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RESEARCH ARTICLE

Comparison of Two Different Methods to Predict Meat Quality and Prediction Possibility Using Digital Image Analysis [1] [2]

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Summary

The objective of this study was to determine muscle colour of beef carcasses using digital image analysis. Fourteen beef carcasses were selected from a slaughterhouse. The data collected on these carcasses included colourmeter measurements and digital images and measurements of muscle colour (*L*, a*, b** values) and muscle pH from longissimus muscle at 24 hours after slaughtering. The discrepancies between colourmeter and digital image analysis values of *L*, a*, b** were large (25.6±3.37, 3.01±3.38 and 2.25±3.56, respectively). There were significant differences between *L** values (P<0.05) but there were non-significant differences between *a** and *b** values (P>0.05). The correlation coefficient was found significant (P<0.05) between pH and *a** values (r=0.83). The results showed that prediction ability of digital image analysis was low for prediction of muscle colour. However, it was concluded that red value *(a*)* can be predicted by digital image analysis and there is a need for further studies in order to develop better techniques to use for prediction.

Keywords: *Beef carcass, Digital image analysis, Meat colour, Meat quality*

Et Kalitesinin Tahmininde İki Farklı Metodun Karşılaştırılması ve Dijital Görüntü Analizi Yöntemi ile Tahmin Olasılığı

Özet

Bu çalışmada sığır karkaslarının kas renginin dijital görüntü analizleri yöntemi kullanılarak belirlenmesi amaçlanmış ve 14 adet sığır karkası kullanılmıştır. Kesimden 24 saat sonra bu karkasların Longissimus kası alanından kas rengi ölçümleri (*L*, a*, b** değerleri) hem kolorimetre ölçümleri ile hem de dijital görüntü analizi yöntemiyle alınmış ve ayrıca pH ölçümlerini içeren veriler de elde edilmiştir. Analizler sonucunda *L*, a*, b** 'nin dijital görüntü ve kolorimetre değerleri arasında büyük farklılık bulunmuştur (sırasıyla 25.6±3.37, 3.01±3.38 ve 2.25±3.56). *L** değerleri arasındaki farklılık istatistiki olarak önemli (P<0.05) fakat *a** ve *b** değerleri arasındaki farklılık istatistiki olarak önemsiz bulunmuştur (P>0.05). Ayrıca pH ve *a** değeri arasındaki korelasyon (r=0.83) önemli bulunmuştur (P<0.05). Sonuçlar, kas renginin tahmininde dijital görüntü analizi yönteminin tahmin doğruluğunun düşük olduğunu göstermiştir. Dijital görüntü analizleri yöntemi ile kırmızı renk değerinin *(a*)* tahmin edilebileceği ancak tahminde kullanılmak üzere daha iyi tekniklerin geliştirilmesi ve bundan öte çalışmaların yapılmasına ihtiyaç olduğu sonucuna varılmıştır.

Anahtar sözcükler: *Sığır karkası, Dijital görüntü analizi, Et rengi, Et kalitesi*

INTRODUCTION

Digital image analysis (DIA) was developed at 1960's to use in space research and currently started to use in food science to evaluate food quality. This technique has been argued in poultry science since 1990's [1]. McDonald and Ohen [2] initiated using this technique in beef quality and they distinguished meat from fat on the base of reflection differences in muscle *(Musculus longissimus dorsi)*.

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Prediction of meat yield has been the major focus of many studies in the developed countries. The value of beef cuts obtained from carcasses of different breeds of cattle is very essential for both consumers and marketing standards which emphasise quality, uniformity and consistency of the meat. Therefore, an evaluation procedure for predicting weights and yields of carcasses and beef retail cuts becomes of great importance for the beef industry [3].

Digital image analysis has been considered to be one of the most promising methods for objective carcass evaluation [4]. It has also been utilized for determination of colour and fat thickness [5], marbling scores in beef [6] and water retention capacity in beef [7].

A grading instrument that would sort beef carcasses based on palatability characteristics of lean and fat (i.e., marbling, lean and fat colour, lean and fat texture, lean and fat firmness, etc.), and could allow enhancements to those characteristics currently assessed in beef because of the capability to quantify *L*, a** and *b** colour parameters of fat and lean-which are known to be correlated with eating quality of beef [8-11].

The objective of this study was to determine muscle colour of beef carcasses using Digital Image Analysis (DIA) and to compare with Minolta Colourmeter (MC) measurement techniques and to evaluate DIA technique in predicting meat quality and in using to determine the possible shelf life of meat products in markets.

MATERIAL and METHODS

This work was carried out at Evren Et Meat Processing Plant in Burdur, Turkey. Fourteen beef cattle carcasses were used and samples of *Longissimus dorsi* muscle were obtained at between 12th and 13th rib cross section area after the carcasses being dissectioned.

