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Comparison of a multispectral vision system and a colorimeter for the assessment of meat color

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ABSTRACT

The color assessment ability of a multispectral vision system is investigated by a comparison study with color measurements from a traditional colorimeter. The experiment involves fresh and processed meat samples. Meat is a complex material; heterogeneous with varying scattering and reflectance properties, so several factors can influence the instrumental assessment of meat color. In order to assess whether two methods are equivalent, the variation due to these factors must be taken into account. A statistical analysis was conducted and showed that on a calibration sheet the two instruments are equally capable of measuring color. Moreover the vision system provides a more color rich assessment of fresh meat samples with a glossier surface, than the colorimeter. Careful studies of the different sources of variation enable an assessment of the order of magnitude of the variability between methods accounting for other sources of variation leading to the conclusion that color assessment using a multispectral vision system is superior to traditional colorimeter assessments.

1. Introduction

Whenever consumers consider buying fresh products, such as fruits, vegetables, and meat, color is used as a quality parameter. Evaluation of the product is based on earlier experiences, and expectations are set accordingly (MacDougall & Hutchings, 2002) and therefore determines the purchase. This fact makes color evaluation an important factor in not only quality control by the producer and manufacturer, but also within research and product development. It is important that such color evaluations are performed in a consistent and objective manner to achieve reliable results (Wu & Sun, 2013). Important as well, is that the color measurements reflect the human perception of color and that they can be performed in a non-invasive manner. It is therefore worthwhile investigating the current and future methods for meat color assessment.

The traditional instrument for assessing meat color is a colorimeter. The colorimeter measurements are based on a number of site measurements and the average of these is the final color measurement. This sampling strategy does not reflect the color variation of the full sample and can be hard to reproduce (Larraín, Schaefer, & Reed, 2008; Mancini & Hunt, 2005). To meet these shortcomings we suggest to use a camera based vision system. A vision system has the advantage of not being in physical contact with the meat and therefore there will be no risk of contaminating the meat by the color measurement. Earlier studies using vision systems for color evaluation have focused on converting RGB images to CIELAB values (Blasco, Aleixos, & Moltó, 2003; Chen, Chao, & Kim, 2002; Larraín et al., 2008; Mendoza, Dejmek, & Aguilera, 2006; O'Sullivan et al., 2003; Yam & Spyridon, 2004). Wu and Sun (2013) emphasize that the RGB images, among other issues, are dependent on the sensitivity of the camera employed, and cannot be directly transformed to the standardized color space, sRGB, in a consistent manner. Therefore, two systems might measure the same sample differently. Despite this issue Yagiz, Balaban, Kristinsson, Welt, and Marshall (2009) present a study on the color of fresh salmon filets where they compare the color outcome from an RGB vision system with the colorimeter measurements. Their study revealed that despite that similar results were obtained from calibration plates for the two assessment methods, the measured color of fresh salmon deviated. The color returned by the vision system had close resemblance to the perceived color of the filets, whereas the colorimeter returned grayish colors. A similar study was carried out by Girolami, Napolitano, Faraone, and Braghieri (2013), where a panel was exposed to an image of a meat sample and next to it two squares on a monitor. One square representing the color returned by the colorimeter and the other representing the color obtained from a computer vision system (CVS). The study clearly showed that the colors returned by the CVS resemble the actual sample color better than the

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colorimeter measurement. The authors explain that one parameter influencing the difference of the two instruments, could be the penetration depth of the illumination source of the colorimeter.

The shortcomings of the RGB vision systems can to some extent be met by a multispectral imaging system. In this paper such a system called VideometerLab with precisely defined spectra was applied – 19 bands in the range 375 nm–970 nm (Videometer A/S, 2014). This gives the opportunity of performing camera based measurements in a spectrally consistent manner (Einarsson et al., 2006; Haeberli, 1992). The multispectral imaging system has previously been applied in meat research. Ljungqvist, Ersbøll, and Frosch (2012) studied the possibility of discriminating between naturally occurring and added, artificial astaxanthin in salmon filets. They compared the predictability of a human color scoring (SalmoFan), a colorimeter and the reflectance spectra from the multispectral imaging system. In that study the colorimeter gave less desirable discriminations than the two other instruments. In a related study for meat spoilage assessment Panagou, Papadopoulou, Carstensen, and Nychas (2014) also employed the VideometerLab by using the reflectance spectra.

To investigate the multispectral imaging system's ability to assess meat color, we chose to exploit the spectral information by simply mapping the multispectral pixel-wise information to CIELAB values with a photometric imaging model (PIM). The model is based on the spectral information of the LED light sources.

