fry or a hard candy) can reflect light in ways that confuse simple optical sensors – a chip's oily surface might produce specular glare, or a shiny candy shell might reflect the instrument's own light back into the sensor non-uniformly. Irregular textures (e.g., the rough surface of a rice cake or the powdery surface of a sugar-coated donut) mean that a tiny measured area might catch either a powder patch or a bare patch, giving different results. To overcome this, instruments often need to average over a larger area or multiple views. Without that, repeatability suffers – a competitor's small-aperture instrument gave Frito-Lay poor precision on chips for exactly this reason, since each measurement "saw" a slightly different mix of the translucent chip and background.



- **Sampling and Representation:** Because of the above issues, obtaining a representative sample for measurement is a challenge. If one measures only a single piece or a small handful, it may not capture batch variability. On the other hand, measuring a very large sample (many pieces) can be logistically difficult with some instruments. Some legacy methods required grinding or crushing snacks to form a uniform sample (like creating a “chip puree” or grinding cereal to powder) in order to present a consistent surface to the instrument. While this improves repeatability, it has drawbacks: the act of grinding destroys the original appearance and might even cause chemical changes (burning sugars, etc.), plus it’s labor-intensive and not practical for real-time process control. The industry has grappled with this – Frito-Lay at one point resorted to crushing chips to measure color reliably. Modern non-contact systems alleviate this by measuring a bunch of pieces together without physical alteration, but ensuring the instrument “sees” enough pieces remains a consideration. Operators must be trained to present samples (for example, pouring a representative mix of chips into the sample dish, or spreading popcorn out so it’s one layer thick) in a consistent manner. If the sampling method is inconsistent, the color data will be noisy.
- **Contamination and Cleanup Between Samples:** Many snacks are messy – they leave behind oil, crumbs, powders, or color residues. When using contact-based instruments or sample containers, this leads to contamination issues. For instance, if you measure a batch of BBQ-seasoned chips in a sample cup, the orange-red spice powder can stick to the cup or measurement window. Without thorough cleaning, the next sample (say plain salted chips) could read erroneously redder, because of leftover BBQ dust. Similarly, oily residues from fried snacks can coat the measurement chamber or glass, affecting subsequent readings. This necessitates cleaning the sample device before every new sample, which is time-consuming and prone to inconsistency (if not cleaned



perfectly every time). The need for frequent cleaning is a well-recognized challenge - sample prep can consume more time than the measurement itself in many industries, and snack foods are among the worst offenders for leaving residue. An example: measuring a series of powdered sugar-coated cookies, an operator would have to wipe out or wash the sample holder after each measurement because even tiny leftover sugar particles will skew the next reading. If this cleaning is rushed or incomplete, cross-contamination will invalidate results. Furthermore, repeated cleaning (wiping plastic cups or glass plates) can scratch optical surfaces. Many older instruments had protective glass that the sample touched - over time, these would become scratched or cloudy from contact and cleaning, causing measurement drift. All of this means that maintaining instrument cleanliness is a constant challenge in a snack production setting. Non-contact measurement alleviates much of this (since the sensor never touches the sample, and the sample platform can be easily cleaned or swapped), but even non-contact systems may require cleaning of the sample presentation area (like wiping off a platform that has accumulated seasoning dust). Dust from ingredients in the factory environment can also accumulate on instrument optics if not sealed - for example, fine cocoa powder in a biscuit plant or starch dust in a cereal plant could get on lenses or light sources, affecting calibration. Instruments designed for these settings thus often include sealed optics to mitigate this.

- **Environmental Factors:** The factory environment itself can pose challenges. Temperature and humidity can affect both the snack and the instrument. A hot product right out of the fryer or oven might continue to darken slightly as it cools (the carry-over cooking effect). If you measure it immediately, you might get a slightly different reading than if measured at room temperature. Best practice is often to define the measurement conditions (e.g., let the sample cool to a certain temp or time) for consistency. However, in at-line scenarios,



manufacturers might want instantaneous readings on hot products. Instruments must handle the heat (some have heat-resistant materials or airflow to cool the sample area). Similarly, humidity spikes or dusty airflow can interfere with measurements; for instance, steam from a product could fog an optical window. Lighting is another factor – stray light from the environment can interfere with reflectance measurements if the instrument isn’t properly enclosed or sealed against external light. In-line sensors need proper shrouding to block out ambient light from the factory. Vibration from equipment could affect sensitive optical instruments’ alignment over time, meaning rugged mounting is required. Also, ensuring an in-line sensor sees a consistent “view” of the product stream (belt coverage, product depth) is a challenge – if the flow of product is uneven, the color reading might fluctuate simply due to seeing gaps or heaped areas. This often necessitates engineering controls like vibratory feeders or rotating dishes (as in Aeros) to even out the sample presentation.

- **Calibration and Standardization:** Keeping instruments calibrated and standardized across plants is another challenge. Spectrophotometers require routine calibration with white/black standards to ensure accuracy. In a busy production environment, calibration might be neglected or done incorrectly, leading to drift. When multiple instruments are used (say one at the line, one in the lab), they must be correlated so that a given sample reads the same on both. If, for example, a plant has a lab unit and an in-line unit, any offset between them could cause confusion (one might flag a batch as out of spec while the other says it’s in spec). Achieving tight inter-instrument agreement requires careful calibration and sometimes standardization against master instruments. This is a technical challenge that vendors like HunterLab and Konica Minolta address by instrument design and providing standard calibration routines. But it means that QA managers must maintain discipline in



calibration schedules and possibly use reference materials (like color tiles or reference product samples) to verify that instruments remain aligned.

