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Effects of lyophilized red cabbage water extract and pH levels on the quality properties of pastırma cemen paste during chilled storage

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ABSTRACT

Pastırma is a dry-cured and dried meat product and its coating with a paste defined as “cemening” is one of the most important stages in the formation of its color and quality. However, discoloration is an important problem during production and storage. In this study, the effects of lyophilized red cabbage water extracts (LRCWE; 0.0%, 0.4%, 0.8% and 1.2%) and pH values (4.0, 4.5, 5.0, 5.5 and 6.0) on the color quality and storage stability of the pastırma cemen paste during chilled storage (4 ± 0.5 °C for 90 days) were investigated. LRCWE contain high amounts of phenolic compounds and anthocyanins. Addition of LRCWE and low pH values improved color properties of the pastırma cemen paste ($P < 0.01$). The best results for the a* value were determined in cemen paste with 1.2% LRCWE. The most effect of the LRCWE was determined in low pH values cemen paste (4.0 and 4.5), thus, pH levels below 5.0 were determined as the threshold value for the effectiveness of extract in pastırma cemen paste. In addition, color stability was maintained better in low pH values cemen paste during storage. By lowering the pH values of the pastırma cemen paste, the color quality was preserved and discoloration during storage was prevented.
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1. Introduction

“Cemening” is a process used for coating of salted or dry-cured meats in the production of pastırma. The paste used for cemening is defined as "cemen paste". In the cemening process, after dry-curing the dried or salted meats and the two drying and pressing processes are completed, the meats are kept in cemen paste at 7 °C for 4–5 days, then the excess paste around the meat is removed, and a thin layer (2–3 mm) remains on the surface of meat and the addition of cemen paste is completed (Aksu et al., 2017). In addition, the cemening process provides a water-salt balance between meat and cemen paste, and the amount of salt in the salted meat is reduced. One of the most important steps in the formation of pastırma quality is the cemening process, and with the cemening process, the typical taste/aroma formation specific to the pastırma is provided as well as improving the color quality and palatability of the pastırma. Additionally, cemen paste affects the free amino acid composition of pastırma (Ceylan and Aksu, 2011).

The main ingredients in cemen paste production are *Trigonella foenum graecum* (fenugreek) seed flour, garlic, paprika, red pepper and water, but their usage rates can vary depending on the producers (Cetin et al., 1996; Aksu et al., 2006, Aksu et al., 2016; Hastaoglu and Vural, 2018). The composition of cemen paste used in pastırma production per kg is generally 500 g fenugreek seed flour, 350 g garlic, 75 g paprika, 75 g red papper and 1200 ml water (Aksu and Kaya 2002, 2005; Aktaş et al., 2005; Erdemir and Aksu, 2017). “Cemen" or “cemen paste” has been described as "fenugreek" in many studies. However, “fenugreek” is the name of the plant *Trigonella foenum graecum* L. Therefore, in this research, the term “cemen paste” was used instead of “fenugreek” due to the compositional differences (Doğruer et al., 1998; Yetim et al., 2017). So, in this paper, the term “cemen paste” is the fenugreek seed flour plus garlic, paprika, red pepper and water.

The color of cemen paste that affects the color quality of the pastırma is due to the red pepper included in its composition. If the red pepper does not have the desired quality and properties, the color of the cemen paste becomes pale and the pastırma allure and quality decreases. Therefore, synthetic food coloring is often used in the production of cemen paste for pastırma, and its color features are improved. In this context, the necessity of adding synthetic food coloring to the cemen paste is emphasized (Kök, 1985). In recent

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research, the use of natural dyes in foods is recommended as the use of synthetic dyes negatively affects human health, and it is emphasized that the best source of color is natural colorants (Jensen et al., 2011; Patras, 2019; Aksu et al., 2020).

Color pigments found in various fruits and vegetables of natural origin include compounds such as betalain, anthocyanin, carotenoid and chlorophyll (Jensen et al., 2011). Anthocyanins are the best natural food dyes that provide bright red color formation in many foods. Due to these properties, it has been stated that anthocyanins can be used as an alternative to synthetic dyes in the coloring of many foods (Giusti and Wrolstad, 2003). The color properties of anthocyanins range from blue to red depending on the pH value being blue at high pH value and red at low pH value. In addition, red cabbage is interesting for consumers not only because of its intense red/purple color, but also because it has important nutritional, oxidative stability and flavor values (Wiczkowski et al., 2015). In this context, anthocyanins are an important alternative natural source for cemen paste, but the pH value (5.9–6.0) of the pastırma cemen paste does not provide the desired redness feature. Therefore, it is important to determine the effects of anthocyanin-rich red cabbage extract on the color values of the pastırma cemen paste with different pH values, and the most suitable level of lyophilized red cabbage water extract for pastırma cemen paste. There are some previous studies on cemen paste quality using natural plant, fruit and vegetable extracts. In one study, it was determined that the use of carrot, red cabbage and black grape extracts in cemen production affects the CIE L*, a*, b* color values of cemen paste stored for 21 days (Yetim et al., 2010). In other studies conducted by Aksu et al. (2015), Aksu et al., 2016 and Aksu et al. (2020), various properties of red cabbage extract were determined and their utilization in cemen paste production was investigated. However, the fact that cemen paste with different extracts in these studies all had same pH prevented the determination of the behavior of anthocyanins. Therefore, there is a deficiency of literature on this subject. The aim of this study was to determine the effect of different levels of lyophilized red cabbage water extract (LRCWE), pH values and storage time on the color quality and stability, and storage stability of the pastırma cemen paste. The current research has the feature of being the first in determining the effect of LRCWE on pastırma cemen paste produced at different pH values.

2. Materials and methods

2.1. Materials

Red cabbage (*Brassica oleracea var. capitata f. rubra*), *Trigonella foenum graecum* L. seed flour, fresh garlic, powdered paprika and powdered hot red pepper were used as cemen materials and the materials were all these purchased at the different store from Erzurum, Turkey.

2.2. Obtaining lyophilized red cabbage water extracts (LRCWE)

After cleaning and washing the red cabbage, it was broken into 1–2 mm pieces in a kitchen mixer (Sinbo SHB- 3042, Turkey). After adding 400 mL of water to 20 g of cabbage, it was homogenized using an Ultra-turrax homogenizer (IKA T25 Werk, Germany), then kept on a magnetic stirrer (Hanna-Hi 190 M, Singapore) for 20 min and filtered through Whatman No: 1 filter paper. The amount of water of the obtained filtrate was reduced with a rotary evaporator (Heidolph Laborota 4000, Germany), then frozen at −38 °C and lyophilized (Freeze dryer, Christ alpha 1–2 LD plus, Germany) at −50 °C. The extracts obtained were kept at refrigerator temperature until use (Alp and Aksu, 2010).

