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Sensory evaluation of the color of mutton by computer vision system

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Keywords

Sheep, Meat color, Sensory evaluation, Mutton

Abstract

Evaluation of meat color by a computer vision system (CVS) is a promising implement to dominate the difficulties when the meat is directly evaluated. In this study, 60 Longissimus dorsi from different carcasses of sheep were provided and cut into samples in 5 mm thickness. Immediately under standard shooting conditions, photographing was carried out by CVS. At the same time, the color of meat was measured with Hunterlab colorimeter. The first photo was taken on samples on a freshly cut surface just arrived at the laboratory and the others on 3rd, 5th,7th, 9th, 11th, and 13th days after slaughtering. Then, seven trained sensory panels were asked to evaluate the color of the photos that were taken during 13 days and graded them in order of preference. In general sensory panel preferred samples with high lightness, a relatively high redness, and yellowness until 7 days after slaughtering.

Abbreviations

CVS: Computer Vision System
WHC: Water Holding Capacity
ISO: International Standard Organization
LED: Light-Emitting Diode
CMOS: Complementary Metal-Oxide Semiconductor sensor
AMSA: American Meat Science Association
RGB: Red, Green and Blue
HSI: Hue, Saturation and Intensity

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Introduction

Meat is an essential component of the diet of human kind and its consumption is affected by various factors. The most important factors affecting consumption are product characteristics (sensory and nutritional properties, price, safety, convenience, etc.), and consumer and environment related characteristics such as health, psychological, climate, family or educational aspects, general economic situation, legislation [1].

Lean quality in fresh meat refers to numerous factors, but predominantly focuses on muscle pH, water holding capacity (WHC) and color. These factors are the main quality attributes that affect directly the raw product attractiveness to potential customers and influence technological properties for processed products [2, 3]. Among these factors, color of meat is the most important characteristics for the consumer. This is because the visual feeling is the first sensation of most foods, so it plays a significant role in consumer decision [4-6]. Mostly, the consumer's willingness to use a food depends on the appearance that depends to the shape, structure, color, quality and the relationship with the surrounding context observed through the eyes. Appearance by itself can affect expectations about other organoleptic characteristics as well [7, 8]. In the case of meat, color is one of the most indispensable organoleptic characteristics. It influences the acceptability of the product and plays a significant role in the purchasing decisions [4-6, 9].

There are several methods to measure the color of meat, like the visual appraisal and instrumental analysis using spectrophotometer and colorimeter [10, 11]. Computer vision system (CVS) is another method for measuring the color of meat. All of these instruments are fast, accurate and easy to apply, but they don't give a measure of consumer preference since they express data as color space coordinates.

Visual appraisal is the meat color assessment most closely related to consumer evaluation. However, it is time-consuming, complex and expensive. The long period for the sensory evaluation negatively affects the meat color stability and acceptability [12]. Difficulties related to the color evaluation of meat by consumer surveys are resolved through the evaluation of images [13-15]. Therefore, this study will provide additional information regarding the role of color as it relates to the quality of fresh meat eating.

The purpose of this study was to evaluate the possibility of using images and CVS for the sensory evaluation of mutton color, to document the effect of meat color on fresh lamb consumption acceptance and develop a descriptive analysis profile for uncooked mutton chops of different color classifications.

Table 1
Evaluation of L*, a*, b* indices in meat kept for 13 days at 4°C using the computer vision system and colorimetric methods

