JAES
Journal of Anatolian Environmental and Animal Sciences
(*Anadolu Çevre ve Hayvancılık Bilimleri Dergisi*)
DOI: https://doi.org/10.35229/jaes.1730463
Year: 10, No: 4, 2025 (464-470)
AÇEH
Yıl: 10, Sayı: 4, 2025 (464-470)
ARAŞTIRMA MAKALESİ RESEARCH PAPER

Correlation Between Visual Assessment and CR 10-14 Color Measurement Devices in Turkish Salmon Fillets

Ayşe KARA[1] **Emre ÇAĞLAK**[1] **Barış KARSLI**[1] **Özen Yusuf ÖĞRETMEN**[1]* **Neslihan ÖĞRETMEN**[1]

[1]*Recep Tayyip Erdoğan University, Faculty of Fisheries, Department of Seafood Processing Technology, Rize, Türkiye*

Received: *30.06.2025* ***Accepted:*** *16.07.2025* ***Published:*** *31.07.2025*

How to cite: **Kara, A., Çağlak, E., Karsli, B., Öğretmen, Ö.Y., Öğretmen, N. (2025).** Correlation Between Visual Assessment and CR 10-14 Color Measurement Devices in Turkish Salmon Fillets. *J. Anatol. Env. Anim. Sci.*, ***10***(4), 464-470. https://doi.org/10.35229/jaes.1730463

Atıf yapmak için: **Kara, A., Çağlak, E., Karsli, B., Öğretmen, Ö.Y., Öğretmen, N. (2025).** Türk Somon Filetolarında Görsel Değerlendirme ile CR 10-14 Renk Ölçüm Cihazları Arasındaki Korelasyon. *Anadolu Çev. Hay. Bil. Derg.*, ***10***(4), 464-470. https://doi.org/10.35229/jaes.1730463

*: https://orcid.org/0000-0002-1767-2693
: https://orcid.org/0000-0002-8448-2144
: https://orcid.org/0000-0002-7376-1359
: https://orcid.org/0000-0002-3944-6988
: https://orcid.org/0000-0002-1767-2693
: https://orcid.org/0009-0003-3709-2447

***Corresponding author's:**
Özen Yusuf ÖĞRETMEN
Recep Tayyip Erdoğan University, Faculty of Fisheries, Department of Seafood Processing Technology, 53100 Rize, Türkiye
: ozenyusuf.ogretmen@erdogan.edu.tr

Abstract: To reduce human errors in color assessments that may cause commercial issues, businesses use color scales and measurement devices. In this study, color measurements performed with the SalmoFan™ color scale and Konica Minolta CR-10 and CR-14 chromameters are comparatively evaluated. The results showed that, except for color scale number 22, there were strong positive or negative correlations between Ea, Eb, and EC values and the color scale readings. Additionally, the study revealed that the non-homogeneous color structure of salmon fillets presents a significant obstacle in accurately relating to the data obtained.

Keywords: Color, visual, Turkish salmon, quality.

Türk Somon Filetolarında Görsel Değerlendirme ile CR 10-14 Renk Ölçüm Cihazları Arasındaki Korelasyon

***Sorumlu yazar:**
Özen Yusuf ÖĞRETMEN
R.T.E. Üniversitesi, Su Ürünleri Fakültesi, Su Ürünleri İşleme Teknolojisi Bölümü, 53100 Rize, Türkiye
: ozenyusuf.ogretmen@erdogan.edu.tr

Öz: İşletmeler, ticari sorunlara yol açabilecek renk değerlendirmelerindeki insan kaynaklı hataları azaltmak amacıyla renk skalaları ve ölçüm cihazları kullanmaktadır. Bu çalışmada, SalmoFan™ renk skalası ile Konica Minolta CR-10 ve CR-14 Kromametre cihazları kullanılarak yapılan renk ölçümleri karşılaştırmalı olarak değerlendirilmiştir. Araştırma sonucunda, 22 numaralı renk skalası hariç tüm renk skalalarında Ea, Eb ve EC değerleri ile renk skalası değerleri arasında güçlü pozitif veya negatif korelasyonlar tespit edilmiştir. Ayrıca çalışmada, somon filetosunun homojen olmayan renk yapısının elde edilen verilerin doğru şekilde ilişkilendirilmesinde önemli bir engel oluşturduğu belirlenmiştir.

Anahtar Kelimeler. Renk, görsel, Türk somonu, kalite.

INTRODUCTION

Sensory analysis is one of the most common methods used as the primary indicator in determining the quality of foods. In the sensory evaluation of a food, four main tests are applied: sight, smell, touch, and taste. Vision is the leading factor in the initial perception of the product during this evaluation. In visual analysis, decisions can be made regarding the quality and characteristics of products in terms of their color. In sensory evaluations of foods, some studies utilize human visual perception to determine the color parameter. However, since various factors of the human factor (such as age, gender, experience, eye health, etc.) may vary, a clear result cannot be obtained in this evaluation. For example, the human eye perceives the color based on the wavelength of light reflected from objects, approximately 400-450 nm for blue, 500-550 nm for green, and 650-750 nm for red (Üren, 1999; Keskin et al., 2017).