2.3. Production of cemen paste and storage

The procedure of production and storage of cemen paste was given in Fig. 1. Cemen paste was prepared as a mixture of *Trigonella foenum graecum* L. seed flour, fresh garlic, powdered paprika, powdered hot red pepper and water (Aksu and Kaya, 2005). Cemen paste prepared according to Fig. 1 was filled in 250 mL sterilized jars. A total of 320 jars of cemen paste was produced, 64 jars of cemen paste for each group with different pH values. The cemen pastes were stored at 4 ± 0.5 °C for 90 days.

2.4. Chemical analyses

DPPH radical scavenging activity, metal chelating activity, total anthocyanin content, total phenolic content, color, titratable acidity and pH analyses were performed on LRCWE used in cemen paste production. Color, pH and moisture analyses of the produced cemen paste were carried out on the 0th, 30th, 60th and 90th days of storage.

2.4.1. Determination of moisture, titration acidity, and pH

The moisture, titration acidity and pH values of LRCWE and cemen pastes produced with these extracts were analyzed according to Cemeroğlu (2010). Moisture content was determined by drying method and 2–3 g sample for extracts and for 10–12 g sample for cemen paste was dried at 100 ± 2 °C until constant weighing was achieved. Titratable acidity (on the basis of citric acid) was determined by titration with 0.1 N NaOH using phenolphthalein as the indicator. The pH values measurement was performed using a calibrated pH-meter with buffer solutions (pH 4.0 and pH 7.0).

2.4.2. Determination of color

The color values of LRCWE and cemen paste samples are measured with a Minolta Chroma Meter CR400 (Ø11mm, Minolta, Co., Ltd., Osaka, Japan) using pulsed xenon lamp (Illuminant D65) as a source of light. CIE Lab (Commision Internationele de l'eClairage) L* (0 = darkness, 100 = lightness), a* (+60 = red, −60 = green) and b* (+60 = yellow, −60 = blue) values were determined as indicators of lightness, redness and yellowness, respectively (Cakici et al., 2015).

2.4.3. Determination of total phenolic compound

Total phenolic compound of LRCWE was analyzed according to Singleton et al. (1999) and calculated as mg/Gallic acid equivalent (GAE)/100 g. Briefly, 1 mL of extract was transferred to each test tube. Subsequently, 500 μL Folin-Ciocalteu and 250 μL Na_2CO_3 (20%) solutions were added and the total volume was adjusted to 10 mL with distilled water. The mixtures were kept at room temperature for 30 min in the dark and the absorbance measurements were performed against the control at 760 nm via spectrophotometer.

2.4.4. Determination of total monomeric anthocyanin

Total monomeric anthocyanin amounts of LRCWE used in the production of cemen paste of pastırma were determined using the method described by Lee et al. (2005). Based on the pH differential procedure, the principle of dilution of the extract with the convenient proportions of potassium chloride (0.025 M, pH 1.0) and sodium acetate (0.4 M, pH 4.50) buffer solutions was followed. Results were calculated mg cyanidine 3 - glucoside per kg.

2.4.5. Determination of metal chelation ratio

Metal chelation ratio analyses were performed according to the method reported by Bursal and Gulcin (2011). Different

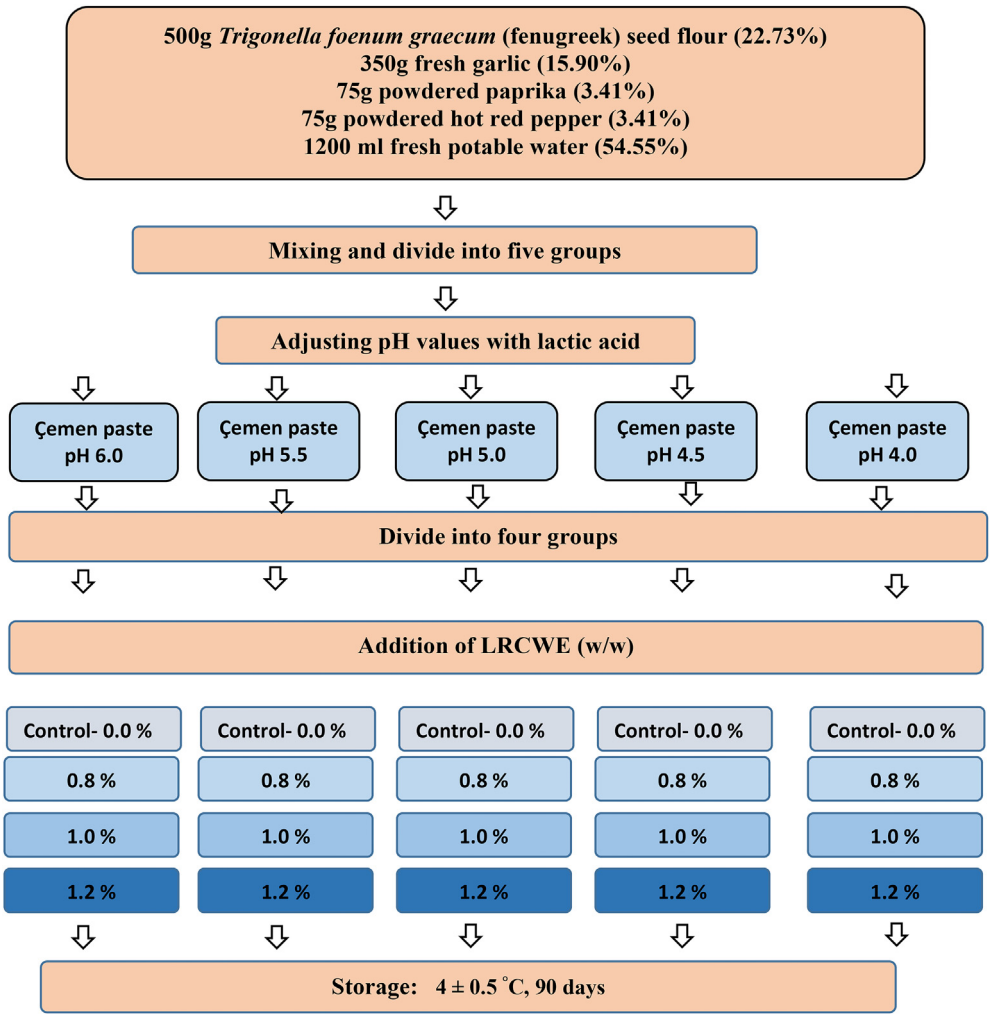

Fig. 1. Production and storage stages of çemen paste with lyophilized red cabbage water extract (LRCWE). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

