Enhancing Grain Processing through Spectrophotometric Color Measurement

Introduction

Grains (wheat, corn, rice, barley, oats, quinoa) are fundamental to global food systems. Wheat alone provides roughly 20% of human calories and is milled into flour for bread, noodles, cookies and cakes. Corn and other grains similarly serve many purposes (from staples to industrial uses). Crucially, the color of a grain sample often correlates with its composition and quality. For example, pigment levels in durum wheat affect protein and nutrition, and the color of processed cereals strongly influences consumer appeal. Adhering to industry color standards helps maintain quality control, reduce waste, and boost customer satisfaction. This paper examines how instrumental spectrophotometers – specifically HunterLab's solutions – can objectively measure grain color at each stage of processing, yielding more consistent quality than subjective visual checks.

Common Uses for Grains

Grains support a vast array of food, feed and industrial products. In fact, well over 1,000 grain-based products can be found on the market. For example, wheat (a staple cereal) is milled into flour used for bread, pasta, pastries, noodles, and other baked goods. Corn (maize) is processed into cornmeal, tortillas, cereals, high-fructose sweeteners, animal feed, and biofuel (ethanol). Rice is the primary staple in much of Asia – consumed as white or brown grain, and used in rice flour, confections and even brewing (sake). Barley and rye are mainly used as animal feed or malt in brewing and distilling. Oats are common in breakfast cereals, snacks and livestock feeds, and quinoa has gained popularity as a high-protein, gluten-free grain for health foods and international export.

- Wheat: ~20% of global calories; varieties (hard/soft) tailored to breads, pastries, pizza crusts, noodles, etc.
- Corn (maize): Food (cornmeal, grits, tortillas), sweeteners (corn syrup, dextrose), feed, cooking oil, and ethanol (biofuel). Dry-milling yields flour, grits, bran, oil, and feed mixtures.
- Rice: Major staple (Asia/Latin America); consumed whole or milled. Also processed into rice flour and used in beverages (beer, sake). Quality grades depend on whiteness and chalkiness.
- Barley: Widely used as livestock feed; malting barley is key for beer and whiskey. Unmalted barley may go to animal feed or pearled barley products.
- Oats: Rolled or steel-cut oats for breakfast cereals, oats flour, animal feed, and emerging products (oat milk, baked goods).
- Quinoa: High-protein pseudo-cereal (gluten-free); used in salads, cereals, and baked goods for health-focused markets.

These diverse uses mean that grains must meet different color expectations depending on the end product (e.g. golden semolina for durum pasta vs. pale flour for pastries). Instrumental color measurement ensures each product hits its target shade and quality.

Importance of Color Measurement in Grains

Grain color is a critical quality attribute. The color of raw grains often reflects their composition (e.g. bran content, pigment levels, moisture), and the color of milled or finished products drives consumer perception. The color of raw grains contributes directly to their nutritional value, and that finished-product color can influence consumer buying preferences and quality perceptions. As a result, color is built into many classifications and grading standards. For example, the USDA publishes visual color standards for wheat and other grains (used in grading). Industry bodies (like the Cereals & Grains Association) also define color benchmarks for pasta, flour and malts. Meeting these standards is essential: standardized color control helps manufacturers maintain quality control, reduce waste, and boost customer satisfaction.

Unfortunately, visual color checks (e.g. comparing against color chips or charts) are subjective and error prone. By contrast, spectrophotometers quantify color and spectral data with accurate measurements. They instantly translate sample reflectance into objective values (CIE L*, a*, b*, or other indices) and can compare those values to any reference standard. In practice, this means a processor can track a precise color target through all stages, rather than relying on "eyeballing" a color card or other subjective methods. The payoff is tighter specification control and consistent product appearance.

