Colour & Appearance Analysis Methodology

Plastic Pellets

:STOT1003

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Chapter One

Introduction

Introduction

The analysis of opaque and powdered samples has been an imperative part of both quality control and research and development processes in many industries for as long as there has been the technology to do so.

The data provided by such analysis can be a key indicator of quality of the product, production errors, substandard ingredients and even highlight the need for the modification of procedures.

The use of Dual-Beam Colorimetric Spectrophotometers in such applications has enabled more reliable procedures to be enforced for quality control testing to ensure a consistently high quality product every time, regardless of industry. Effects of these processes on the products can be monitored at key stages to understand what can be improved, where any costs can be saved during production and, most importantly, provide an alert to prevent out of specification product being shipped to an end user. Reducing costs in manufacturing processes can be ideal for a lot of companies looking to increase consistency, expand or develop a new product and reinforces the justification of producing said product.

This document is designed to achieve accurate data that best represents the sample being measured with a method that is easy to follow and that does not interfere with the manufacturing processes.

The aim of this document is to provide a solution to issues that may have or will occur at some point during the lifetime of the company as a result of an issue with colour and appearance. This document will also aim to assist the manufacturer with producing an excellent quality product that is consistent in appearance and reliability, sample after sample, batch after batch. All aspects of the colour and appearance analysis method will be detailed and explained throughout this document.

For any further clarification on this method and to tailor it for your work, please contact your local Stotto office.

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Chapter Two

Application Insight

Application Insight

Why is measuring the colour of your powder sample important?

Simply put, analysing and numerically quantifying the physical appearance of your powder sample will allow for quality control checks that can monitor the overall efficiency, consistency and accuracy of your manufacturing process. With these quality control checks, any sub-standard Plastic Pellets produced can be identified immediately and the cause rectified before a great deal of money is lost in unusable product, staff hours spent reworking and wasted materials and ingredients.

There are certain appearance anomalies that can instantly indicate an issue with the product and therefore its production method.

For example, in a powder that should be a consistent colour, the presence of particles of a different colour is normally an indicator of an issue during the manufacturing process. Differing colours can be the result of impurities in the ingredients/ materials and the presence of contaminants.

Monitoring the colour of the product over time can also be an indicator of the condition of the product as it ages. This indicator is an asset to quality control when conducting shelf life analysis.

The main aim of colour and appearance analysis is to be able to monitor the effectiveness and reliability of the manufacturing process and identify any areas that may need improving. By addressing any issues, you can guarantee the manufacturing process will result in products of high quality and generic appearance, consistently.

Chapter Three

Apparatus & Part Codes

Apparatus List

This section lists all parts and accessories required for colour analysis of powder samples with the relevant part codes.

1. HunterLab ColorFlex EZ Spectrophotometer (TS-CFEZ-45)

2. 64mm Glass Sample Cup (*TS-04-7209-00*)

3. Port insert for sample cup (*TS-04-6622-00*)

4. Opaque Sample Cover (*TS-04-4000-00)*

Chapter Four

Colour Scales & Indices

Colour Scales & Indices

For the application of measuring the colour and appearance of Plastic Pellets, the data received should be able to give a beneficial insight into the appearance of the physical composition of the sample which will allow for close monitoring and any necessary alterations.

For your application, the colour scales, indices and differences listed below should be used for analysis as these will help you conform to industry standards and provide useful insights into product development opportunities.

CIE L*a*b*
This will give you the colour of the sample and how light or dark the sample is. Colour is a good indicator of changes in the production process or ingredients that can affect the quality of the finished product.

CIE LCh
This colour scale will give you the lightness, chroma (saturation) and hue (colour) of a sample.

CIE L*a*b* Difference Values
These difference or delta values will give the difference between the sample being measured and a pre-determined standard. This standard should be the ideal colour that all subsequent samples should be matching. For a consistently high quality product, the samples measured should have low delta values but the tolerances can vary depending on what is visually acceptable.

CIE LCh Difference Values
These difference or delta values follow the same principles as the CIE L*a*b* delta values and will give the difference between the sample being measured and a pre-determined standard. The standard data should represent the ideal appearance that all subsequent samples should be matching. For a consistently high quality product, the samples measured should have low delta values but the tolerances can vary depending on what is visually acceptable.

YI E313 (D65/10)
This is a Yellowness Index by ASTM where a numeric value is calculated from the spectral data of a sample that describes the change in colour from clear or white to yellow. This index is ideal for testing the effect of aging, weathering or chemical degradation in samples over time but can also indicate issues with the production and manufacturing processes.

WI E313 (D65/10)
This is a Whiteness Index by ASTM where a numeric value is calculated from the spectral data of a sample that describes the quantity of whiteness in a sample. This index is ideal for testing the effect of aging, weathering or chemical degradation in samples over time but can also indicate issues with the production and manufacturing processes, particularly if the whiteness value decreases over time when measuring a white sample.

(*Please see the Glossary chapter and Mathematical Calculations chapter for further information on these scales and indices.*)

Chapter Five

Method

Method

This method is based on the use of a HunterLab ColorFlex EZ Spectrophotometer.

Preparing instrument

1. Turn instrument on and allow to warm up for at least 30 minutes by placing in an appropriate temperature and humidity controlled environment. (*Details of the appropriate operating conditions can be found in the Instrument Specifications section of this document*.) The instrument should be allowed to acclimatise to ensure consistency and reliability of data received from measurements that isn't altered by temperature adjustments to the instrument's internal components.

2. Ensure that the sample cup port plate is situated in the instrument.

3. You will need to Standardise the instrument before use. From the main screen, use the Up/Down arrows to highlight Standardize and press the Go button.

4. Place the black glass tile at the measurement port with the white dot facing forwards and press Go button.

5. Remove the black glass tile and replace with the white standard tile with the white dot facing forwards and press Go button.

6. If the standardisation has been successful, the following message will appear. Press right arrow to return to main menu.

Customising a job file

1. From the main menu, use the arrow keys until Product Setup is highlighted and press Go button.

2. The next screen that appears prompts you to choose which setup you would like to configure. Selecting Yes will allow you to choose from 250 possible setups. Selecting No will revert the instrument to the last used/modified setup.