concentrations of LRCWE (0, 100, 200 and 300 μL) were mixed with 0.125 mL $FeSO_4$.7 H_2O, 0.500 mL Tris–HCl buffer (pH 7.4) and 0.500 mL 2,2′ - bipyridine solutions. The total volume of the mixture was adjusted to 3 mL with distilled water, and then the mixture was incubated at room temperature for 10 min. The absorbance was measured at 522 nm and the results were calculated as equivalent to BHA (butylated hydroxyanisole), BHT (butylated tydroxytoluene) and Tocopherol.

2.4.6. Determination of free radical scavenging ability DPPH

Determination of free radical activity of LRCWE samples were performed according to Blois (1958), and the results were calculated as mmol Trolox Equivalent/100 g and IC50 (μg). Shortly after, different extract dilutions of LRCWE (0, 300, 600 and 900 μL from 1 mg/mL stock solution) were transferred to glass tubes and then final volume was adjusted to 3 mL volume with ethanol. Subsequently, 500 μL of DPPH (0.1 mM) solution was added and the mixtures were mixed thoroughly. Absorbance was determined at 517 nm via a spectrophotometer after waiting 30 min in the dark at room temperature.

2.4.7. Statistical analysis

The results were analyzed by SPSS 20.0 statistical package. A completely randomized design was employed with two replicate. The model included pH levels (4.0, 4.5, 5.0, 5.5 and 6.0), extract levels (0.0%, 0.4%, 0.8% and 1.2%) and storage time (0, 30, 60 and 90 days) as main effects. Comparisons of means was made using the Duncan's Multiple Range Test and statistical significance was determined within the 95% confidence interval ($P < 0.05$). The results of statistical analysis are shown as mean value ± standard deviation in tables.

3. Results and discussion

3.1. Lyophilized red cabbage water extracts

The average pH and titratable acidity of LRCWE were determined as 5.58 and 1.21% citric acid, respectively. The pH values (5.52 ± 0.02) of the LRCWE obtained in the study conducted by Aksu et al. (2020) are compatible with our findings, but the researchers found the titration acidity values in the previous study higher (1.96 ± 1.16%). The pH and acidity value of the extracts are an important factor in determining the quality and color properties, as they show different color properties depending on the pH value. However, there may be partial differences in pH and acidity values in parallel with the quality and ripening characteristics of red cabbage (Aksu et al., 2020); these differences are reflected in the extracts.

The L* and a* color values of LRCWE were found in the present study as 22.74 ± 0.40 and 20.58 ± 0.66, respectively. On the other hand, the b* value expressing the yellowness of its positive value and blue value of its negative value was determined to be negative (−14.42 ± 0.29). The color properties of anthocyanins range from blue to red depending on the pH value (Jensen et al., 2011). Color turns blue at high pH values and red at low pH values, and anthocyanins are red colored compounds. Therefore, a* values of LRCWE were determined as positive values. On the other hand, red cabbage anthocyanins may turn purple at neutral pH values and/or neutral solutions. This approach is one reason why b* values of LRCWE are negative. Therefore, red cabbage is also described as purple cabbage, depending on its levels of ripening and harvest time. In other studies conducted by us, similar L*, a* and b* values were determined for LRCWE (Aksu et al., 2015, 2020).

The total amount of phenolic substances (1664.01 ± 18.25 mg GAE/100g) and DPPH radical scavenging activity (17.02 ± 0.06 mmol TE/100 g, 564.59 ± 1.93 μg IC50) detected in LRCWE was higher than in other research findings. These values were determined as 100.49 ± 4.66 mg GAE/g for total amount of phenolic substances and 79.21 ± 1.91% for DPPH radical scavenging capacity by Aksu et al. (2015). In the current study, the metal chelating activity of LRCWE was determined as 43.14 ± 3.40 mg BHA/100 g, 81.48 ± 6.41 mg BHT/100 g, and 14.38 ± 1.13 mg Tocopherol/100g. The presence of phenolic substances in plants or extracts has significantly been associated with antioxidant capacities (Demirdöven et al., 2015; Mizgier et al., 2016). The amount of anthocyanin of LRCWE were found in the present study as 1313.64 ± 9.64 mg cyanidine 3 - glucoside/100 g. These results showed that LRCWE has a content rich in anthocyanin. Therefore, it confirms the hypothesis that this extract can be used as an alternative to synthetic colored materials in the food industry. Anthocyanins are also compounds that have a positive biological contribution to human health and increase the oxidative stability of foods. Aksu et al. (2020) reported that the total monomeric anthocyanin values of LRCWE were 4712.70 ± 73.94 mg/kg and 5522.50 ± 86.64 mg/kg cyanidine 3 - glucoside and malvidine - 3 - glucoside, respectively. In terms of these parameters, different results between studies are due to the use of cabbage grown in different agronomic conditions (Wiczkowski et al., 2015).

3.2. Pastırma cemen paste

Color values determined during storage in the pastırma cemen paste produced with the addition of different amounts of LRCWE into the cemen paste with different pH levels are shown in Table 1 pH level of cemen paste x amounts of LRCWE x storage time interactions had a significant ($P < 0.01$) effect on the L* (Fig. 2), a* (Fig. 3) and b* (Fig. 4) values of cemen paste. The pH values had a significant effect ($P < 0.01$) on the L* value of cemen paste, and the L* decreased due to the pH values increase ($P < 0.05$). Yetim et al. (2017) examined the effects of food juices and additives on various quality characteristics of cemen paste and found that the addition of food juices decreased the pH of the cemen paste and the L* value changed. The researchers determined that L* values were 29.04 ± 1.88 in control cemen paste (pH 5.60) and 29.39 ± 0.35 and 26.68 ± 0.26 in cemen paste produced by adding citric acid (pH 4.31) and salgam juice (pH 5.32), respectively. These results show that the effect of each acid on pH of the cemen paste is different. The low L* value in cemen paste produced with the addition of salgam juice, produced by lactic acid fermentation, is in parallel with our research findings. Similarly, Walkowiak-Tomczak and Czapski (2007) emphasized that the color properties of the red cabbage solution (20 mg anthocyanins/100 ml) changed depending on the pH value. In the same research determined that low pH values, temperature and anaerobic environment are also advantageous in terms of color stability during storage for 30 days.

