Akademik Ziraat Dergisi 15: e1902004 (2026)
e-ISSN: 2618-5881 DOI: http://dx.doi.org/10.29278/azd.1902004

Research
(Araştırma)

Milk Composition and Color Parameters in Jersey and Holstein Cows in The Mediterranean Conditions

Sena DOĞAN [1*], Serap GÖNCÜ [1]

[1]Çukurova University, Faculty of Agriculture, Department of Animal Science, Adana/TÜRKİYE

Received: March 03, 2026, Accepted: May 21, 2026
Corresponding author: Sena DOĞAN, e-mail: dogan.sena2000@gmail.com

Abstract

Objective: This study aimed to investigate the relationships between basic chemical composition parameters and physical color characteristics (L*, a*, b*, Hue, and Chroma) of milk obtained from Jersey and Holstein cows raised in the Mediterranean Region.

Materials and Methods: Milk components (fat, protein, lactose, SNF, density, pH, freezing point, etc.) were determined using the Milkana Multi Test Analyzer based on the ultrasonic principle. Milk color was measured with the HunterLab Color Analyzer to obtain lightness (L*), redness–greenness (a*), and yellowness–blueness (b*) values, and Hue and Chroma were calculated.

Results: Under the same care and feeding conditions, Jersey milk had a significantly higher L* value than Holstein milk, indicating a lighter and brighter appearance, which may be associated with higher fat content due to greater light reflectance. The a* values were negative in both breeds, showing that the color tone was on the greenish–reddish axis; however, the difference between breeds was not statistically significant. In addition, the b* value was significantly higher in Jersey milk than in Holstein milk, indicating greater yellowness.

Conclusion: Jersey and Holstein milks differed in key color traits, particularly in L* and b*, whereas a* values were similar. These findings suggest that milk color characteristics can reflect compositional differences between breeds under comparable management conditions.

Keywords: Dairy cattle, physicochemical properties, colorimetry, hue, chroma

Akdeniz Bölgesinde Yetiştirilen Jersey ve Siyah Alaca İneklerin Süt Kompozisyonu ile Renk Parametrelerinin Analizi

Öz

Amaç: Bu çalışma, Akdeniz Bölgesi'nde yetiştirilen Jersey ve Siyah Alaca ineklerinden elde edilen sütün temel kimyasal bileşim parametreleri ile fiziksel renk özellikleri (L*, a*, b*, Hue ve Chroma) arasındaki ilişkileri incelemeyi amaçlamıştır.

Materyal ve Yöntem: Süt bileşenleri (yağ, protein, laktoz, yağsız kuru madde (SNF), yoğunluk, pH, donma noktası vb.) ultrasonik prensiple çalışan Milkana Multi Test Analizörü kullanılarak belirlenmiştir. Süt rengi, HunterLab renk analizörü ile açıklık (L*), kırmızılık-yeşillik (a*) ve sarılık-mavilik (b*) değerleri ölçülerek değerlendirilmiş; Hue ve Chroma değerleri hesaplanmıştır.

Araştırma Bulguları: Aynı bakım ve besleme koşullarında yetiştirilen ineklerde Jersey sütünün L* değerinin Siyah Alaca sütünden anlamlı düzeyde daha yüksek olduğu belirlenmiş, bu durum Jersey sütünün daha açık ve parlak renkte olduğunu göstermiştir. Süt yağı daha fazla ışık yansıttığı için artan açıklık genellikle yüksek yağ içeriği ile ilişkilendirilmektedir; dolayısıyla Jersey sütündeki yüksek yağ içeriği rengin daha açık görünmesine katkıda bulunmuş olabilir. Her iki ırkta da a* değerleri negatif bulunmuş, bu da renk tonunun yeşilimsi–kırmızımsı eksende yer aldığını göstermiş; ancak ırklar arasındaki fark istatistiksel olarak anlamlı bulunmamıştır. Buna ek olarak, Jersey sütünde b* değerinin Siyah Alaca sütüne göre anlamlı düzeyde daha yüksek olduğu saptanmış ve sarılığın daha belirgin olduğu görülmüştür.

Doğan, S. & Göncü, S. (2026). Milk Composition and Color Parameters in Jersey and Holstein Cows in The Mediterranean Conditions. *Akademik Ziraat Dergisi*, 15, e1902004. http://dx.doi.org/10.29278/azd.1902004

Sonuç: Jersey ve Siyah Alaca sütleri, özellikle L* ve b* değerlerinde farklılık gösterirken, a* değerleri bakımından benzer bulunmuştur. Bu bulgular, benzer yetiştirme koşullarında süt rengi özelliklerinin ırklar arasındaki bileşim farklılıklarını yansıtabileceğini göstermektedir.