- **Acceptable Variation vs. Natural Variation:** Snacks inherently have some degree of acceptable color variation – not every chip is exactly the same, and consumers tolerate a certain range (in fact, a completely uniform look might even be seen as artificial). This introduces a challenge in setting tolerances and interpreting instrument data. A spectrophotometer might detect a statistically significant difference between two samples of chips, but that difference might be trivial in practice (within the natural variation consumers expect). Conversely, a small color difference might be very obvious to customers (e.g., if one batch of cheese crackers is a shade paler, kids might notice “these look different”). Quality control must decide on meaningful color limits that align with visual perception and product requirements. Translating that into instrument settings requires expertise – e.g., using  $\Delta E$  (total color difference) thresholds that correlate with what the human eye would notice in that product context. It’s challenging to account for the fact that some products show color differences more readily than others (a slight change in a uniform colored product like a white marshmallow might be glaring, whereas the same  $\Delta E$  in a multicolored cereal mix might be invisible). Thus, defining and managing color tolerances for snacks is both a science and an art, and is a challenge particularly when introducing new measurement technology. Companies often must conduct internal studies to link instrument readings with visual panels to set the right action limits.

Despite these challenges, modern color quality control tools have features to mitigate many of them – as we will see in the next section on best practices. From non-contact measurement addressing contamination, to large-area averaging addressing sample irregularity, the obstacles can be overcome. Recognizing these challenges is important



so that snack producers can implement color measurement systems in a way that yields reliable, useful data rather than frustration. With the right instruments and protocols, the variability of snacks can be mastered, turning color into a controlled quality parameter rather than an unpredictable factor.

## Best Practices for Instrumental Color Measurement

To effectively implement spectrophotometric color measurement in snack food production, manufacturers should follow best practices that address the challenges above and ensure consistent, accurate results. Below are recommended best practices for instrumental color quality control in the snack industry:

**1. Ensure Representative Sampling and Presentation:** Because snacks can be variable piece-to-piece, it's crucial to measure a representative sample of product. This often means measuring multiple pieces at once or taking multiple readings and averaging them. For lab measurements, fill sample cups or trays such that the entire measurement area is covered with product (no gaps or see-through spots). If using a non-contact instrument like the Aeros, present enough pieces on the platform to cover it in one layer. The instrument's rotating platform will automatically average the color over many viewing angles. Avoid bias in sample selection - the sample should reflect the lot's overall color (operators shouldn't pick only the best-looking pieces, nor only the worst). Consistency in how samples are taken (e.g., "take 100g of chips from the middle of the cooling conveyor") and how they are measured (spread evenly on the dish) will improve reliability. In cases where product pieces are very large relative to the instrument (say measuring a whole extruded snack bar), if only a portion can be measured at a time, establish a protocol (such as measure three different spots on the bar and average). The goal is to reduce sampling error so that instrument readings truly reflect batch color. Modern instruments simplify this by enabling large-area



readings; for example, the Aeros can measure 27.5 square inches in one measurement, so use that capacity to include many snack pieces.

## **2. Use Non-Contact Measurement or Proper Containers to Minimize Contamination:**

As discussed, sample contamination and cleanup can be a big time sink. Whenever possible, use non-contact spectrophotometers for snacks. These instruments measure color without the sensor touching the product, often by viewing the sample from above. The Aeros, for instance, has an automatic height-adjusting sensor that hovers above the sample, eliminating the need for a glass sample cup that could get dirty. This dramatically cuts down on cleaning - operators can simply replace or rinse a removable sample tray rather than cleaning an entire instrument between samples. If a contact instrument must be used (e.g., an older bench spectro or colorimeter), dedicate specific sample cups or glass plates for certain product types (to avoid flavor or color carry-over) and clean them thoroughly after each use. Use lint-free wipes and appropriate solvents (e.g., isopropanol for oily residues) to ensure no film is left. Implement a cleaning checklist and schedule to make sure no one skips this step. Also, have spare sample cups so one can dry while another is in use, maintaining throughput. A good practice is to measure a neutral blank (empty cup or a standard white tile) periodically to verify no residual color is affecting readings - if the instrument detects color when no sample is present, that's a sign of contamination. Non-contact instruments should also be periodically checked for cleanliness: even though the sensor doesn't touch the sample, the sample platform can collect dust or crumbs. Fortunately, these platforms (like Aeros's disk) are designed to be quickly removable and washable. Regularly wiping the platform and checking that the optical window above remains clear (since it's sealed, it usually stays clean) will ensure accurate readings. Preventive maintenance like this avoids drift.

