# COLOR CLASSIFICATION OF VEAL CARCASSES: PAST, PRESENT AND FUTURE

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## ABSTRACT

In The Netherlands, veal carcasses are classified on color, conformation and fatness. In the past 20 years, major efforts have been put into the development of a reliable color classification system. Initially, the color of the *musculus rectus abdominis* was visually matched to a 10-point scale. Later on, the visual classification was replaced by instrumental classification. A handheld tri-stimulus colorimeter measures XYZ values which are converted into a color class on the 10-point scale. The algorithms underlying this conversion were derived from comparison of the measured L*a*b* values with the visually assigned color classes. At present, the quality and stability of the color measurements have been improved by new instruments, by using an additional calibration tile and an improved quality control procedure. Also, a new algorithm was developed to convert XYZ measurements into a color class. This algorithm is based on the conventional ΔE color difference metric and was tuned for optimal performance with respect to historical databases containing visual classifications. In the future, we expect to further benefit from technological breakthroughs in color measurement.

## 1. INTRODUCTION

In compliance with EC Directives, in Dutch slaughterhouses veal carcasses are classified on the basis of three factors: conformation, fatness and color. Of these factors, color has become an important parameter in the pricing system, involving both farmers and buyers. In the past 20 years, major efforts have been put into the development of a reliable color classification system. Such a system is necessary to guarantee uniform classification results among different slaughterhouses in the Netherlands, but also to provide a sound basis for international trading since the majority of veal meat produced in the Netherlands is exported to other countries. In this field the Netherlands has a leading position in Europe and third countries.

This paper presents the main issues involved in the development of the color classification method, discussing both the historical perspective and current state-of-the-art. We also take a look at future possibilities.

## 2. PAST: FROM VISUAL TO INSTRUMENTAL COLOR CLASSIFICATION

Initially, the color classification at the different slaughterhouses was performed visually by certified employees of the Central Office for Slaughter Livestock Services (BV CBS). At 45 minutes post mortem, the color of the *musculus rectus abdominis* (muscle tissue) was visually matched to a 10-point scale (Figure 1) ranging from light (1) to dark (10), under prescribed lighting conditions. The colors of the 10-point scale were determined from analysis of the gamut in CIELAB color space encompassed by representative variations in veal meat samples.

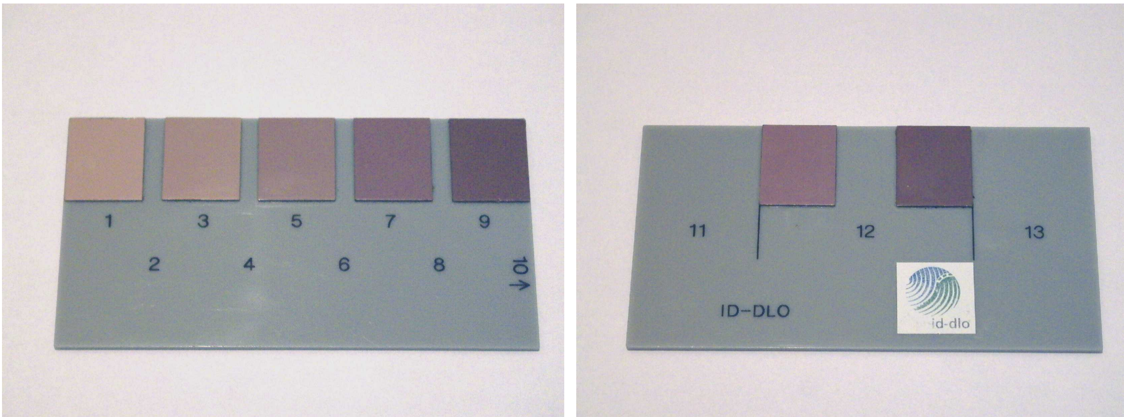


*Figure 1: Scales used for visual color classification of white (left) and pink (right) veal meat.*

As a logical next step, the subjective visual color classification was replaced by objective instrumental color classification. A handheld tri-stimulus colorimeter (Konica-Minolta CR300), operated by certified personnel, measures XYZ tristimulus values of the same muscle tissue (*musculus rectus abdominis)*, which are then converted into a color class on the 10-point scale. The algorithms underlying this conversion were derived from comparison of the measured L*a*b* values with the visually assigned color classes. Functions derived by discriminant analysis were applied to calculate the most likely color class belonging to the measured L*a*b* values, as described in Hulsegge et al. (2003).