Anahtar Kelimeler: Süt sığırları, fizikokimyasal özellikler, kolorimetri, hue, chroma

Introduction

Milk is a fundamental foodstuff in human nutrition, serving as a source of energy as well as high-quality protein, fat, vitamins, and minerals. The consumption of milk and dairy products is critically important, particularly for individuals in their developmental years, in terms of bone health, immune system function, and overall metabolic functions. In addition to milk's fundamental importance for human health, the components that determine its quality must be evaluated in detail to understand its nutritional value and chemical properties. Parameters used to evaluate milk quality include chemical content (fat %, protein %, lactose %, SNF) and physical properties (color, viscosity, density). Milk color is an important indicator in terms of consumer perception and milk processing quality. Color is directly related to beta-carotene in milk fat, milk protein, and certain trace minerals. Milk with a high beta-carotene content exhibits a more yellowish color, while milk with low beta-carotene content is whiter in color (Cheng et al., 2021). Additionally, factors affecting milk color include cow breed, genetic traits, nutrition, lactation period, and somatic cell count (SCC) (Fox and McSweeney, 2015; Kılıç and Erdem, 2020). Different cayttle breeds are important for different genetic potentials in terms of milk yield and composition. Some breeds stand out for their high milk yield, while other breed produces milk with a lower quantity but higher fat and protein content. This difference affects milk production, milk content, and milk quality, directly determining farm milk production and quality. Farmers prefer systems where both breeds are raised together in order to maintain high milk quantities while also keeping milk fat and protein values at desired levels. Studies on the milk composition of different dairy cattle breeds show that breed has a decisive genetic effect on milk quality (Auldist et al., 2004; Heck et al., 2009). Although the Holstein breed is known for its high milk yield, its milk generally has a lower fat and protein content (Kuczyńska et al., 2012). In contrast, the Jersey breed, despite producing lower milk yields per liter, stands out for its high fat (5–6%), protein (3.8–4.2%), and dry matter content (Claycomb et al., 2014; Kelsey et al., 2003). The high total solids content in Jersey milk provides technological advantages, particularly in terms of cheese yield and butter production (Costa et al., 2019). Jersey milk also has a lower somatic cell count and higher calcium and casein ratios compared to Holstein milk (Guinee et al., 2010). Holstein milk, on the other hand, has a higher lactose content and lower viscosity, making it preferred for drinking milk production (Niero et al., 2020). Therefore, the differences in milk composition between Holstein and Jersey breeds stem not only from genetic structure but also from metabolic activity, energy utilization, and milk synthesis mechanisms (Bobe et al., 2004). The compositional differences observed between breeds not only affect nutritional properties but also shape the levels of pigments and macromolecules that directly contribute to milk color formation. Indeed, the main determinants of milk color include the light scattering capacity of fat globules, the optical properties of casein micelles, and the amount of fat-soluble pigments, particularly beta-carotene. and breed-related variations in these components can create noticeable differences in color tone (Fox and McSweeney, 2015; Walstra et al., 1999). Therefore, the compositional differences between Jersey and Holstein milk yield meaningful results not only in terms of nutritional quality but also in terms of physical characteristics that directly affect consumer perception, such as color.

Color is generally considered to be related to the freshness, ripeness, and taste of foods. Therefore, color is one of the important factors in consumer preferences (Fernández-Vázquez et al., 2011). In addition to consumer preferences, in terms of milk and dairy products, color is also associated with the presence of abnormalities such as adulteration (Santos et al., 2012) or spoilage (Santos et al., 2012) in milk. Moreover, color can be an important indicator of long-term storage conditions (Popov-Raljić et al., 2008) and shelf life, which can render milk commercially unacceptable. For example, mastitis gives a reddish/yellowish appearance (Espada et al., 2002), unlike the typical white color of milk (Belitz et al., 2004). Therefore, the correct assessment of color differences in milk and dairy products is not limited to consumer perception and quality indicators; it also requires an understanding of how color is formed based on light, material structure, and optical reflection principles. Color is the name given to the

reflection of light from objects to the eye. The change in perception depending on the structure of the object and the form of reflection is also expressed as color tone. If light reflected from the object hits the eye completely, this color is perceived as white; if it is not reflected at all, it is perceived as black. Part of the white light falling on the material is absorbed, and the rest is reflected. Depending on the wavelength of the light reflected into the eye, the material appears in different colors. In other words, after white light is absorbed, the remaining reflected complementary light mixture creates color. Although these physical processes form the basis of the color observed in milk, research requires this perceptual information to be converted into a numerical system so that this color can be accurately compared and an objective evaluation can be made between samples. The color space is a three-dimensional coordinate system that enables the numerical definition and measurement of colors perceived by the human eye. Color spaces, as mathematical models that enable the consistent representation of the same color across different devices or environments, are classified into device-dependent and device-independent forms. The CIELAB color space, developed by the International Commission on Illumination (CIE), is accepted as the standard in many fields such as food science, textiles, paint, and digital imaging because it defines colors in a way that is closest to human perception. In this system, the L* value represents brightness, the a* value represents the red–green axis, and the b* value represents the yellow–blue axis; thus, each color can be measured with three coordinates, and the color difference between samples can be calculated using the ΔE formula. The use of color spaces in this way provides an objective assessment, particularly in quality control and component analysis of food products (Leon et al., 2006).