3. If you have selected Yes, choose the correct setup from the list available.

4. Configure all necessary aspects covered under the Product Setup page using the arrow keys.

5. The settings for your application should be as follows:

Colour Scales: CIE L*a*b*, CIE LCh
Indices: YI E313 (D65/10) and WI E313 (D65/10)
Illuminant & Observer: D65/10
Differences: dL*, da*, db* and dE*
Average: 3

Sample preparation

1. Fill the 64mm glass sample cup detailed earlier (*also see Appendix for further information*) in the document with the sample requiring testing. Due to the opaque nature of the sample, half-filling the cup is sufficient but aim to use the same amount of sample for each measurement.

2. Once the sample has been loaded into the sample cup, gently shake (without spilling and not on any surface) so the sample can settle and form a smooth, opaque surface at the base of the cup.

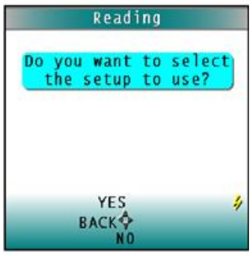
3. Wipe the sides and base of the cup carefully with a lint-free cloth or tissue to ensure there is no sample residue on the outside of the cell that could affect measurements or dirty the instrument.

4. If preparing a series of samples, make sure all samples are prepared and handled in the same way using the same sample cup size; this will allow for conformity in results.

Taking a measurement

1. From the main menu, use the Up/Down arrows to highlight Read and press Go.

2. When prompted, choose the setup you wish to use. Pressing the Up arrow for Yes will allow you to choose between 250 possible setups; pressing the Down arrow for No will revert to the last used/modified setup.



3. Make sure the sample cup port plate is inserted into the instrument.

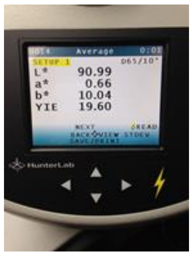
4. Carefully load the sample cup onto the instrument at the port and cover with the opaque sample cover. This prevents any external light from interfering with the measurements.

5. Press Go button to take a measurement.

6. Once the first measurement has been taken, remove the opaque sample cover, lift the sample cup and turn it a third of a full turn before replacing back onto the instrument. Replace the opaque sample cover.

7. Press read to take another measurement and repeat the above step to take the remaining measurement.

8. Select View Average (View Avg).



9. Once the measurements have been taken, the data will appear. Press the Up arrow to alternate between the different views to see the rest of your data.

10. In general, the more measurements taken of a sample the more accurate the average data will be at representing the physical characteristics of that sample. A minimum of 3 measurements of each sample should be taken for this application.

11. Repeat the above process to take measurements of any future samples.

<u>Saving your job</u>

1. Once measurements have been taken, there will be the option to press the Down arrow for Save/Print. If the ColorFlex EZ is connected to the USB Thermal Printer (*see Appendix*) then pressing the down arrow will print the results. If not, then the data will be saved to the instrument's memory. (*Please refer to Instrument Specifications Chapter for details on storage capacity.*)

This instrument can also be used with colour measurement software that will allow for any measurement data to be saved to a PC or a Network. (*Please refer to the Future Analysis chapter for more details*).

Chapter Six

Setting Standards

Setting Standards

Once you have conducted quality analysis and discovered where, if any, problems are occurring during production and addressed the issue, the next step would be to put a procedure in place to monitor all subsequent batches of the product. The method below instructs the user on how to set standard data.

Acquiring Standard Data

1. To create a set of reliable standard values, data should be collected from a batch deemed visually acceptable by the relevant personnel responsible for quality checks and setting company parameters.

2. The data collected should be in the colour scale that will be used for all subsequent sample measurements, for example the CIE L*a*b* colour scale. Using this colour scale will also allow for delta (difference) values to be calculated to determine how different a sample's L* a* b* values are from a standard and also the total difference (delta E*) between a sample and the standard. (*Please refer to the Glossary and Mathematical Calculations chapters for more details*.)

3. An average needs to be taken of a good number of measurements from the perfected batch. Generally speaking, the more measurements taken, the more accurate the average. It is advisable that data should be collected from at least 30% of a batch of product and an average calculated from these sample measurements.

4. Once the percentage of the batch has been collected ready for analysis, make a note of how many sample measurements the ColorFlex EZ will need to take.

5. Under the Product Setup menu, choose a setup that you can use specifically for standard creation.

6. Under your chosen setup, change the Average number to the number of samples you wish to measure to create this average standard data.

7. Under Views, change the colour scale to your required scale (CIE L*a*b*).

8. Return to the Main Menu and Standardise the instrument with the sample cup port plate in place.

9. Select Read and use the last configured setup (press Down arrow for No).

10. Place the first sample (in its sample cup) on the instrument and cover with opaque sample cover. Press Read.

11. When prompted for the next measurement, replace the sample you have just measured with another sample from the same batch and read. Repeat this process for the remaining measurements.

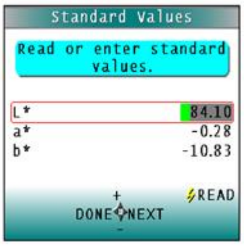
12. Once all measurements have been completed, select the Average button to receive the averaged data; this data is now to be used as your standard data.

Setting the data as Standard Values

1. Under the Product Setup menu, choose the setup that correlates with the standard data acquired.

2. Use the Up/Down arrows to highlight Standard and use the Right arrow to change this to Numeric. (*Please refer to the Glossary Chapter for details on the different types of Standards*).

3. Use the Up/Down arrows to highlight Standard Values and press Right arrow.



4. Use the arrow keys to enter the standard data values for your product. Press the Left arrow for Done when you have completed this step.

N.B

It is recommended as part of a team to select your totally acceptable sample/batch and get official sign off from your customer. It is advisable to view this sample under a light booth and use the analysis of at least 30% of this batch to make a decision.

A similar procedure should take place when selecting “bad” or “not acceptable at all” to enable tolerance creation.

It is recommended to read our document on “making, setting and deciding tolerances” for further guidance.

