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ARAŞTIRMA MAKALESİ

Investigation of Correlations Between Color, Texture and Physico-chemical Properties in Yogurts

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Abstract

The aim of this study is to investigate the correlations between color parameters, textural and physicochemical properties of yogurt samples sold in Erzurum province. The samples were taken from yogurt produced in local dairy farms in Erzurum province and sold in markets. The yogurt samples were subjected to instrumental color and texture analysis, and the results were evaluated using descriptive and Pearson correlation analyses. The results of the statistical analysis showed that there were significant correlations between the properties compared. Highly significant positive correlations were found between the dry matter and a*, b*, C* and ΔE values, and between pH and the color parameters of L*, a*, C* and ΔE in the yogurt samples. Conversely, significant negative correlations were found between the water holding capacity (WHC) of the samples and the textural properties of adhesiveness, springiness, and cohesiveness values. In this study, the textural and physicochemical properties of locally produced yogurts sold in Erzurum were also comprehensively characterized.

Yoğurtlarda Renk, Doku ve Fiziko-Kimyasal Özellikler Arasındaki Korelasyonların İncelenmesi

Özet

Bu çalışmanın amacı, Erzurum ilinde satışa sunulan yoğurt örneklerinin renk parametreleri ile tekstürel ve fizikokimyasal özellikleri arasındaki korelasyonları araştırmaktır. Örnekler, Erzurum ilindeki süt işleme fabrikalarında üretilip satışa sunulan yoğurtlardan alınmıştır. Yoğurt örneklerinin enstrümantal renk ve tekstür analiz sonuçları deskriptif ve pearson korelasyon analizleri kullanılarak değerlendirilmiştir. İstatistiksel analiz sonuçları, incelenen özellikler arasında önemli korelasyonlar olduğunu ortaya koymuştur. Yoğurt örneklerinde kuru madde miktarı ile a*, b*, C* ve ΔE renk parametreleri arasında ve pH değeri ile L*, a*, C* ve ΔE renk parametreleri arasında önemli pozitif korelasyonlar tespit edilmiştir. Ayrıca, su tutma kapasitesi (WHC) ile yapışkanlık, elastikiyet ve kohezyon değerleri arasında önemli negatif korelasyonlar belirlenmiştir. Bu çalışma ile Erzurum'da satışa sunulan yerel üretim yoğurtların tekstürel ve fizikokimyasal özellikleri de kapsamlı bir şekilde karakterize edilmiştir.

Introduction

Yogurt is known as a fresh fermented dairy product with health-promoting effects. It has now become a universally consumed food all over the world. Yogurt is produced by fermenting milk with bacterial strains *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus* (Bakırcı et al., 2017; Aktaş et al., 2022). These strains are defined as part of bacteria (LAB) family that ferment lactose in milk into the end product lactic acid (Tabora et al., 2024). LAB are known for their antimicrobial, antiviral and immunomodulatory properties, and have been successfully used in the treatment of many digestive system diseases.

Yogurt serves as a model for research into nutrition and human health and plays a key role in studies investigating their relationship. The potential health benefits of regular yogurt consumption include controlling high blood pressure and cholesterol levels (Fernandez and Maretta, 2017), improving lactose digestion and reducing the symptoms of lactose intolerance, strengthening the immune system (Guarner et al., 2005), promoting digestion, reducing the risk of intestinal infections (Liu et al., 2011), helping weight control and preventing obesity (Cormier et al., 2016) and preventing type 2 diabetes (O'Connor et al., 2014). Furthermore, *S. thermophilus*, in particular, has probiotic potential due to its moderate persistence and survivability in the gastrointestinal tract (Gobbetti and Calasso, 2014). Yogurt bacteria have been found to partially fulfill the criteria for being classified as probiotic bacteria due to their various health benefits. Yogurt is considered a probiotic food due to its positive effect in reducing lactose intolerance symptoms (Guarner et al., 2005). Yogurt is rich in essential nutrients, especially some minerals and vitamins, and is a highly nutritious and easily digestible dairy product. Yogurt proteins have high biological value and provide almost all essential amino acids for maintaining good health (Weerathilake et al., 2014).

Color is one of the components that influence the appearance of food; however, it is not the only factor. It is a common misconception that the color of food is the most important factor influencing consumer choice (Hutchings, 2002). The textural parameters are also important factor in consumer acceptance. The texture of yogurt is affected by many factors. These include the composition of the milk, its fat and dry matter content, the type of starter culture and the storage time (Paseephol et al., 2008). The color of food can be used to predict the potential taste and texture of the food, as well as expected satisfaction. The appearance of food raises consumers expectations. In fact, consumer choice is determined by a hierarchy of appearance characteristics, of which color is only one component. These components guide the consumer towards choice and acceptance (Hutchings, 2002).