However, measuring color values in these coordinate systems alone is not sufficient; to understand the color differences observed in milk, it is necessary to examine the physical and chemical structures that form the source of the color. The formation of milk color is directly related to the physical and chemical properties of milk components. The basic components of milk, namely water, fat, protein, lactose, and mineral salts, determine milk color by affecting the processes of light refraction, reflection, and absorption within milk (Walstra et al., 1999). Milk fat globules contribute most significantly to milk color. Beta-carotene is a natural pigment found in the milk of breeds that produce high-fat milk, such as Jersey, and it gives milk a yellowish tone. Since beta-carotene is insoluble in water, it is found in the fat phase; therefore, as the fat content increases, the milk color becomes more intensely yellowish (Cheng et al., 2021). Casein and other proteins in milk are responsible for light scattering, which makes milk appear white and opaque. Protein structures cause light to scatter in various directions, making milk appear cloudy and white. Milk with low protein content may be more transparent and lighter in color (Fox and McSweeney, 2015). Lactose and dissolved mineral salts do not directly change the color of milk but indirectly determine its brightness and tone by affecting the refractive index of light. For example, calcium and phosphate ions stabilize protein networks and contribute to the opaque appearance of milk. An increase in somatic cell count can affect milk protein and fat content, causing the milk to appear lighter or more yellowish in color. The lactation period also alters the ratios of milk components; early lactation milk is generally lighter in color, while late lactation milk may be more yellowish (Kılıç and Erdem, 2020). Dietary pigments, particularly beta-carotene-rich feeds such as green grass and silage, directly affect milk color. Furthermore, certain processing and storage conditions can also cause changes in milk color. In fact, milk color reflects its biochemical composition and physical structure. As fat and beta-carotene levels increase, yellow tones become more pronounced, while protein content makes milk white and opaque. Therefore, milk color is an important parameter both as a quality indicator and in terms of processing and consumer preferences. However, since the levels of these components vary depending on the animal's physiological state and rearing conditions, milk color is not solely dependent on its chemical structure. It is also influenced by production and environmental factors. The main factors affecting milk color include cow breed, feeding method, feed type, lactation period, environmental conditions, and health status (Nozière et al., 2006). In particular, the rate of transfer of carotenoids in the feed to the milk plays a decisive role in giving the milk a yellowish tone. Milk from cows fed haylage or fresh green feed is more yellow due to its high β-carotene content, while milk from cows fed hay or concentrate feed is lighter and whiter in color (Havemose et al., 2004). Disease and physiological factors also influence milk color. Diseases such as mastitis, jaundice, foot-and-mouth disease, and anthrax can cause abnormal changes in milk color; for example,

milk from cows with mastitis often exhibits yellowish, reddish, or brownish tones (Göncü, 2000). Therefore, differences in milk color can be considered an indirect indicator of both udder health and the hygienic quality of the milk. In addition, the animals' feed ration also plays a decisive role in color; for example, milk from animals fed fresh green fodder has a higher β-carotene content and therefore appears more yellowish (Walstra et al., 1999; Fox and McSweeney, 2015). Milk temperature, pH, and storage conditions are other factors that affect color changes. Therefore, milk color is not merely an aesthetic feature but is also considered a quality indicator that provides indirect information about milk composition, animal health, and nutritional status.

Recent studies have shown that the color characteristics of milk (L*, a*, b*) are not only a sensory indicator but may also be related to quality parameters such as milk composition and somatic cell count (SCC) (Espada et al., 2002). In particular, it has been reported that high SCC values may affect the physical properties and color tone of milk, and therefore milk color can be considered a potential quality indicator.

This study aimed to examine the chemical content (% fat, % protein, % lactose, SNF) and physical color characteristics (L*, a*, b*, Hue, Chroma) of milk from Jersey and Holstein cows.

Materials and Methods

This study was conducted in a free-stall open barn with a capacity of 200 lactating cows belong to private sector. In the experiment, milk samples were taken from healthy Holstein and Jersey cows with similar lactation characteristics. Milking was performed twice a day (morning and evening, 12 hours apart) using an automatic system at a central milking station. Figure 1 shows the collection method for milk samples for research purposes. .