The use of LRCWE in cemen paste and storage time significantly ($P < 0.01$) affected L* values. Depending on the amounts of extract added and storage time, the L* value of cemen paste decreased

Table 1
Mean values and Duncan Multiple Comparison Test results ($p < 0.05$) of L*, a*, b*, pH and moisture of cemen paste produced with different amounts of LRCWE and different pH values.

Treatments	L*	a*	b*	pH value	Moisture (%)
pH values of çemen paste					
4.00	46.21 ± 2.93^{b}	19.12 ± 1.71^{a}	32.29 ± 3.95^{b}	4.15 ± 0.08^{e}	65.84 ± 0.77^{e}
4.50	46.89 ± 2.62^{a}	16.83 ± 1.30^{b}	32.62 ± 3.64^{a}	4.55 ± 0.06^{d}	66.81 ± 0.52^{d}
5.00	46.13 ± 3.09^{b}	12.81 ± 1.35^{c}	29.48 ± 3.62^{c}	5.03 ± 0.09^{c}	67.21 ± 0.54^{c}
5.50	43.72 ± 3.02^{c}	11.08 ± 1.68^{e}	26.56 ± 3.43^{d}	5.58 ± 0.11^{b}	68.62 ± 1.50^{b}
6.00	42.51 ± 3.57^{d}	11.24 ± 2.02^{d}	26.32 ± 3.88^{d}	5.90 ± 0.07^{a}	70.79 ± 0.27^{a}
SEM	0.099	0.034	0.085	0.001	0.143
P	**	**	**	**	**
Extract Level					
Control (0.0%)	48.49 ± 2.77^{a}	13.80 ± 2.58^{d}	34.17 ± 3.80^{a}	5.06 ± 0.69^{a}	67.73 ± 2.26
0.4%	46.05 ± 2.55^{b}	14.06 ± 3.24^{c}	30.76 ± 2.81^{b}	5.04 ± 0.66^{c}	67.73 ± 1.59
0.8%	43.64 ± 1.95^{c}	14.31 ± 3.92^{b}	27.54 ± 2.89^{c}	5.04 ± 0.64^{b}	68.04 ± 1.90
1.2%	42.19 ± 2.72^{d}	14.69 ± 4.44^{a}	25.35 ± 2.89^{d}	5.03 ± 0.62^{d}	67.90 ± 1.91
SEM	0.088	0.031	0.076	0.001	0.128
P	**	**	**	**	NS
Storage Time (Days)					
0	46.16 ± 4.12^{a}	16.41 ± 2.80^{a}	29.57 ± 5.60^{b}	4.95 ± 0.65^{d}	67.83 ± 1.75
30	43.71 ± 3.43^{c}	13.92 ± 3.41^{b}	29.99 ± 4.35^{a}	5.07 ± 0.69^{b}	–
60	45.23 ± 3.02^{b}	13.43 ± 3.62^{c}	29.08 ± 3.97^{c}	5.12 ± 0.63^{a}	–
90	45.26 ± 2.79^{b}	13.10 ± 3.62^{d}	29.18 ± 4.21^{c}	5.04 ± 0.63^{c}	67.88 ± 2.07
SEM	0.088	0.031	0.076	0.001	0.065
P	**	**	**	**	NS

a-e: Any means in the same column and the same section with the same letters are not significantly different at $P < 0.05$.
SEM: Standard error of means.
±: Standard deviation, **$P < 0.01$, NS: Non significant $P > 0.05$.