Chapter Seven

Setting Tolerances

Setting Tolerances

Setting Tolerances for a standard is particularly helpful when using colour and appearance analysis to monitor the physical characteristics of a product and gauge whether or not it is of sufficient quality to be shipped.
These tolerances can be used for giving a Pass or Fail notification so that all users can be assured that a sample is acceptable or not.

Calculating Tolerances

1. Setting tolerances relies on collecting the data of samples that are visually acceptable when viewed under the same light source in a light booth (*please see Appendix for more information on Light Booths*).

2. A large number of visually acceptable sample measurements should be taken over a period of time; for this application, taking approximately 10 measurements per batch for as many batches as are available and suitable will be more beneficial.

3. The L*a*b* values of all these samples should be noted.

4. The tolerances for each L*a*b* value are calculated as follows:

   L*

   Positive dL* tolerances = highest sample L* value – standard L* value
   Negative dL* tolerances = standard L* value – lowest sample L* value

   a*

   Positive da* tolerances = highest sample a* value – standard a* value
   Negative da* tolerances = standard a* value – lowest sample a* value

   b*

   Positive db* tolerances = highest sample b* value – standard b* value
   Negative db* tolerances = standard b* value – lowest sample b* value

Once these tolerances have been calculated, their accuracy should be checked by taking a further 100 measurements of both visually acceptable and unacceptable samples and checking that Pass and Fail notifications are correct for each. If adjustments to the tolerances need to be made, follow the calculations above.

Setting Tolerances on the ColorFlex EZ

1. From the Main Menu, open the Product Setup menu and choose the appropriate setup.

2. Use the Up/Down arrows to highlight Tolerances and press Right arrow to select.

3. Use the arrow keys to change the tolerances to the necessary values.

Chapter Eight

Data Interpretation

Data Interpretation

Below are images of how the results will be displayed when conducting colour and appearance analysis on a HunterLab ColorFlex EZ.

If we look at the data above, we can make the following observations.

Repeatable?

The first point to note is if the samples measured are repeatable. Having samples that give repeatable results means that each sample with give reliably accurate data so any erroneous results would be caused by the sample itself and not the way in which it is presented.

Reproducible?

The reproducibility of a sample depends on how similar the data received is after the sample has been measured, removed, replaced and measured again. Any differences in values after replacement can be a cause of possible contaminants in the sample and any inconsistencies in the colour of the sample as a whole.

(*Please request our reproducibility spreadsheet for further details.*)

Colour?

The next values to look at are the CIE L*a*b* values and see if what they depict matches what the eye sees.

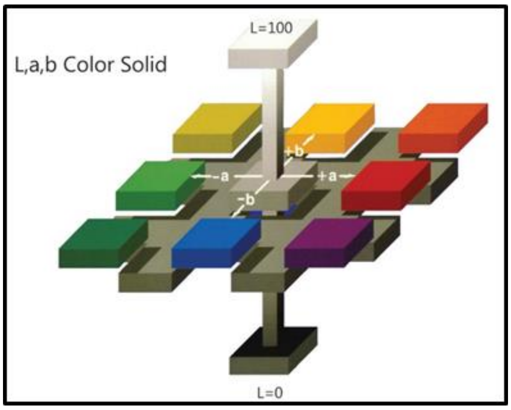
The L* value tells us how light to dark a sample is with 100 being light and 0 being dark.

The a* value tells us how red to green a sample is with a positive a* value being red and a negative a* value being green.

The b* value tells us how yellow to blue a sample is with a positive b* value being yellow and a negative b* value being blue.

There are no limits for the a* and b* axes.

Please view the L, a, b colour space below for a visual explanation.



To decipher what colour the sample is by looking at the data alone, you first begin by looking at the L* value. In this example, it is very high which tells us that the sample is very light or white in colour.

Next we look at the a* and b* values. Regardless of whether the number is positive or negative, you always look at the largest number first. For example, in the table above the larger of the a* and b* values is b* at approximately 10.04. This tells us instantly that the sample may be slightly yellow in colour.

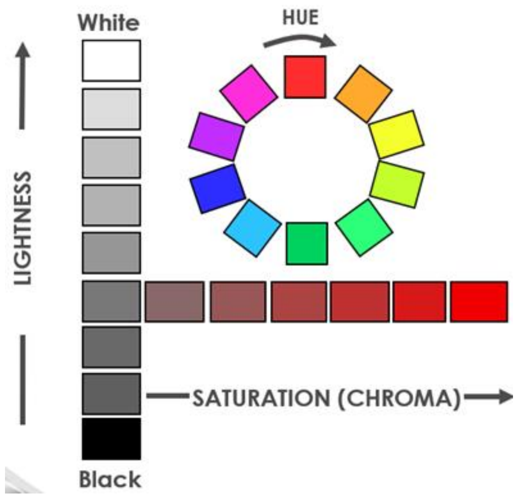
The a* value, at 0.66, is very low so this will have very little effect on the overall appearance of the sample.

Another helpful colour scale to use is the LCh scale which looks at lightness, chroma and hue. (For more details, please see the Glossary section.)

The lightness data would be the same as that in the CIE L*a*b* colour scale as they are measuring the same feature of the sample.

The hue value is an angle that depicts the general colour of a sample. If you follow the Lab colour solid diagram above: 0° is red, 90° is yellow, 180° is green and 270° is blue.

The chroma value represents how saturated with colour a sample is. Please see the diagram below.



The YI E313 value of 19.60 indicates that there is a shade of yellowness present. The higher the YI E313 value, the more yellowness is being quantified in the sample.