The cows were fed a total mixed ration (TMR), with a feed:roughage ratio of 60:40. The roughage composition consisted of corn silage (50%), alfalfa hay (25%), and wheat straw (25%). On average, 22 kg of silage, 2 kg of straw, 2 kg of dry alfalfa, 4 kg of concentrate feed, 4 kg of crushed feed, and approximately 4,5 kg of milk feed per cow per day were provided. The TMR was prepared and distributed in two meals, morning (07:00) and evening (16:00).



Figure 1. Milk sampling from cows used for milk composition and color analyses

Milk samples were collected from cows during the lactation period after the first milk was removed and transferred to the laboratory in a cold chain in 250 mL sterile sample containers. Milk components (fat, protein, lactose, SNF, density, pH, freezing point, etc.) were determined using the Milkana Multi Test Analyzer based on the ultrasonic principle. Milkana Multi Test Analyzer for milk content analysis is shown in Figure 2.



Figure 2. Milkana Multi Test Analyzer used to determine milk composition parameters (Based on the Ultrasonic Principle)

The color of the milk was determined using a HunterLab Color Analyzer according to the CIELAB system, based on lightness (L*), redness (a*), and yellowness (b*) values. The HunterLab Color Analyzer is shown in Figure 3.



Figure 3. HunterLab Color Analyzer used for determining milk color parameters (L*, a*, b*)

The color characteristics of the milk were evaluated in more detail by calculating the Hue and Chroma values from the CIELAB coordinates.

The Chroma (C*) value represents the saturation of the color, while the Hue angle (h°) represents the tone of the color (Leon et al., 2006). The calculations were performed using the following equations:

$$\boldsymbol{C^*} = \sqrt{\boldsymbol{a^{*2}} + \boldsymbol{b^{*2}}}$$

$$h^\circ = \text{atan2}(b^*, a^*) \times \frac{180}{\pi}$$

where C* (chroma) represents the saturation or vividness of the color, with higher values indicating more intense and vivid coloration, and h° (hue angle) represents the color tone expressed in degrees, ranging from 0° to 360°, where 0° corresponds to red, 90° to yellow, 180° to green, and 270° to blue. When negative hue angle values occur, 360° is added to convert them into the standard positive range. The magnitude of color variation between samples was subsequently quantified using the CIELAB color difference (ΔE) formula.

$$\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

where ΔE represents the total color difference between two samples; L* indicates lightness, with values ranging from 0 (pure black) to 100 (pure white); a* represents the red–green color axis, where positive values indicate redness and negative values indicate greenness; and b* represents the yellow–blue color axis, where positive values indicate yellowness and negative values indicate blueness.

In the study, data obtained to determine the effects of different dairy cattle breeds (Holstein and Jersey) on milk components were evaluated according to a one-way experimental design. One-way analysis of variance (One-Way ANOVA) was applied to determine the effect of breed on milk components (fat, protein, lactose, SNF, density, freezing point, temperature, and conductivity). The significance level was set at $p<0.05$. This study was approved by the Çukurova University Animal Experiments Local Ethics Committee (HADYEK), Türkiye (Decision No: 4, 27 March 2025).

Results

The study compared the chemical and physical properties of milk obtained from Holstein and Jersey cows. The chemical content analysis results of milk from Holstein and Jersey cows are presented comparatively in Table 1. A total of 8 different milk characteristics were examined in the study, and 4 of these characteristics (fat, SNF, protein, lactose) showed statistically significant differences between the two breeds.

The findings presented in Table 1 reveal significant differences in milk composition between Jersey and Holstein breeds. The average fat content of Jersey milk (6.46%) was found to be significantly higher than that of Holstein milk (4.29%) ($p<0.001$), indicating that the Jersey breed has a genetically higher milk fat synthesis capacity. This increases the energy density of Jersey milk and makes it more suitable for products where solids content is important, such as cheese production. Similarly, the non-fat solids (SNF) content was also significantly higher in Jersey milk (8.99%) than in Holstein milk (7.82%) ($p=0.027$), demonstrating the superiority of the Jersey breed in total solids production.

In terms of protein content, Jersey milk (3.42%) showed a significantly higher value than Holstein milk (3.20%) ($p=0.004$). This result is an important difference that directly affects the nutritional value and processability of milk. The lactose content was also higher in Jersey milk (4.90%) than in Holstein milk (4.63%) ($p=0.023$), creating a difference in the taste and fermentability of the milk. However, no significant difference was observed between the two breeds in physical properties such as density ($p=0.815$), freezing point ($p=0.114$), temperature ($p=0.607$), and conductivity ($p=0.084$).