Method	Sample	Days	L*	a*	b*
			Mean ± SD	Mean ± SD	Mean ± SD
CVS	A	1	41.3 ± 1.86	14.46 ± 0.1	11.9 ± 0.05
	B	3	41.7 ± 0.11	13.71 ± 0.06	12.02 ± 0.1
	C	5	41.8 ± 1.89	13.66 ± 0.1	12.04 ± 0.05
	D	7	42.18 ± 1.55	13.36 ± 1.06	12.58 ± 1.13
	E	9	40.9 ± 0.62	13.68 ± 0.1	12.11 ± 0.1
	F	11	36.24 ± 0.52	13.98 ± 0.05	11.57 ± 0.03
	G	13	30.46 ± 0.88	14.23 ± 0.02	10.41 ± 0.36
Colorimeter	A	1	38.61 ± 0.16	17.33 ± 0.18	11.54 ± 0.12
	B	3	40.18 ± 0.66	12.02 ± 0.05	12.14 ± 0.05
	C	5	40.60 ± 0.39	11.45 ± 0.02	13.53 ± 0.08
	D	7	42.18 ± 0.85	11.87 ± 0.17	14.06 ± 0.38
	E	9	41.90 ± 0.25	12.05 ± 0.18	13.02 ± 0.06
	F	11	38.62 ± 0.26	13.25 ± 0.1	12.25 ± 0.15
	G	13	32.91 ± 0.79	14.85 ± 0.05	9.36 ± 0.57

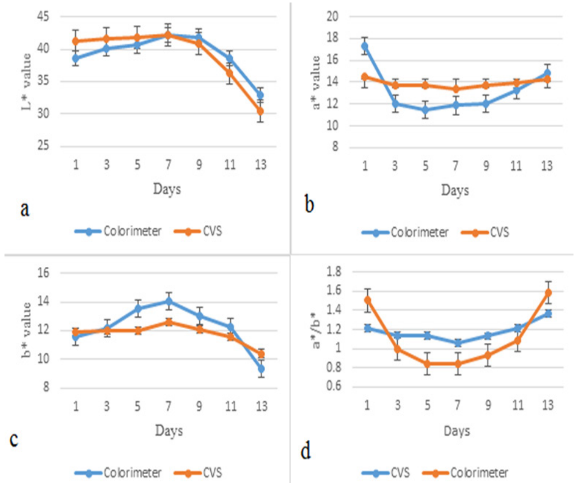

Figure 1
Changing indexes of L*, a* and b* as measured by the colorimetric method and a computer vision system during 13 days storage of meat at refrigerator. The amount of *Chi-Square* was 134.016 by the Friedman test.

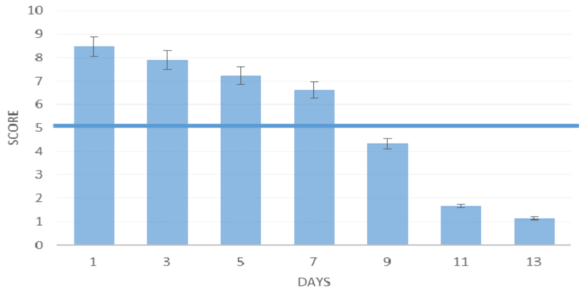

Figure 2
Average rates of assessment given to photos taken in 13 days. Line 5 shows the acceptable level of meat color.

Results

Table 1 illustrates the obtained results from high lightness (L*), a relatively high redness (a*), and yellowness (b*) indexes throughout 13 days of meat storage in the refrigerator using colorimetric and CVS methods. The changes of these indexes throughout 13 days storage at refrigerator have also been shown in Figure 1 (a, b and c). The quantities of L* and b* values in photos, measured by two devices, the colorimeter and CVS, increased until the seventh day and then decreased. On the contrary, the amount of a* value decreased until the seventh day and then increased and a slight reduction of the a*/b* ratio was observed.

An acceptable preference was noticed between the images of samples until the seventh day and day seven afterward. With regard to this finding, it should be noted that the samples remained in storage at the same time temperature, which could have caused the surfaces discoloration. On the previous days, the consumers could not distinguish the samples properly, which led to the presence of the three forms of myoglobin on the meat surface. According to the images, samples A, B, C and D were preferred to the other samples ($p < 0.05$). In addition, the sample G was labeled the least proper sample ($p < 0.05$).

