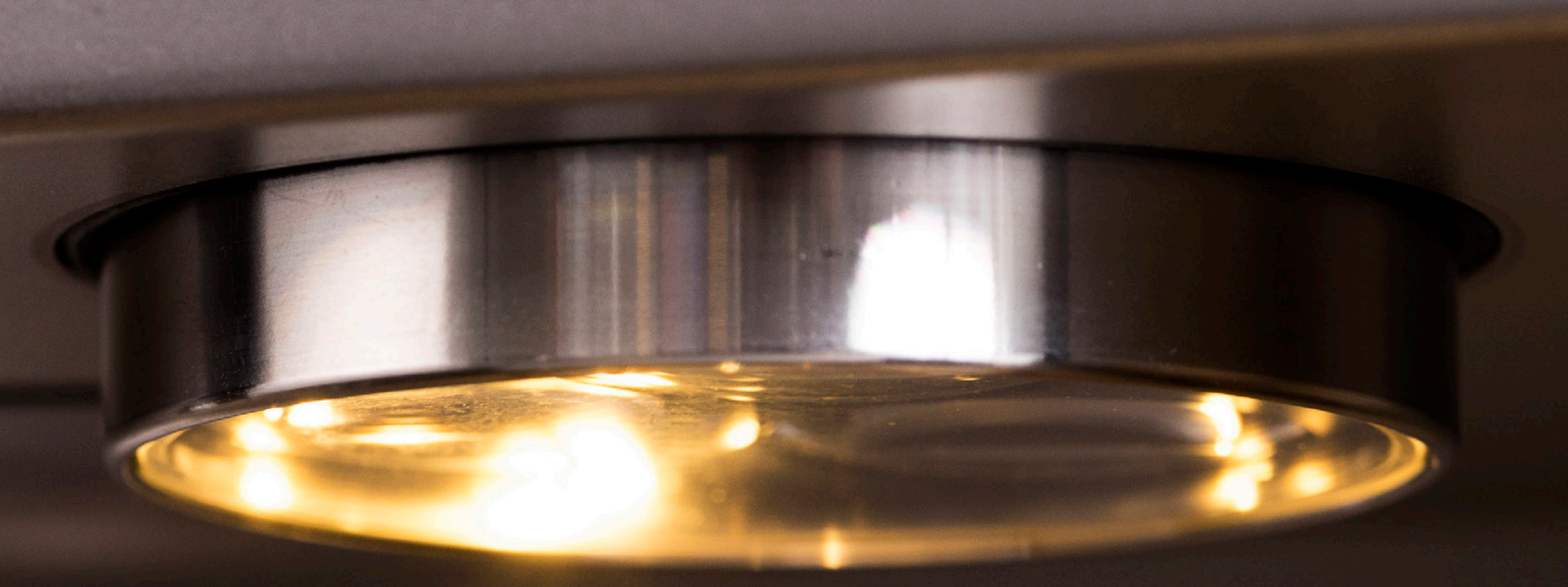
FOSS



A WHITE PAPER FROM FOSS:

# USING SPECTROMETRY FOR SIMULTANEOUS MEASUREMENT OF COLOUR AND COMPOSITION IN FOOD SAMPLES

ANALYTICS BEYOND MEASURE

By: Barbara Tobijaszewska, Richard Mills, Jakob Jøns
May 2018
fossanalytics.com

# Introduction

Colour is an increasingly important quality for food producers, but measurement typically requires a time-consuming and subjective visual method or a dedicated item of equipment. But what if the intrinsic capability of spectroscopy-based food analysers can be exploited to measure colour simultaneously with compositional parameters such as protein and moisture?

Such a concept promises the ability to perform a rapid and consistent colour measurement and a raft of compositional parameters at the same time using a platform that is robust and proven for the rigours of routine food analysis.

