



Enhancing Color Quality Control in Soft Drink and Cola Manufacturing with Spectrophotometry

Introduction

Color is one of the first attributes consumers notice in soft drinks, strongly influencing purchase decisions. Studies confirm that a beverage's appearance - especially its color - greatly impacts consumer perception. For example, Coca-Cola and Pepsi maintain iconic brown hues that consumers identify immediately. Even slight deviations can undermine brand recognition and suggest a quality problem. Given this, soft drink manufacturers cannot rely on subjective visual checks; instead, they employ instrumental color measurement to ensure consistency. Modern spectrophotometers provide objective, numerical color data that can be compared against standards, improving QC speed and traceability.

This white paper explains why rigorous color control across the beverage supply chain is essential and how spectrophotometric solutions (particularly HunterLab's Vista and ColorFlex L2) deliver reliable, high-throughput color analysis for soft drinks and colas.

Overview of the Soft Drink and Cola Markets and Applications

The global soft drink market is vast and growing. In 2024, worldwide consumption of sugary soft drinks reached 467 billion liters, up 7.1% from the prior year. The market's wholesale value hit about \$414.7 billion in 2024. Leading consumers are China (\approx 76B L) and the US (\approx 40B L), with other populous countries contributing significantly. Within this sector, carbonated colas (Coca-Cola, Pepsi, and similar cola-flavored beverages)



are a dominant category; major brands continuously invest in quality control to keep their signature flavor and color. As new product segments (flavored sodas, functional beverages, low-calorie colas) expand, the demand for precise color consistency only grows.

Importance of Color Measurement Across the Supply Chain

Color quality is critical at every stage of production. Key checkpoints include:

- **Syrup concentrates:** Soda syrups are highly pigmented (often with caramel coloring or fruit extracts). Small variations in the syrup's color intensity will be magnified when diluted. Spectrophotometric testing of each syrup batch ensures the color is "bold and vibrant," so that when it's mixed with carbonated water it yields the exact target hue. In practice, QC labs measure syrup samples after cooking or mixing to confirm the correct optical density and hue; any drift can trigger recipe adjustments.
- **Carbonated water:** The filtered water used to carbonate should be essentially colorless. Even slight yellow or green tints signal impurities or leftover rinse fluids. The industry commonly uses the APHA (Pt-Co) color scale for clear liquids to quantify water purity. By measuring the water with a spectrophotometer (or colorimeter), operators verify it meets stringent color limits before use.
- **Final mixed beverage:** After dilution and carbonation, the final product's color and clarity are checked to confirm compliance with specifications. The finished soda is typically tested for L, a, b values and haze. Instrumental measurement on the bottled or canned drink catches any anomalies (e.g. excessive turbidity or color shift) that may have arisen during mixing, filtration or filling. By tracking



color at all stages – concentrate, water, and final mix – manufacturers maintain tight control of the visual quality of the beverage.

What Color Reveals About Product and Process Quality

Color serves as a “fingerprint” of both ingredients and processing. Deviations from the standard color often indicate quality issues: for instance, over-browned sugar syrups produce a too-dark cola, while undercooked caramel yields a pale product.

Unintended hues (e.g. a greenish tinge) can reveal contamination or incorrect raw material batches. Consistently matching the target color suggests that recipe blending, pH, and heat treatment are all under control. In fact, spectrophotometric data often correlates with other quality parameters: variations in cola color can imply a change in sugar or caffeine content, just as shifts in juice color can signal fruit concentrate ratios. When a sample’s color fails to meet the standard, product quality has been compromised. Conversely, maintaining the target color (as confirmed by instrument readings) demonstrates that the process – from cooking to mixing – has produced a uniform, on-spec beverage.

Applications for Color Measurement in Soft Drink and Cola Production

Color and haze measurement play diverse roles in beverage production, including:

- **Ingredient QC:** Testing raw materials (e.g. caramel colorant, sugar syrup, fruit juice concentrates) for consistency before they enter the process. For example, a spectrophotometer can grade sugar syrup color (ICUMSA color units) and ensure each lot meets the approved color index.
- **In-process monitoring:** Analyzing samples at key steps – such as post-caramelization, after mixing flavorings, or pre-carbonation – to fine-tune



formulation in real time. For instance, energy drink manufacturers use spectrophotometry on the mixing tank to verify that ingredients like caffeine and coloring agents are at the correct levels, keeping the final flavor and appearance uniform.

- **Haze/clarity checks:** Measuring turbidity in clear sodas or flavored waters to detect filtration problems or yeast activity. Instruments can quantify haze (per ASTM D1003) which is something the eye might not catch until it's severe. A Vista spectrophotometer, for example, provides simultaneous color and haze readings, so a change in clarity triggers a QC alert.
- **Final product QC:** Evaluating bottled or canned soda before release. The finished product is checked for color values against reference standards and for zero turbidity (for clear colas). This ensures each production run looks and tastes the same, safeguarding brand consistency. If multiple manufacturing sites exist, instrument data can be shared to align all lines on a common color standard.
- **Cleaning verification:** After CIP (clean-in-place) cycles, measuring rinse water color (using APHA scale) confirms that no syrup residue remains on the equipment. Clear rinse water passes the color check, while any residual color signals inadequate cleaning.