In the food industry and in seafood products, the color parameter is important in various areas. In these areas, to eliminate human error, several color measurement systems (Munsell, Hunter, CIE, etc.) have been developed instead of visual color scales. Color measurement systems are devices/systems that present the color of an object in numerical data, as determined by the device (CR 10, CR 14, CR 200, CR 300, Tindometer, Colorimeter, etc.), based on transmission or reflection properties. The CIE color system, introduced in 1931 and continuously developed, is the first three-dimensional color measurement system. The CIE system is widely used today in various industries to calculate/obtain different values (Yxy, Lab*, etc.) in the color field (Üren, 1999). In seafood, appearance is an important parameter in terms of both acceptability and consumer preference. The first factor influencing whether a product is accepted or rejected by consumers is its color and other visual characteristics. In fish, especially in fillet form, color is affected by the muscle structure characteristics and pigment concentrations (Cai et al., 2014; Şengör et al., 2019). In Turkish salmon fillets, carotenoid (astaxanthin and canthaxanthin) pigments in the diet highlight the importance of color in meat quality (Choubert and Baccaunaud, 2006). In salmon, the color parameter is one of the most important factors for freshness criteria and high market values. Various studies have been conducted on the effect of color on the meat quality of salmon and other fish (Skrede et al., 1990; Choubert, 1997; Choubert and Baccaunaud, 2006; Yagiz et al., 2009; Wu et al., 2012; Oliveria and Balaban, 2006; Şengör et al., 2019). In addition to these studies, research into the development of standards through human and computer-based new technologies is also increasing. The Turkish salmon processing industry has gained a significant place in global exports. The standard of fillet-like products to be marketed plays a key role in maintaining this position and ensuring consistent quality. In export products, color scales are especially used to determine the standard. In this context, it is important to establish a correlation between the color scales and color measurement devices used intensively in the industry to avoid human error. For this purpose, the present study aims to analyze the findings obtained from color scale and CIE color system data and identify specific parameter values based on the statistical relationship between them.

MATERIALS AND METHODS

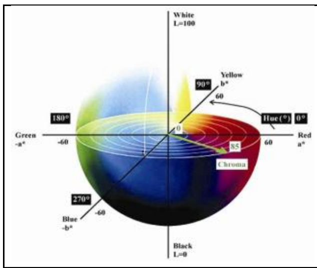
Fish Sample and Preparation: A total of 30 fish with an average length of 51,70±1,96 cm and an average weight of 2,40±0,30 kg were used in the study. After the harvesting process, the fish were processed within 2 hours under cold storage conditions (+4°C) in a hygienic laboratory environment. All the fish were subjected to a simple washing process under running cold water, and after a 5-minute draining procedure, filleting was performed. The filleting process was carried out as E-Trim, as shown in Figure 1.

E – Trim

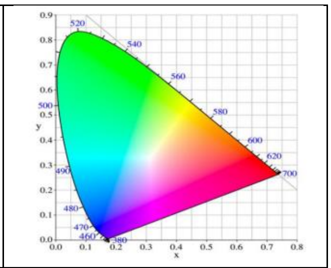
- No dorsal and abdominal bones
- No fins and fin tissues
- No pectoral and dorsal bones
- No embedded bones in the skin
- Skinless
- Completely cut and trimmed

Figure 1. Turkish salmon (Oncorhynchus Mykiss) fillet (E-Trim).

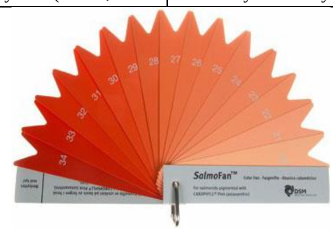
Color Measurement: In this study, color measurements were carried out by a team of five experts with the necessary knowledge and experience in seafood processing and evaluation. Konica Minolta-Japan (CR 10 and CR14 Chroma Meter) color measurement devices and the SalmoFan™ color scale were used for the color analysis of the samples. The L, a, b*, Y*, x*, and y* values used in the color analysis were determined according to the CIE color chart. According to this chart, L* represents lightness (0=white and 100=black), a* represents greenness (-) /redness (+), b* represents blueness (-)/yellowness (+), Y* represents brightness on a scale of 0-100, x* represents redness, and y* represents greenness. The SalmoFan™ color scale parameters range from reference values 20 to 34 from light to dark. The relevant color evaluation parameters are shown in Figure 2.



CIE 'Lab' Color System (URL1, 2025



CIE 'Yxy' Color System (URL2, 2025)



SalmoFan Color Scale (URL3, 2025)

Figure 2. Color systems used in color measurement.

Measurements with the color measurement devices were performed 10 times around the lateral line of the fillet. The color scale measurement was carried out by 5 different evaluators, and the average value was concluded based on the nearest color scale score. Hue and Chroma values were calculated according to McGuire (1992) (Formula 1).

$$h° = \tan^{-1}\left(\frac{b}{a}\right) \quad \text{Chroma value} = (a^{*2} + b^{*2})^{1/2} \qquad (1)$$

Delta E, WI, and YI values were calculated according to Ortiz-Duarte et al. (2019) and Kaya et al. (2021) (Formula 2).

$$\Delta E = \sqrt{(\Delta L^{*2}) + (\Delta a^{*2}) + (\Delta b^{*2})}$$
$$WI = 100 - \sqrt{(100 - L^{*})^2 + (a^{*})^2 + (b^{*})^2} \quad (2)$$
$$YI = 142.86\frac{b}{L}$$

Statistical Analysis: All analyses were performed in triplicate and the results were expressed as mean values with standard deviations. A one-way ANOVA (analysis of variance) method followed by the smallest significant difference (LSD) test was used to determine the differences among the treatments at $p < .05$ using JMP software (SAS Institute, Inc.; Sokal & Rohlf, 1987). Statistical analysis was performed using SPSS version 15.0 (SPSS Inc., Chicago, IL, USA). The data were expressed as mean ± standard deviation (SD), and significant differences were calculated using one-way analysis of variance (ANOVA). To determine the correlation between the mean values, Pearson correlation test was conducted within OriginPro (2024), and the results were presented in the form of a correlogram.