## 3. PRESENT: IMPROVEMENTS IN HARDWARE AND SOFTWARE

Today, the instrumental classification is still in place, albeit in optimized format. To increase the quality and stability of the color measurements, the instruments have been replaced by newer versions (Konica-Minolta CR400). Before doing so, several options were considered. A switch from a tristimulus meter to a spectrophotometer would allow illuminant metamerism to be considered (Berns, 2000), but at the same time it would increase the risk of fouling the integrating sphere of the spectrophotometer. Also, a larger measurement aperture would minimize the effect of spatial variations in the meat tissue being measured. However, in order not to lose the connection with historical databases containing both measurements and visual assessments, and knowing that sufficient accuracy could be reached using a proper calibration procedure, it was decided to stick to the same color measurement technique with a tristimulus colorimeter.

After introduction of the new color instruments in the slaughterhouses, the instrument calibration procedure was improved. Up till then, the daily instrument calibration check involved verification of XYZ values measured on a white calibration tile. Whenever the difference between any of the measured X,Y or Z values with the target values exceeded a given percentage, it was required to inspect the instrument for possible contamination, clean the instrument and calibration tile and re-measure, or even replace the instrument by a spare one, if necessary. In the new procedure, an additional calibration tile having a color representative for veal meat is also measured. This so called *user calibration* not only is a direct verification of the proper functioning of the instrument in the target area of color space, it is also beneficial for maintaining the *Inter Instrument Agreement* (IIA) between different instruments (of the same type) at an acceptable level. Differences between measured and target values are now expressed in the $\Delta E_{94}$ color difference metric (CIE, 1995), the value of which lies in one of three categories indicating the instrument's operational status. The latter is labeled either code green (instrument OK), code yellow (instrument still OK but may need attention) or code red (instrument not OK: clean and re-measure). After a year of testing in practice, the stability and IIA are considered as excellent. The choice for the relatively simple $\Delta E_{94}$ metric, and not the more recent and complex $\Delta E_{00}$ (CIE, 2001) was motivated by the fact that the colors of white veal meat are restricted to a limited "reddish" area in CIELAB space (see Figure 2). Application of the $\Delta E_{00}$ is said to be most helpful in the blue area of color space and for near-achromatic colors. Also, the equations underlying the computation of $\Delta E_{00}$ do not support an easy interpretation of visually perceived differences.