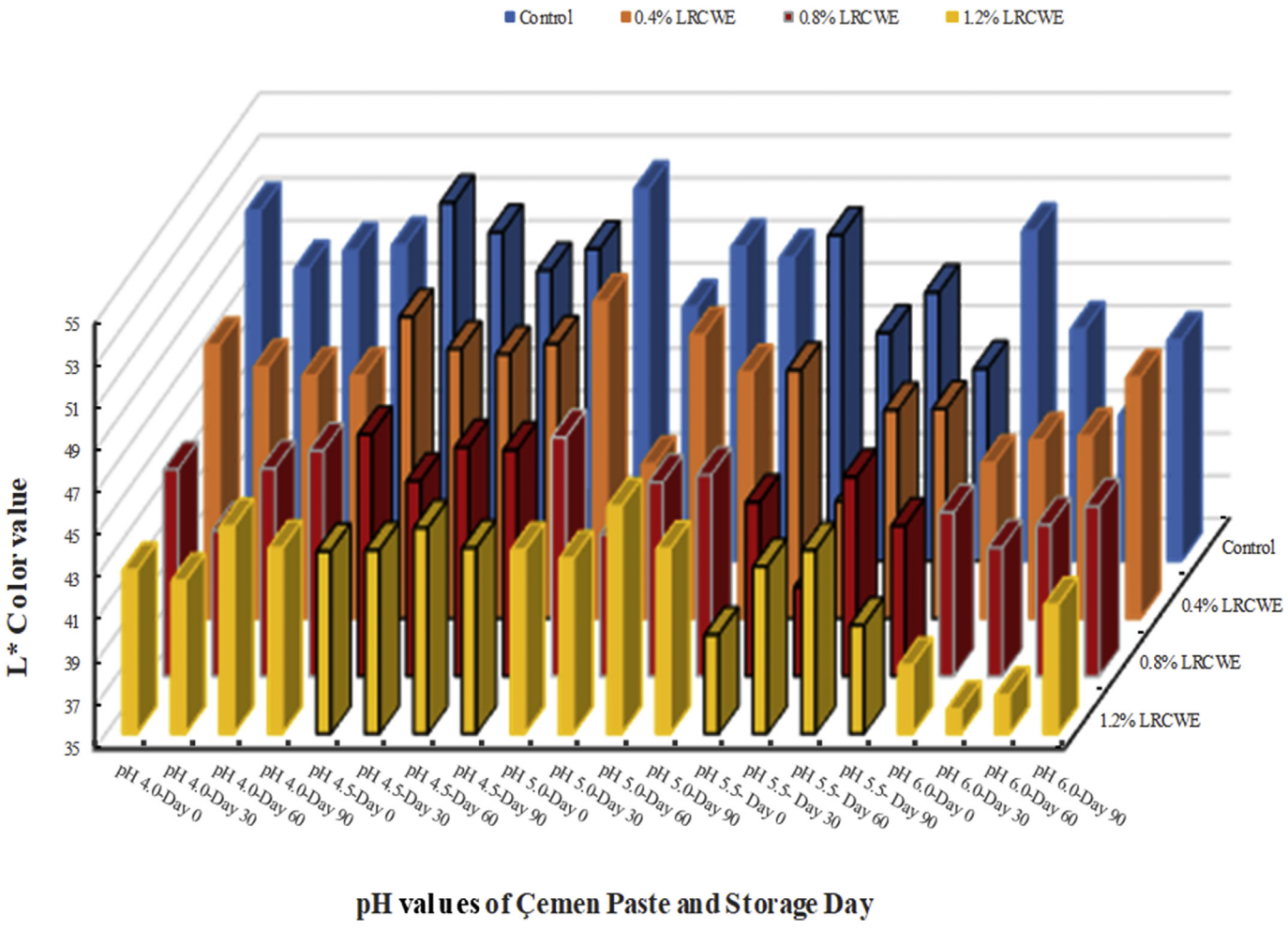

Fig. 2. The effect of pH values of cemen paste x levels of LRCWE x storage time interaction on the L* color value. LRCWE: Lyophilized Red Cabbage Water Extract. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

($P < 0.05$) (Table 1). As seen in Table 2, the L* values of extract added cemen paste are lower than control cemen paste at all pH values. It is thought that the decrease of L* value in cemen paste due to the addition of extracts is caused by the extracts with binding the water and reducing the brightness. In cemen paste with pH values of 4.0 and 4.5, the L* value remained more stable during storage. However, there was variability during storage in higher pH values cemen paste groups (Table 2). The L* value decreased on the 30th day of storage in the control samples and groups with 0.4% and 0.8% LRCWE, afterwards increased partially, and was more stable in the group with 1.2% LRCWE (Fig. 2). As seen in Table 2, the L* value was affected by all treatment groups. The greatest effect was observed in the cemen paste group where pH was 6.0. The lowest mean L* value for this group was determined on the 30th day of storage in the group with the addition of 1.2% LRCWE (Table 1). Since cemen paste structure takes time to fully form, cemen paste is usually chilled for a day after preparation and then used for pastırma production. In this process, a tighter and more conservative structure is formed. The addition of the extract made this structure tighter, thus reducing the brightness of the cemen paste. Işıklı and Karababa (2005) stated that the fenugreek paste had structural changes in time and the structure showed rheopectic behavior. Similar changes were determined during the 30 - day storage of cemen paste prepared by Yetim et al. (2017). Researchers stated that the cemen paste has a spreadable texture and the substances used to increase the color characteristics of the paste have a significant effect on the textural properties of the final product (Yetim et al., 2017). It has been seen in the current research results that the brightness of the cemen paste has been significantly affected by pH, extract levels and storage time. This is thought to be due to a reflection of the structural formation differences in the cemen pastes.

It was determined that the pH levels of cemen paste, extract levels and storage times had significant effects ($P < 0.01$) on the a* color value of cemen paste (Table 1). The a* value is an important quality criterion desired both in cemen paste and pastırma. For this reason, synthetic dyes are used in pastırma and cemen paste production as stated in the introduction. As it is known, the pH value is important for the effectiveness of color substances or components (Aksu et al., 2020). In this context, it was seen in this study that natural color substances such as anthocyanins are more effective at low pH values than high pH values. In parallel with this literature knowledge, in this study, due to the pH decrease in cemen paste, the mean a* value increased (Table 1). Another factor that increases redness values of cemen paste in this research is the addition of extracts. As the amount of LRCWE in cemen paste increased, the a* value also increased. It was determined that LRCWE increased the a* value in all cemen paste with different pH values (Fig. 3). As seen in Table 3, the effect of different amounts of extract was more pronounced in the low pH cemen paste. Considering the general