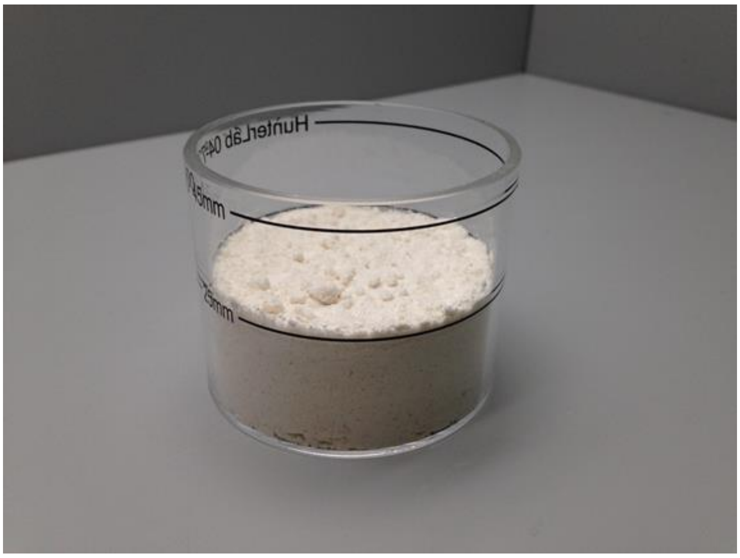
The WI E313 value of 31.27 indicates that the sample has a high level of whiteness. Again, the higher the WI E313 value, the more whiteness is being quantified in the sample.

For more information, visit **https://www.colourmeasure.com/IntroductiontoColour.pdf**

Check your sample

If we look at the image of the sample below, we can see that the sample visually matches the data we have received. It is always a good idea to compare what the spectrophotometric data tells you with how the sample appears visually.

Samples should always be visually assessed in a light booth to control the environment that they are being viewed in as various light sources can make samples appear different to the eye. (*See Appendix*.)



What your data tells you

Please refer to the table below to interpret your results.

ABSOLUTE VALUES

Observation	Conclusion
Larger positive (+) a* value	Red in hue
Larger negative (-) a* value	Green in hue
Larger positive (+) b* value	Yellow in hue
Larger negative (-) b* value	Blue in hue
High L* value	Light
Low L* value	Dark
High YI E313 value	Sample appears more yellow
Low YI E313 value	Sample appears less yellow
High WI E313 value	Sample appears more white
Low WI E313 value	Sample appears less white

DIFFERENCE VALUES

Positive dL* (Delta L*) value	Sample is lighter than standard
Negative dL* (Delta L*) value	Sample is darker than standard
Positive da* (Delta a*) value	Sample is more red than standard
Negative da* (Delta a*) value	Sample is more green than standard
Positive db* (Delta b*) value	Sample is more yellow than standard
Negative db* (Delta b*) value	Sample is more blue than standard
Positive dC* (Delta C*) value	Sample is more saturated/strong in colour than standard
Negative dC* (Delta C*) value	Sample is less saturated/stronger in colour than standard
Positive dh* (Delta h*) value	Hue angle is altered
Negative dh* (Delta h*) value	Hue angle is altered

Chapter Nine

Glossary

Glossary

Below are the commonly used terms that may arise throughout the method and during
Colour & Appearance analysis.

ADMI
ADMI stands for American Dye Manufacturer's Institute and is a colour index used to monitor the colour of wastewater as an indicator of water quality.

APHA/PtCo/Hazen
APHA stands for American Public Health Association. This colour scale acts as a yellowness index, allowing for accurate measurements of transparent liquids. The APHA colour scale ranges from 0 (clean water) to 500 (distorted waste water).

The PtCo or Platinum Cobalt Colour Scale is equal to the APHA Colour Scale as they are both used predominately to measure the colour and quality of water.

The Hazen Colour Scale is again equal to the APHA and PtCo although can sometimes be referred to as Hazen Colour or 1500 Hazen Colour. If this is the case then the range often goes above the 500 units associated with APHA.

These colour scales play an important role in a range of industries as they can quantify trace amounts of yellowness caused by exposure to light or heat, an error in processing or the presence of impurities.

ASBC Turbidity
ASBC Turbidity is based on a simple spectral method that measures absorbance at two points – one in the blue region (430nm) and one in the red region (700nm). If the absorbance in these two regions is significantly different then a sample is said to be turbid (large amount of scattered light). If there is little to no difference then a sample is said to be free of turbidity.

ASTM D1500
ASTM D1500 is the standard test method for the ASTM colour of Petroleum Products.

Chroma
Also known as saturation, the term chroma is used to describe how saturated with colour the sample is.

CIE L*a*b*
The CIE L*a*b* colour scale is also known as the CIE 1976 L*a*b* Colour Space and gives data for sample depicting how light to dark, red to green and yellow to blue a sample is.

CIE LCh
The CIE LCh colour scale gives numerical data for samples with regards to lightness, chroma and hue. The higher the Lightness value, the lighter the sample appears. The higher the Chroma value, the more saturated with colour the sample is (as opposed to grey.) The Hue value is depicted as circular angle degrees; 0° being red, 90° being yellow, 180° being green and 270° being blue.

CIE Observer Functions

The CIE $\bar{x}$, $\bar{y}$ and $\bar{z}$ functions were derived to be able to quantify the red, green and blue cone sensitivity in the eye of the average human observer.

CIE XYZ

The X, Y and Z values are tristimulus values that are calculated by using the $\bar{x}$, $\bar{y}$ and $\bar{z}$ standard observer functions that quantify the red, green and blue cone sensitivity of the eye, the illuminant and the reflectance or transmittance of a sample. (*Please see the Mathematic Calculations Chapter for further details*.)

Colorimeter
An instrument for measuring the colour and intensity of colour of a variety of sample types.

Delta L* (dL*) / (dL) / (ΔL*) / (ΔL)
This is the difference between the L* value of a standard and that of a sample. (*Please refer to the Mathematic Calculations Chapter for further details*.)

Delta a* (da*) / (da) / (Δa*) / (Δa)
This is the difference between the a* value of a standard and that of a sample. (*Please refer to the Mathematic Calculations Chapter for further details*.)

Delta b* (db*) / (db) / (Δb*) / (Δb)
This is the difference between the b* value of a standard and that of a sample. (*Please refer to the Mathematic Calculations Chapter for further details*.)

Delta E* (dE*) / (dE) / (ΔE*) / (ΔE)
This is the total difference between a standard and a sample. (*Please refer to the Mathematic Calculations Chapter for further details*.)