RESULTS AND DISCUSSION

The data obtained from the measurements with the CR 10 and CR14 Chroma Meter color measurement devices for the SalmoFan™ color scale values are presented in Table 1. The measurements showed that the values of L, Y, y*, WI, and Hue angle decreased as the color scale scores increased. In contrast, the values of a*, x*, Delta E, YI, and Chroma generally increased in parallel with the increase in color scale scores. It was found that the b* values, which showed fluctuating changes according to the color scale scores, were distributed between a minimum of 34.36 and a maximum of 40.8. During the color analysis of the salmon fillets obtained for the study, color tones corresponding to scale numbers 33 and 34 on the SalmoFan™ color scale were not observed. As a result, data on the color values of those with scale scores of 33 and 34 could not be obtained and the measurements corresponding to these scale numbers could not be given in the study.

In the study, the device measurements (CR10 and CR14 Chroma Meter Minolta-Japan) corresponding to the visual color evaluation results of the fillet are shown in Table 2. Since the values 33 and 34 on the color scale were not observed in the measurements on the fillet, device measurements were not made. Changes were observed in the L, a, b, Y, x, y, hue, delta E, WI, YI, and Chroma values corresponding to the color scale parameters on the fish fillet. Specifically, as the Hue angle values decreased from the 20 scale value towards the 32 scale value, an increase in YI values was observed. In the evaluation of L, a, b*, Y*, chroma, Delta E, and WI values, no significant change was observed in comparison to the increase in scale scores. Notably, x* and y* values showed no change according to the scale score variations.

Table 1. Values corresponding to the SalmoFan™ score for the Konica Minolta CR 10 and CR14 color measurement devices.

SalmoFan score	"L"	"a"	"b"	"Y"	"x"	"y"	Hue angle	Chroma value	Delta E	WI	YI
20	62.88 ± 0.59^{a}	27.68 ± 0.57^{k}	36.32 ± 0.15^{f}	70.90 ± 0.98^{a}	0.42 ± 0.01^{k}	0.37 ± 0.01^{a}	52.68 ± 0.48^{a}	45.67 ± 0.45^{h}	38.26 ± 0.45^{j}	41.15 ± 0.42^{a}	82.52 ± 0.82^{j}
21	60.82 ± 0.31^{b}	33.52 ± 0.41^{j}	36.44 ± 0.05^{f}	65.22 ± 0.13^{b}	0.43 ± 0.01^{jk}	0.36 ± 0.01^{ab}	47.39 ± 0.36^{b}	49.51 ± 0.27^{gf}	42.97 ± 0.28^{i}	36.86 ± 0.25^{b}	85.6 ± 0.5^{ij}