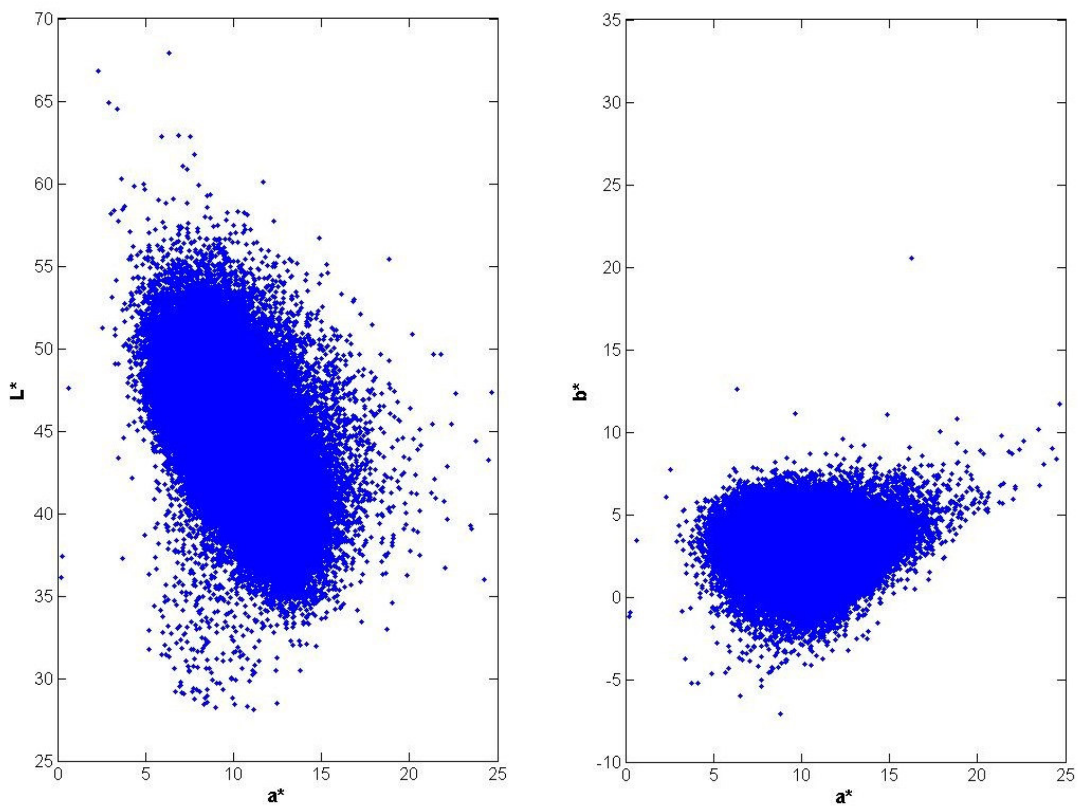


*Figure 2: Scatterplots showing the gamut of measured white veal carcass color in CIELAB color space (n=113,556).*

Finally, a new algorithm was developed to convert measured XYZ values into a color class along the 10-point scale. The "old" algorithm, using discriminant functions that disregarded the measured b*-value, did not seem to optimally cover the gamut of veal meat color anymore. The new algorithm incorporates the same metric as used for the instrument calibration check, $\Delta E_{94}$, for which we now optimized the parameters $k_L$, $k_C$ and $k_H$. Ten center points were selected in CIELAB space that represent the 10 color classes and have a structured pattern in their mutual spacing. For each color measurement we compute the color difference between the measured L*, a*, b* values with each of the 10 central points. The class associated with the central point having the smallest $\Delta E_{94}$ is then assigned as the final color class. The optimization of the parameters $k_L$, $k_C$ and $k_H$ and the selection of the 10 center points is done with respect to historical databases containing both the classifications of the previous algorithm and visual classifications. As Figure 3 shows, the distribution of assigned color classes of the new algorithm closely resembles that of the old algorithm. This is important from both a technical and a commercial point of view.

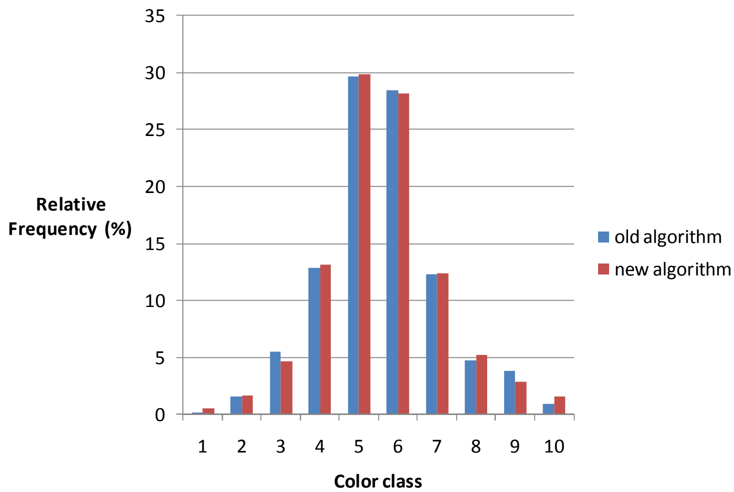


*Figure 3: Relative frequency distribution of veal carcass color classes, determined with the old and the new algorithm. The latter is based on the minimum color difference with the centers of the 10 point scale in CIELAB space, being more stable and more easy to comprehend.*

## 4. FUTURE PERSPECTIVE

In the future, we may expect to further benefit from technological breakthroughs in color measurement. Developments in LED technology offer the possibility to use LEDs as the internal light source, which are even more stable, energy efficient and have a longer life-time, and thus may require less calibration efforts.

Operational research can be conducted in the different slaughterhouses to investigate local factors that may cause differences between slaughterhouses. Differences in conditions like temperature, humidity, but also transportation and animal stress may lead to unwanted variations in the measured color, and hence in the assigned color class.

With the upcoming possibilities of image processing (Du and Sun, 2004), camera based, non-contact color measurement would seem to be the next step. However, this implies that the color of veal meat should be measured on the outside of the carcass. It is questionable whether this correlates well enough with the color of the *musculus rectus abdominis*, which has been previously suggested as the preferred indicator of veal meat color (Denoyelle and Berny, 1999). In addition, it would require substantial attention to calibrated lighting conditions in the slaughterhouses. In particular the glossiness of the moist carcasses as well of the fat coverage are difficult hurdles to pass. It is generally known that non-contact color measurement is more suitable to assess differences in color then to determine the absolute color. Perhaps the need for exact (calibrated) lighting may be relaxed by using smart portions of the wavelength area (Aporta, Hernández and Sañudo, 1996) or by smart calibrations to known color references (Connolly, Leung and Nobbs, 1996; Pointer, 2000).

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