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Measurement of meat color using a computer vision system

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ABSTRACT

The limits of the colorimeter and a technique of image analysis in evaluating the color of beef, pork, and chicken were investigated. The Minolta CR-400 colorimeter and a computer vision system (CVS) were employed to measure colorimetric characteristics. To evaluate the chromatic fidelity of the image of the sample displayed on the monitor, a similarity test was carried out using a trained panel. The panelists found the digital images of the samples visualized on the monitor very similar to the actual ones ($P<0.001$). During the first similarity test the panelists observed at the same time both the actual meat sample and the sample image on the monitor in order to evaluate the similarity between them (test A). Moreover, the panelists were asked to evaluate the similarity between two colors, both generated by the software Adobe Photoshop CS3 one using the L*, a* and b* values read by the colorimeter and the other obtained using the CVS (test B); which of the two colors was more similar to the sample visualized on the monitor was also assessed (test C). The panelists found the digital images very similar to the actual samples ($P<0.001$). As to the similarity (test B) between the CVS- and colorimeter-based colors the panelists found significant differences between them ($P<0.001$). Test C showed that the color of the sample on the monitor was more similar to the CVS generated color than to the colorimeter generated color. The differences between the values of the L*, a*, b*, hue angle and chroma obtained with the CVS and the colorimeter were statistically significant ($P<0.05$–0.001). These results showed that the colorimeter did not generate coordinates corresponding to the true color of meat. Instead, the CVS method seemed to give valid measurements that reproduced a color very similar to the real one.

1. Introduction

The first sensation most foods arise is the visual one. The consumer's willingness to consume often depends on the appearance, that is the information perceived through the eyes concerning shape, structure, color and relationship with the surrounding context. Appearance can in turn affect expectations concerning other organoleptic characteristics.

In the case of meat, color is one of the most important organoleptic characteristics. It influences the acceptability of the product and plays a major role in the purchase decision (Mancini & Hunt, 2005; Mitsumoto, O'Grady, Kerry, & Buckley, 2005; Ramirez & Cava, 2007; Risvik, 1994; Zanardi, Novelli, Ghiretti, Dorigoni, & Chizzolini, 1999). The consumer often tends to associate color with flavor, tenderness, safety, storage time, nutritional value and satisfaction level (Pedreschi, Leòn, Mery, & Moyano, 2006). Color allows the detection of certain anomalies or defects that food items may present (Abdullah, Guan, Lim, & Karim, 2004; Du & Sun, 2004; Hatcher, Symons, & Manivannan, 2004) and the consumer uses color variations as an indicator of freshness and wholesomeness. The surface color goes on changing during display and storage, influencing the consumer's acceptance of meat.

Meat color mostly depends on myoglobin in the sarcoplasm of muscular fibers. This protein is an unstable chemical compound and when the oxygen availability is high, it changes to oxymyoglobin giving meat a bright red color. On the contrary, if the oxygen tension is low, an oxidation reaction happens and metmyoglobin of brown color is formed. The above mentioned reactions are reversible in relation to the amount of oxygen on the meat surface.

As to color evaluation, one the most important problems is working out methodologies to obtain meaningful information, compare and improve products, whether foods or not. More and more versatile, fast and economically accessible color measuring equipments have noticeably increased the interest in product color both in research (Briones & Aguilera, 2005; Brosnan & Sun, 2004; Du & Sun, 2004; Lu, Tan, Shatadal, & Gerrard, 2000a, 2000b; O'Sullivan et al., 2003; Pedreschi et al., 2006; Timmermans, 1998; Zheng, Sun, & Zheng, 2006) and in production.

Color is a subjective psycho-physical characteristic as it exists only in the observer's eyes and brain. As it is not a characteristic proper to the object under observation, it was necessary to find out parameters in order to measure, classify and reproduce it. Currently, food color is measured in terms of CIE L*, a*, b* values, hue angle and chroma. The L* a* b*, or CIELab, color space is an international standard for color measurement, adopted by the Commission International d'Eclairage (CIE) in 1976 (Oleari, 2008): L* is the lightness component, which ranges from 0 to 100 (from black to white) and the parameters a* (from green if negative to red if positive) and b* (from blue if negative to yellow if positive) are two chromatic components which range

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from −120 to +120 (Papadakis, Abdul-Malek, Kamdem, & Yam, 2000; Yam & Papadakis, 2004).

Meat color is often evaluated using a 'spot' (with a surface of about 2–5 cm^2) colorimeter that is unable to measure the color of the whole surface, if non-homogeneous, in a single measurement (Kang, East, & Trujillo, 2008). Meat does not have a homogeneous surface because of its structure, its connective content and its intramuscular fat. The enlargement of the measured area would possibly include fat and connective tissue, thus yielding unreliable measures.

Another problem is the interaction of the light emitted with the surface to be analyzed. Color depends on the physical and chemical characteristics of the product. The light beam (the one the colorimeter emits) can be transmitted, refracted, reflected, diffused and absorbed by the object. An optically non-homogeneous medium such as meat (its refraction index is not uniform) has air, liquids, and granules of different materials scattered inside. This therefore causes multiple reflections and refractions where optical discontinuities are present, resulting in a diffusion of light (scattering) (Oleari, 2008). In addition, the colorimeter measures the light reflectance of a given portion of the matrix, giving a color evaluation without any information about its local variability (Antonelli et al., 2004).