22	58.30 ± 0.07^{c}	35.96 ± 0.09^{i}	37.66 ± 0.05^{ed}	58.16 ± 0.11^{c}	0.44 ± 0.01^{ij}	0.36 ± 0.01^{bc}	46.32 ± 0.06^{b}	52.07 ± 0.09^{f}	46.22 ± 0.1^{h}	33.29 ± 0.09^{c}	92.78 ± 0.22^{hi}
23	56.06 ± 0.05^{d}	38.22 ± 0.15^{hi}	36.70 ± 0.12^{f}	53.10 ± 0.07^{d}	0.44 ± 0.01^{hi}	0.36 ± 0.01^{bcd}	43.84 ± 0.03^{c}	52.99 ± 0.19^{f}	48.05 ± 0.18^{g}	31.16 ± 0.15^{d}	93.52 ± 0.33^{h}
24	54.38 ± 0.08^{e}	40.26 ± 0.18^{h}	36.70 ± 0.14^{f}	49.26 ± 0.11^{e}	0.46 ± 0.01^{ghi}	0.36 ± 0.01^{bcde}	42.35 ± 0.21^{cd}	54.48 ± 0.11^{f}	50.18 ± 0.12^{f}	28.94 ± 0.11^{e}	96.41 ± 0.34^{gh}
25	53.38 ± 0.16^{e}	42.7 ± 0.12^{g}	$38.18\pm0.19cd^{ef}$	46.52 ± 0.04^{ef}	0.47 ± 0.01^{fgh}	0.36 ± 0.01^{cde}	41.80 ± 0.21^{d}	57.28 ± 0.09^{e}	53.19 ± 0.09^{e}	26.15 ± 0.11^{f}	102.18 ± 0.49^{fg}
26	51.68 ± 0.11^{f}	43.76 ± 0.13^{fg}	38.62 ± 0.08^{bcde}	43.28 ± 0.18^{fg}	0.48 ± 0.01^{efg}	0.35 ± 0.01^{cde}	41.43 ± 0.10^{d}	58.36 ± 0.12^{de}	54.85 ± 0.09^{e}	24.23 ± 0.06^{g}	106.76 ± 0.12^{ef}
27	50.68 ± 0.08^{f}	45.1 ± 0.07^{ef}	39.58 ± 0.11^{abcd}	40.86 ± 0.05^{g}	0.48 ± 0.01^{def}	0.36 ± 0.01^{cde}	41.27 ± 0.06^{d}	60.00 ± 0.11^{cd}	56.76 ± 0.08^{d}	22.33 ± 0.06^{h}	111.57 ± 0.21^{e}
28	47.84 ± 0.42^{g}	46.14 ± 0.45^{de}	40.06 ± 0.43^{ab}	35.46 ± 1.16^{h}	0.49 ± 0.01^{de}	0.35 ± 0.01^{de}	40.97 ± 0.29^{d}	61.10 ± 0.54^{b}	58.92 ± 0.34^{c}	19.66 ± 0.21^{i}	119.63 ± 0.57^{d}
29	47.1 ± 0.25^{gh}	$49.3\pm0.26b^{c}$	40.22 ± 0.13^{ab}	33.96 ± 0.50^{hi}	0.51 ± 0.01^{cd}	0.35 ± 0.01^{ef}	39.21 ± 0.11^{e}	63.62 ± 0.27^{b}	61.69 ± 0.21^{b}	17.26 ± 0.17^{j}	121.99 ± 0.6^{cd}
30	45.86 ± 0.05^{h}	52.66 ± 0.15^{a}	40.80 ± 0.22^{a}	31.48 ± 0.56^{ij}	0.52 ± 0.01^{bc}	0.34 ± 0.01^{fg}	37.77 ± 0.11^{ef}	66.62 ± 0.24^{a}	65.07 ± 0.21^{a}	14.16 ± 0.19^{k}	127.1 ± 0.68^{bc}
31	43.02 ± 0.36^{i}	52.58 ± 0.49^{a}	39.62 ± 0.32^{abc}	27.72 ± 0.58^{jk}	0.53 ± 0.01^{ab}	0.34 ± 0.01^{fg}	37.00 ± 0.27^{fg}	65.84 ± 0.49^{ab}	65.66 ± 0.3^{a}	12.93 ± 0.15^{k}	131.57 ± 0.92^{b}
32	42.12 ± 0.54^{i}	52.84 ± 1.09^{a}	37.74 ± 0.91^{def}	26.80 ± 0.52^{k}	0.54 ± 0.01^{a}	0.34 ± 0.01^{gh}	35.54 ± 0.43^{fg}	64.93 ± 1.33^{ab}	65.44 ± 1.09^{a}	13.01 ± 0.92^{k}	128.02 ± 3.52^{bc}
33	38.48 ± 1.69^{j}	51.2 ± 2.8^{ab}	38.14 ± 2.29^{cdef}	24.28 ± 0.02^{kl}	0.53 ± 0.01^{abc}	0.33 ± 0.01^{h}	36.68 ± 1.78^{g}	63.84 ± 3.04^{b}	66.19 ± 1.98^{a}	11.28 ± 1.48^{k}	141.77 ± 9.9^{a}
34	37.38 ± 0.83^{j}	47.92 ± 2.4^{cd}	34.36 ± 1.97^{g}	22.00 ± 0.01^{l}	0.51 ± 0.01^{bc}	0.33 ± 0.01^{h}	35.64 ± 2.03^{g}	58.97 ± 2.33^{cde}	62.76 ± 1.59^{b}	13.94 ± 1.1^{l}	131.25 ± 5.35^{b}