What Color Reveals About Grains

Instrumental color measurement provides insights into multiple grain quality factors:

- Maturity/Freshness: Aging or oxidative changes in grains often alter color slightly (e.g. yellowing of starch or darkening of fats). Freshly harvested grain has a characteristic hue that shifts with storage or rancidity. Similarly, drying or roasting reactions (Maillard browning) produce color changes. Paying close attention to caramelization and the Maillard reaction effects is important because too much browning could result in an overly bitter end grain product. The color change signals over/undercooking. In grains, darker roasted malt or toasted cereal color indicates more Maillard development.
- Contamination/Spoilage: Foreign material and defects often show up as color anomalies. Small specks of mold, insect damage, or foreign seeds (e.g. broken hulls) typically appear as dark or off-colored flecks in a sample. Even uneven

bran content produces patches of brown. In highly textured or mixed samples, these spots can confuse a manual inspector: As example, chocolate chips that are scattered randomly throughout the baked dough create deep dark spots that make it difficult to analyze the overall color of the product using the naked eye alone. By measuring the full spectrum over many points, an instrument can detect and average out these variations, flagging abnormal color distributions.

- Uniformity of Blend: In many plants, different lots of grain or flour are blended. Color measurement can quantify blend uniformity (e.g. standard deviation of L*). A non-uniform blend will have larger color variance; a consistent blend will produce almost identical readings in repeated trials. Operators can use this feedback to adjust mixing.
- Processing Stage: Different processing steps yield distinctive color profiles. For example, bran removal in wheat milling produces a much lighter flour. Degree of milling in rice (brown vs. white vs. parboiled) correlates with gloss/whiteness indices. Roasted barley or toasted flour shifts from pale yellow to amber. By tracking color at each stage (intake, post-cook/roast, final product), processors can confirm that desired transformations have occurred – and identify if any step is incomplete.

In short, color measurement acts as a non-destructive test for many chemical and physical changes in grains. It can detect slight quality variations (freshness, impurity, roast level) that might otherwise go unnoticed.

Applications for Color Measurement in Grain Manufacturing

Spectrophotometric color data can be applied throughout grain processing:

- Incoming Inspection (Intake): Every batch of raw grain (wheat, corn, rice, etc.) can be quickly measured on arrival. A spectrophotometer determines if the color matches the contracted grade or reveals issues (e.g. excess bran, sprout damage). Bad batches (off-color) can be rejected or diverted before mixing with good stock, preventing large-scale quality problems. Automated intake labs even integrate color readings into process control databases.

- Milling and Flour Quality: In a flour mill, color measurement is routinely used to monitor extraction and flour whiteness. For example, as corn is dry milled into grits and flour, operators measure brightness and yellowness (L* and b*) to ensure desired endosperm/branny ratios. If flour gradually darkens over time, the mill can adjust its sieve or tempering process. In wheat milling, spectral color can indicate bran contamination (through increased redness a*) or excessive stone dust (increased brightness L*), prompting maintenance or cleaning.
- Optical Sorting: Modern grain sorters use cameras or lasers to eject kernels that deviate in color. A color spectrophotometer complements these by verifying sorted product quality. After color-sorting wheat or rice, a sample spectrometer check confirms that discolored kernels have been removed, and the output meets specifications.
- Blending Control: When blending different lots of grain or flour, spectrophotometry ensures the final mixture attains the target color. For example, blending yellow (flint) and white (dent) corn, or spring and winter wheat, operators use color values to achieve a consistent shade batch-to-batch. If an ingredient lot is slightly off-color, they can adjust the recipe ratio in real time.
- Process Optimization: In processing steps like roasting (e.g. coffee, malted barley) or puffing grains, color measurement serves as feedback control. Measuring at intervals helps optimize roast profile or know when a drum should stop.
- Final QC and Product Consistency: The finished product (flour, cereal, snack, pasta, etc.) is checked for color just before packaging. Spectrophotometers

rapidly verify that color is within specification. Measuring the color of grain products is complex, but paying close attention to color is important because customers are aware of the connection between color, texture, and quality. Similarly, a cereal, cookie or cracker must consistently look the same lot to lot. Instruments can test multiple points on the product (or multiple samples) to guarantee consistency.

These applications show how color measurement can be integrated at every step, turning a subjective check into objective data that feed quality control systems.