The demand for yogurt consumption is growing rapidly due to the health benefits of lactic acid bacteria and increasing consumer awareness of the importance of gut bacteria. Consumers are now aware that yogurt is a healthy food. In addition to being a healthy food, yogurt is also a preferred food in terms of delivering probiotic bacteria to humans. In this study, yogurt samples produced in different dairies in Erzurum province were examined in terms of color and texture parameters. This study aims to identify possible correlations between the color parameters of yogurt and various physicochemical properties. Another aim of the study is to analyze the correlations between the texture parameters of yogurts and the physicochemical properties and to determine how certain properties differ depending on the situation. This study will also contribute to the literature by investigating the relationships between

color, texture and physicochemical properties of yogurt.

Materıals and Methods

Materials

A total of 24 yogurt samples from different producers were purchased from retail markets in Erzurum province. The yogurts included in the study were standard commercial yogurts. The yogurts were brought to our laboratory via cold chain and analyzed for physicochemical and textural properties.

Methods

Physicochemical Analysis

The dry matter (DM) of the yogurt samples was determined by subjecting the samples to a drying process at 103 °C until a constant weight was achieved. The fat content was determined using the Gerber method according to AOAC (1995). Water holding capacity (WHC) was determined according to the method described by Turgut and Diler (2023). Each yogurt sample (10 g) was subjected to a centrifugal process (4500×g for 30 min at 4 °C). The filtrate was weighed, and the WHC value was calculated according to the formula:

$$WHC(\%) = [1 - \frac{filtrate\ weight}{initial\ weight}] \times 100 \quad \textbf{(1)}$$

The pH of the yogurts was measured using a digital table pH meter (Hanna, Portugal). The determination of titratable acidity (TA) was expressed in terms of lactic acid according to the method described by Kurt et al. (1996). Each sample (10 g) was diluted with 10 mL of distilled warm water, and subsequently titrated with NaOH (0.1 N). The titration was conducted using 0.5 mL of phenolphthalein employed as an indicator. TA (%) was calculated using the following formula:

$$TA\ (\%) = \frac{V\ (mL\ NaOH) \times 0.009}{m} \times 100 \quad \textbf{(2)}$$

Color Analysis

The color parameters of the yogurt samples were determined using a PCE XXM-20 colorimeter (PCE Instruments, Germany). The results were expressed as L*a*b* values according to the CIELAB color space system under LED illumination. Measurements were performed in 2 cm high plastic containers. The parameters are defined as follows: L scale: Luminosity (from 0-50 to 51-100, dark-light), a scale: (from +a* to -a*, red-green), and b scale: (from +b* to -b*, yellow-blue). In addition, the color difference (ΔE), the chroma (C*) (CIEHLC color space) and the yellowing index (YI) were determined according to the following equations. ΔE is used to define the difference between the color of each sample and the ideal whiteness pattern, while the chroma C* value indicates the color intensity.

$$\Delta \mathbf{E} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad \textbf{(3)}$$

$$\boldsymbol{C}^* = \sqrt{(a^*)^2 + (b^*)^2} \quad \textbf{(4)}$$

$$\mathbf{YI} = 142.86.\, b^*.\, L^{-1} \quad \textbf{(5)}$$

L* represents lightness, a* represents redness, and b* represents yellowness, $\Delta a^* = a_0 - a_i$, $\Delta b^* = b_0 - b_i$, and $\Delta L^* = L_0 - L_i$. The color parameters of the white standard were used as reference values (L_0: 100, a_0: 0, b_0: 0). These parameters provide a quantitative assessment of the color properties of the yogurt and allow comparison with standards or other samples.

Texture Analysis

The texture analysis of the yogurts was performed according to the methods of Turgut and Diler (2023) by means of a TA-XT Plus texture analyser (Stable Micro Systems, UK) equipped with a 500 g load cell. The yogurt samples were subjected to analysis upon their removal from the

refrigerator. A compression test was performed using extruded aluminum cylindrical probe with a diameter of 25 mm (P/25P). The testing speed was 1.0 mm/s until reaching a depth of 30 mm. The speed of the probe during compression and relaxation of the sample was set to 1 mm/s. The basic texture parameters, which include hardness, springiness, adhesiveness, cohesiveness, fracturability, gumminess and resilience, were calculated using exponent software (Exponent, version 4.0.9.0, Stable Micro System). All analyses were performed in duplicate.