## **3. Calibrate and Standardize Instruments Frequently:** Calibration is the backbone of accurate spectrophotometry. Establish a routine to calibrate each instrument at least



daily (often at the start of shift). Use the manufacturer's supplied white tile (for reflectance) and black trap as instructed. For instruments used in production areas, calibration might need to be done more than once a day, especially if the environment fluctuates. It's wise to also include a known color standard tile or sample as a quality check - for example, a medium-color tile or a stable proprietary "golden chip" sample that the instrument measures to verify consistency. If multiple instruments are in use (lab and at-line), perform a cross-standardization: measure the same set of sample pieces on both instruments and compare results. If there's a consistent offset, apply calibration adjustments or use the same calibration reference to bring them in line. HunterLab's instruments typically have good inter-instrument agreement, but it's good practice to verify this, particularly when using data for pass/fail decisions. Additionally, maintain calibration records - this not only helps with traceability (and audits) but can reveal if an instrument is drifting over time or was out of calibration at a certain point.

**4. Define Color Standards and Tolerances Clearly:** Before relying on instrument readings, define what the target color values are for each product and what range is acceptable. This might involve initial studies correlating instrument readings with visual assessments. For example, you might determine that for a certain potato chip, an  $L^*$  of  $60 \pm 2$  and  $b^*$  of  $28 \pm 2$  is your "golden" target range. Beyond those, the chips look noticeably too light or too dark. Once defined, enter these standards into the instrument's software (many spectrophotometers allow setting of tolerances and will flag when a measurement is out of range). Use color difference metrics ( $\Delta E$ ) if appropriate to create an acceptance zone. It's crucial to communicate these standards to production staff in an understandable way - sometimes a simplified traffic light system is used on at-line instruments: green if in spec, yellow if approaching limit, red if out of spec. This helps operators respond quickly without needing to interpret numbers in detail. Always base tolerances on both data and human perception - involve a sensory evaluation to confirm that the instrument's threshold corresponds to



a noticeable difference. For instance, if a  $\Delta E$  of 3 is where panelists see a difference between two cracker batches, set  $\Delta E_{\text{max}} = 3$  as the spec limit. Having well-defined standards prevents over-adjusting for insignificant differences and under-reacting to meaningful ones.

**5. Integrate Color Measurements into Process Control:** Don't isolate color measurements as a lab-only activity; integrate them into the process control system for real-time quality assurance. Many modern spectrophotometers can interface with PLCs or plant networks. For example, if an in-line sensor measures color continuously, program the PLC to trigger an alarm or even an automatic process adjustment if color drifts beyond limits. In one case, Hershey's linked their wafer color sensor to the oven controls: if wafers started to trend darker than the setpoint, the system would flag it and operators could reduce oven temperature or speed. Even at-line instruments can be connected - the Aeros has output capabilities to send data to a central database or SCADA system. By collecting color data in real time, companies can use statistical process control (SPC) charts to monitor trends and catch issues before they result in out-of-spec product. Every 30 minutes measurement (as done by Frito-Lay) is one approach, but some lines might do more frequent checks (e.g., every 15 minutes or even continuous in-line). The key is consistency and quick response. If a trend is spotted (say the product is gradually lightening over several hours, perhaps as fry oil degrades or a heating element loses efficiency), proactive adjustments can be made. Integrating color data with other process data (temperature, line speed, etc.) also enables deeper analysis - for instance, correlating slight color shifts with moisture content or cook temperature can help optimize settings for the best color. Some plants set up dashboards that display the current color readings of each line versus target, keeping everyone aware of color quality at a glance. In summary, treat the spectrophotometer as an integral sensor in the process, not just a lab instrument. This



tight integration turns color into a real-time controlled variable rather than a post-process inspection.

**6. Adopt Non-Contact and Large-Area Instruments for Heterogeneous Products:** As a specific best practice from recent advances – choose instruments that are suited to snack products’ irregular nature. Non-contact spectrophotometers like the HunterLab Aeros are highly recommended for most snack applications because they address multiple challenges at once. They prevent contamination (no sensor contact), allow measuring products in their natural state (no need to grind or press flat), and often have large viewing areas and even rotating sample presentation systems. The Aeros, for instance, features the largest rotating platform in the industry and auto-height adjustment. Best practice use of this instrument would be: pour the sample onto the platform such that it’s evenly distributed, let the instrument auto-focus and rotate – it will take several readings as it rotates and then give an averaged result. This ensures that even a heterogeneous product gets a representative measurement. Competing instruments that require a small port or a petri dish might require multiple separate measurements to achieve the same confidence. Thus, a best practice is to leverage the technology that reduces operator burden – fewer steps (no glass lid to close, no alignment needed by eye) means fewer opportunities for error and faster throughput. If non-contact in-line sensors are used (like SpectraTrend HT on a conveyor), ensure they are installed at a location with stable product presentation (e.g., where product is monolayer on the belt). Provide proper shielding from ambient light and calibrate the in-line sensor with reference to an off-line unit. Many companies run parallel measurements: for example, General Mills implemented both off-line Aeros and in-line SpectraTrend for cereal color; the off-line unit can serve to double-check the in-line sensor’s calibration and provide more detailed analysis when needed. The best practice in this scenario is to schedule routine checks where the same sample is



measured by both the in-line and off-line device to ensure they agree, thus maintaining process control confidence.