Colour values (*L*, a** and *b**) of *longissimus dorsi* muscle were determined using minolta colourmeter (MC), *L* indicates lightness, *a* is redness and *b* is yellowness value indicator; and then the collected measurements were compared with Digital Image Analysis (DIA) measurements of the same muscles (n=14). Images were captured using a Canon digital camera MV850i. The camera was set on a standard quality (640×512 pixel resolution) and kept the distance between the sample and the lens (50 cm), and photographed against a black background. Illumination conditions, location of camera and camera settings were tried to be the same and uniform for all samples. All influences of the varied lightening conditions (shadow, sun rays and lighting) in the slaughterhouse were eliminated. Digital images were downloaded from the camera to a computer file and processed using Image Pro Plus 5 software to obtain RGB (Red, Green, Blue) colour space components of meat from the images. This software can separate out different colours from irregularly shaped surfaces and be used to calculate relative areas that each colour represents within the video image, as well as provide feedback on Commission Internationale de l'Eclairage (International Commission on Illumination; CIE) values for *L** (psychometric lightness; dark = 0, white = 100), *a** (red = + values; green = - values) and *b** (yellow = + values; blue = - values) colour parameters or colour measurements that reflect how the human eye perceives colour.

In carcasses, pH measurements were also taken from 24 h post mortem *longissimus muscle* (LM) samples with pH meter (Crison Instruments, Spain).

Statistical Analysis

The differences between MC and DIA *L*, a** and *b** values were examined by *"Students't test"* using the statistical package program Minitab v.13 for windows (Minitab12). The *L*, a** and *b** values determined by MC and DIA can also be defined as *"observed"* and *"predicted"* values respectively. The *"observed"* and *"predicted" L*, a** and *b** values were also compared using the Mean-Square Prediction Error (MSPE):

$$MSPE = \frac{1}{n}\sum_{i=1}^{n}(Oi-Pi)^2$$

Where n is the number of pairs of observed and predicted values being compared.

i = (1, 2, 3,……, n)
Oi is the observed *L*, a*, b** values with ith variable.
Pi is the predicted *L*, a*, b** values with ith variable.

The MSPE can be considered as the sum of three components described by Rook et al.[13].

$$MSPE = (\overline{O} - \overline{P})^2 + S^2{}_P(1-b)^2 + (1-r^2)S^2{}_o$$

Where, $S_O{}^2$ and $S_P{}^2$ are the variances of the observed and predicted LMs respectively. $\overline{O}$ and $\overline{P}$ are the means of the observed and predicted LMs, *b* is the slope of the regression of observed values on predicted and r is the correlation coefficient between $\overline{O}$ and $\overline{P}$.

Besides common regression analysis, MSPE has been used to determine the prediction ability of regression models and sources of error components in many studies by Smoler et al.[14], Bozkurt and Ap Dewi [15], Fuentes-Pila et al.[16], Yan et al.[17], Bozkurt and Ozkaya [18] and Bozkurt [19,20].

RESULTS

Descriptive statistics of *L*, a** and *b** values measured by MC and DIA are presented in *Table 1*.

Table 1. *Descriptive statistics of L*, a* and b* values by MC and DIA*

Tablo 1. *MC ve DIA ile elde edilen L*, a* ve b* değerlerine ait tanımlayıcı istatistikler*

Methods	Variables (n=14)	Mean±SE
DIA	*L*	51.00±1.59
	a	15.26±1.58
	b	5.88±0.79
MC	*L*	25.40±0.74
	a	12.25±0.57
	b	3.63±1.34
	pH	5.81±0.31

SE: Standard Error

DIA predicted *L** values 50% higher than the *L** values determined by MC and differences were found to be statistically significant (P<0.05). The *"predicted" L*, a** and *b** values determined by two methods are compared in *Table 2*.

Table 1. *Descriptive statistics of L*, a* and b* values by MC and DIA*

Tablo 1. *MC ve DIA ile elde edilen L*, a* ve b* değerlerine ait tanımlayıcı istatistikler*

Observed parameters		Mean	S.D.	S.E.	Variance	R^2	r
L*	**MC**	25.40	2.77	0.74	7.7		
	DIA	51.00	5.94	1.59	35.3	0.072	0.27
a*	**MC**	12.25	2.15	0.57	4.6		
	DIA	15.26	5.93	1.58	35.2	0.046	0.21
b*	**MC**	3.63	5.02	1.34	25.2		
	DIA	5.88	2.94	0.79	8.6	0.022	0.15

S.D.: Standard Deviation, S.E.: Standard Error

DIA produced twice as high prediction as MC method (51 *v* 25.4). Coefficient of determination (R^2) and correlation coefficient (r) values were determined as 7.2% and 0.27 for *L** values respectively. It was observed that DIA predicted higher *a** value (15.26) compared to MC (12.25). R^2 and r values for *a** were 4.6% and 0.21. Similarly, DIA method predicted slightly higher *b** values (5.88) compared to *b** values measured by MC (3.63). R^2 and r values for *b** were 2.2% and 0.15 *(Table 2)*. However, while there were significant differences (P<0.05) in *L** values determined by DIA and MC methods, non-significant (P>0.05) differences were observed for *a** and *b** values determined by two methods *(Table 2)*.