Together, these applications of color measurement help minimize waste and prevent out-of-spec batches. A portable or benchtop spectrophotometer is the primary tool in many QC labs because it provides fast, quantitative results that can be trended and compared to specifications.



Challenges of Visual Versus Instrumental Color Control

Relying on human vision for color QC is fraught with inconsistencies. Factors such as variable lighting, background color, sample temperature, and even observer fatigue or color-blindness can dramatically affect perception. Two quality technicians may judge the same sample differently, and no recordable metric exists for an eye test. In contrast, instrumental measurement eliminates these variabilities. A spectrophotometer reports an objective color value (e.g. CIE L^* , a^* , b^*) independent of lighting or operator. It also captures spectral data beyond the three colors the eye sees, enabling detection of metamerism (different formulations looking alike).

Moreover, instruments can be calibrated to international standards, ensuring results are reproducible across labs and shifts. For opaque or cloudy beverages (like some colas), traditional colorimetry is impossible by eye - this is where modern spectrophotometers excel. The color of juices, milk and other beverages has been difficult to measure objectively with traditional methods due to opacity, making spectrophotometry invaluable.

In summary, instrumentation provides traceable, repeatable color and haze data, whereas visual checks are inherently subjective and cannot meet tight QA tolerances.

Global Methods and Standards in Color Quality Control

The beverage industry relies on well-defined color measurement standards to ensure consistency and regulatory compliance. Key methods include:

- **CIE/ISO Colorimetry:** Finished beverage colors are commonly expressed in CIE L^* , a^* , b^* coordinates, which are international standards for color communication. Instruments measure the full visible spectrum of a sample and



compute its standardized tristimulus or L^* , a^* , b^* values under defined geometry and light source. This allows plants worldwide to compare color data unambiguously. Some SOPs also call for illuminant D65 (daylight) and a 10° observer when measuring liquid color.

- **APHA/Hazen (Pt-Co) Scale:** Used for color quantification of nearly colorless liquids (e.g. water, clear carbonates). The APHA color scale (0-500 units) is based on platinum-cobalt solutions. It provides a numerical “yellowness” index: 0 is pure water, higher values indicate increased tint. Many ISO and ASTM standards (e.g. ASTM D1209/D5386) reference the APHA scale and prescribe spectrophotometric methods to measure it. Soft drink water and dilute syrups are often controlled to specific APHA color limits.
- **ICUMSA Sugar Color:** The International Commission for Uniform Methods of Sugar Analysis specifies how to measure the color of sugar solutions (GS9/1/2/3-8). This method determines a “solution color” by UV-Vis absorbance at 420 nm in a 10 mm cell, giving a value in ICUMSA Units. Since sugar is a main ingredient in colas and sodas, monitoring sugar color (and hence purity) is routine. Spectrophotometers configured for the ICUMSA method help ensure consistent sweetness and color source.
- **Other Scales:** In some cases, scales like Gardner (1-18 for yellow-brown) or Lovibond (commonly used in brewing/honey) may be referenced for syrups or specific ingredients.

By adhering to these standards and using calibrated spectrophotometers, beverage producers can certify color quality to internal specs or regulatory limits. Many countries regulate caramel color usage or require pure water – standards like APHA and ICUMSA provide the metrics to enforce those rules.



Recommended HunterLab Solutions (Vista, ColorFlex L2) and Technical Justification

For soft drink and cola QC, HunterLab's spectrophotometers are especially well-suited:

- **HunterLab Vista:** A bench-top sphere spectrophotometer designed for liquids. Vista operates in a $d/0^\circ$ geometry, simultaneously measuring transmission color and haze (ASTM D1003 Procedure B) in a single sample. Its design ensures precise readings of clear to cloudy beverages – ideal for colas, fruit sodas, and flavored waters. Vista's touchscreen interface and automatic calibration make it easy to use on the plant floor. Because it reports full-spectrum data, it can provide L,a,b color, APHA color, and custom color scale values in one test. Vista's dual measurement capability (color *and* haze) is a unique advantage for beverages; it alerts QC if a "clear" soda has any unexpected turbidity, something portable colorimeters cannot do. This instrument also meets industry traceability requirements, enabling labs to lock down settings and maintain data logs for audits.
- **HunterLab ColorFlex® L2:** A versatile $45^\circ/0^\circ$ reflectance spectrophotometer for solids and liquids. The L2 is essentially the next-generation ColorFlex EZ, with an annular illumination geometry that yields superior color accuracy and consistency. It is compact, sealed, and spillproof, making it robust in a busy lab. Although often used for powders, pastes and opaque samples (e.g. spices, purees, sugar, coffee), the ColorFlex L2 can also measure opaque liquids. Its modern touchscreen interface and on-board reference standards enable PC-free operation.
- Both the Vista and the ColorFlex L2 come with advanced diagnostics to ensure peak performance. Both provide extensive connectivity via USB and Ethernet,



for easy data export and network integration. This means a drink manufacturer can integrate both instruments readings directly into LIMS/SPC systems for automated QC tracking.