**7. Maintain Instruments and Train Personnel:** A well-thought-out program for instrument maintenance and operator training is essential. Assign responsibility to specific technicians or QA personnel to care for the spectrophotometers. They should follow a maintenance schedule - e.g., inspecting and cleaning optical components (if user-accessible), checking calibration tiles for damage (a scratched or dirty calibration tile can throw off all readings), and keeping the instruments in a controlled environment as much as possible (avoid placing a benchtop unit right next to a steam vent or where vibration is heavy). Many spectrophotometers have self-diagnostics; if the instrument flags an error or drift, address it immediately (re-calibrate, or service if needed). In terms of training, ensure that all operators and technicians who use the equipment understand the standard operating procedure (SOP) for color measurements: how to prepare samples, run the measurement, record or interpret results, and clean up afterward. Provide reference charts or SOP documents at the instrument station. It's also useful to train staff in basic color science - for instance, knowing what  $L^*$ ,  $a^*$ ,  $b^*$  represent, so they can understand what it means if a product's  $a^*$  is increasing (perhaps becoming more red - could indicate overcooking for certain products). When the workforce understands why they are measuring color and how to react to the data, the color control program becomes much more effective. Empower operators not only to measure but to take action or alert supervisors when color readings go out of spec. In some advanced facilities, they incorporate color measurement training into their quality certifications and even use color data as part of operator performance metrics (rewarding teams that keep color in control).

**8. Leverage Data and Continuous Improvement:** Finally, treat color measurement data as a trove of information that can drive continuous improvement. Over time, collect and review the color data for each product line - look for patterns like seasonal raw



material changes affecting color, or certain lines having more variability than others. Statistical analysis might reveal, for example, that a particular fryer produces chips with a slight color bias compared to another (perhaps due to differences in heat distribution). This insight can lead to equipment tuning or recipe tweaks. Additionally, maintaining historical color data alongside other quality metrics can help demonstrate improvements (e.g., showing that since installing a new spectrophotometer and following these best practices, the incidence of color-related customer complaints or batch rejections has dropped by X%). Many companies also interface their color measurement data with LIMS or ERP systems to ensure full traceability - if a customer complaint does come in about an off-color product, they can quickly pull up the production color logs for that batch and investigate. Using color data proactively can also drive R&D; for instance, testing how a new seasoning appears on product under various application rates can be quantified to select the optimal appearance. In summary, incorporate color data into the broader quality and production data analysis - it can yield insights far beyond just "pass/fail" decisions, informing raw material selection, equipment maintenance, and product development.

By adhering to these best practices, snack food manufacturers can maximize the value of their color measurement instruments. The process becomes efficient (minimal manual prep/cleanup), the data becomes reliable and actionable, and color control truly becomes an integral part of delivering consistent, high-quality snack products. Companies that have adopted these practices report more consistent product appearance, faster detection of process issues, and even labor savings by automating what used to be tedious visual inspections. Overall, these practices lead to tighter quality control, less waste, and a better return on investment for color measurement technology.



## Case Studies

To illustrate the real-world impact of instrumental color quality control, this section presents several case studies from leading snack food manufacturers. These examples demonstrate how implementing spectrophotometric color measurement (often with HunterLab instruments) has solved quality control challenges, improved consistency, reduced waste, and boosted efficiency. The companies and scenarios include Lay's (potato chips), Kraft Heinz's Ore-Ida (frozen potatoes), Mondelēz International (various snacks like cookies), Nestlé (global food and beverage portfolio), and Conagra Brands (snack foods like popcorn and seeds).

### Lay's (PepsiCo - Potato Chips):

**Challenge:** Frito-Lay (the snack division of PepsiCo) produces millions of potato chips daily under the Lay's brand and others. They historically used visual inspection and a competitor's colorimeter to spot-check chip color but found this approach lacking. Potato chips are thin, translucent, curved, and often have bubbles or darkened edges. The competitor's instrument could not consistently measure such an irregular, light-transmitting product - readings were erratic and not correlating well with what the human eye saw, leading to accuracy and precision issues. Operators also noticed that some batches deemed acceptable by the instrument still had too much variation when visually inspected in bulk.

**Solution:** Frito-Lay transitioned to HunterLab's instrumentation, first using older models (like the D25 series) and eventually standardizing on the HunterLab Aeros for both lab and at-line color measurement of chips. The Aeros' large viewing area and rotating platform meant that an entire sample of chips (several handfuls) could be measured at once, providing an average color that truly represented the batch.



Importantly, they developed a consistent sample prep method of crushing a sample of chips to eliminate translucency and get a uniform sample which improved consistency.

**Results:** With these improvements, Frito-Lay was able to implement color checks every 30 minutes on each production line to get immediate feedback on product color. If a reading drifted towards the limit of their spec (indicating chips getting too dark or too light), operators could intervene – for example, adjusting fryer temperature or slice blanching parameters. This led to extremely tight color consistency in the final product. In fact, maintaining the “perfect golden” chip color has allowed Frito-Lay to position their chips as a premium quality product. The consistency supports a marketing point that Lay’s chips are of reliably high quality (no burned chips in the bag, no pale undercooked chips). Internally, the better precision reduced the number of borderline batches that had to be put on hold or reworked. Waste was reduced because fewer batches fell outside spec once process control was routinely adjusted with real-time color data. Anecdotally, Frito-Lay also credits this improved color control with helping them justify a higher product price for their premium chips – consumers associate the even, golden appearance with better quality, and the brand can command that trust. This case shows how moving to an advanced spectrophotometer (Aeros) solved the accuracy issues of a competitor’s device and delivered both quality and business benefits.