Research done on meat color has hitherto been mainly based on the colorimeter with its limitations. For this reason, the technology of the digital camera is being increasingly adopted, as the whole image of the product, not only the color of one point or of a reduced area such as the area spotted by the colorimeter, can be analyzed. In particular, the computer vision system (CVS) method allows estimating the overall color of the sample and its heterogeneity. The CVS captures, processes and analyzes images and assesses the color with a non-destructive and objective method (Timmermans, 1998; Zheng et al., 2006). This system offers the possibility of analyzing the entire surface of the foods and their characteristics and defects (Brosnan & Sun, 2004; Du & Sun, 2004; O'Sullivan et al., 2003).

Different electronic devices detect colors in different ways. Consequently, the same image may have more or less different colors by varying the type of monitor and camera. In order to have a homogeneity in the Ra (color rendering index), a calibration of the equipment is necessary. It consists in a group of operations performed by software aiming at unifying the chromatic results among the different devices.

The technology of digital color management has the objective of preserving as much as possible the chromatic fidelity of an image when it is visualized as a digital image on a monitor or printed on different peripherals; e.g. when visualized on the monitor, a photo taken by a digital camera should be the same or very similar to the captured shot.

However, in high-fidelity color reproduction and color measurements some important issues are to be considered. The digital color image is represented in RGB form with three components per pixel in the range 0–255. These three intensity images are electronically combined to produce a digital color picture. It is obvious that RGB generated signals are device-dependent because each camera has its own color sensor yielding different RGB responses for the same image when it is displayed through a standard monitor. Therefore, calibration and characterization of the entire equipment are needed (e.g. Valous, Mendoza, Sun, & Allen, 2009).

Before starting the present study, we decided to verify if the L*, a*, and b* values obtained with the colorimeter on meat samples would visualize on the monitor, through the Adobe Photoshop software, a color similar to that of the true sample. Unfortunately, we had to notice that the color on the screen was different. The L*, a*, and b* values we found with our colorimeter were, for the most part, similar to those other authors had obtained with different colorimeters (Table 1). Therefore, we asked ourselves two questions: first, why have the colorimeter values visualized a color which is different from that of the analyzed surface? And second, is the colorimeter a device suitable to measure meat color, considering the particular structure of this matrix? Our research arose from these questions and aimed to (a) investigate the limits of the colorimeter for meat color evaluation, (b) define an alternative technique of image analysis based on the CVS and (c) test the validity of this system.

2. Materials and methods

The research was carried out on muscle samples of 15 animals for each of the three following species: cattle (*Longissimus dorsi*, *Semimembranosus* and *Semitendinosus*), pig (*Longissimus dorsi*) and chicken (*Pectoralis major*). The samples (15 for each muscle) were chosen to obtain a large variability in terms of composition, structure and color. The variability was obtained by examining three species and, as to cattle, three different muscles. The age of the animal was about 18 months for cattle, 7 months for pigs and 50 days for chicken. The samples were analyzed about seven days post mortem for beef, four days for pork and three days for chicken. We selected the samples in a retail setting.

Before color analysis, freshly cut meat samples, about 2.00 cm thick in beef and pork and 1.5 cm in chicken, were individually placed on white polystyrene foam trays with a consistent color and overwrapped with a transparent PVC film permeable to oxygen (13,200 $cc/m^2/24h/bar$). Then they were placed in a bench refrigerator at 4 °C for 45 min to obtain myoglobin oxygenation. The PVC film was removed before color measurement.

Table 1
CIE L*, a* and b* values reported by different authors.

L*	a*	b*	Equipment	Reference
Beef — *Longissimus dorsi* muscle				
40.70	25.20	13.40	Minolta CR-200	Zembayashi, Lunt, and Smith (1999)
35.26	21.45	11.24	Minolta	María, Villarroel, Sañudo, Olleta, and Gebresenbet (2003)
36.46	22.58	8.67	Minolta CR-310	Kim and Lee (2003)
39.57	15.76	3.07	Minolta CR-200	Kim, Yoon, Song, and Lee (2003)
33.80	20.45	8.77	Minolta CR-210	Realini, Duckett, Brito, Dalla Rizza, and De Matteos (2004))
40.87	22.58	8.57	Minolta CR-300	D'Agata, Russo, Preziuso, and Filippini (2005)
39.80	20.30	10.70	Minolta CR-300	Razminowicz, Kreuzer, and Scheeder (2006)
Pork — *Longissimus dorsi* muscle				
46.01	6.66	3.72	Minolta CR-200	Zanardi et al. (1999)
54.30	7.55	5.49	Minolta CR-300	Hamilton, Ellis, McKeith, and Eggert (2003)
52.90	12.60	2.90	Minolta CR-210	Kwak and Kang (2006)
51.64	8.72	4.84	Minolta CR-300	Aaslyng et al. (2007)
48.90	10.20	4.30	Minolta CR-300	Ramirez and Cava (2007)
54.67	6.04	5.08	Minolta CR-300	Rosenvold, Bertram, and Young (2007)
52.00	17.00	3.40	Minolta CR-310	Sullivan, Honeyman, Gibson, and Prusa (2007)
Chicken — *Pectoralis major* muscle				
59.23	4.96	5.16	Minolta CR-200	Castellini, Mugnai, and Dal Bosco (2002))
50.70	6.70	16.10	HunterLab	Liu, Fan, Chen, and Thayer (2003)
43.40	0.37	6.10	Minolta CR-300	Mitsumoto et al. (2005))
49.50	3.30	11.40	HunterLab	Chouliara, Karatapanis, Savvaidis, and Kontominas (2007))
50.93	1.65	9.34	Minolta CM-508d	Babić, Cantalejo, and Arroqui (2009))