Delta E CMC / (dE CMC) / (ΔE CMC)
Delta E CMC is a 3-dimensional elliptical tolerance developed by the Colour Measurement Committee of the Society of Dyers and Colorists that defines the colour difference between a standard and a sample. Colour differences calculated using the CMC method are believed to correlate better with visual assessment than other colour differences. The CMC ellipse is unique in that the shape of it changes depending on where the standard is in colour space.

Delta XYZ / (dXYZ) / (ΔXYZ)
This is the difference between the CIE XYZ values of a standard and that of a sample. Each difference will be written as dX, dY and dZ. (*Please refer to the Mathematic Calculations Chapter for further details*.)

Delta Yxy / (dYxy) / (ΔYxy)
The difference values for Yxy depict the difference between the Y, x and y values for a standard and a sample.

EBC
EBC is very similar to the SRM (Standard Reference Method) for beer colour specification.
SRM measures the absorbance of beer at a wavelength of 430nm with ½ inch path length. The absorbance is then multiplied by 10 to get the SRM value (also known as degrees Lovibond.)
SRM can be converted into EBC using the following calculations: SRM = EBC / 1.97
EBC = 1.97 x SRM

European Pharmacopeia (EP)
A regional pharmacopeia that provides quality standards throughout the pharmaceutical industry to control the quality of medicines and other pharmaceutical products.

Gardner
The Gardner Colour Scale is a single number, one-dimensional colour scale to measure the shade of the colour yellow. This scale ranges from pale yellow to red in shade with numerical values ranging from 1 – 18.

Haze
In a transparent solid or liquid sample, haze is the term given to a texture or appearance that causes a scattering of light in that sample.

Hue
Hue is the term for the general colour of a sample, i.e. red, green, blue etc.

Hunter Lab
A uniform colour scale devised by Hunter in 1958 for use in a colour difference meter.

Illuminant
Illuminants are the different variations in light sources that a sample can be measured under and are normally written with a corresponding observer, for example D65/10 or C/2. They are as follows:

D65 – Average Daylight
A – Tungsten
F02 – Fluorescent
C – Daylight

Lightness
A term used to describe how light to dark a sample is.

Observer
The CIE Standard Observer was originally developed by conductingan experiment that used a 2° observational view. When it was discovered that the cones in the eye that are responsible for seeing colour were spread further that first thought, the experiment that first gave the 1931 2° Standard Observer was re-done to give the more commonly used 1964 10° Standard Observer.

Saybolt
The Saybolt Colour Scale is used in the measurement of clear to slightly yellowish samples as its colour range is similar to that of the APHA/PtCo/Hazen Colour Scales. It is primarily used in the analysis of light-coloured petroleum products.

Spectrophotometer
A Colorimetric Spectrophotometer uses a light source to illuminate a sample. The reflected light then passes through a grating which breaks the light down into its spectral components. The sample signal at each wavelength is then determined as the light falls onto a diode array. This spectral data is then sent to an internal processor which allows for multiplication with illuminant and observer values to give CIE XYZ colour values. With the use of either external or built in software, the spectrophotometer is able to give data in a wide range of colour scales and indices with varying illuminant and observers.

Standards
Four types of standards are available for selection in the ColorFlex EZ, depending on the measurements and data needed.

Working
Used when several different standards and samples are measured in a single session. A working standard is measured immediately prior to measuring its corresponding samples, such as comparing the end of one roll to the beginning of another. Its measurement values will be overwritten the next time a standard is read using this product setup.

Physical
Used when an actual product specimen is available that represents the target colour to which samples will be compared on a regular basis. A physical standard is measured and stored in the product setup for as long as desired.

Numeric
Used when a physical specimen does not exist for measurement, but the target colour values are known from previous measurements. The colour values for a numeric standard are entered and stored in the product setup for as long as desired.

Hitch
Used to alter the readings made on the ColorFlex EZ to better correlate to another colour measurement instrument. A specific standard with known colour values from the other (reference) instrument will then be read with the ColorFlex EZ and that reading manually adjusted within the product setup to match the reference instrument. The modified standard is stored in the product setup for as long as desired.

Standardisation
The process of preparing a spectrophotometer or colorimeter for colour and appearance measurement. Standardising or "calibrating" a spectrophotometer "scales" the instrument by setting the bottom and the top of the L value on the colour measurement scale.

Transmission
When light is shone through a sample, there are three types of transmitted light that a spectrophotometer can use in its calculations: Regular, Diffuse and Total.
Regular transmission is transmitted straight through a transparent solid or liquid sample. This is where transmitted colour is primarily seen.
Any surface texture in the sample can cause the light to scatter or diffuse. Diffuse transmission also contains the colour of the sample.
Total transmission is the combined transmission of the Regular transmission and Diffuse transmission.

Tristimulus
Tristimulus values give the amount of the 3 colours red, green and blue that are combined to form other colours.

Turbidity
The turbidity value for a sample depicts how distorted the clarity of a sample is as a result of bubbles present in the liquid. These are commonly written as NTU, National Turbidity Units.

Whiteness Indices
Whiteness indices, such as WI E313, are used to quantify the whiteness of a sample. For samples that should be a pure white, low whiteness index values can indicate contamination of the product.

Yellowness Indices
The Yellowness indices, such as YI E313 and YI D1925 are used to quantify traces of yellowness in clear samples. This yellowness can be the indicator of contamination to the product or evidence of the presence of impurities.

Y Transmittance
Y Transmittance is another name for the 1924 CIE Luminosity or Brightness Function which quantifies the way people perceive the relative brightness of equal energy spectral hues. The Y Transmittance value quantifies the overall transmittance of transparent colours.

Yxy
CIE xy are chromaticity coordinates that depict the colour of a sample. The Y value represents brightness or how light to dark a sample is. If looking to measure luminance, Y / 100 = Beta value which represents the luminance of a sample.

Chapter
Ten

Mathematic Calculations

Mathematical Calculations

Below are the relevant calculations used by the HunterLab ColorFlex EZ to achieve the data shown.