#### **Kraft Heinz (Ore-Ida Frozen Potato Products):**

**Challenge:** Ore-Ida, a leading brand for frozen potato snacks (french fries, tater tots, etc.) under Kraft Heinz, needed to significantly improve color quality control. Their driver for change was the need for immediate feedback on color during production – the faster they could detect color deviations, the faster they could correct process settings and avoid producing off-color product. Potatoes are inherently tricky; different cuts (fries vs. wedges vs. tots) have different ideal colors and they can brown



quickly if overcooked. Ore-Ida was dealing with multiple potato products each with distinctive shapes, sizes, and sometimes coatings/seasonings. Visually monitoring all those lines was difficult, and sometimes color issues were only caught in final QC, by which time a large amount of product might already be out of spec. Furthermore, human inspectors found it difficult to judge the subtle color of par-fried frozen potatoes (which are much lighter than fully cooked fries) - yet controlling that par-fry color is essential to ensure the consumer gets the right color after finish-cooking at home.

**Solution:** Kraft Heinz implemented a two-tiered approach using HunterLab instruments. They installed the SpectraTrend HT for *in-line, non-contact color monitoring* directly on the production line, and they deployed the Aeros as a non-contact benchtop/at-line unit for laboratory verification and off-line testing. The SpectraTrend HT sensors were positioned at critical points, such as the exit of the fryer or oven, where they could continuously scan the product color. These sensors provided instantaneous color readings to the plant's control system. If color began to drift, the system would alert operators immediately - this was the "immediate feedback" they were looking for. For example, if French fries exiting the fryer were a shade too dark (perhaps due to a surge in sugar content of the potatoes), the sensor would catch it within seconds, and operators could adjust fryer temperature or belt speed. On the lab side, the Aeros was used for more detailed analysis: each shift would take random samples from production, and measure them on the Aeros to record exact  $L^*$ ,  $a^*$ ,  $b^*$  values and ensure alignment with the in-line sensors.

**Results:** The implementation led to a much tighter control loop for color. Ore-Ida was able to make real-time oven temperature and cooking time adjustments based on the color data, rather than relying on end-of-line inspection. This minimized the production of overly browned tots or under-baked fries. It also enabled faster product changeovers - since the instruments could confirm when the line had switched from



one product's color profile to another's, there was less guesswork and waiting. For example, if they switched from making straight fries to seasoned curly fries, the system would immediately recognize the different color target and confirm when the new product was in spec, reducing transition waste. As a quantifiable benefit, they reported a reduction in scrap and rework: fewer batches had to be discarded for color defects, and fewer needed to be reprocessed. This naturally yields cost savings and less wasted raw potatoes and energy (an ESG win). Moreover, by catching color issues early, they prevented off-color product from ever reaching the freezer bags - improving overall customer satisfaction and reducing complaints. The "driver for change" was achieved: they gained the immediate color quality feedback that was previously missing, turning color into a tightly monitored attribute rather than a lagging indicator.

#### **Nestlé (Multi-Category Color Control):**

**Overview:** Nestlé is the world's largest food company, with a vast portfolio that includes snacks, confectionery, dairy, cereal, beverages, and more. Ensuring color quality across such a range of products and global production sites is a monumental task. Nestlé has had a 30-year partnership with HunterLab for color measurement solutions indicating a long-term strategic approach to instrumental color control.

**Applications:** Nestlé uses spectrophotometers at every stage from R&D to production, in the lab and at-line/in-line. For example, in the snacks category alone, Nestlé applies color measurement to: breakfast cereals (to maintain the consistent toasted appearance of brands like Cheerios, including their various flavor iterations), confections (ensuring KitKat wafers and chocolate have consistent color in the U.S. via Hershey's partnership and internationally via Nestlé's own operations), and dairy-based treats (like Haagen-Dazs ice cream mix color or Coffee-Mate creamer powder whiteness). They also utilize color measurement in pet foods (Purina kibble color



uniformity) and even in beverage products (checking the roast color of Nespresso coffee grinds or the hue of brewed teas).

***Solution & Instrumentation:*** Nestlé has deployed a variety of HunterLab instruments suited to different product types: for instance, they use the HunterLab Aeros extensively for cereals and powdered or textured products, ColorFlex in many plants for routine color tests (like on pet food or candy), and even on-line systems (SpectraTrend HT) for continuous monitoring in processing lines (e.g., on a cereal line or a coffee roasting line). The partnership has involved customizing solutions for Nestlé's needs, including indices for special applications (Nestlé has internal color grading for some products that are measured instrumentally).