The concept is explored in this whitepaper in relation to the recently released FOSS FoodScan™ 2 instrument including a definition of the colour measurement parameter, how it works and a comparison of results obtained on the instrument against results from a standard colour meter. To put this ability in context of modern-day food processing, we start out with a background for colour measurement in food processing, a short definition of colour measurement parameters and how it is measured.

# Contents

# 1. Colour in food production today

From the ancient Chinese proverb that says: ‘We eat with our eyes first’ to the latest studies indicating the growing importance of colour in consumer preference, it is not hard to build a case for improved control of colour in food manufacture.

A cursory online search on ’importance of colour for consumer preference’ reveals many hits such as: Color of low-fat cheese influences flavor perception and consumer liking, 2012* which established a significant effect of color on overall liking of low-fat versions of Cheddar cheese. Study participants were negatively influenced when the cheese appearance was too translucent or too white.

Other conclusions are simply common sense derived from universal expectations built over our lifetimes. We automatically think: ‘this yellow desert is going to have a nice sweet vanilla taste or this meat has a nice fresh shade of red’. Accordingly, industry standards and guidelines aim to helping producers to meet expectations. Examples include the American Meat Science Association ‘Meat Color Measurement Guidelines’ – a thorough document of over 100 pages covering the many aspects of colour measurement that producers need to consider. Similarly, the Norwegian ‘Bransjestandard for Fisk’ with a special section on salmon colour provides a clear target range for producers.

While the importance of colour in food is only growing, so are the challenges facing producers in achieving the required colour consistency. Traditionally, producers may have leaned on preservatives such as nitrates and salt to ensure colour remains as it should do on the supermarket shelf, but legal restrictions are forcing a rethink. Likewise, the use of E number preservatives is under pressure, not just from legislation, but from consumer sentiment. Studies indicate that consumers want the colours in food and drink products to be natural. According to a report from Nielsen** on ingredient trends, 2016, 61 percent of consumers say that they try to avoid artificial colours. In Europe, the number of new products with natural colourants grew by 5.6 percent in 2015, compared to a decline of 5.2 percent for artificial colours.

Reaching for alternatives however leads to complications for producers, for instance, how will reduced or no use of nitrate-based preservatives affect the colour once the packet is open?

To conduct both product research and perform routine quality checks, there are currently two main options. Either the colour can be assessed subjectively by human eye using a colour charts (section 2) or a colour measurement analyser can be used. Both are proven, but involve significant costs. In the first instance, through the need for trained personnel and a special location with consistent lighting and in the second, through the need for a dedicated analyser. The burden on quality control operations is significant when other analytical tasks such as compositional analysis are considered.

**IR.WadhwaniD.J.McMahon: www.sciencedirect.com/science/article/pii/S0022030212002019*
***Nielsen ingredient trends, 2016: www.nielsen.com/content/dam/nielsenglobal/eu/docs/pdf/Global%20Ingredient%20and%20Out-of-Home%20Dining%20Trends%20Report.pdf*

Against this backdrop, there is scope for a greater exploitation of increasingly powerful spectroscopy solutions to provide both colour and compositional analysis simultaneously. This can be achieved by combining the optimal method for measuring colour (reflectence in the visual range) with the method required for compositonal analysis (transmittance in the infrared range) in a single unit.

Firstly, a common reference for discussion about colour measurement is required.

*The FoodScan™ analyser from FOSS measures colour in food products simultaneously with compositional parameters*

# 2. Colour: definition and measurement principle

Definitions along the lines of those to be found online and in handbooks focus on colour as a quality that is determined visually by reflected light with respect to hue, saturation and brightness.

The pantone color matching system is one familiar way to provide a common reference for visual assessment. In food production, the U.S. National Cheese Institute's Colour Standards are a similar example taking the form of a series of colour references for the visual color grading of hard cheese.  Another is the Norwegian standard for salmon mentioned in section 1 with a specified colour chart range to adhere to.

Superficially, the idea of glancing at a colour chart next to a sample sounds like a simple approach, but visual assessment has significant drawbacks. It is subjective, thereby leading to irregularities in tests from one person to another or from the same person over time. It requires a location with consistent lighting and it can be time-consuming.