Statistical Analysis

Statistical analyses were carried out using SPSS 20.0 for Windows OS. Descriptive statistical analyses including mean, standard error, minimum and maximum values, variance, and coefficient of variation were calculated for the data obtained in the study. Pearson correlation analysis between pairs of response variables was performed to determine the significance of the linear relationship**.**

Results and Discussion

Physicochemical properties

The results of some physicochemical analysis of the yogurt samples are presented in Table 1. The dry matter of the yogurt samples showed a variation of 10.75% - 16.84%, with a mean value of 13.62%. The dry matter values determined in the study are similar to the results of Gürbüz et al. (2023) and are compatible with the average DM reported by them (18.86%). The whiteness of the yogurt is due to the components of the dry matter, such as milk fat and casein. The correlations between DM and the a* and b* color values of the yogurt samples were strong (r = 0.565 and r = 0.541, respectively). The average fat content of the yogurts was determined to be 3.56%, with the lowest and highest values ranging from 1.7% to 5.70% (Table 1). The coefficient of variation of the fat content was quite high. This shows that the yogurt samples on the market are not uniform in terms of fat content. Only 29.16% of the yogurt samples tested had a fat content of 3.8% or more and thus meet the criteria for full-fat yogurt (Anon, 2022). The correlations between the fat content and the color parameters of the yogurt were insignificant (Table 2). This phenomenon can be attributed to the presence of a limited quantity of carotenoid pigments such as carotene and xanthophyll, which are responsible for the coloration of the milk fat. The pH of the yogurt samples ranged from 3.82 to 4.30, with a mean value of 4.09. The coefficient of variation of the pH values was found to be low (2.95%), indicating that the pH of the yogurts was relatively homogeneous. Although the relationship between pH, color and quality has been demonstrated in red meat (Qiao et al., 2001), this relationship has not yet been investigated in yogurts. High positive correlations were found between the pH of yogurt samples and the color parameters (L* and a*). This result is important because it can be used as an indicator to estimate the number of bacteria in yogurts. Donkor et al. (2006) stated that yogurt bacteria are responsible for lowering pH and increasing acidity of yogurt. Similar findings were reported by Öztürk and Öner (1999) and Bakırcı and Kavaz (2008).

Table 1. Physicochemical, textural, and color properties of yogurt samples

	N	Mean ±SD	Variance	Minimum	Maximum	Coefficient of variation (%)
Physicochemical Properties						
Dry matter (%)	24	13.62±1.81	3.28	10.75	16.84	13.29
WHC (%)	24	49.19±6.39	40.86	36.48	59.27	13.00
pH	24	4.09±0.12	0.01	3.82	4.30	2.95
Fat (%)	24	3.56±0.98	0.96	1.70	5.70	27.49
Fat/Dry matter (%)	24	26.27±6.44	41.44	11.97	36.76	24.51
Textural properties						
Hardness	24	-0.43±13.23	175.05	-8.41	41.67	-3064.72
Adhesiveness	24	-61.05±47.74	2279.53	-142.38	-1.26	-78.20
Springiness	24	0.98±0.02	0.00	0.94	1.00	1.60
Cohesiveness	24	0.88±0.05	0.00	0.76	0.95	5.63
Gumminess	24	-0.51±11.76	138.37	-7.09	35.24	-2325.57
Resilience	24	0.20±0.16	0.03	0.03	0.48	78.98
Color properties						
L*	24	85.44± 1.22	1.48	83.29	87.48	1.42
a*	24	-42.19±2.28	5.19	-46.67	-38.52	-5.40
b*	24	7.59±0.93	0.86	5.80	9.77	12.23
C*	24	42.87±2.23	4.96	39.48	47.12	5.20
ΔE	24	45.29±2.36	5.55	42.25	49.77	5.20
YI	24	12.69±1.54	2.39	9.52	16.13	12.17

SD: Standard deviation

The WHC value is one of the quality parameters of yogurt and the higher the WHC value, the higher the quality of the yogurt (Gyawali and İbrahim, 2016). The WHC value is linked to the dry matter content of the yogurt. Higher WHC values may be associated with a higher DM content. The mean WHC value of the yogurts was determined to be 49.19%, with the lowest and highest values ranging from 36.48% to 59.27%. Significant positive and negative correlations were found between the WHC value and the color parameters L*, a*, C* and ΔE value. The whiteness in yogurt is caused by the presence of colloidal particles such as milk fat globules and casein micelles, which can scatter light in the visible spectrum. Pretreatments of the milk significantly change the light-reflecting properties of the yogurt. The WHC values obtained in this study were lower than those reported by Karaca et al. (2012) and Falah et al. (2021). However, the results were similar to those reported by Bakırcı et al. (2017).