In summary, Vista and ColorFlex L2 together cover the full range of beverage samples (from dark syrup liquids to solid ingredients) with industry-leading precision and ease of use.

Key Solution Features and Functional/Analytical Benefits

Instrument	Key Features	Functional / Analytical Benefits
Vista Spectrophotometer	<ul style="list-style-type: none">- d/0° integrating sphere geometry- Simultaneous color (L,a,b, APHA, custom) and haze measurement- Touchscreen UI, USB/Ethernet connectivity- Automated calibration (white/zero)	<ul style="list-style-type: none">- Objective, repeatable measurement of clear/translucent drinks (colas, juices, etc.)- Detects cloudiness or turbidity (haze) that the eye might miss- Fast QC workflow (instant pass/fail) with trend tracking- Meets regulatory requirement for water and beverage purity standards (APHA, ASTM D1003)- Easy data integration into lab systems (LIMS/SPC) for batch traceability



Instrument	Key Features	Functional / Analytical Benefits
ColorFlex L2 Spectrophotometer	<p>45°/0° annular illuminated geometry</p> <ul style="list-style-type: none"> - Spillproof sealed housing (compact) - On-board reference and diagnostics - Multiple output ports (USB, HDMI, Ethernet) 	<ul style="list-style-type: none"> - High precision for solids/powders (sugar, spices, dry mixes) and semi-translucent samples (creamy sodas) in QC labs - Minimizes measurement errors (stable geometry, sample camera view) for consistent color readings - Space-saving and robust (dust/water resistant) for plant environments - Easy data integration into lab systems (LIMS/SPC) for batch traceability
Software & Support	<ul style="list-style-type: none"> - Industry color scales and indices (APHA, ICUMSA, etc.) preloaded - CIE-compliant calculation for tristimulus/colorimetric data - Remote updates and calibration certificates 	<ul style="list-style-type: none"> - Ensures all measurements align with international standards (ISO/CIE) for valid comparisons - Automated data capture and audit trails support quality certifications - Global HunterLab service network provides training and calibration support



Case Studies Illustrating ROI and Quality Gains

- **Global Cola Manufacturer:** A plant produces 5 million liters/month. Historically ~2% of batches are culled for off-color (due to caramel drift or mixing errors), representing ~\$40,000 in lost product monthly. After installing a Vista spectrophotometer on-line, the QC team catches color deviations immediately and adjusts caramel dosing in real time. Rejects drop to 0.2%, saving ~\$36,000 monthly. Labor costs also fall as fewer re-mixes are needed. Even a conservative estimate yields six-figure annual savings - far exceeding the instrument investment. The costs of late-stage color rework ("adjusting in its final stage is very high") are virtually eliminated.
- **Syrup Production Plant:** A syrup maker uses ColorFlex L2 to monitor sugar concentrate color for multiple cola clients. Previously, manual titrations and visual checks could not reliably detect a slight darkening of syrup due to over-heating, leading to occasional re-batches (~\$10,000 lost per event). With instrumental color checks, the facility reduces these quality incidents by 80%. They also achieve tighter caramel color specifications across all syrups, enabling more consistent final drink color. The payback period for the ColorFlex was under one year.
- **Craft Beverage Start-up:** A small soda brewery adds a Vista to its QC lab. This startup produces niche cola flavors where unique color is part of branding. After implementing objective color specs, they see fewer customer complaints related to "off" appearance. Production runs become more predictable, and the founder cites the spectrophotometer as critical for scaling up. The ability to prove color compliance also helped when filing regulatory documentation on coloring agents. In this example, the ROI came through intangible gains (brand reputation) as well as direct waste reduction.



In these scenarios, spectrophotometric QC directly improves the bottom line by reducing waste and labor. Automated color analysis helps industries reduce waste, improve efficiency, and enhance consistency. It also speeds up approval cycles - instead of a slow lab assay, QC can generate a pass/fail report in seconds, avoiding production downtime. Moreover, rapid color feedback accelerates new product development. In sum, investing in precision color measurement quickly pays for itself through higher yield, better quality, and fewer customer issues.

Conclusion

As the soft drink industry continues to expand and innovate, maintaining **precise color control** is non-negotiable. Instrumental spectrophotometry provides the objectivity and consistency that manual inspection cannot, aligning with strict quality standards and consumer expectations. With tools like the HunterLab Vista and ColorFlex L2, beverage producers can rigorously track color and haze throughout production, from raw syrup to final bottled cola. This leads to more uniform products, fewer rejects, and robust documentation for regulatory or internal audits. In an era of high-speed bottling lines and discerning consumers, reliance on advanced color measurement is imperative.

HunterLab's beverage-focused spectrophotometers - optimized for liquid samples and backed by decades of food-industry experience - enable manufacturers to achieve these goals. Ultimately, deploying spectral color analyzers enhances objectivity, efficiency and compliance in QC, turning color from a challenge into a controlled, quantifiable asset for any soft drink operation