Alternatively, colour measurement technologies go beyond the subjective human gaze and allow us to objectively quantify a rainbow of colours to provide a common language of colour. For instance, a measurement taken in one location can be compared with another location or a different time in an internationally accepted terminology. This eliminates colour perceptions and judgmental differences between technicians. Such instruments can be found under different names: colorimeter and  spectrophotometers.

Colorimeters mimic human eye-brain perception using filters to distill colour information. A spectrophotometer instrument uses a full spectrum colour measurement to provide a more sophisticated measurement, see below under basic principle of objective methods.

In addition, as discussed in this whitepaper, a spectrometer commonly used for near infrared applications can provide a technology platform that can be harnessed to measure colour simultaneously with compositional tests.

## Basic principle of objective methods

All of the analysers mentioned above can be said to measure the colour as a light beam's intensity as a function of its wavelength. The colorimeter uses sensors to mimic human vision using three photocells as receptors, just like the human eye. Spectrophotometers or spectrometers collect whole spectra (for each wavelength) and mathematically (algorithmically) transform them into values corresponding to human eye perception.

For any situation, it is necessary to describe visual sensation by mathematical functions.

So called "tristimulus" values are used to measure light intensity based on the three primary colour values: Red, green and blue. These are represented by X, Y and Z coordinates which facilitates the use of charts to define colours.

The system has been widely used for decades as a common standard for objective colour measurement and has been defined by the International Commission on Illumination (CIE)

XYZ colour space standard (1931). The XYZ spectral responses are readily found on internet.

The XYZ system was built on in the seventies to create a more sophisticated model that also includes the extra dimension of lightness, known as L*a*b* colour coordinates (also known as CIELAB), colour space. The model was established as a standard in 1976 in accordance to CIE. This gives us the CIELAB standard for colour measurement (figure 1).