Consumers were able to distinguish the samples of the 1st, 3rd, 5th and 7th days from those belonging to the 9th, 11th and 13th day. Therefore, the color assessment could be more accurate if carried out on a freshly cut surface and after 7 days of keeping the samples in the refrigerator.

The instrumental color measurements of the seven samples are reported in Table 1. It is not straightforward to compare the results of the preference test with those of the instrumental analysis and to find out the relationships between a single preference decision with the trichromatic proportions which are linked to each other in different ways. The panels did not approve of many samples such as samples F and G, due to low lightness. As can be seen in image G, the highest a*/b* ratio in sample G was indicative of the deep, dark red color of the meat. However the consumers preferred sample A, which had a bright red color, with the highest lightness and relatively high yellowness. Samples B, C and D which had the same a* and b* values as sample A, were also assessed at the lowest lightness.

According to Figure 2, the images of the meat samples which were kept in the refrigerator, were considered acceptable by the consumers until day seven (line 5 shows the acceptable level). As mentioned earlier, the lightness of the surface of meat increased until day seven and reduced afterwards, denoting the freshness of meat in the viewpoint of the observers..

Discussion

Computer vision (CV) system has been widely used for measuring color, fat, and other physical characteristics of meat. Studies have been reported developments of novel hardware for machine vision systems and software algorithms for image processing to extract useful information for rapid and non-destructive detection of physical quality attributes of meat. Chen et al., (2010) used a com-

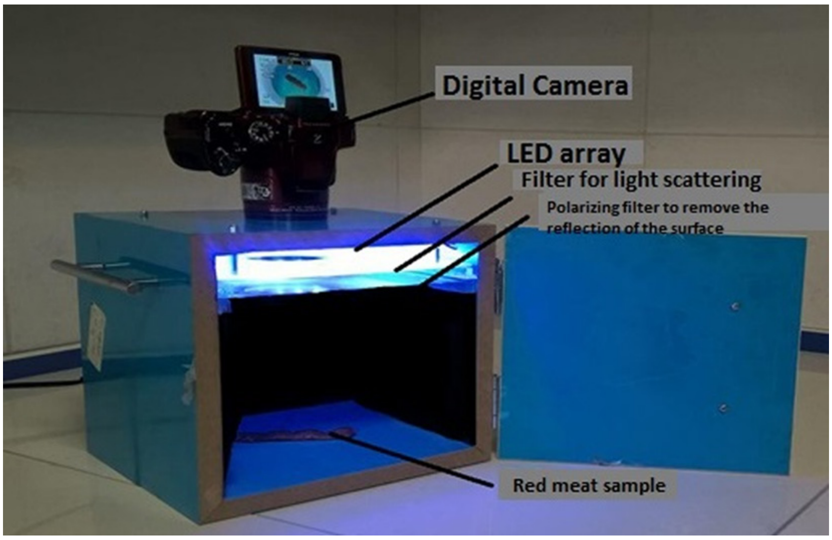

Figure 3
Computer vision system

puter vision system and a color digital camera to measure the fat color of beef for quality grading [16]. Girolami et al. (2013) utilized two instruments as Minolta CR-400 chronometer and CVS in order to investigate the color of beef, pork, and chicken meat. They compared these two methods to traditional method of meat quality determination by panellists. Therefore, by using three tests, the panelists realized the similarity of the digital images to the actual samples ($p < 0.001$). The results of this study revealed the fact that CVS illustrated more realistic colors than colorimeter [8].

Sun et al., (2014) reported extraction of color features (means and standard deviations) in terms of RGB (Red, Green and Blue) and HSI (hue, saturation, and intensity). The color in the sample images was correlated to the moisture content obtained by chemical analysis, which showed encouraging correlation coefficients of 0.56 (for models built by PLSR) and 0.45 (for models built by a neural network algorithm). The study showed a potential for machine vision and image processing for detection of chemical contents in meat. Research on the relationship of color to chemical, physical, and biological changes can enhance the accuracy of image processing for rapid and non-destructive detection of meat quality attributes. Application of a digital camera with an auxiliary lighting system was reported for prediction of troponin-T degradation in beef Longissimus dorsi using texture features from color images [17].