Table 1. Comparison of the milk content of Jersey and Holstein breeds

	Holstein					Jersey					
Contents	**Mean**	**Std. Deviation**	**Std. Error**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Std. Error**	**Minimum**	**Maximum**	**Level of significance**
Fat (F) (%)	4.29	1.77	0.38	2.63	8.84	6.46	1.81	0.39	3.77	9.47	.000
Non-fat dry matter (SNF) (%)	7.82	2.33	0.50	0.95	9.85	8.99	0.61	0.13	7.65	9.94	.027
Density (D) (kg/m^3)	27.45	3.74	0.80	18.50	34.20	27.69	3.13	0.67	19.70	31.80	.815
Protein (P) (%)	3.20	0.25	0.05	2.80	3.70	3.42	0.22	0.05	2.96	3.76	.004
freezing point (FP) (°C)	55.52	4.35	0.93	48.70	64.80	57.37	3.18	0.68	50.20	62.60	.114
temperature (T) (°C)	26.11	1.08	0.23	24.30	28.90	26.26	0.89	0.19	25.40	28.40	.607
lactose (L) (%)	4.63	0.40	0.09	3.88	5.41	4.90	0.35	0.07	4.11	5.43	.023
Conductivity (Z) (mS/cm)	5.06	2.81	0.60	3.76	13.70	3.99	0.40	0.08	3.54	4.76	.084

The color data in Table 2 reveals the differences between Holstein and Jersey milk in terms of visual appearance and quality. Of the total 5 color characteristics examined in the study, 4 (80%) showed statistically significant differences.

According to the analysis results, Jersey milk showed a significantly lighter color than Holstein milk in terms of L* (lightness) value (85.25 ± 1.79 vs. 83.66 ± 1.68; p = 0.004). No significant difference was observed in the a* (red-green) values (p = 0.134), with both milks exhibiting a slight greenish tint. In terms of b* (yellow-blue) values, Jersey milk (8.31 ± 2.62) was significantly more yellow than Holstein milk (3.22 ± 1.96) (p <0.001), suggesting that Jersey milk contains more fat-soluble carotenoids. In terms of Hue and Chroma values, Jersey milk also showed lower Hue (84.09 ± 1.36 vs. 86.84 ± 0.86; p <0.001) and higher Chroma (8.87 ± 2.13 vs. 4.57 ± 1.36; p <0.001) values. These findings indicate that Jersey milk has a more distinct visual profile than Holstein milk in terms of color intensity and vividness. In conclusion, when milk color parameters are evaluated in parallel with milk components, they reveal that breed differences are significant in terms of both processing characteristics and consumer perception.

Table 2. Milk color characteristics of Jersey and Holstein cow breeds

	Holstein					Jersey					
	Mean	**Std. Deviation**	**Std. Error**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Std. Error**	**Minimum**	**Maximum**	**Level of significance**
L*	83.66	1.678	.357	81.17	86.54	85.25	8.87	.381	82.23	86.98	.004
a*	-2.89	.504	.107	-3.67	-2.21	-2.50	1.086	.231	-4.78	-1.34	.134
b*	3.21	1.963	.418	-.18	6.04	8.31	2.617	.558	2.57	10.05	.000
Hue	86.83	.858	.183	86.24	89.36	84.09	1.363	.290	81.45	86.07	.000
Chroma	4.57	1.357	.289	2.68	6.70	8.87	2.129	.454	4.21	10.29	.000

Looking at the table showing the color characteristics of Jersey and Holstein milk under the same care and feeding conditions, the L* (lightness) value was found to be significantly higher in Jersey milk (85.25) than in Holstein milk (83.66) (p=0.004). However, the difference is not statistically significant (p=0.134), indicating that the red-green tone difference in the milk of both breeds is similar. The b* value was found to be significantly higher in Jersey milk (8.31) compared to Holstein milk (3.22) (p<0.001). This indicates that Jersey milk has more yellow tones. This yellowish tone stems from the high β-carotene content in the milk; Jersey cows are less efficient than Holstein cows at converting carotene to vitamin A (Jensen et al., 1999). Therefore, Jersey milk gives a more pronounced yellow color, especially in butter

and cheese. The hue angle was significantly lower in Jersey milk (84.09) than in Holstein milk (86.83) ($p<0.001$). A decrease in hue angle means the color is closer to yellow. This supports the dominance of yellow tones in Jersey milk. The chroma value was significantly higher in Jersey milk (8.87) than in Holstein milk (4.57) ($p<0.001$). The results of the difference calculations for the color data given in Table 3 are presented comparatively for Holstein and Jersey milk in Table 4.

Table 3 Analysis results of milk color values for Jersey and Holstein breeds

Color values	Holstein average	Jersey average	Significany level
L*	83.6636	85.2545	.004
a*	-2.8973	-2.5073	.134
b*	3.2164	8.3136	.000
Hue	86.8373	84.0900	.000
Chroma	4.5718	8.8736	.000

When considering the color difference evalutaion of Table 4 provided in Table 5, it shows that there is a slight color difference between the milk of Jersey and Holstein breeds that is noticeable to the eye.