CIE L*a*b*

If X/X_n, Y/Y_n and Z/Z_n are all greater than 0.008856 then

$$L^* = 116 \sqrt[3]{Y/Y_n} - 16$$

$$a^* = 500 \left(\sqrt[3]{X/X_n} - \sqrt[3]{Y/Y_n} \right)$$

$$b^* = 200 \left(\sqrt[3]{Y/Y_n} - \sqrt[3]{Z/Z_n} \right)$$

If any of X/X_n, Y/Y_n and Z/Z_n is equal to or less than 0.008856 then

$$L^* = 903.3 \, (Y/Y_n)$$

$$a^* = 500 \left(f(X/X_n) - f(Y/Y_n) \right)$$

$$b^* = 200 \left(f(Y/Y_n) - f(Z/Z_n) \right)$$

Where

X, Y and Z are the CIE Tristimulus values
X_n. Y_n, and Z_n are the tristimulus values for the illuminant.
Y_n is 100.00.
X_n and Z_n are listed in the tables below.

CIE 2 Degree Standard Observer

Illuminant	X_n	Z_n
A	109.83	35.55
C	98.04	118.11
D_{65}	95.02	108.82
F2	98.09	67.53
TL 4	101.40	65.90
UL 3000	107.99	33.91
D_{50}	96.38	82.45
D_{50}	95.23	100.86
D_{75}	94.96	122.53

CIE 10 Degree Standard Observer

Illuminant	X_n	Z_n
A	111.16	35.19
C	97.30	116.14
D_{65}	94.83	107.38
F2	102.13	69.37
TL 4	103.82	66.90
UL 3000	111.12	35.21
D_{50}	96.72	81.45
D_{50}	95.21	99.60
D_{75}	94.45	120.70

$f(X/X_n) = \sqrt[3]{X/X_n}$ when $X/X_n > 0.008856$

$f(X/X_n) = 7.87 \left(\frac{X}{X_n}\right) + \frac{16}{116}$ when $X/X_n < 0.008856$

$f(Y/Y_n) = \sqrt[3]{Y/Y_n}$ when $Y/Y_n > 0.008856$

$f(Y/Y_n) = 7.87 \left(\frac{Y}{Y_n}\right) + \frac{16}{116}$ when $Y/Y_n < 0.008856$

$f(Z/Z_n) = \sqrt[3]{Z/Z_n}$ when $Z/Z_n > 0.008856$

$f(Z/Z_n) = 7.87 \left(\frac{Z}{Z_n}\right) + \frac{16}{116}$ when $Z/Z_n < 0.008856$

Hunter Lab

$$L = 100\sqrt{\frac{Y}{Y_n}}$$

$$a = K_a\left(\frac{X / X_n - Y / Y_n}{Y / Y_n}\right)$$

$$b = K_b\left(\frac{Y / Y_n - Z / Z_n}{Y / Y_n}\right)$$

Where

X, Y and Z are the CIE Tristimulus values

X_n. Y_n, and Z_n are the tristimulus values for the illuminant.

Y_n is 100.00.

X_n and Z_n are listed in the tables below.

K_a and K_b are chromaticity coefficients for the illuminant and are listed in the tables below.

CIE 2 Degree Standard Observer

Illuminant	X_n	Z_n	K_a	K_b
A	109.83	35.55	185.20	38.40
C	98.04	118.11	175.00	70.00
D_{65}	95.02	108.82	172.30	67.20
F2	98.09	67.53	175.00	52.90
TL 4	101.40	65.90	178.00	52.30
UL 3000	107.99	33.91	183.70	37.50
D_{50}	96.38	82.45	173.51	58.48
D_{50}	95.23	100.86	172.47	64.72
D_{75}	94.96	122.53	172.22	71.30

CIE 10 Degree Standard Observer

Illuminant	X_n	Z_n	K_a	K_b
A	111.16	35.19	186.30	38.20
C	97.30	116.14	174.30	69.40
D_{65}	94.83	107.38	172.10	66.70
F2	102.13	69.37	178.60	53.60
TL 4	103.82	66.90	180.10	52.70
UL 3000	111.12	35.21	186.30	38.20
D_{50}	96.72	81.45	173.82	58.13
D_{50}	95.21	99.60	172.45	64.28
D_{75}	94.45	120.70	171.76	70.76

CIE XYZ

CIE Illuminant x Reflectance of a sample = Visual Stimulus

	CIE x Observer	= CIE X Tristimulus
Visual Stimulus x	CIE y Observer	= CIE Y Tristimulus
	CIE z Observer	= CIE Z Tristimulus

Delta L* (dL*)

= L* value of sample – L* value of standard.

Delta a* (da*)

= a* value of sample – a* value of standard.

Delta b* (db*)

= b* value of sample – b* value of standard.

Delta E* (dE*)

$$= \sqrt{(dL^{*2} + da^{*2} + db^{*2})}$$

Delta XYZ

dX = X value of a standard – X value of a sample.

dY = Y value of a standard – Y value of a sample.

dZ = Z value of a standard – Z value of a sample.

Haze % (D65/10)

$$Haze = \frac{Y\ Diffuse\ Transmission}{Y\ Total\ Transmission} \times 100$$

YI E313

$YI = (100(C_xX - C_zZ)) / Y$

Where the X, Y and Z values are the CIE XYZ tristimulus values.
The values of C_x and C_z are subject to change with illuminant/observer differences.

For D65/10
$C_x = 1.3013$
$C_z = 1.1498$

For C/2
$C_x = 1.2769$
$C_z = 1.0592$

Chapter Eleven

Instrument Specifications

Instrument Specifications

Below are the specifications for the HunterLab ColorFlex EZ Spectrophotometer.