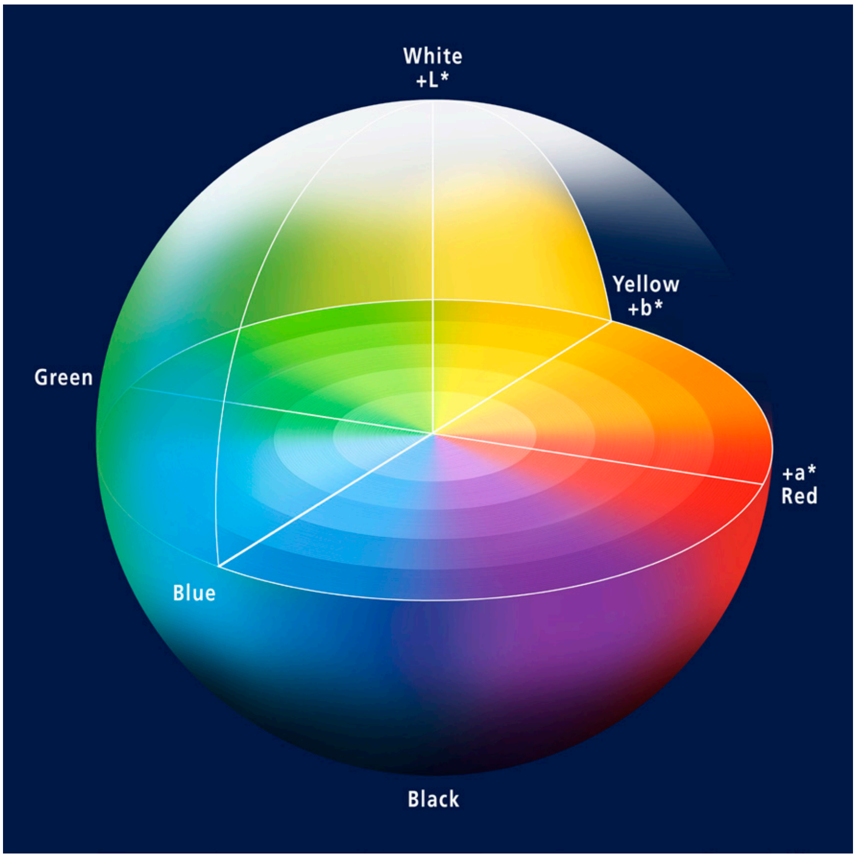



*Fig. 1 LAB and sphere diagram illustrating the comprehensive description that is provided by the CIELAB colour space definition. L* describes lightness – between 0 for black and 100 for bright. Positive a* points into red and negative into green. b* changes between yellow (positive ) and blue (negative).*

## Spectroscopy approach

To make a measurement, a sample is exposed to light and the amount of light collected for each wavelength is measured. Depending on the absorption and reflection, the spectral characteristics of the sample give a clear signature that correlates to impression of colour, Figures 2 and 3.

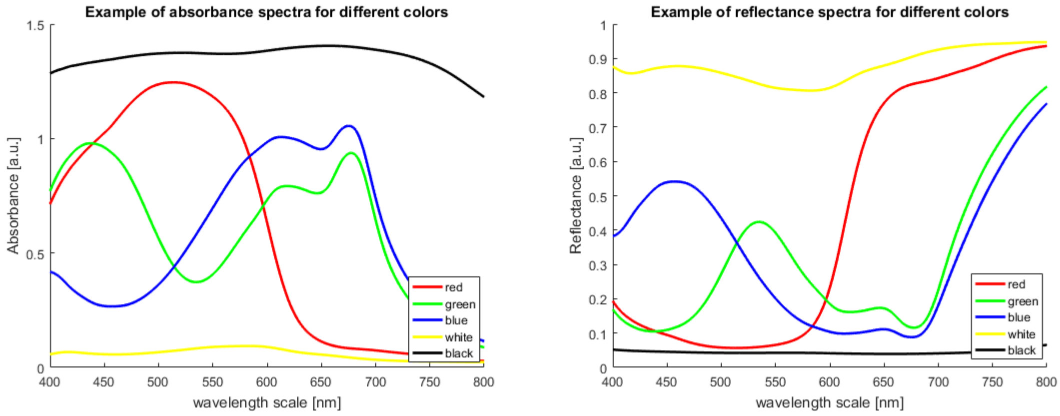



*Fig 2 Measurements of different color charts (paper samples) – In the left panel absorption spectra and in the right corresponding reflectance.*

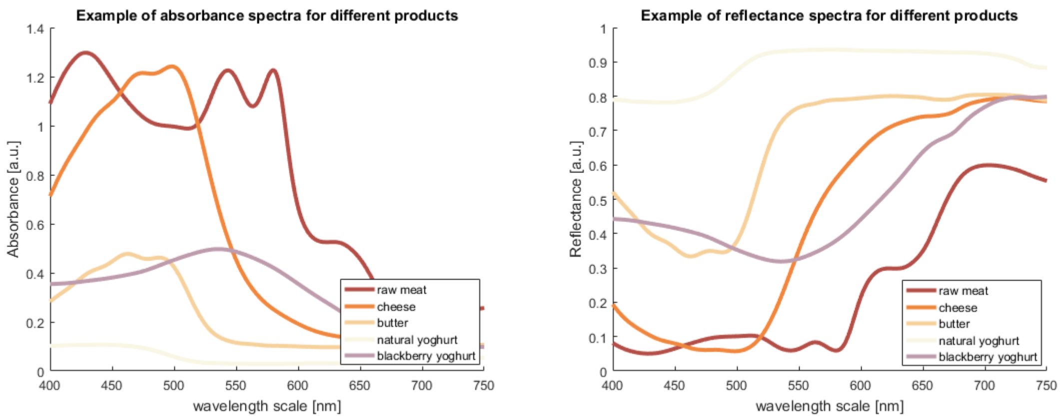



*Fig. 3 Measurements of different products– In the left panel absorption spectra and in the right corresponding reflectance. Line color corresponds to product color.*

# 3. Combined compositional and visual analysis with FoodScan 2

A spectroscopy -based analyser with the proper range encompassing both infrared and visual wavelengths can provide a rapid way to test colour simultaneously with compositional testing of food.