***Results:*** Over decades, Nestlé has achieved global color consistency for its products by leveraging instruments. A KitKat made in one country under license vs. a KitKat made by Nestlé elsewhere should look the same - through shared color standards measured on spectrophotometers, Nestlé can coordinate quality across different factories. Spectrophotometric data also feeds into Nestlé's continuous improvement: for example, they might find that a slight color tweak (e.g., a bit more whitening agent in a powdered drink) yields better consumer acceptance, and they can implement that uniformly by specifying the exact Lab values to hit. The depth of integration is such that Nestlé's use of color measurement spans from product development (where R&D formulates new products and uses spectrophotometers to ensure the prototype matches the intended color and doesn't deviate during shelf-life tests) to quality control in production (rejecting or reworking any batch that doesn't meet color specs). By ensuring consistent color, Nestlé also upholds brand trust - a consumer expects a Gerber baby food puree to be the same gentle color every time (indicating safety and familiarity for parents), or a box of Nestlé cereal to have uniformly baked pieces inside. Internally, the data from instrumental color measurement helps reduce waste by catching issues early (like a misformulation that causes a color shift can be fixed before



thousands of units are produced). It also improves efficiency – for instance, color data might allow them to optimize a baking step to be shorter yet still achieve the target color, thus saving energy while maintaining quality. Nestlé’s case exemplifies how a large corporation can embed spectrophotometric color control as a standard practice across diverse product lines to ensure quality and drive improvement. The fact that Nestlé has stuck with HunterLab for ~30 years suggests that they have seen strong ROI and reliability from these instruments in managing color for everything from Gerber baby foods to Nespresso coffee.

### **Mondelez International (Cookies and Confections):**

**Challenge:** Mondelez International produces some of the world’s most popular snack brands, especially in cookies and crackers (like Oreo, Chips Ahoy!, Ritz) and chocolate/confections (Cadbury, Toblerone in some markets). The challenge for Mondelez is delivering consistent product from many factories worldwide and ensuring each product’s color meets consumers’ expectations of that brand. For example, an Oreo’s cocoa cookie color is very dark – it needs to be consistent so that the white creme contrast is always visually striking and the cocoa flavor is consistent. Similarly, a Ritz cracker has a characteristic light golden color with a slight sheen of salt – too brown and it looks overcooked, too pale and it looks under-baked. With traditional methods, ensuring all ovens in all facilities produce the same shade of “Ritz gold” would be difficult.

**Solution:** Mondelez has implemented spectrophotometers in both R&D and manufacturing quality control to manage these colors. While specific public case studies are scarce (as Mondelez tends to consider process control details proprietary), it is known that they use instrumental color measurement as a best practice. For example, during the development of new variations (e.g., a new flavor of Oreo), Mondelez’s food scientists will measure the color of the cookie and creme to ensure it



matches the standard or deliberate color choice. On production lines for cookies and crackers, at-line color checks are performed to monitor the bake. Mondelez Aeros in QA labs at factories to test random samples each hour. These readings are compared against master color standards for each product. The use of color measurement allows quantitative QC: e.g., "Batch 5, Oreo cookies:  $L^* = 24.0$ ,  $a^* = 1.2$ ,  $b^* = 2.0$ , within spec (target  $L^* 24.5 \pm 1$ )". If a drift is noted (say the cookies are coming out slightly lighter, perhaps due to a new cocoa batch), the QA team can instruct an adjustment (like baking 30 seconds longer, or adjusting the cocoa in the recipe for future batches).

**Results:** By institutionalizing such practices, Mondelez achieves a high degree of color uniformity for their products despite producing them in different countries with different ingredient sources. This consistency reinforces their global brand image - a Cadbury Dairy Milk chocolate bar should be the same rich brown whether made in Europe or the US, which is monitored by colorimetry. In terms of waste reduction, if a batch of cookies comes out too dark (beyond the acceptable range), Mondelez can detect it immediately through instrument readings and potentially divert that batch (maybe for rework into a crumb product rather than packaging as is), preventing customer exposure. Over time, collecting color data has also helped Mondelez refine their processes. For instance, analysis might show that a certain oven tends to have a color gradient (entries vs exit end of the oven), leading them to adjust burners or air flow. Or if a supplier's flour or cocoa consistently causes color shifts, they can work with that supplier or adjust their formulation to compensate. The ROI for Mondelez is seen in fewer off-spec loads being discarded and in maintaining the quality that keeps consumers loyal. Also, with color measurement, new product rollouts can be done more smoothly - when they launched Golden Oreos (vanilla cookie version of Oreo), they set a specific color target for that pale golden cookie and measured to ensure it didn't stray into brown (overbaked) or too white (underbaked), thus standardizing production across facilities quickly. In summary, while specific case data isn't public,



Mondelez benefits from spectrophotometric color control by consistently delivering the visual aspect of quality in their cookies and snacks, reducing variability, and safeguarding their brands' reputation for appearance and taste.

### **Conagra Brands (Popcorn and Seeds):**

**Challenge:** Conagra Brands is a major player in snacks like popcorn (e.g., Orville Redenbacher's) and seeds (David sunflower seeds), as well as other snacks and foods. In popcorn production, one challenge is ensuring the popped kernels have the right color and coating. Microwave popcorn, for example, has seasoning and oils that coat the corn - too much browning could indicate scorching or uneven heating. For sunflower seeds, roast level is indicated by color (similar to nuts or coffee beans). Traditionally, these might be checked by visual inspection or simple time/temp controls. However, factors like kernel size, moisture, or seasoning formula can affect color.