Measurement

Measurement Principle:	Port up or Port forward dual-beam spectrophotometer
Geometry:	Directional annular 45° illumination / 0° viewing
Spectrophotometer:	Sealed optics; 256-element diode array and a high-resolution concave holographic grating
Port Diameter/View Diameter:	31.8 mm (1.25 in) illuminated/ 25.4 mm (1 in) measured
Specular Component:	Excluded
Spectral Range:	400 nm - 700 nm
Spectral Resolution:	< 3 nm
Effective Bandwidth:	10 nm equivalent triangular
Reporting Interval:	10 nm
Photometric Range:	0 to 150 %
Light Source:	Pulsed Xenon
Lamp Flashes per Measurement:	1 flash
Lamp Life:	> 1 million flashes
Measurement Time:	< 1 second from button push to measurement 2 seconds from button push to data display
Minimum Interval between Measurements:	3 seconds
Standards Conformance:	CIE 15:2004, ISO 7724/1, ASTM E1164, DIN 5033, Teil 7 and JIS Z 8722 Condition C
Standards Traceability:	Instrument standard assignment in accordance with National Institute of Standards and Technology (NIST) following practices described in CIE Publication 44 and ASTM E259

Performance

Inter-Instrument Agreement:	ΔE*< 0.15 CIE L*a*b* (Avg) on BCRA II Tile Set ΔE*< 0.25 CIE L*a*b* (Max) on BCRA II Tile Set
Colorimetric Repeatability: **(20 Readings)**	ΔE*< 0.05 CIE L*a*b* on white tile

Firmware

Data Views: Colour Data, Colour Difference Data, Tristimulus Colour Plot, Spectral Data, Spectral Difference Data, Spectral Plot, Spectral Difference Plot

USB Flash Drive Features: Backup of Setups and Data, Setup Transfer to Multiple Units, Data Export to Excel

Other Features: Pass/Fail, Average Multiple Readings, Search for Closest Standard

Illuminants: A, C, D50, D55, D65, D75, F2, F7, F11

Observers: 2° and 10°

Colour Scales: CIE L*a*b*, Hunter Lab, CIE L*C*h, CIE Yxy, CIE XYZ

Colour Difference Scales: ΔL*a*b*, ΔLab, ΔL*C*H, ΔL*C*h, ΔYxy, ΔXYZ Colour Difference Indices: ΔE*, ΔE, ΔC*, ΔC and ΔEcmc

Indices and Metrics: E313 Whiteness and Tint (C/2° or D65/10°), E313 Yellowness (C/2° or D65/10°), D1925 Yellowness (C/2°), Y Brightness, Z%, 457 nm Brightness, Opacity, Colour Strength (Average and Single Wavelength), Grey Change, Grey Stain, Metamerism Index, Shade Number

Tomato Colour Model Only: Tomato Colour Scores:

- TPS - Tomato Paste Score
- TSS - Tomato Sauce Score
- TCS - Tomato Catsup Score
- TJS - Tomato Juice Score
- Tomato a/b Ratio
- Lycopene Index

Citrus Colour Model Only: Citrus Number, Citrus Redness, Citrus Yellowness

Data Storage: As Standard - 250 spectral or tristimulus with Pass/Fail tolerances as Working, Physical, Numeric and Hitch
As Sample - 2000 spectral

Languages: Chinese, English, French, German, Italian, Japanese, Spanish

Physical / Electrical

Dimensions: Height: 16 cm (6.3 in.)
Width: 13 cm (5.1 in.)
Depth: 36 cm (14.2 in.)
Weight: 4.5 kg (9.9 lbs)

Display: 7.1 cm x 5.4 cm (2.8 in. x 2.1 in.) backlit colour LCD

Interface: 3 USB 2.0 ports

Power: 100 to 240 VAC 47 to 63 Hz

Operating Environment: 10° to 40°C (50° to 104° F), 10 % to 90 % RH, noncondensing

Storage Environment: -20° to 65°C (-5° to 150° F), 10 % to 90 % RH, noncondensing

Standard Accessories: • Calibrated instrument white tile • Certificate of traceability • Black glass • Green diagnostic tile • Universal AC adaptor • Computer interface cable • USB flash drive • ColorFlex EZ User guide

Chapter Twelve

Instrument Maintenance

Instrument Maintenance

For reliable data that accurately represents the samples being measured, keeping the instrument in a fully functioning condition is vital. Below are some instructions on maintaining the HunterLab ColorFlex EZ Spectrophotometer.

Cleaning the instrument

- The ColorFlex EZ is not waterproof but the outside may be wiped with a slightly damp cloth.
- To clean the outside case, remove any dust with a lens brush or gentle air dusting.
- Wipe clean with a small amount of soapy water on a lint-free cloth or towel.
- Do not spray any cleaning fluids directly onto instrument.
- Please see Appendix section for recommended cleaning supplies.

Using the instrument

- Do not spill any liquids on instrument.
- Fill all sample cups away from instrument.
- Ensure the outside of all sample cups are wiped clean before loading onto instrument.
- Clean up any spillages immediately.
- Upon finding any issue with the instrument, contact your instrument distributor immediately.
- Do not attempt to dismantle the instrument.
- Do not drop the instrument.
- Carry out regular diagnostic testing.
- If the instrument requires relocation, use the original packaging where possible, travel flat and place instrument gently on new surface - do not drop onto surface.

Service Options

Preventative maintenance services are an integral asset to maintaining a HunterLab ColorFlex EZ Spectrophotometer to ensure it gives accurate data at all times. Below are the different levels of service offered.

Bronze Service Contract - TS-SER-02

Instrument Verification service includes:

a. On-site preventative maintenance service visit
b. Tile check and traceability exercise to NPL (National Physical Laboratory)
c. Diagnostic checks including long term drift check and historic record storing
d. Application recap with follow up document
e. Supporting documentation
f. Discount off call-out, labour and repair services

Silver Service Contract - TS-SER-20

Call-outs, collections and labour included.

a. On-site preventative maintenance service visit
b. Tile check and traceability exercise to NPL (National Physical Laboratory)
c. Diagnostic checks including long term drift check and historic record storing
d. Application recap with follow up document
e. Supporting documentation
f. Discount off parts
g. Call-outs
h. Collect and Repair service
i. Labour for repair

Gold Service Contract - TS-SER-08

Full Protection—Including parts and labour.

a. On-site preventative maintenance service visit
b. Tile check and traceability exercise to NPL (National Physical Laboratory)
c. Diagnostic checks including long term drift check and historic record storing
d. Application recap with follow up document
e. Supporting documentation
f. Includes: replacement power supplies, communication boards, lamp modules
g. Excludes: replacement spheres and optics, wavelength alignment, factory restoration, accidental damages and consumables
h. Includes labour to repair included boards
i. Includes phone support for application, troubleshooting and software
j. Includes on-site call-outs after telephone diagnostic and the use of our collect and return service
k. Includes free uninterruptable power supply

Chapter Thirteen

FAQs

FAQs

These are the most commonly asked questions when conducting colour and appearance analysis and their answers.