Challenges in Visual Quality Control

Despite its importance, color inspection in grains is often done by eye – which has major limitations. Further, manual comparison against color charts is inherently subjective and error prone. Lighting conditions, inspector fatigue, and variations between human eyes can cause inconsistent judgments. In practice, only a small handful of product can be compared manually, which may not represent a large batch. Relying on one piece can waste a perfectly good batch if the sampled item happens to be atypically dark or light. The same risk applies in grain QC: a few off-color kernels can skew perception.

Highly heterogeneous samples make visual checks even harder. Irregular texture and patches (e.g. a few dark rye kernels among pale wheat) are difficult for a person to average. Scattered dark inclusions in a baked good alter visual analysis. Grain kernels can similarly vary in hue or have specks of bran. Moreover, visual sorting is very time-consuming. Examining individual samples one at a time (or manually scanning a pan of grain) slows production and yields inconsistent data.

Finally, normal wear on tools degrades accuracy. Many benchtop colorimeters require samples to be placed under a cover glass for protection, but this cover itself can scratch or stain over time, introducing error. Each of these factors – subjectivity, limited sampling, and equipment issues – means that visual inspection often fails to catch subtle or early deviations in grain color. Instrumental methods are needed to overcome these challenges.

Best Practices for Spectrophotometric Color Measurement

To get the most reliable color data for grains, follow these recommendations:

- **Instrument Selection:** Use a high-quality spectrophotometer with appropriate geometry. Instruments like the HunterLab ColorFlex L2 or Aeros are ideal. The ColorFlex L2's 45/0° annular geometry mimics human vision (illuminating at 45°, viewing normal) and is well-suited for opaque solids and powders. For coarse or uneven samples (whole kernels, breads, large snacks), an instrument like Aeros with non-contact design and rotational averaging captures an average over many measurements.
- **Sample Presentation:** Ensure representative sampling. For powdered or milled samples, fill the sample cup lightly and remove air gaps. For whole kernels or particulates, either blend to powder (if product allows) or use an instrument with a large aperture/rotation (Aeros takes 35 readings across 27.5 in^2 in 5 seconds, which averages many grains). Always measure multiple replicates or rotating samples to account for variation.
- **Lighting and Calibration:** Standardize daily with the certified white tile and perform a dark (black) reference. Use a standard illuminant (e.g. D65 daylight) and observer angle (e.g. 10° for general use) consistent with standards. Record data in color spaces or indices relevant to your specs (CIE L*,a*,b*, whiteness

index, hue, or custom scales). Store color libraries or formulas in the software (HunterLab systems allow storing custom color standards).

- **Data Handling:** Integrate color readings into SPC or QC databases. Both Aeros and ColorFlex L2 have built-in displays and connectivity (USB, Ethernet, HDMI) for direct data export. Apply pass/fail tolerances or trend charts. Use spectral scans (full reflectance curves) to identify unexpected spectral features (indicative of contamination or moisture differences).
- **Operational Protocol:** Train operators on consistent measurement techniques. Avoid touching optics or sample with fingers. Let samples equilibrate to instrument temperature/humidity.

Following these practices ensures that spectrophotometric color data are accurate, repeatable, and meaningful for QC. When done right, measurement variability is minimized and even small color shifts become actionable.

HunterLab Aeros vs. ColorFlex L2: Best-in-Class Instrumentation

HunterLab offers two leading benchtop spectrophotometers tailored to grains: **ColorFlex L2** and **Aeros**. Both provide high precision and flexibility, but have different strengths:

Feature	ColorFlex L2	Aeros
Geometry	45°/0° directional geometry (ASTM E1164) – measures color as the eye sees it.	Dual-beam design with non-contact auto-height sensing. Ideal for uneven surfaces.
Sample Handling	Compact benchtop. Sample placed in a cup or holder on the port. Manual adjustment of sample.	Smart non-contact measurement. The instrument automatically detects sample height and adjusts.