Quality controllers can thus gain knowledge about the increasingly important colour parameter without having to set up a visual assessment room and rely on experienced staff. Most importantly for the laboratory budget, only one instrument is required instead of two.

## Colour measured in visual range with reflectance

Colour can be measured with spectroscopy by both reflectance and transmittance methods, but reflectance in the visual wavelength (400 – 750 nm) immediately adjacent to infrared is particularly effective because the colour of food is largely defined by the characteristics of the surface, thus on reflected light, except of course for transparent and liquid samples.

Composition, on the other hand, is best determined if as much of the sample as possible can be scanned. This is particularly important for inhomogeneous samples such as ground meat where transmittance provides a representative scan of sample 'under the surface'.

## Colour measurement with the FoodScan 2

FoodScan 2 uses visible light spectrum reflected at 45° from the plain of the sample to elevate the colour.

The sample is illuminated from the top by the broadband source. The illumination source is scanned using a monochromator. In order to acquire reflection spectra, the detection of the reflected light is synchronised with scanning of the source.

To evaluate the colour of the sample, the reflection spectrum is normalised to the spectrum of a Diffuse Reference Sample (DRS).

The sample reflection spectra are converted to XYZ colour parameters by mathematically filtering the normalised spectra with predefined spectral profiles for X,Y and Z parameters (Fig 4.) and converted to CIELAB  (Fig.5)

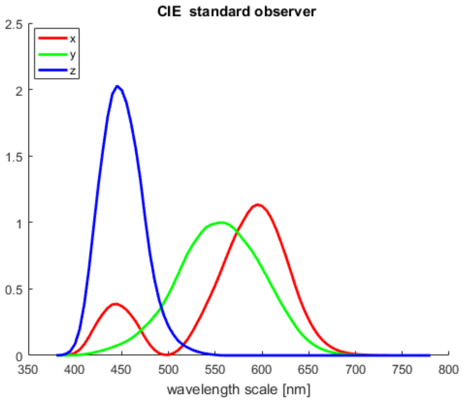



*Fig 4. CIELAB tristimulus functions.*

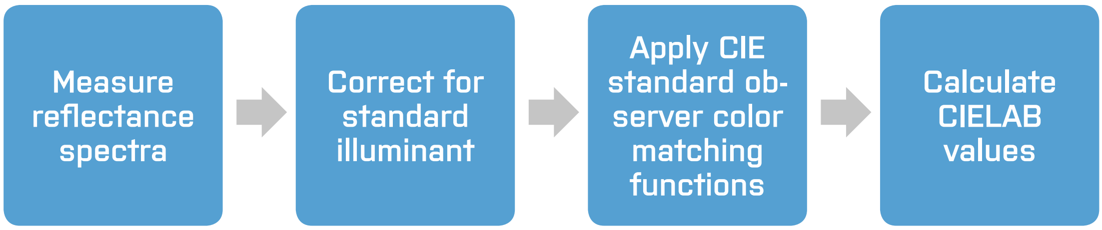



*Fig.5 As per the CIELAB standard, the steps from collection of the light reflected from the sample to the L*a*b values presented on the FoodScan 2 screen.*

The mechanics of measuring colour in a food production environment have been carefully considered and the instrument has been built according to key design principles mentioned here:

- Robustness – the instrument can withstand routine direct contact with food samples and will be easy to clean without affecting performance.
- The surface of a sample can be measured with direct exposure to air, i.e. without need for a cover. This enables study of atmosphere interaction with the sample for instance, with rapid results allowing assessment of how meat changes colour when in contact with air.
- No risk that ambient light will impact measurement performance. This is achieved by a specially designed sample chamber.
- User-friendly presentation of results for pass or fail and accompanied by L*a*b* format results.
- Calibration transferability across FoodScan 2 instruments for consistent measurements and low instrument management – a particularly important aspect for users running more than one unit, perhaps across different sites.