Color analysis

Table 1 gives an overview of the color parameters of the yogurt samples. The color of yogurt is considered an indicator of quality, freshness, expected flavor and acceptability. The color of yogurts is directly influenced by the types of milk used (Yılmaz Ersan and Topçuoğlu, 2022). In general, consumers demand for food products is primarly determined by its appearance. Appearance, including color, plays an important role in food selection and preference. In addition to the impact on the overall acceptability of the food, the possible relationship between the color parameters and other

characteristics of the food should not be ignored. The color of foods has been reported to be related to its taste or texture properties (Jaros and Rohm, 2001). Color is an essential factor in consumer preference and is often used to determine the sensory quality of yogurts. The L* values of the yogurts varied between 83.29 and 87.48, and the mean value was 85.44. The low coefficient of variation of the L* values (1.42%) shows that the yogurts are relatively homogeneous in their lightness. The L* values were not influenced by the fat content. The ΔE values were high for all yogurt samples. These results show that all yogurt samples have an attractive degree of lightness. The a* values of the yogurts, corresponding to the position on the red-green axis, varied between -46.67 and -38.52; the average a* value was -42.19. The b* values varied between 5.80 and 9.77, and the average value was found to be 7.59. The fact that the coefficients of variation of the a* and b* values of the yogurt samples are larger than those found for the L* value confirms the color distribution in the yogurts. This may be due to the different sizes of the fat globules in the yogurts, as well as the effect of acidity. The b* values confirm the presence of a yellowish color in yogurts. All color parameters of the yogurt samples except the L* value were influenced by the DM content.

Table 2. Pearson correlation coefficients and probabilities of yogurt samples between physiochemical and color properties

	WHC	pH	Fat (%)	Fat/DM	L*	a*	b*	C*	ΔE	YI
Dry Matter	0.423	0.391	0.338	-0.189	0.088	0.565	0.541	-0.527	-0.486	0.529
p-value	0.040	0.059	0.107	0.375	0.681	0.004	0.006	0.008	0.016	0.008
WHC		0.342	0.160	-0.071	0.594	0.716	-0.039	-0.723	-0.745	-0.107
p-value		0.102	0.454	0.742	0.002	0.001	0.857	0.001	0.001	0.617
pH			-0.088	-0.301	0.515	0.492	0.203	-0.478	-0.513	0.140
p-value			0.682	0.152	0.010	0.015	0.342	0.018	0.010	0.514
Fat (%)				0.856	-0.094	-0.010	-0.007	0.008	0.023	0.004
p-value				0.001	0.662	0.962	0.974	0.969	0.914	0.987
Fat/Dry Matter					-0.133	-0.307	-0.296	0.286	0.278	-0.279
p-value					0.534	0.144	0.160	0.176	0.189	0.186
L*						0.583	0.064	-0.582	-0.688	-0.049
p-value						0.003	0.768	0.003	0.001	0.820
a*							0.114	-0.997	-0.988	0.049
p-value							0.596	0.001	0.001	0.821
b*								-0.040	-0.046	0.994
p-value								0.853	0.830	0.001
C*									0.991	0.025
p-value									0.001	0.907
ΔE										0.031
p-value										0.886

L*: lightness, from 0 to 100 (lightness); a*: redness, from - a* to + a* (green- red); b*: yellowness, from – b* to +b* (blue- yellow); ΔE: color difference; C*: chroma; YI: yellowing index

Table 2 summarizes the Pearson correlation coefficients and probabilities (p) between the yogurt response variables. Highly positive correlations ($r = 0.545$, $p<0.0004$) and ($r = 0.541$, $p<0.0006$) were found between the a* value and DM content, and between the b* value and DM content, respectively. This indicates that reddening and yellowing increase with increasing DM content. A negative

correlation (r = -0.527, p<0.0008) was found between the C* value and DM content. This shows that the DM content is inversely proportional to the color intensity to a certain extent. The chroma C* value indicates the distance from the center of the axes. The higher the DM content, the less intense the color of the yogurt. Scibisz et al. (2019) stated that color intensity and color stability are related to the acidity in yogurt. The study found a negative correlation (r = -0.478, p<0.018) between the chroma C* value and the pH of yogurts. The L* and a* values of the yogurt samples showed a significant positive correlation with acidity (p<0.05). This result is consistent with the findings of Jaros and Rohm (2001).