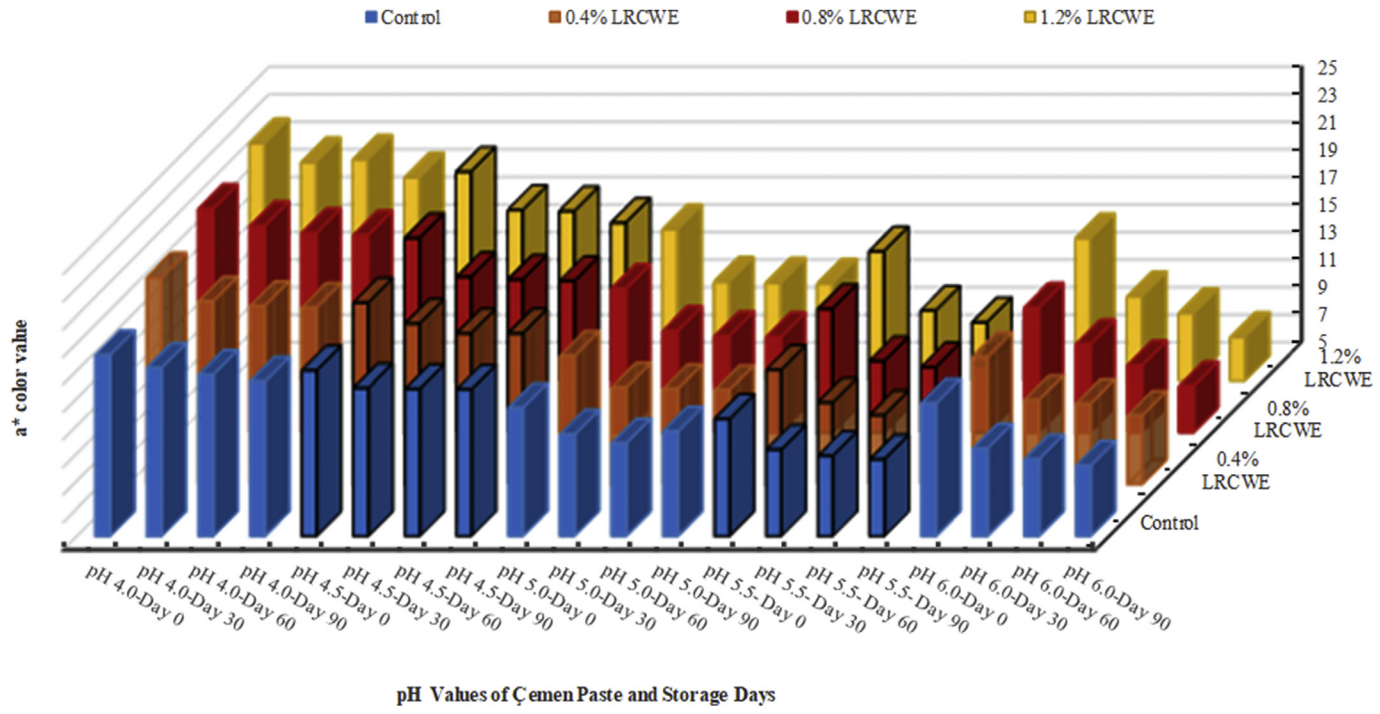

Fig. 3. The effect of pH values of cemen paste x levels of LRCWE x storage time interaction on the a* color value. LRCWE: Lyophilized Red Cabbage Water Extract. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

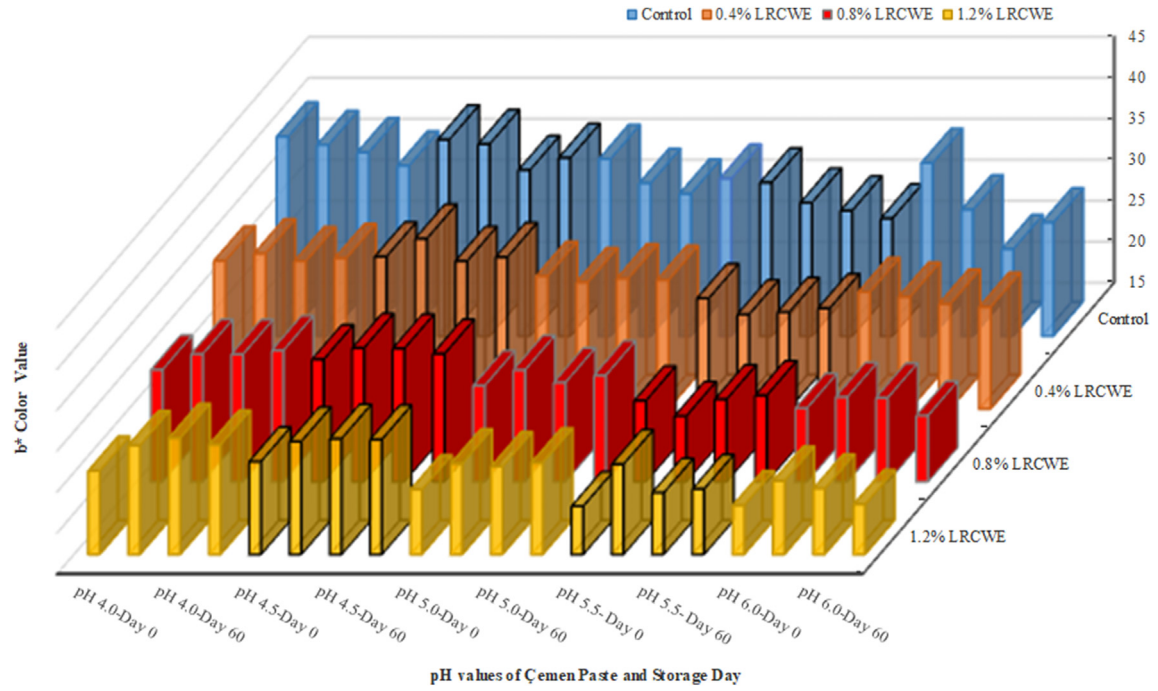

Fig. 4. The effect of pH values of cemen paste x levels of LRCWE x storage time interaction on the b* color value. LRCWE: Lyophilized Red Cabbage Water Extract. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

cemen paste composition produced in the research, it can be said that the threshold value for pH is < 5.0 to reveal the effectiveness of the color substances. Because the effect of red pepper, which gives red color to cemen paste, on a* value was limited in pH 5.0, 5.5 and 6.0 cemen paste, it was more in pH 4.0 and 4.5 (Table 3). In the research carried out by Aksu et al. (2016b), it was emphasized that the a* values increased in the cemen paste (pH 5.99 ± 0.12) produced with the addition of LRCWE, so that it can be used in the production of cemen paste. In these studies, it was emphasized that lowering the pH of the extracts can be an effective factor in increasing the a* value. However, it was emphasized by Aksu (2016) that the effects of extracts on color quality should be investigated in

Table 2
The L* values and Duncan Multiple Comparison Test results ($p < 0.05$) of cemen pastes produced with different amounts of LRCWE and different pH values during the 90 days of storage at 4 ± 0.5 °C.