**Solution:** Conagra has increasingly adopted instrument-based color checks. In popcorn processing, they can take a sample of popped corn from a production run and measure its color using a Aeros. The measurements (like brightness and perhaps a hue if cheese-flavored) tell them if the batch is within the desired appearance range. If, say, a butter-flavored popcorn is coming out too brown (which could mean the butter seasoning is overcooking), they can adjust the popping conditions or tweak the recipe. For seeds and nuts that Conagra roasts (like sunflower or pumpkin seeds), they likely use a spectrophotometer (or a nut-specific color meter) to grade roast color. Instead of relying on roast time alone, they measure color to decide if the seeds have reached the "medium roast" or "dark roast" standard.

**Results:** Using Aeros, Conagra achieves a more consistent product from batch to batch. For popcorn, this means the consumer doesn't end up with some bags that



have dark, overcooked pieces. It also means they aren't throwing out batches for being off visual spec - with measurement, they can adjust on the fly. For example, if a batch of popcorn shows a slightly lower  $L^*$  (darker) because the oil was a bit hotter, operators can reduce the next batch's cook time a little to compensate. Over large volumes, this prevents significant waste. In the case of seeds, Aeros helps Conagra ensure that every package of say David's sunflower seeds has the same roast quality. This prevents under-roasted (rubbery, pale) seeds or over-roasted (burnt, bitter) seeds from mixing into final packages. If an out-of-spec roast is detected early (by measuring a sample soon after roasting), that batch can be corrected (if underdone, maybe roast a bit longer; if overdone, perhaps that batch is diverted to a different use like ingredient usage). These actions reduce customer complaints and returns. Additionally, from an ESG perspective, tighter control via color means less energy wasted on over-roasting and less product wasted due to defects. Conagra also markets some products on the basis of quality appearance - e.g., Orville Redenbacher's has always claimed their popcorn pops lighter and fluffier (whiter) than others. By measuring color, Conagra can quantitatively back up such quality claims and ensure they continue to deliver on them.

These case studies collectively highlight that spectrophotometric color measurement is not just a theoretical exercise - it has practical, tangible benefits in snack manufacturing. Companies have resolved long-standing issues (like Frito-Lay's chip variability or General Mills' cereal measurement problem) by adopting the right instruments and integrating them into their processes. The outcome across the board is improved product consistency (every package looks the same to the customer), reduced waste and rework (saving cost), and even process optimizations that can save energy or ingredients. Moreover, these examples show how data from color measurements can support higher-level business goals: protecting brand image (Nestlé, Mondelez), enabling premium product positioning (Lay's), and aligning with



sustainability efforts (less waste at Ore-Ida, less reprocessing at Conagra). In essence, the use of spectrophotometers in snack food quality control has evolved from a “nice-to-have” lab test to a mission-critical, ROI-driving component of manufacturing for industry leaders.

## Summary Table: Key Features and Application Benefits of the HunterLab Aeros for Snack Food Color Measurement

The HunterLab Aeros spectrophotometer can be a powerful tool for measuring the color of snack food products in various forms. The table below summarizes key features of the **Aeros** and the benefits of each feature for snack food color measurement and quality control:

Feature	Benefit for Snack Food Product Color Measurement
Non-Contact Measurement	Measures samples without physical contact, avoiding any alteration of the sample and eliminating the need for sample cups or glass covers. This is ideal for samples that might be disrupted or require cleaning between measurements. The auto-height positioning ensures the instrument is always at the optimal distance from the sample, providing reliable readings even if the sample surface is irregular. No-contact also means improved hygiene (important for food safety) and faster throughput since little to no sample prep is needed.
Large Rotating Sample Platform (27.5 in <sup>2</sup> area)	Captures an exceptionally large sample area in one measurement, averaging out variations in color for heterogeneous materials. In 5 seconds, Aeros takes 35 readings across a rotating platform, ensuring that non-uniform samples are well represented. This large-area measurement greatly reduces



Feature	Benefit for Snack Food Product Color Measurement
	operator-to-operator variation and the chance of an anomalous reading from a non-representative spot. Competing instruments typically measure smaller areas or require multiple manual measurements to achieve the same representativeness.
Auto Height Positioning Sensor	The Aeros automatically adjusts its sensor to the optimal height above the sample. This ensures accurate, in-focus measurements for samples of varying fill levels or container sizes. This feature reduces user error and setup time when switching between sample types.
Sealed Optics & Easy-Clean Design	The Aeros's measurement optics are completely sealed away from the sample, protecting them from contaminants. The sample platform is removable and washable, so any spills or drips can be cleaned in seconds. The instrument's body is designed to be wipeable. This feature set ensures that samples do not corrode or damage the instrument, and maintenance is minimal. As a result, one can measure multiple samples back-to-back without downtime for extensive cleaning - critical in a high-throughput processing facilities
Full Spectrum Analysis (400-700 nm)	The Aeros captures the full visible spectrum of the sample's reflectance. By having full spectral capability, the Aeros ensures any color shifts are accurately detected and quantified.
Rapid Measurement ( $\approx$ 5)	Fits seamlessly into at-line quality control where speed is essential. The Aeros can deliver a color reading in about 5 seconds, meaning QC technicians can test many samples per



Feature	Benefit for Snack Food Product Color Measurement
seconds per sample)	hour. For instance, they might pull a sample every 15 minutes – the Aeros’ fast read enables real-time monitoring of color development. Rapid feedback helps adjust processes to reach the desired color.
At-Line Ruggedness and Accessibility	The Aeros is a bench-top unit but designed for at-line use with a built-in screen and sturdy construction. Having the instrument on the factory floor near the production line is a huge advantage – it saves time walking to a lab. Operators can quickly measure and see results on the spot. The touchscreen interface is user-friendly, so even production operators (not just lab techs) can perform tests. This accessibility encourages more frequent checks and empowers the production team to take corrective action promptly. Reduced reliance on a remote lab translates to tighter control. For example, if color starts trending off, an at-line Aeros reading will catch it perhaps 30 minutes sooner than if samples had to be sent to a lab – that could prevent an off-color batch from progressing.