# 4. Comparison of FoodScan™ 2 colour measurement with a commercially available colour meter

The design goal for FoodScan 2 colour measurement is to provide a measurement that is comparable to measurements with a standard colour meter using the spectrophometer principle.

To this end, colour measurements made with a FoodScan 2 were compared to those of a standard colour meter for all major FoodScan 2 applications, these being meat and meat products, cheese, fermented products and butter & spreads. Samples were tested in replicates on the Foodscan 2 and the colour meter. The test also included analysis of artificial samples. The results from both artificial and real sample analysis are presented below. Repeatability of results indicating performance and reproducibility of results indicating transferability was also examined.

## Comparison with dedicated colour meter

There is good agreement between the colour meter and the FoodScan 2 for direct surface measurement (Figure 6).

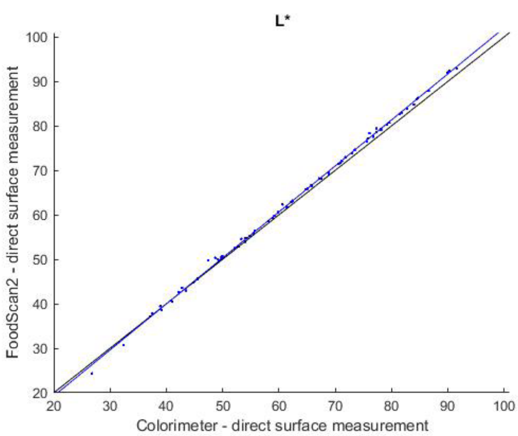



*Figure 6. Example of brightness (L*) direct surface measurement.*

Measurements can differ due to different sample presentation (Fig. 7) i.e. if we measure through for example, a petri dish with the colour meter and compare with the direct surface measurement with the Foodscan 2.
A number of factors can impact the compatibility, these being:

- Minor differences in the CIELAB algorithm, as a Colour meter is based on wavelengths from 380 nm, and the FoodScan 2 on wavelengths from 400 nm.
- Differences in sample presentation.
- Specific Colour meter settings, for instance, it is important to use the same convention standard when comparing with a colorimeter. CIELAB defines two standards: the 1931 standard for observations from a 2° degree angle and the standard from 1964 defines a 10° Standard Observer angle. The model used for the comparison test was for 10°.
- Inhomogeneity of the sample. As a FoodScan 2 will scan up to 20 times more of the surface of the sample, it may be required to scan the sample with the colour meter in multiple positions and use the average value to align with FoodScan 2.

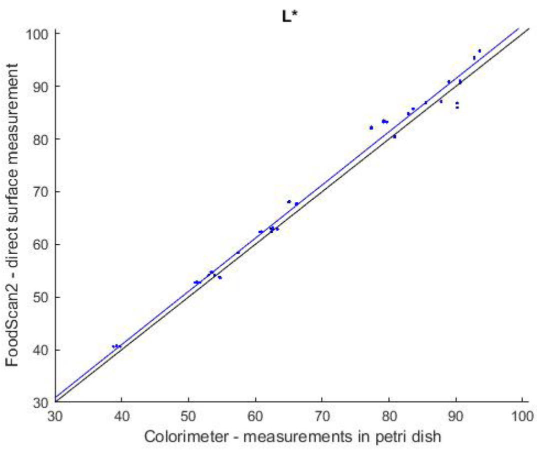



*Figure 7. Comparison of direct measurement against measurement made through a petri dish.*