Table 3. *Mean bias, MSPE and proportion of MSPE (%)*

Tablo 3. *Ortalama fark, MSPE ve MSPE oranları (%)*

N=14						Proportion of MSPE (%)		
		Mean	**S.E.**	**Mean Bias**	**MSPE**	**Bias**	**Line**	**Random**
L*	**MC**	25.40	0.74					
	DIA	51.00	1.59	25.6±3.37	689.49	0.95	0.039	0.010
a*	**MC**	12.25	0.57					
	DIA	15.26	1.58	3.01±3.38 ns	43.36	0.21	0.689	0.102
b*	**MC**	3.63	1.34					
	DIA	5.88	0.79	2.25±3.56 ns	43.26	0.12	0.314	0.569

MSPE: Mean Square Prediction Error, MC: Minolta colourmeter
S.E.: Standard Error, DIA: Digital Image Analysis

Mean bias, MSPE and proportion of MSPE (%) between two prediction methods for *L*, a** and *b** values are given in *Table 3*.

Mean bias was positive for *L** values (25.6±3.37) and differences in *L** values between two methods were statistically significant (P<0.05). MSPE value of predicted *L** was 689.49 and percentage values of bias, line and random error were 95, 3.9 and 1% as a proportion of MSPE *(Table 3)*. The highest percentage was found in bias and the lowest percentage was found at random.

Mean bias was also positive for a* values (3.01±3.38) and differences between two values were not statistically significant (P>0.05). MSPE value of predicted *a** was 43.36 and in terms of contribution of components to MSPE; the values of bias, line and random error were 21, 68.9 and 10.2% respectively *(Table 3)*. The highest percentage was found at line and the lowest percentage was found at random.

Similarly, mean bias was positive for *b** values (2.25±3.56) and differences between two values were statistically not significant (P>0.05). MSPE value of predicted *b** was 43.26 and as contribution of components to MSPE; the values of bias, line and random error were 12, 31.4 and 56.9% respectively. The highest percentage was found at random and the lowest percentage was found at bias *(Table 3)*. Correlation coefficients (r) between pH and *L*, a** and *b** values are shown in *Table 4*.

Statistically significant correlation (P<0.05) was determined between *a** values and pH of meat (P<0.05)

Table 4. *Correlation coefficients (r) between pH and L*, a* and b* values*
Tablo 4. *pH ve L*, a* ve b* değerleri arasındaki korelasyon katsayıları (r)*

Meat Colours	pH	*L**	*a**
L*	-0.01		
a*	0.83	0.44 ns	
b*	-0.41 ns	-0.36 ns	-0.41 ns

ns: nonsignificant (P>0.05)

(r=0.83). Correlation between *a** and *L** was found to be statistically insignificant (P>0.05) (r=0.44). While there were negative and statistically not significant correlations between pH, *L** and *b** values, high positive correlation was found between pH and *a** value, with increasing pH values *a** values increased *(Table 4)*. The reason for that, with increasing pH, denaturation of myoglobin decreases. The RGB values determined by digital image processing are shown in *Table 5*.

Table 5. *Descriptive statistics for RGB colour space values*
Tablo 5. *RGB renk uzayına ait tanımlayıcı istatistikler*

Colour values (n=14)	Means	S.E.	CV
R	78.08	4.37	18.58
G	45.62	2.96	21.53
B	47.84	3.33	23.14

CV: Coefficient of Variation, S.E.: Standard Error

The highest R value in RGB colour space indicated more redness in muscle colour. The components of R and B values were higher than G values indicating darker coloured meat and also relatively increasing B values showed the change of colour towards purple and the higher values of R and G colour components showed the change of colour from redness to yellowness which may possibly be associated with fat content in meat. However, this should be verified by chemical analysis of fat content.

DISCUSSION

Objective measures of beef quality have been a long-time desire of the industry and there have been many research efforts in developing instruments. One popular, and obvious, approach has been to measure the mechanical properties as indicators of tenderness and meat colour. In previous studies colour had been efficiently described in the RGB colour space which is common for digital cameras and computer monitors. Each pixel has a certain amount of red, green and blue. The simplicity of the RGB space makes it highly suitable for arithmetic manipulations. Alternative colour spaces such as HSI (Hue, Saturation and Intensity) may better represent the workings of the human eye but are not as convenient as the RGB histograms.

The lower R^2 values found between MC and DIA *L*, a*,* and *b** in this study may be associated with the fact that a narrower range of colours were evaluated. Schutte et al.[21] indicated that high correlation was observed between colour values of DIA and that of well trained panalists (r=0.90). Dosiewicz et al.[22] showed that there is very strong relationship between marbling score and RGB values and they concluded that DIA can be used in chemical composition, texture and quality of meat. Illumination condition in obtaining images may have also affected the conversion from RGB color space to *L*, a*, b** colour space, likely improving the precision of the colour predictions in this study.

The results in this study showed that prediction ability of digital image analysis was low for prediction of muscle colour. However, it was concluded that colour image processing is a useful technique for meat quality evaluation. Quality attributes such as muscle colour, marbling, maturity and muscle texture can be effectively quantified and characterized and that red value *(a*)* can be predicted by digital image analysis. This technique can open up new dimensions in determining the shelf life of meat products for easy and fast detection in markets. Furthermore, there is a need for futher studies in order to develop better techniques, especially in segmentation of images to use for prediction.

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