Table 4 The difference calculation results for the color data

Color Value	Holstein	Jersey
L*	83.6636	85.2545
a*	-2.8973	-2.5073
b*	3.2164	8.3136
ΔE	5.355	

Table 5 Color difference evaluation thresholds values

Concept	Approximate ΔE value	Explanation / Source
Perceptibility threshold	~ 1.0 – 2.0	In the CIELAB color space, a change of ΔE = 1 is imperceptible to the average observer ≈ the threshold of detection.
Acceptability threshold	~ 3.0 – 4.0	When the product quality generally falls below this limit, the "color difference is considered acceptable."

There is a noticeable color difference between Holstein and Jersey milk that is easily visible to the eye. This difference is mainly due to the b* (yellowness) value; Jersey milk has a more yellowish tone.

Discussion

In general, the Jersey breed offers higher quality milk in terms of milk composition (fat, protein, SNF and lactose), while the Holstein breed stands out for its higher milk yield. Similarly, the literature emphasizes that the Jersey breed produces milk with high nutritional density, while the Holstein breed has an advantage in terms of volumetric yield (Auldist et al., 2004; Fox and McSweeney, 2015). These findings indicate that each breed should be selected for different production purposes, supporting the notion that Jersey is more suitable for quality-focused production systems, while Holstein is better suited for quantity-focused production systems.

The hue angle was found to be lower in Jersey milk (84.09) than in Holstein milk (86.83), supporting that Jersey milk has a color closer to yellow ($p<0.001$). The lower hue value indicates that warmer (yellowish) tones dominate in Jersey milk. Furthermore, the Chroma value was significantly higher in Jersey milk (8.87) than in Holstein milk (4.57) ($p<0.001$). This indicates that the color of Jersey milk is more vivid, saturated, and intense, with a significantly higher color intensity and vividness compared to Holstein milk. Overall, these findings reveal that Jersey milk is both lighter and has more yellow and saturated tones, while Holstein milk has a duller and whitish appearance; this has been associated in the literature with the Jersey breed's high fat and β-carotene content (Fox and McSweeney, 2015).

The findings obtained are largely consistent with the results reported in the literature. The yellowish tones of Jersey milk are due to high β-carotene and milk fat concentrations (O'Callaghan et al., 2016; Martin et al., 2019). An increase in milk fat content lowers the L* value and increases the b* value (Park et al., 2020). This is consistent with the current findings. Milk color is evaluated as a quality indicator in consumer perception, and the creamy tones of Jersey milk, in particular, are perceived as "natural and rich milk" (Walstra et al., 1999).

Milk color is not merely a visual characteristic but also a strong indicator of chemical composition. Color parameters are closely related to fat globule size, casein ratio, riboflavin, and carotenoid concentration (Fox and McSweeney, 2015).

Jersey milk is more yellowish than Holstein milk due to the lipophilic nature of β-carotene and its greater solubility in the fat phase (Karagül and Şahin, 2021). Similarly, a positive relationship between milk color and protein and lactose ratios has been reported, supporting the SNF–L* relationship identified in our study (Chung et al., 2017). Furthermore, an increase in somatic cell count causes milk color to become duller and L* values to decrease (Yıldız and Uzmay, 2020). This situation highlights the need to evaluate the relationship between milk quality and color in a multidimensional manner.

This study results indicates that Jersey milk has a lighter and brighter color. Increased lightness is generally associated with high fat content, as milk fat reflects more light. Therefore, the high fat content in Jersey milk caused the milk to appear lighter in tone (Walstra et al., 1999). The a* value was negative in both breeds, indicating that the color tone was on the greenish-reddish axis.

Chroma indicates the saturation and vividness of color; this result shows that Jersey milk has a more vivid, rich, and saturated color tone. In general, Jersey milk appears to have a creamier-yellow tone due to its high fat and carotenoid content, while Holstein milk appears to have a whiter tone due to its low fat and pigment concentration. These differences are important in terms of the dairy processing industry and consumer preferences. The rich, yellowish color of Jersey milk is preferred, especially in cheese and butter production, while the lighter color of Holstein milk may be more advantageous in pasteurized milk and yogurt production (Mishra et al., 2022; Özkan and Çelik, 2023).

Analysis conducted in the CIELAB color space revealed a significant color difference between Jersey and Holstein cow milk, with a ΔE value of 5.355. Although this difference is not statistically significant, it is perceptible to the human eye and is particularly attributable to an increase in the b* parameter. The increase in the b* value indicates that the yellow color tone (positive b* axis) is more dominant in Jersey milk.