pH Values	LRCWE* Levels	Storage Times (days)			
		0	30	60	90
4.00	**Control**	51.45 ± 0.50^{bA}	48.74 ± 3.21^{bB}	49.57 ± 2.82^{aB}	49.83 ± 1.82^{aB}
	0.4%	47.83 ± 0.90^{eAB}	46.80 ± 2.53^{cdBC}	46.40 ± 2.63^{cdC}	48.40 ± 1.70^{abA}
	0.8%	44.72 ± 1.05^{gA}	41.83 ± 2.76^{ghiB}	44.75 ± 4.26^{defA}	45.59 ± 1.90^{cdeA}
	1.2%	42.68 ± 0.80^{hiBC}	42.17 ± 4.34^{ghiC}	44.84 ± 1.38^{defA}	43.72 ± 1.59^{ghAB}
4.50	**Control**	51.83 ± 0.56^{abA}	50.44 ± 1.38^{aB}	48.65 ± 1.51^{abC}	49.66 ± 2.02^{aB}
	0.4%	49.17 ± 0.59^{dA}	47.67 ± 1.71^{bcB}	47.42 ± 3.35^{bcB}	47.91 ± 2.10^{bB}
	0.8%	46.36 ± 0.56^{fA}	44.17 ± 1.85^{efB}	45.75 ± 2.85^{deA}	45.63 ± 0.97^{cdeA}
	1.2%	43.58 ± 0.68^{hA}	43.63 ± 2.44^{fgA}	44.67 ± 2.09^{efA}	43.74 ± 2.39^{ghA}
5.00	**Control**	52.47 ± 0.77^{aA}	46.91 ± 3.22^{cdC}	49.74 ± 1.36^{aB}	49.25 ± 2.57^{abB}
	0.4%	49.88 ± 0.55^{cdA}	42.24 ± 3.87^{ghiD}	48.31 ± 2.13^{abB}	46.56 ± 1.87^{cC}
	0.8%	46.21 ± 0.72^{fA}	41.67 ± 2.78^{hiC}	44.10 ± 3.22^{efB}	44.45 ± 2.42^{efghB}
	1.2%	43.62 ± 0.90^{hB}	43.23 ± 2.39^{fghB}	45.69 ± 1.61^{deA}	43.69 ± 2.91^{ghB}
5.50	**Control**	50.31 ± 1.13^{cA}	45.70 ± 2.58^{deC}	47.62 ± 2.26^{bcB}	44.03 ± 2.90^{fghD}
	0.4%	46.67 ± 1.90^{fA}	40.50 ± 2.62^{ijC}	44.80 ± 2.82^{defB}	44.85 ± 2.12^{defgB}
	0.8%	43.17 ± 2.88^{hiAB}	39.18 ± 2.69^{jC}	44.36 ± 2.17^{efA}	42.06 ± 2.35^{ijB}
	1.2%	39.65 ± 2.39^{jB}	42.86 ± 1.81^{fghA}	43.63 ± 1.81^{fgA}	40.10 ± 3.30^{kB}
6.00	**Control**	50.49 ± 1.35^{cA}	45.87 ± 3.46^{dB}	41.84 ± 2.25^{hC}	$45.37 \pm 2.20^{\ cdefB}$
	0.4%	42.30 ± 3.90^{iB}	43.36 ± 3.20^{fghB}	43.56 ± 2.88^{fgB}	46.33 ± 2.53^{cdA}
	0.8%	42.69 ± 1.83^{hiAB}	41.03 ± 2.64^{iB}	42.10 ± 3.45^{ghAB}	42.97 ± 3.06^{hiA}
	1.2%	38.21 ± 2.58^{kB}	36.15 ± 2.59^{kC}	36.81 ± 3.13^{iBC}	41.05 ± 2.82^{jkA}

* LRCWE: Lyophilized red cabbage water extracts.
a-k: Means with different lowercase letters in the same column compare the different pH and extract levels and show significant differences at $P < 0.05$.
A-D: Means with different capital letters in the same row compare the storage times and show significant differences at $P < 0.05$.
±: Standard deviation.

Table 3
The a* values and Duncan Multiple Comparison Test results ($p < 0.05$) of cemen pastes produced with different amounts of LRCWE and different pH values during the 90 days of storage at 4 ± 0.5 °C.

pH Values	LRCWE* Levels	Storage Times (days)			
		0	30	60	90
4.00	**Control**	18.14 ± 0.45^{eA}	17.20 ± 0.50^{dB}	16.70 ± 0.59^{eC}	16.23 ± 0.67^{deD}
	0.4%	20.00 ± 0.39^{cA}	18.26 ± 0.68^{cB}	17.93 ± 0.65^{cBC}	17.81 ± 0.52^{cD}
	0.8%	21.21 ± 0.46^{bA}	19.95 ± 0.50^{bB}	19.44 ± 0.92^{bC}	19.29 ± 0.84^{bC}
	1.2%	22.21 ± 0.32^{aA}	20.83 ± 0.96^{aB}	21.02 ± 0.56^{aB}	19.73 ± 0.55^{aC}
4.50	**Control**	17.02 ± 0.32^{fA}	15.73 ± 0.48^{gB}	15.66 ± 0.62^{gB}	15.61 ± 0.71^{fB}
	0.4%	18.16 ± 0.23^{eA}	16.64 ± 0.51^{eB}	15.93 ± 0.48^{fgC}	15.93 ± 0.53^{efC}
	0.8%	19.09 ± 0.39^{dA}	16.27 ± 0.62^{fB}	16.08 ± 0.54^{fB}	15.97 ± 0.52^{efB}
	1.2%	20.14 ± 0.39^{cA}	17.37 ± 0.42^{dB}	17.29 ± 0.44^{dB}	16.44 ± 0.54^{dC}
5.00	**Control**	14.29 ± 0.47^{jA}	12.37 ± 0.40^{hB}	11.72 ± 0.39^{iC}	12.59 ± 0.45^{gB}
	0.4%	14.31 ± 0.49^{jA}	12.01 ± 0.64^{hB}	11.91 ± 0.32^{hiB}	11.82 ± 0.35^{iB}
	0.8%	15.41 ± 0.43^{hA}	12.35 ± 0.48^{hB}	11.96 ± 0.54^{hiC}	11.90 ± 0.40^{hC}
	1.2%	15.97 ± 0.58^{gA}	12.16 ± 0.45^{hB}	12.09 ± 0.31^{hB}	12.04 ± 0.54^{hB}
5.50	**Control**	13.50 ± 0.50^{lA}	11.26 ± 0.42^{ijB}	10.81 ± 0.39^{jC}	10.55 ± 0.56^{jC}
	0.4%	13.29 ± 0.41^{lA}	10.91 ± 0.71^{jB}	9.99 ± 0.54^{kC}	10.10 ± 0.37^{kC}
	0.8%	13.95 ± 0.56^{kA}	10.16 ± 0.42^{kB}	9.72 ± 0.39^{kC}	9.91 ± 0.44^{kBC}
	1.2%	14.35 ± 0.40^{jA}	10.07 ± 0.33^{kB}	9.22 ± 0.33^{lC}	9.43 ± 0.52^{lC}
6.00	**Control**	14.63 ± 0.39^{iA}	11.35 ± 0.88^{iB}	10.56 ± 0.56^{jC}	10.12 ± 0.62^{kD}
	0.4%	14.25 ± 0.76^{jA}	11.09 ± 0.58^{ijB}	10.83 ± 0.50^{jB}	9.97 ± 0.49^{kC}
	0.8%	14.05 ± 0.66^{jkA}	11.38 ± 0.80^{iB}	9.86 ± 0.45^{kC}	8.35 ± 0.58^{mD}
	1.2%	14.31 ± 0.70^{jA}	11.10 ± 0.54^{ijB}	9.87 ± 0.34^{kC}	8.16 ± 0.63^{mD}

* LRCWE: Lyophilized red cabbage water extracts.
a-m: Means with different lowercase letters in the same column compare the different pH and extract levels and show significant differences at $P < 0.05$.
A-D: Means with different capital letters in the same row compare the storage times and show significant differences at $P < 0.05$.
±: Standard deviation.

the cemen paste with different pH.