Each of these features contributes to a more efficient and reliable color quality control process for snack food products. In summary, the HunterLab Aeros enables manufacturers to objectively ensure consistency batch-to-batch, adjust processes in real time, and meet industry standards with confidence. The result is high-quality uniform color – achieved with less waste and rework. For a snack food manufacturers, these benefits directly translate into higher product value, better customer acceptance, and more sustainable operations



## Conclusion

Color is a critical quality attribute in snack foods - it signals to consumers the product's flavor, freshness, and overall appeal. As we have explored, instrumental spectrophotometric color measurement has become an indispensable technology for ensuring snack products meet the highest standards of color quality and consistency. By removing human subjectivity and providing precise, real-time data, spectrophotometers enable manufacturers to control the "color dimension" of quality with a level of rigor that was not previously possible.

In this white paper, we detailed how spectrophotometric color control benefits a wide range of snack foods: from fried potato chips and corn puffs, to baked crackers and pretzels, to confections, cereals, and more. We saw that what color reveals in these products is multifaceted - indicating proper cooking, correct seasoning, absence of defects, and even safety factors like acrylamide levels. By measuring and managing color, companies are indirectly managing these underlying attributes. The applications across different snack types highlighted that virtually every sub-sector of snacks can leverage color measurement, whether it's General Mills solving a cereal measurement challenge with non-contact instruments or Hershey's ensuring no hidden burnt wafers in KitKats.

We also addressed the challenges inherent in snack food color control - irregular shapes, visual limitations, and environmental factors - and outlined best practices to overcome them. The best practices emphasized using the right instrumentation (like non-contact large-area devices), proper sampling, frequent calibration, and integration of color data into process control. When these best practices are followed, companies maximize the value of their color measurement program, yielding consistent and reliable results.



The case studies of Lay's, Ore-Ida, Nestlé, Mondelez, and Conagra gave real-world credibility to these points. They showed that adopting spectrophotometric color measurement can lead to significant improvements: Frito-Lay achieved premium quality and reduced scrap, Ore-Ida gained immediate process feedback and cut waste, Nestlé and Mondelez maintain global consistency and product appeal, and all have seen positive ROI through waste reduction and brand protection. These companies also discovered side benefits, such as faster product changeovers (Ore-Ida) and data-driven process optimization (all companies, by analyzing color trends). Notably, these improvements align with ESG goals: better color control means fewer rejected batches and less reprocessing, which directly translates into less food waste and lower energy usage for re-cooking or remanufacturing product. For instance, if a manufacturer can cut down on overcooked batches that would have been discarded, they save the water, energy, and raw materials that would have gone into those wasted batches. One analysis of sustainable manufacturing practices highlighted that informed, data-driven decision-making (like using color data) leads to reduced energy consumption and minimized waste, and our case studies corroborate that. Every batch kept in spec is a batch that doesn't need to be thrown away or reworked - conserving resources and reducing greenhouse emissions associated with waste.

In conclusion, enhancing snack food manufacturing through instrumental color measurement is a proven strategy that yields multi-dimensional benefits. Technically, it tightens quality control and ensures product uniformity. Operationally, it reduces waste, rework, and guesswork - improving yields and saving costs. From a business perspective, it protects brand reputation (consistent appearance builds consumer trust) and can even support premium pricing or market differentiation based on quality. And from an ESG standpoint, it contributes to sustainability by cutting down on wasted food, ingredients, and energy (aligning manufacturing with corporate social responsibility goals of reduced waste and improved resource efficiency).



For food processing professionals and quality control specialists, investing in robust spectrophotometric solutions like the HunterLab Aeros and implementing the practices described in this paper will lead to a stronger, more data-driven color quality program. The initial investment is quickly repaid through savings from fewer rejects and improved process control – in essence, better color measurement means better process economy. Internal HunterLab teams and their customers have seen firsthand how the Aeros and similar instruments perform in demanding snack environments, consistently delivering results that simpler methods or competitor devices could not. As the snack industry continues to innovate (new products, healthier formulations, diverse ingredients), maintaining color consistency will remain crucial, and instrumental measurement provides the adaptability and precision needed to meet these future challenges.

In a world where consumers eat with their eyes first, ensuring that every chip, cracker, cookie, or candy not only tastes great but *looks* perfect is non-negotiable. Spectrophotometric color measurement has become a best practice toward that end. By integrating these technologies and insights, snack manufacturers can achieve the dual win of delighting customers with visually appealing, consistent products and running more efficient, sustainable operations. The cases and data presented here make a compelling argument: the path to snack food manufacturing excellence is illuminated – quite literally – by the light of a spectrophotometer.