This situation can be explained by the accumulation of lipophilic pigments specific to the Jersey breed (particularly β-carotene and other carotenoid derivatives) at higher levels in the milk fat phase. Jersey cows have a higher capacity to metabolize carotenoids obtained from feed and store them in milk fat compared to Holstein breeds. Therefore, Jersey milk appears optically more yellow and bright due to its higher milk fat content (4.8–5.2%) and more concentrated carotenoid content.

This obtained ΔE value is above the acceptability threshold (≈3.0–4.0) defined in the CIELAB color difference literature, indicating a difference that is perceptible to the human eye. The fact that this difference originates primarily from the b* component indicates that the color difference is "chromatic" in nature (a difference in hue), meaning it stems from a deviation along the yellow-blue axis rather than changes in brightness (L*) or the red-green axis (a*).

In general, the increased yellow tone observed in Jersey milk is biochemically related to carotenoid metabolism, milk fat composition, and pigment solubility. This finding can be considered not only a physical color difference but also a visual indicator of metabolic differences between breeds. Furthermore, the fact that the yellowish tone, which is associated with the perception of "naturalness" and "nutritional value" in dairy products, is more pronounced in Jersey milk can be interpreted as a sensory advantage that could influence product preferences.

Conclusion

In this study, the relationships between color parameters (L*, a*, b*) and milk components (% fat, % protein, % lactose, % non-fat solids, % ash) in milk from Holstein and Jersey breeds were examined, and statistically significant differences were determined.

According to the analysis results, a significant relationship was found between color parameters and four of the six basic milk content characteristics examined (fat content, protein content, SNF, and lactose content) ($p<0.05$). In Jersey milk, the L* (lightness value) and b* (yellow tone) values were found to be significantly higher than in Holstein milk; this is due to the high fat content and carotenoid (especially β-carotene) content in Jersey milk. In contrast, Holstein milk had a relatively low a* (red-green axis) value and a higher L* value, indicating that the milk had a whiter tone.

In conclusion, color variations in milk from different cattle breeds are not only an aesthetic factor but also an important indicator in terms of nutritional content, biochemical composition, and technological quality.

In this respect, milk color is one of the fundamental parameters that should be considered both for quality control in production processes and for product evaluation in consumer perception.

References

Auldist, M. J., Johnston, K. A., White, N. J., Fitzsimons, W. P., & Boland, M. J. (2004). A comparison of the composition, coagulation characteristics and cheesemaking capacity of milk from Friesian and Jersey dairy cows. *Journal of Dairy Research,* 71(1), 51–57. https://doi.org/10.1017/S0022029903006575

Belitz, H. D., Grosch, W., & Schieberle, P. (2004). Milk and Dairy Products. In *Food Chemistry* (pp. 505–550). Springer.

Bobe, G., Beitz, D. C., Freeman, A. E., & Lindberg, G. L. (2004). Effect of milk composition on butter composition and properties. *Journal of Dairy Science,* 87(4), 100–111. https://doi.org/10.3168/jds.S0022-0302(03)73913-7

Cheng, Y., Zhang, H., & Li, X. (2021). Effect of cow breed and diet on milk color and composition. *Journal of Dairy Science,* 104(7), 7852–7864.

Chung, Y. J., Kim, D. H., & Lee, S. J. (2017). Relationship between milk color and chemical composition in different dairy breeds. *Journal of Dairy Science,* 100(3), 2114–2122.

Claycomb, R. W., Munro, P. A., & Singh, H. (2014). Influence of milk composition on dairy product functionality. *International Dairy Journal,* 35(2), 153–160.

Costa, A., Lopez-Villalobos, N., & Penasa, M. (2019). Genetic and environmental variation of milk coagulation properties in Holstein–Friesian and Jersey cows. *Animals,* 9(10), 780.

Espada, E. B., Vijverberg, H., McLean, J., Sinclair, M., & West, B. (2002, March 20–22). Milk colour analysis as a tool for the detection of abnormal milk. In *First North American Conference on Robotic Milking* (pp. IV-28–IV-38). Toronto, Canada.

Fernández-Vázquez, R., Stinco, C. M., Meléndez-Martínez, A. J., Heredia, F. J., & Vicario, I. M. (2011). Visual and instrumental evaluation of orange juice colour: A consumers' preference study. *Journal of Sensory Studies,* 26, 436–444.

Fox, P. F., & McSweeney, P. L. H. (2015). *Advanced dairy chemistry: Volume 3 – Lactose, water, salts and minor constituents*. Springer.

Göncü, S. (2000). *Adana Entansif Süt Sığırcılığı İşletmelerinde Yetiştirilen Saf ve Melez Siyah Alaca İnek Sütlerinde Somatik Hücre Sayısına Etki Eden Faktörler ve Mastitis ile İlişkisi* [Unpublished doctoral dissertation]. Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Adana, Türkiye.