Table 2. Trout fillet color scale scores and Konica Minolta CR 10 and CR14 color measurement device values.

SalmoFan score	"L"	"a"	"b"	"Y"	"x"	"y"	Hue angle	Chroma value	Delta E	WI	YI
20	43 ± 1.92^{ab}	$13.4\pm0.18d$	17.32 ± 0.24^{b}	13.32 ± 0.90^{ab}	0.40 ± 0.00^{e}	0.36 ± 0.00^{abc}	52.25 ± 1.04^{a}	2.19 ± 0.29^{c}	30.13 ± 1.89^{ef}	42.96 ± 1.91^{abc}	57.50 ± 0.67^{d}
21	43.98 ± 1.44^{a}	$19.26\pm0.14abc$	21.78 ± 0.14^{a}	13.68 ± 1.20^{ab}	0.43 ± 0.41^{bcd}	0.36 ± 0.35^{a}	48.53 ± 0.47^{b}	2.91 ± 0.20^{ab}	29.06 ± 1.41^{f}	43.90 ± 1.44^{a}	70.81 ± 0.44^{bcd}
22	41.92 ± 1.55^{abcd}	17.28 ± 0.24^{cd}	19.60 ± 0.26^{ab}	12.38 ± 0.90^{bc}	0.41 ± 0.01^{cde}	0.35 ± 0.00^{abc}	48.61 ± 2.22^{b}	2.61 ± 0.34^{bc}	31.11 ± 1.44^{cdef}	41.86 ± 1.56^{abcd}	67.10 ± 1.09^{cd}
23	43.52 ± 1.39^{a}	21.0 ± 0.12^{abc}	21.54 ± 0.14^{a}	14.90 ± 1.39^{a}	0.43 ± 0.01^{bcd}	0.35 ± 0.01^{c}	45.72 ± 0.78^{bc}	3.01 ± 0.18^{ab}	29.51 ± 1.38^{f}	43.44 ± 1.38^{ab}	70.73 ± 0.22^{bcd}
24	38.71 ± 1.35^{e}	22.76 ± 0.18^{a}	21.86 ± 0.19^{a}	9.82 ± 0.65^{de}	0.45 ± 0.01^{a}	0.36 ± 0.00^{ab}	43.84 ± 2.72^{c}	3.16 ± 0.22^{a}	34.19 ± 1.32^{b}	38.62 ± 1.34^{e}	80.74 ± 0.73^{abc}
25	39.88 ± 0.65^{cde}	17.74 ± 0.11^{bc}	18.74 ± 0.19^{ab}	11.20 ± 1.43^{cd}	0.43 ± 0.01^{bcd}	0.36 ± 0.00^{abc}	46.50 ± 1.55^{bc}	2.58 ± 0.21^{bc}	33.11 ± 0.59^{bcd}	39.82 ± 0.66^{de}	67.21 ± 0.79^{abc}
26	40.18 ± 0.88^{bcde}	21.62 ± 0.16^{ab}	21.76 ± 0.20^{a}	9.32 ± 0.38^{def}	0.41 ± 0.01^{de}	0.35 ± 0.00^{bc}	45.15 ± 0.87^{c}	3.07 ± 0.25^{ab}	32.75 ± 0.87^{bcde}	40.10 ± 0.88^{cde}	77.44 ± 0.70^{bc}
27	40.04 ± 0.69^{bcde}	19.92 ± 0.11^{abc}	20.88 ± 0.15^{ab}	7.66 ± 0.21^{f}	0.44 ± 0.01^{ab}	0.36 ± 0.00^{abc}	46.41 ± 093^{bc}	2.88 ± 0.18^{ab}	32.91 ± 0.71^{bcde}	39.97 ± 0.69^{de}	74.42 ± 0.44^{bc}
28	38.88 ± 1.44^{de}	20.64 ± 0.17^{abc}	21.38 ± 0.16^{ab}	9.74 ± 0.45^{de}	0.44 ± 0.01^{abc}	0.36 ± 0.00^{abc}	46.02 ± 1.11^{bc}	2.97 ± 0.23^{ab}	34.03 ± 1.44^{b}	38.81 ± 1.43^{e}	78.50 ± 0.32^{abc}
29	41.02 ± 1.08^{abcde}	22.24 ± 0.11^{a}	22.86 ± 0.12^{a}	9.66 ± 1.13^{de}	0.44 ± 0.03^{ab}	0.36 ± 0.00^{abc}	45.78 ± 0.53^{bc}	3.19 ± 0.16^{a}	31.91 ± 1.04^{bcdef}	40.93 ± 1.09^{bcde}	79.73 ± 0.55^{abc}
30	35.48 ± 1.95^{f}	21.94 ± 1.46^{a}	22.02 ± 1.36^{a}	8.56 ± 0.86^{ef}	0.44 ± 0.01^{ab}	0.35 ± 0.00^{abc}	45.11 ± 0.37^{c}	31.08 ± 1.99^{ab}	43.60 ± 0.84^{a}	28.35 ± 1.06^{f}	88.61 ± 2.39^{a}
31	38.94 ± 1.31^{de}	23.14 ± 0.29^{a}	22.74 ± 0.30^{a}	8.94 ± 0.78^{ef}	0.45 ± 0.01^{a}	0.36 ± 0.00^{abc}	44.48 ± 0.90^{c}	3.24 ± 0.42^{a}	33.94 ± 1.33^{bc}	38.85 ± 1.29^{e}	83.32 ± 0.89^{ab}
32	42.2 ± 1.93^{abc}	23.06 ± 0.23^{a}	22.84 ± 0.09^{a}	12.04 ± 0.34^{bc}	0.43 ± 0.01^{abcd}	0.35 ± 0.00^{abc}	44.82 ± 2.38^{c}	3.25 ± 0.20^{a}	30.76 ± 1.89^{def}	42.11 ± 1.93^{abcd}	77.40 ± 0.38^{abc}
33	*	*	*	*	*	*	*	*	*	*	*
34	*	*	*	*	*	*	*	*	*	*	*

* No measurements were taken because the values on the color scale were not observed.

* Renk skalasındaki değerler gözlenmediği için ölçüm yapılmadı.

In the study, the data obtained from the device measurements (CR10 and CR14 Chroma Meter Minolta-Japan) corresponding to the visual evaluation results of the trout fillet color scale values were analyzed. It was observed that no similar values/relationships were found when examining the relationships between the color scale and meat color values for a, b, Y*, and Chroma. On the other hand, although similar data relationships were observed for x* and y* values, it was determined that the x* and y* results did not present a distinctive difference in color measurement. Upon examining the L* values, it was found that only similar results occurred at color scale scores 31 and 32. When examining the Hue angle results, a similar relationship was found between all the color scale values and meat color values.