In this study meat from livestock and poultry, both fresh and processed types, are exposed to color measurements by the multispectral imaging system and a standard colorimeter. Considering these fresh and processed product types under the same conditions makes it possible to investigate how changes in the reflectance properties by processing of the meat influence the color assessment. The foundation of the analysis is a variance component analysis considering all possible effects influencing the color assessment. By performing a variance component analysis of the color measurements on the diverse set of meat samples, it will be possible to determine the order of magnitude of the different sources of variation. Thus it can be established whether the two different methods evaluate color in the same way when meat samples are considered despite a heterogenous and anisotropic material. The goal is to reach a method that can describe the true color variation across a wide variety of samples. Some preliminary results were presented in Trinderup, Dahl, Jensen, Carstensen, and Conradsen (2013).

2. Materials and methods

The set-up of the experiment will reflect that the goal of the study is to establish whether the two types of equipment for color assessment actually measure meat color in a similar manner. As stated in the introduction, it has been concluded that the two instruments assess color equally well when a color checker is concerned. The experiment is therefore set up such that the possible differences in assessment will be evident.

2.1. Samples

The experiment involved meat samples chosen such that they represented the natural color variation in different meat types. Samples ranging from dark red filet steak to lighter red pork loin and turkey breast are included as well as different products of processed meat. In the latter group of samples the meat samples have been processed by mincing, boiling and frying. In total, 12 different meat products were investigated: Seven fresh and five processed products. Within each product category there were five samples, giving a total of 60 samples. Table 1 gives an overview of the samples considered in the study.

The non-processed meat types have been frozen and thawed in a refrigerator at 5 °C prior to the experiment. The five samples within each type of product, originate from larger products. The larger products were cut into slices of approximately 2 cm in height. Since the scope of the study is to investigate the color assessment abilities of two instruments, the possible color change happening at thawing is not important in this study. These pieces are split in two and placed with the adjacent surfaces upwards for a blooming period. This meant 60 min for all samples, except veal and beef that bloomed for 80 min. This procedure made the samples mirrored, as shown in Fig. 1, and left two identical samples – one for measurement with the colorimeter and one for measurement with the multispectral vision system. Hence it was possible to perform the color measurements simultaneously.

Table 1
Table of samples and measurements. The numbers reflect the experimental set-up.

Meat type	Processing	Type*	Sample**	Method	Location***
Pork loin	No	1	1-5	1-2	1-4
Round of pork	No	2	1-5	1-2	1-4
Veal loin	No	3	1-5	1-2	1-4
Round of veal	No	4	1-5	1-2	1-4
Beef loin	No	5	1-5	1-2	1-4
Round of beef	No	6	1-5	1-2	1-4
Turkey breast	No	7	1-5	1-2	1-4
Sausage A	Yes	1	1-5	1-2	1-4
Sausage B	Yes	2	1-5	1-2	1-4
Cooked ham	Yes	3	1-5	1-2	1-4
Cooked turkey	Yes	4	1-5	1-2	1-4
Fried meat balls	Yes	5	1-5	1-2	1-4

* Type is a nested factor within processing.
** Sample is a nested factor within type and processing.
*** Location is a random factor nested within the processing, type, and sample.

2.2. Color evaluation equipment

In this study a Minolta CR-300 colorimeter was employed. This is a handheld instrument that filters the reflected light to obtain color values (Hunt et al., 1991). In Fig. 2 the colorimeter is seen while performing a measurement of a calibration plate. Measurements are influenced by the light spectrum, which can be expressed as the color temperature. It was chosen to use the D65 lightning for the colorimeter. The measurement head of the colorimeter covers a circular area with a diameter of 11 mm and the measurement sites on the sample are chosen by the operator. These sites are chosen depending on the sample, e.g. to avoid meat tendons and intramuscular fat.

The VideometerLab, which is employed for capturing the multispectral images is seen in Fig. 2. It has 20 spectral bands in the range 410 nm–955 nm where each image is 2056 × 2056 pixels, where wavelength specific LEDs and a light-integrating sphere ensure diffuse illumination in order to minimize specular reflectance. To gain color information from the multispectral images a PIM is employed to obtain CIELAB color measurements (Hardeberg, 2001; Lasarte, Vilaseca, Pujol, & Arjona, 2006). The VideometerLab has 12 bands in the visible spectrum, and their intensity distributions are the core of the PIM. Their distributions are seen in Fig. 3. From the International Commission on Illumination (CIE) we know the distribution of the CIE XYZ components under the D65 illumination, also denoted color matching functions (ISO, 11664 - 1, 2007; ISO, 11664 - 2, 1976; ISO, 11664 - 3, 1976; ISO/CIE Standard, 1976), seen in Fig. 3. The intensities of the spectra of the LEDs of the VideometerLab are fitted to the color matching functions by linear least squares fitting

$$\min_x \|AX - B\|_2^2, \quad (1)$$

where $A \in \mathbb{R}^{81\times 12}$ is the LED spectra, $B \in \mathbb{R}^{81\times 3}$ is the known CIE XYZ values, and $X \in \mathbb{R}^{12\times 3}$ is the weighting between these. The fit of the LED spectra to the CMFs are seen in Fig. 3. Hence we can now use this weighting to convert the multispectral images to CIE XYZ pixelwise.