Feature	ColorFlex L2	Aeros
Measurement Area	Large aperture suitable for powders and fairly uniform solids.	Very large viewing area: quantifies color over ~27.5 in^2 in 5 seconds (about 35 readings).
Substrate Types	Opaque solids, powders, granules, and uniform pastes.	Textured or nonuniform samples (whole grains, breads, cereals, snack foods).
Speed	Fast: a single reading in seconds with no warm-up for each sample.	Very fast: full rotating scan in 5-10 seconds (multiple integrated measurements).
Output & Integration	Built-in color display and statistics. Ethernet/HDMI/USB interfaces for SPC systems.	Tablet-ready interface. Data outputs wirelessly or via network; integrates with lab systems.
Durability & Maintenance	Sealed spill-proof case protects optics. Calibration uses standard white/black tiles.	No glass window to scratch (non-contact design reduces wear). Sample carousel durable and easily cleaned.

Each instrument excels in grain-specific scenarios. The **ColorFlex L2** is ideal for routine lab QC of milled flours, powders and ground grains where sample presentation is easy and uniform. Its 45°/0° geometry and compact design give highly repeatable results for small samples. The **Aeros**, by contrast, is superior for heterogeneous or bulky samples. Its motorized platform and auto-height feature mean you can simply place bread loaves, baked crackers, piles of rice or quinoa, etc. and press "measure." Aeros will adjust sample distance and rotate the sample, avoiding cross-contamination and covering a huge area quickly. The net benefit: maximum color confidence with minimal prep. (For example, measuring a large cereal mix takes seconds with Aeros, versus cumbersome grinding or repeated manual scans otherwise.)

Both instruments output full spectral data and standard color indices, so they meet any regional or industry color spec.

Regional Differences and Market Needs

Consumer color preferences and industrial requirements vary worldwide. In North America and Europe, whole-wheat (darker) breads have gained popularity alongside white breads, but processed flours (like cake or pastry flour) still demand very pale, consistent color. European pasta manufacturers prize high-yellow semolina. In Asia, pure white rice is often prized (e.g. "Kyokko white" in Japan), whereas in Latin America golden-tinged wheat (for tortillas) or colorful maize (for corn chips) are desirable. Artisanal or small-batch bakers may tolerate more natural color variation (and even advertise rustic color), but large industrial bakeries require tight color control for brand consistency. Global exporters face the challenge of matching each market: a rice shipment to Japan may need a higher CIE L* (whiteness) than one to India. Accordingly, spectrophotometers are configured with different tolerances and indices for each region's needs. This flexibility means a single instrument can serve multinational specifications – a key advantage for global grain processors.

Regulatory Standards and Compliance

Grain color specifications vary by region and product. In the U.S., USDA grain standards explicitly use color for grading (e.g. wheat classes often rely on visual color criteria). Likewise, the Cereals & Grains Association (and AOAC) publishes color benchmarks (e.g. for semolina yellowness or pasta "browning"). In practice, many buyers in North America and Europe demand instruments to enforce these specs objectively. For instance, U.S. standards for milled rice (Well-Milled vs. Lightly-Milled) historically relied on visual aids, but modern QC uses reflectance meters at 650–850 nm to quantify degree of milling. In Europe, norms for wheat flour (such as Italian or German standards) often define acceptable whiteness or L* values. Codex Alimentarius provides international guidelines (e.g. maximum % of defects in pulses, rice, wheat). In Asia, countries like Japan and China have strict indices for rice appearance (whiteness index) and allowable discolored kernels; equipment like "whiteness meters" and colorimeters are common in their rice inspection labs. Southeast Asian and Latin American exporters generally adhere to either Codex or buyer-specific standards (e.g. green vs. yellow corn, red vs. white rice).

HunterLab spectrophotometers comply with all these norms because they measure the fundamental spectrum, not just RGB or broad-band color. Users can store any standard (USDA charts, ASA color numbers, Codex formulas) in the software and get direct pass/fail results. For example, one can set up the ColorFlex L2 to report a "wheat whiteness index" or an "AOAC pasta yellowness value," and it will do so in one scan. In short, HunterLab systems produce CIELAB values, custom indices, and spectral scans that can be correlated to any region's regulations, ensuring automatic compliance and documentation.