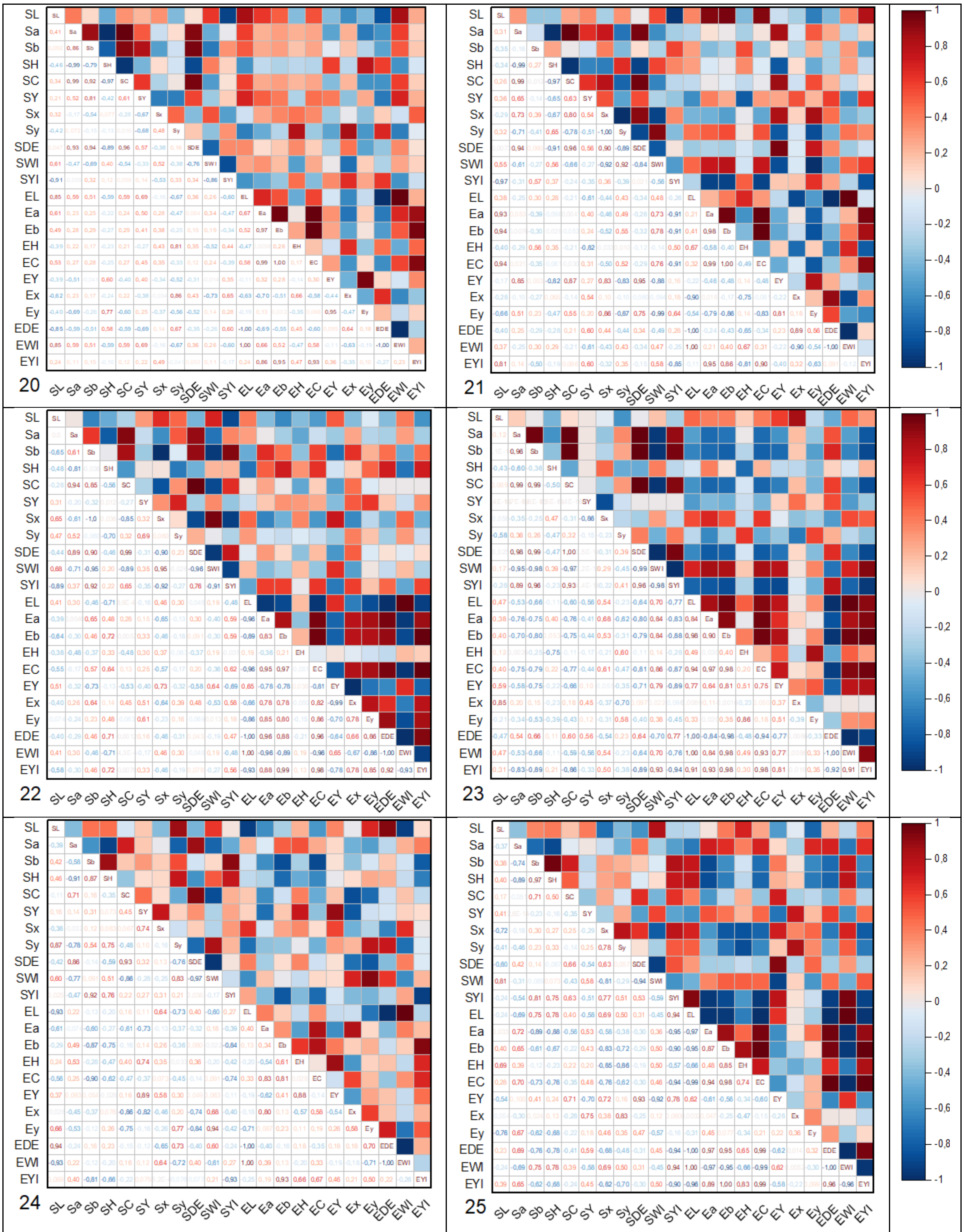


Figure 3. Correlogram of Pearson correlation for Colour 20-25 (Fish Meat and Scale).

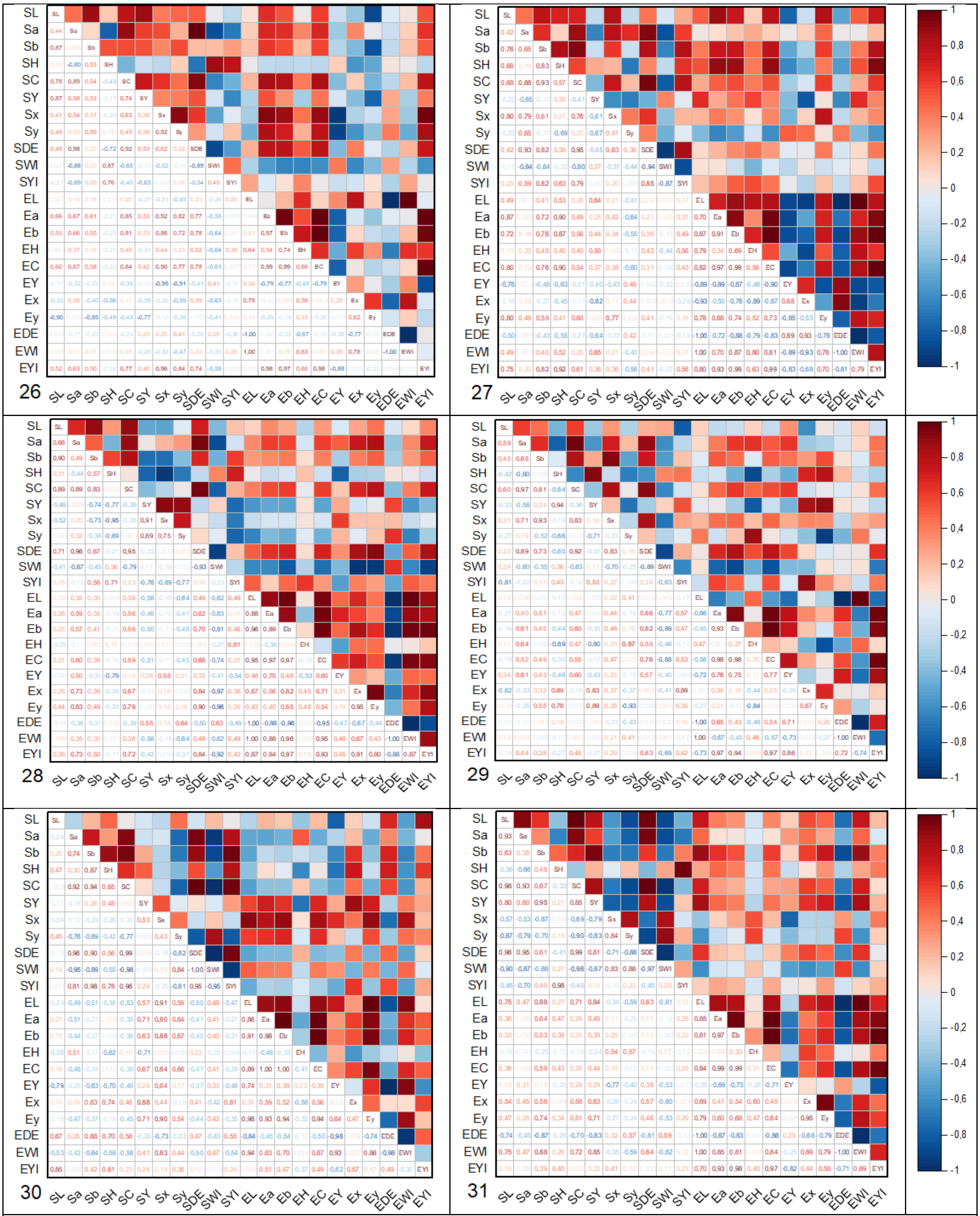


Figure 3. Correlogram of Pearson correlation for Colour 26-31 (Fish Meat and Scale).