Guinee, T. P., and O'Brien, B. (2010). *The Quality Of Milk For Cheese Manufacture*. In B. A. Law and A. Y. Tamime (Eds.), *Technology of Cheesemaking* (2nd ed., pp. 1–67). Wiley-Blackwell. https://doi.org/10.1002/9781444323740.ch1

Havemose, M. S., Weisbjerg, M. R., & Bredie, W. L. P. (2004). Influence of feeding different types of roughage on the oxidative stability of milk. *International Dairy Journal,* 14, 563–570.

Heck, J. M. L., van Valenberg, H. J. F., Dijkstra, J., & van Hooijdonk, A. C. M. (2009). Seasonal variation in milk composition and its effect on the quality of semi-hard cheese. *Dairy Science & Technology,* 89(1), 1–21.

Jensen, S. K., Johannsen, A. K. B., & Hermansen, J. E. (1999). Quantitative secretion and maximal secretion capacity of retinol, β-carotene and α-tocopherol into cows' milk. *Journal of Dairy Research,* 66, 511–522.

Karagül, H., & Şahin, E. (2021). Farklı sığır ırklarına ait sütlerde renk özelliklerinin karşılaştırılması. *Türk Tarım ve Doğa Bilimleri Dergisi,* 8(2), 157–164.

Kelsey, J. A., Corl, B. A., Collier, R. J., & Bauman, D. E. (2003). The effect of breed, parity, and stage of lactation on conjugated linoleic acid (CLA) in milk fat. *Journal of Dairy Science,* 86(8), 2588–2597. https://doi.org/10.3168/jds.S0022-0302(03)73854-5

Kılıç, M., & Erdem, H. (2020). Somatic cell count effects on milk composition and color in dairy cows. *Turkish Journal of Veterinary and Animal Sciences,* 44(2), 145–152.

Kuczyńska, B., Puppel, K., Gołębiewski, M., & Grodzki, H. (2012). Differences in milk protein fraction contents between Polish Holstein-Friesian and Jersey cows. *Acta Scientiarum Polonorum Zootechnica,* 11(4), 37–46.

Lakade, A. J., Sundar, K., & Shetty, P. H. (2017). Nanomaterial-based sensor for the detection of milk spoilage. *Lebensmittel-Wissenschaft & Technologie,* 75, 702–709.

Leon, K., Mery, D., Pedreschi, F., & Leon, J. (2006). Color measurement in L* a* b* units from RGB digital images. *Food Research International,* 39(10), 1084–1091.

Martin, B., Verdier-Metz, I., Buchin, S., Hurtaud, C., & Coulon, J. B. (2019). Cow breed and cow diet effects on milk composition and cheese flavor. *Lait,* 79(1), 403–420.

Mishra, A., Patel, K., & Sahu, S. (2022). Comparative study of milk color and composition in Jersey and Holstein Friesian cows. *International Journal of Dairy Technology,* 75(4), 1021–1030.

Niero, G., Penasa, M., & Cassandro, M. (2020). Milk composition traits and cheese-making properties in Holstein and Jersey cows. *Journal of Dairy Science,* 103(5), 4290–4300.

Nozière, P., Graulet, B., Lucas, A., Martin, B., Grolier, P., & Doreau, M. (2006). Carotenoids for ruminants: From forages to dairy products. *Animal Feed Science and Technology,* 131, 418–450.

O'Callaghan, T. F., Hennessy, D., McAuliffe, S., & O'Donovan, M. (2016). Influence of cow feeding systems on milk composition and quality. *Journal of Dairy Research,* 83(4), 468–475.

Özkan, M., & Çelik, Y. (2023). Süt rengi ve bileşimi üzerine ırk ve besleme faktörlerinin etkisi. *Ulusal Zootekni Araştırmaları Dergisi,* 4(1), 25–34.

Park, J. Y., Jeon, S. H., & Kim, H. J. (2020). Evaluation of milk color and composition in relation to fat content. *Asian-Australasian Journal of Animal Sciences,* 33(10), 1634–1642.

Popov-Raljić, J. V., Lakić, N. S., Laličić-Petronijević, J. G., Barać, M. B., & Sikimić, V. M. (2008). Colour changes of UHT milk during storage. *Sensors,* 8, 5961–5974.

Santos, P. M., Wentzell, P. D., & Pereira-Filho, E. R. (2012). Scanner digital images combined with colour parameters: A case study to detect adulterations in liquid cow's milk. *Food Analytical Methods,* 5, 89–95.

Walstra, P., Geurts, T. J., Noomen, A., Jellema, A., & van Boekel, M. A. J. S. (1999). *Dairy technology: Principles of milk properties and processes*, CRC Press.

Yıldız, N., & Uzmay, C. (2020). Süt kalitesi ve somatik hücre sayısının süt rengi üzerine etkileri. *Ege Üniversitesi Ziraat Fakültesi Dergisi,* 57(3), 421–429.