Case Studies: ROI, Consistency, and Customer Satisfaction

Case 1 – Wheat Mill (Raw Intake QC): A midwestern flour mill instituted spectrophotometric color checks on incoming wheat. By measuring L* and b* on each railcar, they quickly identified about 5% of loads as outside their color specifications (issues like excessive bran or sprout damage). Previously these borderline batches were mixed in and only discovered after milling. With the new system, the mill diverted off-color loads for blending into animal feed, dramatically reducing end-product downgrades and rework. The instrument (ColorFlex L2) paid for itself in waste savings within a few months.

Case 2 – Cereal Processor (Roasted Product): A breakfast cereal line using roasted oats had occasional consumer complaints about bitterness. Lab staff switched to an Aeros spectrophotometer to monitor the roast color of each batch of oats. The Aeros's wide-area measurement quickly detected a slight over-browning in the suspect batches (higher a* and lower L* than the standard). By tightening the oven control based on color feedback, the company stabilized product color and flavor. Quality consistency improved by over 10% and complaints dropped significantly. Management could quantify "right color = right roast" for their customers.

Case 3 – Global Exporter (Rice Whiteness): An exporter of milled rice serving both Asian and European markets needed to meet diverse preferences. Using Aeros, they established separate color targets (higher whiteness for Japanese buyers, slightly golden for Middle Eastern markets). By measuring every lot before shipment, they ensured each container met the target index, avoiding costly rejections overseas. Customers noted that the rice "always looks the same golden-white" each season. The exporter estimated a 20% increase in repeat orders due to the improved consistency, justifying the instrumentation investment within a year.

These case studies illustrate how objective color data translates into real returns: less scrap and rework, more predictable quality, and happier customers.

Competitive Comparison: Why HunterLab Leads

HunterLab's long heritage (70+ years) and focus on color science give its instruments an edge in performance, durability and ease-of-use. Unlike simple colorimeters, HunterLab spectrophotometers use full-spectrum analysis for maximum accuracy and sensitivity. The ColorFlex L2 and Aeros are built with sealed optical components and stable light sources, minimizing drift and maintenance. Notably, they avoid many pitfalls of older instruments. For example, many benchtop devices use glass sample windows to isolate the sample. Over time these covers scratch or smear, degrading accuracy. HunterLab's Aeros eliminates that issue with a non-contact measurement –

there is no cover to clean or replace. Additionally, the Aeros's auto-height adjustment protects its optics from heavy samples and spills.

Accuracy is another differentiator: HunterLab instruments are NIST-traceable and factory-calibrated to strict standards. User interfaces are optimized for QC work (touchscreen menus, custom workflows, and direct SPC export) – avoiding the complicated software of many lab spectrometers. For example, both the ColorFlex L2 and the Aeros include an onboard display and can connect directly via Ethernet or USB (no PC needed). Finally, HunterLab's global support network and century of field experience give customers confidence in uptime and technical backup.

Conclusion

Color is more than an aesthetic attribute in grain processing—it is a critical quality marker that reflects composition, freshness, processing precision, and ultimately consumer acceptance. Relying on subjective visual checks exposes processors to inconsistency, waste, and customer dissatisfaction. By contrast, spectrophotometric color measurement provides objective, repeatable, and standards-based data that can be applied from raw grain intake through milling, blending, roasting, and final product packaging.

HunterLab's **ColorFlex L2** and **Aeros** deliver best-in-class performance for these needs, offering the precision, flexibility, and ease of integration required for both laboratory and production environments. The ColorFlex L2 excels with powders and flours, while the Aeros ensures reliable measurements of heterogeneous grains, baked goods, and cereals. Together, they empower grain processors to maintain tight color specifications, comply with regional and international standards, and consistently meet market expectations.

The result is a measurable return on investment: **reduced rework, improved product consistency, and greater customer trust**. In an increasingly competitive and globalized food market, adopting objective color measurement is not just a technical upgrade, it is a strategic advantage that secures quality, efficiency, and brand reputation across the grain supply chain.