The correlation relationships of each color scale value based on the visual identification of the fish meat and device measurements are shown in Figure 3. The Pearson correlation coefficient provides data on the positive/negative relationship and strength between two variables. In this coefficient, which ranges from +1 to -1, the relationship weakens as the value approaches zero and strengthens as it nears 1 (0.00-0.19 no correlation, 0.20-0.39 weak correlation, 0.40-0.69 moderate correlation, 0.70-0.89 strong correlation, and 0.90-1.00 very strong correlation) (Öztuna et al., 2008; Choi et al., 2010; Sheskin, 2011). In the evaluation based on Figure 3, both strong and very strong correlations were considered for negative and positive values. In the correlation performed, strong relationships were observed for scale L values (SL) with meat L (EL) and meat WI (EWI) (+) and meat DE (EDE) (-) for color scale 20. For color scale 21, SL and scale WI (SWI) values showed a strong relationship for meat a (Ea), meat b (Eb), and meat chroma value (EC) (+), while scale YI (SYI) values showed a very strong relationship for the same variables (-). For color scale 22, scale H (SH) values provided strong correlations for Eb, EDE, and meat YI (EYI) values (+), while EWI showed a negative strong correlation (-). For color scale 23, Ea values showed strong correlations with scale a (Sa), scale b (Sb), scale chroma (SC), scale DE (SDE), and SYI values (-), and with SWI (+). In color scale 24, Eb showed a strong negative correlation with SYI, SH, and Sb, while EC and EYI values showed strong and very strong negative correlations with SYI and Sb. In color scale 25, Ea and EC values showed a positive strong correlation with Sa, while Sb and SH values showed a negative strong correlation. SYI values showed a very strong positive correlation with EL and EWI, and a very strong negative correlation with EYI, meat delta E (EDE), EC, Eb, and Ea values. In color scale 26, it was observed that SDE and SC values had a strong positive correlation with Ea, Eb, EC, and EYI values. In color scale 27, SL and Sb values showed a strong positive correlation with Ea, Eb, EC, and EYI, while SH showed a very strong positive correlation with Ea, EC, and EYI. In color scale 28, SWI values showed a strong negative correlation with Eb and EC, a very strong negative correlation with EYI, and a strong positive correlation with SDE, SC, and Sa. In color scale 29, SWI values showed a strong negative correlation with Ea and EC, and a strong positive correlation with Eb. The SDE value had a strong positive correlation with Eb and EC, and the meat Hue angle value (EH) had a strong negative correlation with scale Y (SY) and scale Hue angle value (SH). In color scale 30, a strong positive correlation was observed between SY and Ea, while a strong negative correlation was found between EH and SY. Additionally, a strong positive correlation was observed between SH and EDE, and a strong negative correlation with meat Y (EY). In color scale 31, EL and EWI values showed a positive strong correlation with SL, Sb, SC, and SY values, while EDE showed a negative strong correlation with the same values. In color scale 32, Sa values showed a strong relationship with Ea, Eb, and EYI, and a very strong negative relationship with EC. EC values showed a strong correlation with Ea, EC, and EYI, and a very strong negative relationship with Eb. SWI and SDE values showed a strong correlation with EC and a very strong negative correlation with Eb. In the general evaluation, it was found that, except for color scale 22, Ea, Eb, and EC values showed strong positive/negative correlation values with color scale values in all the color scales.

CONCLUSIONS

In the measurements performed with color devices for the SalmoFan™ color scale values between 20 and 34, a notable change was observed in the L, Y, y*, WI, and Hue values showing a decrease, while a noticeable increase was observed in a*, x*, Chroma, Delta E, and YI values (excluding scale values 33 and 34). In the color measurements of Turkish salmon fillet, although the changes were not as distinct as those in the color scale, similar trends were observed, with particularly the Hue values decreasing in response to increasing scale scores. To establish the relationship between the color measurements of Turkish salmon fillet and the color scale measurements, Pearson Correlation changes were performed. In the results obtained, except for color scale 22, a strong positive/negative correlation between the Ea, Eb, and EC values and the color scale values were detected in all color scales. The more distinct results in the measurements of the color scale devices compared to the Turkish salmon fillet can be explained by the lack of a homogeneous color content in the fillet, which results from the varying fat, water, and protein structures in the meat. To establish a complete relationship in these studies, higher-level imaging devices and more samples could help reduce error margins.

Credit authorship contribution statement:
AK: Conceptualization, Writing -review and editing;
EÇ: Formal Analysis, Investigation, Methodology;
BK: Resources, Writing -review and editing;
ÖYÖ: Supervision, Writing review and editing and
NÖ: Investigation, Methodology.