Table 2
Hedonic scales for consumer panels.

Color description
Extremely desirable or acceptable color
Very desirable or acceptable color
Moderately desirable or acceptable color
Slightly desirable or acceptable color
Neither acceptable or unacceptable color
Slightly undesirable or unacceptable color
Moderately undesirable or unacceptable color
Very undesirable or unacceptable color
Extremely undesirable or unacceptable color

The results of this study indicate that the lighting surface of meat increased until the seventh day and then reduced. This issue illustrates the freshness of meat through the vision of beholder. According to chemical reactions taken place in fresh meat, the color of sliced meat is reddish-purple. This color can be observed in the parts not having reached any oxygen. After contacting the meat with the air, its surface turns red. Moreover the surface of the meat increased by 2-3 millimeters. After keeping the red meat for 1-3 days at 2-40°C, one brownish layer of metmyoglobin is formed in the deepest layer of oxymyoglobin. Metmyoglobin is formed quickly and this is due to its high capability of absorbing oxygen from deoxymyoglobin and oxymyoglobin. After some days keeping, oxymyoglobin thickness reduces and correspondingly metmyoglobin thickness increases. This issue was observed to diminish the lighting of the surface of meat during preservation [18].

Leon et al. (2006) presented a precise method for extracting L*, a*, and b* indices from RGB images taken by one digital camera. These researchers in order to perform this conversion made use of five models such as direct model, gamma, linear, second order, and neutral network model. These models are capable of measuring the color in color device of L*, a*, and b* and also of measuring all intended pixels of color indices simultaneously. Of the mentioned models, the best results were allotted to second order and neural network methods having an error near to 1% [19].

A wide range of methods and applications in machine vision system have been reported in the literature for detection of different quality attributes of beef. Jackman et al., (2008), predicted the color, marbling, and surface texture of meat [20]. Larrain et al., (2008), measured the L*, a*, b*, hue angle, and chroma according to the Commision Internationale d'Eclairage (CIE) [21]. . Jackman et al., (2009), did automatic segmentation of the longissimus dorsi muscle and marbling [22]. Pena et al., (2013), classificated the fresh and stained meat samples based on marbling in the Longissimus thoracis muscle [23].

Although computer vision system and image analysis have proven useful for quantifying the quality of different meat and meat products, little research has been reported on the measurement of lamb quality attributes. Chandraratne et al., (2006), predicted the cooked lamb tenderness by geometric and texture analyses of images obtained from a color digital camera. Also, they used a machine vision system consisting of three CCD digital color cameras for grading lamb carcasses [24].

In conclusion, when the meat is directly evaluated, using the sensory evaluation of meat color by computer vision system is a confident tool to overcome the difficulties. Images can be used for a long time, with the ability to collect a large number of ratings from many consumers. However, it is very important to standardize shooting conditions such as camera setting, lighting and background to obtain true reproduction of the meat. For this purpose, a color chart is a useful tool for adjusting the color correctness of the image and checking the validated parameters.

Materials and methods

Preparation of samples

This study was carried out on 60 Longissimus dorsi of mutton samples. The age of the sheep was a year and around. Having been slaughtered, samples were provided in approximately 24 hours. Before analyzing color, samples were divided into similar slices with 5mm thickness using the cutter. Then, the samples' superficial moisture was removed by a cloth and squeezed to reduce surface reflection [25]. In order to evaluate the color of the meat through three evaluation methods, the meat piece was kept in the refrigerator for 13 days and imaged in the 1st, 3rd, 5th, 9th, 11th and 13th days after the analysis of the images, the color indices were used for further assessment. Simultaneously, the meat color indices were obtained through a colorimetric device. Furthermore, color sensory evaluation was performed, as explained in Table 2.