Q. Is the Hunter Lab colour scale the same as the CIE L*a*b* colour scale?

A. No. During calculations to create the different Lab scales, the Hunter Lab scale is based on a square-root transformation of colour data whereas the CIE L*a*b* scale is based on a cubed-root transformation. (*Please refer to the Mathematical Calculations chapter for more details*).

Q. What is NPL?

A. NPL stands for National Physical Laboratory. They are developers of some of the most accurate measurement standards for science and technology.

Q. You don't mention what we currently do… Why?

A. We try to be as industry standard as possible. Please let us know your current method and we will provide an explanation and alteration to include what you do.

Chapter Fourteen

Future Analysis

Future Analysis

Following on from the colour and appearance analysis you have completed, please read below to see how this innovative instrument and other analysis equipment can benefit you further.

Measurement of solid samples

This instrument can be used with alternative port plates of different sizes to accommodate the measurement of a variety of solid samples.

For example, protein bars and similar products can be placed on the ColorFlex EZ to analyse their colour and appearance. (*Please request information on our Solid Food Product Methodology for more details*).

EasyMatch QC software

The ColorFlex EZ can be used in conjunction with EasyMatch QC software that allows for a more visual analysis of the product and easier formatting of results. (*Please request information on EasyMatch QC software and our Powder Colour & Appearance Analysis with EasyMatch QC Software Methodology: STOT1002 for more details*).

Light booth analysis

For the visual analysis of samples being used for setting standards or tolerances, a calibrated light booth would be beneficial as samples would seem different in appearance when viewed under different light sources. Using a light booth would mean that all visual assessments can be carried out in a controlled environment where any visual differences noted would be the cause of the sample itself and not external factors.

Online Measurement

Online, no-contact colour and appearance measurement is a time-saving option to detect any issues with the product right on the production line. Having a quality check here would allow for any issues or defective products being produced to be stopped and the issue rectified immediately without any unnecessary sub-standard product continuing to be manufactured. (*Please request information on our on-line spectrophotometers and our On-Line Bulk Product Colour & Appearance Analysis Method : STOT4001 for more details*).

Chapter Fifteen

Appendix

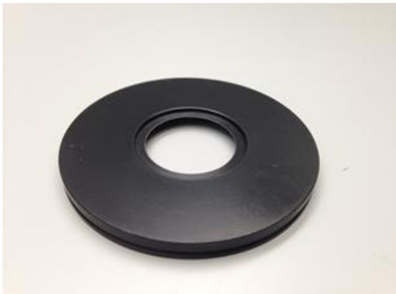
Appendix

Alternative Powder Sample Handling Apparatus and other Accessories for the analysis of colour and appearance.

Sample cell for use with powder samples for reflectance measurements.

64mm Glass Sample Cup	**34mm Glass Sample Cup**
TS004-7209-00	**TS-FMS-8000-B24**
	

Port inserts for use with above sample cells.

Open Port Insert for Sample Cup (64mm)	**Open Port Insert for Sample Cup (34mm)**
TS-04-6622-00	**TS-FMS-8000-Z12**
	

USB Thermal Printer
TS-A13-1014-259

USB Flexible Keyboard
TS-A13-1014-294

USB Barcode Scanner
TS-A13-1014-254

Light Booth

The light booth is used for visually assessing sample appearance. As samples can appear different in colour and appearance depending on the light they are viewed under, it is imperative that all samples are visually analysed under the same lighting environment.

Name	**MM-1e**	**MM-2e**
Viewing Area (H x W x D)	36cm x 61cm x 34cm	33cm x 46cm x 25cm
Light Sources	- Artificial Daylight (D65 or D50) - Store Light (CWF or TL84) - Home Light (Incandescent A)	- Artificial Daylight (D65 or D50) - Store Light (CWF or TL84) - Home Light (Incandescent A)
Optional Light Sources	Ultraviolet LED	Ultraviolet LED
Extra Features	Light sources controlled by individual rocker switches	Light sources controlled by individual rocker switches
Codes	TS-GTI-MM-1e	TS-GTI-MM-2e

Name	MM-4e	MM-2448e	MM-2460e
Viewing Area (H x W x D)	36cm x 61cm x 41cm	58cm x 122cm x 58cm	58cm x 152cm x 58cm
Light Sources	- Artificial Daylight (D65 or D50) - Store Light (CWF or TL84) - Home Light (Incandescent A)	- Artificial Daylight (D65 or D50) - Store Light (CWF or TL84) - Home Light (Incandescent A)	- Artificial Daylight (D65 or D50) - Store Light (CWF or TL84) - Home Light (Incandescent A)
Optional Light Sources	D50, TL84, TL83, Horizon, LED, Ultraviolet	D50, TL84, TL83, Horizon, LED, Ultraviolet	D50, TL84, TL83, Horizon, LED, Ultraviolet
Extra Features	- Built-in Daylight timer - Illuminated push button controls - One-touch automatic light sequencing	- Built-in Daylight timer - Illuminated push button controls - One-touch automatic light sequencing	- Built-in Daylight timer - Illuminated push button controls - One-touch automatic light sequencing
Codes	TS-GTI-MM-4e	TS-GTI-MM-2448e	TS-GTI-MM-2460e

Cleaning Supplies
Recommended cleaning products for the HunterLab ColorFlex EZ
Please contact us for part codes.

Isopropyl Alcohol	**Laboratory Grade Cleaning Wipes**	**Compressed Air Canister**
Used for cleaning calibrated standard tiles and glass on the ColorFlex EZ	Used for cleaning of the external covers of the HunterLab ColorFlex EZ and calibrated standard tiles.	Used for gently air-dusting the HunterLab ColorFlex EZ to remove any dust or powder.