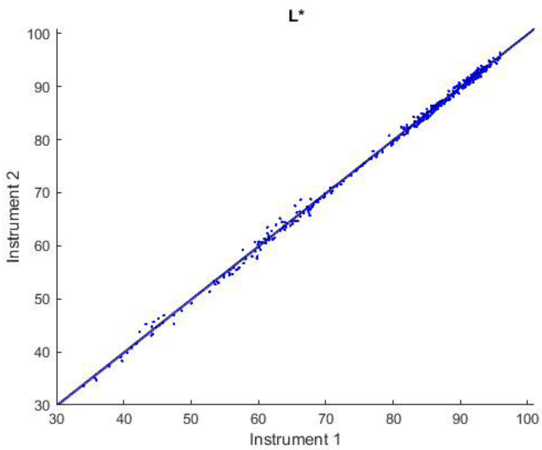



*Figure 8. Reproducibility of brightness in food products (meat, cheese, yoghurt and butter) measured by two FoodScan 2 instruments.*

## Reproducibility of measurements (transferability)

Figure 8 above shows a comparison of values obtained from two different FoodScan 2 analysers. Yoghurt, cheese, meat products and butter were measured and values predicted by two different instruments and then compared. The example shown is for brightness (L*).

## Repeatability of results

A good repeatability is the basis for any good method. As repeatability depends on the sample homogeneity and sample presentation, a study was made where the sample types described above were tested by scanning a sample in 4 replicates on a FoodScan 2.

Samples were prepared in a medium and a large cup, to establish the effect of scanning as much sample surface area as possible. For reference, the sample prepared in a medium cup was also scanned in a standard commercially available spectrophotometer colour meter.

| Product type | | FS2 medium cup | FS2 large cup |
|---|---|---|---|
| **Meat** | L* | 0.20 | 0.19 |
| | a* | 0.10 | 0.05 |
| | b* | 0.05 | 0.02 |
| **Cheese** | L* | 0.38 | 0.13 |
| | a* | 0.04 | 0.03 |
| | b* | 0.20 | 0.10 |
| **Yoghurt** | L* | 0.04 | 0.08 |
| | a* | 0.01 | 0.01 |
| | b* | 0.01 | 0.01 |
| **Butter** | L* | 0.04 | 0.01 |
| | a* | 0.02 | 0.01 |
| | b* | 0.21 | 0.14 |

*Table 1, In addition to repeatability of measurements made on the same product (for example Cheese), the repeatability of measurements across large and small sample cups was examined. This was done to take different surface properties due to inhomogeneous samples into consideration. Table 1, shows repeatability in relation to product type and sample cup with figures giving the average of four tests, the smaller the figure the less variation. There is a clear correlation between surface-scanning area and repeatability, for example, for cheese brightness (L).*

It is clear from the study that the more inhomogeneous the sample is, the more reliable result is obtained by scanning a larger surface area of the sample.

# 5. Conclusion: Advantages of integrated colour measurement

FoodScan 2 promises a timely new ability to perform a rapid and consistent colour measurement of food and a raft of compositional parameters at the same time. As such, it offers a 'two-in-one' alternative to either subjective and time-consuming assessment of colour by eye or the need for dedicated colour measurement equipment.

It provides rapid measurements in the standard CIELAB format as part of a robust food analyser designed for use in food production environments. Thus, FoodScan 2 offers a solid platform for routine testing against colour standards and for research and development of food products, for example, it could be valuable when testing repercussions of reduced nitrate-based preservatives and salt in food products.

Measurements are repeatable and reproducible. The results of the study show that FoodScan 2 is comparable the colour meter used. Further, the robust measurement chain of FoodScan 2 can be harnessed to give a stable platform for colour measurement in food production environments. Reproducibility also lives up to high standards of the Foodscan 2 platform.

There are some differences against colour meter measurements due to sample inhomogeneity or sample presentation. The differences can be said to reinforce the notion of a highly stable solution due to the fact that the FoodScan 2 scans up to 20 times more of the surface of the sample than a standard colour meter.

FOSS

FOSS
Foss Allé 1
DK-3400 Hilleroed
Denmark

Tel.: +45 7010 3370
Fax: +45 7010 3371

info@foss.dk
www.fossanalytics.com