Computer vision system

The CVS for taking photos in this study was a Nikon (Coolpix P510, Japan) digital camera with complementary metal-oxide semiconductor sensor (CMOS) which located at the distance of 20cm vertically from the sample. Camera settings were as follows: exposure: f4: 0, sensor sensitivity to light: 400, camera flash: deactivated or switched off, shutter speed: 1.50 frame per second, sensitivity to fluorescent light: activated or turned on, camera zoom: none, focal length: 33mm and image resolution 4608*3456 pixels. The light-emitting diode (LED) arrays were settled at 20cm distance from the sample inside and over ceiling wooden box. Also, the camera was settled outside and over a wooden box covered with black opaque sheets. In order to minimize reflection, black opaque sheets were substantial. The CVS in this study is shown in Figure 3.

Color assessment

In this study, the color of the samples was evaluated using the Hunterlab instrument (45/0, CX2547, USA). The intended instrument reveals the color of food in solution and solid states through three indices as L*, a*, and b*. This device includes one circular glassy cell with limited beam in which food materials are placed into it and reveals the average color indices for its covering domain. Therefore, this method would not be suitable especially for foods, excluding homogeneous color changes.

Sensory analysis

Selection of panelists was carried out according to a method previously described by Girolami et al. (2013). This selection was conducted by applying the Ishihara tables [26] to identify possible visual abnormalities such as color-blindness in the red spectrum. After selecting the panel, the candidates with normal vision were also subjected to a triangle test conducted in accordance with international standard 4120/2004 (ISO 2004), to determine the odd one among 3 colored samples. The minimum passing score was 8 out of 10.

Sensory assessment was performed by using nine-point hedonic scale (1 for unacceptable and 9 for acceptable color of meat) according to American Meat Science Association (AMSA) instruction [18] (Table 2) and CIE17 international standard [16]. 7 referees were selected for this research, belonging to the production and meat quality control sections of Mashhad, and they were all familiar with meat characteristics. After slaughtering, the provided images from the sliced mutton with 5mm diameter were at the referees' disposal in the 1st, 3rd, 5th, 9th, 11th, and 13th days and tellingly were asked to score each image from 1 to 9.

According to the CIE17 standard [16], observations were carried out in a suitable place under the light controlled conditions (type, amount, and direction), the environmental circumstance, and geometric conditions such as the relative light source position, sample, and the eye. In this experiment, artificial light (fluorescent light) was provided in a room, which was composed of white walls and floors, in order to prevent the reciprocal interactions or color adjustments, while also inhibiting the effect of light reflecting for accurate assessment of the panelists' viewpoints.

As far as changes in the lighting, sample, eye position of the panellist, influence the obtained results, therefore; geometrical condition should be standardized.

Furthermore, the taken images from the sample were placed in one stable spot of the room and the panelists were asked to enter the room separately to evaluate the images.

For minimizing the direct reflection of the light from the surface, the angle between the panellists' eye-tracking and the surface in over which the samples were placed had to be different from the angle at which the light from the light source meets the surface. In this direction, the images were placed in such a way that they made 45 degrees with panellist's vision. Also, the lighting resource was placed over the ceiling and shined vertically over the sample.

Statistical analysis

The evaluation of this test was conducted through IBM SPSS Software (Version 20.0). The Student's t-test was used to locate differences between colorimeter and CVS measurements. P-values of 0.05 or less were considered significant. The correlation coefficient between CVS and colorimeter measures was evaluated using the Spearman rank correlation test. Friedman's test was used to evaluate the average rates of assigned to the images by the panelists during the 13-day period.

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Author Contributions

All authors contributed to the design of study, data analysis and manuscript preparation.

Conflict of Interest

The authors declare that there is no conflict of interest.

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