REFERENCES

Alçiçek, Z., & Balaban, M.Ö. 2012. Development and application of "The Two Image" method for accurate object recognition and color analysis. *Journal of Food Engineering*, ***111***, 46-51. DOI: 10.1016/j.jfoodeng.2012.01.031

Cai, L., Wu, X., Li, X., Zhong, K., Li, Y., & Li, J. (2014). Effects of different freezing treatments on physicochemical responses and microbial characteristics of Japanese sea bass (*Lateolabrax japonicas*) fillets during refrigerated storage. *LWT–Food Science and Technology*, ***59***, 122-129. DOI: 10.1016/j.lwt.2014.04.062

Choubert, G., Blanc, J-M., & Vallde, F. (1997). Colour measurement, using the CIELCH colour space, of muscle of rainbow trout, *Oncorhunchus mykiss* (Walbaum), fed astaxanthin:effects of family, ploidy, sex, and location of reading. *Aquaculture Research*, ***28***, 15-22.

Choubert, G., & Baccaunaud, M. (2006). Colour changes of fillets of rainbow trout (*Oncorhynchus mykiss* W.) fed astaxanthin or canthaxanthin during storage under controlled or modified atmosphere. *LWT*, ***39***, 1203-1213.

Choi, J., Peters, M., & Mueller, R.O. (2010). Correlation analysis of ordinal data: from Pearson's r to Bayesian polycoric correlation. *Asia Pacific Educ. Rev.*, ***11***, 459-466.

Cheng, J-H., Sun, D-W., Zeng, X-A., & Liu, D. (2015). Recent advances in methods and techniques for freshness quality determination and evaluation of fish and fish fillets: A review. *Critical Reviews in Food Science and Nutrition*, ***55***(7), 1012-1225. DOI: 10.1080/10408398.2013.769934

Gümüş, B., Balaban, M.Ö., & Ünlüsayın, M. (2011). Machine vision applications to aquatic foods: A review. *Turkish Journal of Fisheries and Aquatic Sciences*, ***11***, 171-181. DOI: 10.4194/trjfas.2011.0124

Hassoun, A., & Karoui, R. (2017). Quality evaluation of fish and other seafood by traditional and nondestructive instrumental methods: Advantages and limitations. *Critical Reviews in Food Science and Nutrition*, ***57***(9), 1976-1998. DOI: 10.1080/10408398.2015.1047926

Keskin, M., Setlek, P., & Demir, S. (2017). Use of Color Measurement Systems in Food Science and Agriculture. Internetional Advanced Research & Engineering Congress Proceeding Book, 16-18 November, Osmaniye/Türkiye, 2350-2359 p.

Leon, A.P., Vina, S.Z., Frezza, D., Chaves, A., & Chiesa, A. (2007). Estimation of Chlorophyll Contents by Correlations between SPAD-502 Meter and Chroma Meter in Butterhead Lettuce. *Communications in Soil Science and Plant Analysis*, ***38***, 2877-2885. DOI: 10.1080/00103620701631115

McGuire, R.G. (1992). Reporting of objective colour measurement. *Hortscience*, ***27***, 1254-1255.

Origin Scientific Analysis and Graphing Software OriginLab Corporation. (2024). OriginPro.

Oliveira, A.C.M., & Balaban, M.O. (2006). Comparison Of A Calorimeter With A Machine Vision System In Measuring Color Of Gulf Of Mexico Sturgeon Fillets. *American Society of Agricultural and Biological Engineers*, ***22***(4), 583-587.

Öztuna, D., Elhan, A.H., & Kurşun, N. (2008). Sağlık Araştırmalarında Kullanılan İlişki Katsayıları. *Türkiye Klinikleri*, ***28***, 160-165.

URL1. (2025). https://sensing.konicaminolta.asia/id/what-is-cie-1976-lab-color-space/

URL2. (2025). https://wolfcrow.com/what-is-the-difference-between-cie-lab-cie-rgb-cie-xyy-and-cie-xyz/

URL3, (2025). https://www.dsm-firmenich.com/anh/products-and services/tools/salmofan.html

Üren, A. (1999). Üç Boyutlu Renk Ölçme Yöntemleri. *Gıda*, ***24***(3), 1993-200.

Sheskin D. (2011). Handbook of Parametric and Nonparametric Statistical Procedures Test, Chapman and Hall/CRC, Fifth Edition, S. 800.

Sokal, R.R., & Rohlf, F.J. (1987). Introduction to biostatistics (2nd ed.). Freeman.

Skrede, G., Rısvık, E., Huber, M., Enersen, G., & Blümlein, L. (1990). Developing a Color Card for Raw Flesh of Astaxanthin-fed Salmon. *Journal of Food Science*, ***55***(2), 361-363.

Şengör, Ü.F.G., Balaban, O.M., Topaloğlu, B., Ayvaz, Z., Ceylan, Z., & Doğruyol, H. (2019). Color assessment by different techniques of gilthead seabream (*Sparus aurata*) during cold storage). *Food Sci. Technol.*, ***39***(3), 696-703. DOI: 10.1590/fst.02018

Wu, D., Sun, D-W., & He, Y. (2012). Application of long-wave near infrared hyperspectral imaging for measurement of color distribution in salmon fillet. *Innovative Food Science and Emerging Technologies*, ***16***, 361-372. DOI: 10.1016/j.ifset.2012.08.003

Yagiz, Y., Balaban, M.O., Kristinsson, H.G., Welt, B.A., & Marshall, M.R. (2008). Comparison of Minolta colorimeter and machine vision system in measuring colour of irradiated Atlantic salmon. *Journal of Science of Food and Agriculture*, ***89***(4): 728-730. https://doi.org/10.1002/jsfa.3467