Textural Analysis

Physicochemical analyses were performed to obtain evidence that supporting texture profile analysis (TPA) of yogurt samples. The texture of yogurt is principally influenced by factors such as the pH of the yogurt, the amount of dry matter, fat and protein, the heating process, homogenization, the use of stabilisers, and the type of starter culture (Yılmaz Ersan and Topçuoğlu 2022). The evaluation of the texture of a yogurt is an important indicator of its quality and plays an important role in consumer perception and satisfaction (Akalın et al., 2012, Cheng et al., 2017). The TPA values of the yogurt samples are summarized in Table 1.

Table 3. Pearson correlation coefficients and probabilities of yogurt samples between physiochemical and textural properties

	WHC	pH	Fat (%)	Fat/ DM	Hardness	Adhesiveness	Springiness	Cohesiveness	Gumminess	Resilience
DM (%)	0.42	0.391	0.338	-0.189	-0.100	-0.217	-0.233	-0.182	-0.101	-0.343
p-value	0.04	0.059	0.107	0.375	0.642	0.333	0.298	0.418	0.654	0.118
WHC (%)		0.342	0.160	-0.071	0.200	-0.728	-0.813	-0.561	0.257	-0.734
p-value		0.102	0.454	0.742	0.349	0.001	0.001	0.007	0.249	0.001
pH			-0.088	-0.301	-0.031	-0.541	-0.565	-0.565	-0.029	-0.591
p-value			0.682	0.152	0.886	0.009	0.006	0.006	0.897	0.004
Fat (%)				0.856	-0.051	0.432	0.202	0.235	-0.052	0.369
p-value				0.001	0.814	0.045	0.366	0.292	0.819	0.091
Fat/ DM					-0.021	0.572	0.325	0.350	-0.025	0.559
p-value					0.921	0.005	0.139	0.111	0.912	0.007
Hardness						-0.380	-0.141	-0.097	1.000	-0.128
p-value						0.081	0.531	0.666	0.001	0.571
Adhesiveness							0.854	0.700	-0.382	0.921
p-value							0.001	0.001	0.079	0.001
Springiness								0.859	-0.147	0.899
p-value								0.001	0.515	0.001
Cohesiveness									-0.108	0.748
p-value									0.632	0.001
Gumminess										-0.130
p-value										0.564

Hardness, defined as the force required to achieve specific deformation, is an important factor in determining the quality of yogurt. If the hardness value is higher, the yogurt is firmer (Yılmaz Ersan and Topçuoğlu 2022). The coefficient of variation of hardness values has been found quite high. This shows that the yogurt samples on the market are not the same in terms of hardness. In present study, no significant correlation was found between the hardness value and physicochemical

parameters. Adhesiveness is a degree of the stickiness of yogurts. The adhesiveness value was negatively correlated with the physicochemical properties (WHC and pH), ($-0.73 \leq r \leq -0.54$), but was positively correlated with fat/DM ($r = 0.57$). Springiness is another most important parameter in determinig the texture of food product. Strong negative correlations were found between springiness and WHC values ($r = -0.727$, $p<0.001$), and springiness and pH ($r = -0.541$, $p< 0.009$). The coefficient of variation for springiness was found to be quite low. This shows that the yogurt samples on the market are similar in terms of springiness. The cohesiveness value showed negative correlations with the physicochemical parameters (DM, WHC and pH) with ($-0.565 \leq r \leq 0.182$).

Conclusion

In this study, the existence of relationships between color and texture parameters and physicochemical values of yogurt samples was investigated. Significant correlations were found between the instrumental characterization of the yogurt samples and the physicochemical results. The correlations between the color parameters of the samples and the DM content of the yogurts were strong; however, these correlations were weak in relation to the fat content. It is therefore evident that there is still a lack of information on the relationship between color analysis and yogurt quality.

The correlations between the WHC of the samples and the DM content of the yogurts were weak, and a similar weakness was found in the correlations between the pH and the WHC of the yogurts. It was noted that there were correlations between some of the texture analysis results of the yogurts and the WHC and pH values. There were highly negative correlations between the adhesiveness, springiness, cohesiveness, and resilience values of the samples and the WHC and pH values of the yogurts, but these correlations were not strong for hardness.

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