The average a* values of cemen paste decreased during storage; the a* value which was 16.41 ± 2.80 at the beginning of storage decreased to an average of 13.10 ± 3.62 at the end the 90 - day storage period (Table 1). The highest reduction in all of the cemen paste with different pH was determined in the first 30 days of storage (Table 1). In the cemen paste with pH 6.0, a decrease was observed during storage compared to other cemen paste groups (Table 3). The a* value of cemen paste with pH 4.0, 4.5, 5.0, 5.5 and 6.0 decreased 2.13, 2.61, 2.90, 3.78 and 5.16 units, respectively, between 0 and 90 days of storage. The a* value of cemen paste with control (0.0%), 0.4%, 0.8% and 1.2% LRCWE decreased during storage. In all cemen paste produced by adding different amounts of extracts, the a* value decreased most between 0 and 30 days of storage. In longer storage periods, there was limited difference among cemen paste groups with or without extract in terms of a* value (Fig. 3). As seen in Table 3, the a* values of 0.8% and 1.2% extract added cemen paste were higher at low pH values (pH 4.0 and pH 4.5). Also, the highest a* values were determined in these groups than other groups regardless of pH during storage. These

Table 4
The b* values and Duncan Multiple Comparison Test results ($p < 0.05$) of cemen pastes produced with different amounts of LRCWE and different pH values during the 90 days of storage at 4 ± 0.5 °C.

pH Values	LRCWE* Levels	Storage Times (days)			
		0	30	60	90
4.00	**Control**	39.37 ± 0.66^{aA}	38.34 ± 1.49^{aB}	37.42 ± 1.53^{aC}	35.83 ± 1.62^{bD}
	0.4%	33.10 ± 0.77^{dAB}	33.98 ± 1.63^{cA}	33.04 ± 1.69^{cB}	33.40 ± 1.57^{cAB}
	0.8%	28.69 ± 0.51^{hB}	30.59 ± 1.18^{dA}	30.57 ± 1.81^{deA}	31.03 ± 1.55^{dA}
	1.2%	25.23 ± 0.56^{jC}	28.34 ± 1.87^{eB}	29.23 ± 1.06^{fA}	28.40 ± 0.95^{fgB}
4.50	**Control**	39.00 ± 0.44^{aA}	38.44 ± 1.05^{aA}	35.27 ± 1.75^{bC}	36.76 ± 1.55^{aB}
	0.4%	33.61 ± 0.48^{cdB}	35.79 ± 1.43^{bA}	33.06 ± 0.98^{cB}	33.54 ± 1.38^{cB}
	0.8%	29.94 ± 0.51^{fC}	31.32 ± 1.46^{dA}	31.24 ± 1.09^{dAB}	30.61 ± 1.14^{dB}
	1.2%	26.35 ± 0.54^{iB}	28.79 ± 0.63^{eA}	29.13 ± 1.01^{fA}	29.03 ± 1.28^{efA}
5.00	**Control**	36.63 ± 0.83^{bA}	33.70 ± 1.12^{cB}	32.40 ± 1.07^{cC}	34.23 ± 0.83^{cB}
	0.4%	31.22 ± 0.77^{eA}	30.46 ± 1.59^{dB}	30.92 ± 0.91^{deAB}	30.73 ± 1.13^{dAB}
	0.8%	26.75 ± 0.69^{iB}	28.66 ± 1.79^{eA}	27.12 ± 1.18^{hB}	27.99 ± 1.07^{ghA}
	1.2%	22.93 ± 0.86^{lB}	26.11 ± 1.15^{fgA}	25.58 ± 1.05^{iA}	26.21 ± 1.41^{iA}
5.50	**Control**	33.75 ± 1.15^{cA}	31.30 ± 1.09^{dB}	30.34 ± 0.98^{eC}	29.39 ± 2.18^{eD}
	0.4%	28.51 ± 0.71^{hA}	26.54 ± 1.36^{fC}	26.83 ± 1.37^{hBC}	27.28 ± 1.29^{hB}
	0.8%	24.91 ± 1.17^{jA}	23.03 ± 1.71^{iB}	25.06 ± 1.25^{iA}	25.55 ± 1.14^{iA}
	1.2%	20.89 ± 0.94^{mC}	26.02 ± 0.83^{fgA}	22.54 ± 0.63^{jB}	22.99 ± 1.01^{jB}
6.00	**Control**	36.15 ± 0.97^{bA}	30.45 ± 2.71^{dB}	25.63 ± 1.70^{iD}	28.90 ± 2.17^{efC}
	0.4%	29.27 ± 1.21^{gA}	28.69 ± 1.65^{eA}	27.83 ± 1.13^{gB}	27.45 ± 1.33^{hB}
	0.8%	24.00 ± 1.58^{kB}	25.35 ± 1.59^{gA}	25.25 ± 1.11^{iA}	23.08 ± 1.75^{jC}
	1.2%	21.01 ± 1.50^{mC}	23.99 ± 1.79^{hA}	23.05 ± 0.83^{jB}	21.12 ± 1.82^{kC}

* LRCWE: Lyophilized red cabbage water extracts.
a-m: Means with different lowercase letters in the same column compare the different pH and extract levels and show significant differences at $P < 0.05$.
A-D: Means with different capital letters in the same row compare the storage times and show significant differences at $P < 0.05$.
±: Standard deviation.

results show that cemen paste with low pH values had higher color stability during storage. Torskangerpoll and Andersen (2005) reported that cyanidin 3 - (2″ - (2‴- sinapoylglucosyl) - 6″ - sinapoylglucoside) - 5 - glucoside as anthocyanin showed higher color stability in solutions with pH 4.1 and 5.1 over 98 days storage. Stintzing et al. (2006) determined that the color tones formed by mixing the extracts containing anthocyanin and betalain content were best at pH 4.0 and 5.0. Yetim et al. (2010) reported that the a* value decreased during storage (at 4 °C for 21 days) of cemen paste produced by adding 20 ppm red cabbage extract.

With increasing pH values of cemen paste, b* values decreased (Table 1). The b* value, which was determined as an average of 34.17 ± 3.80 in control cemen paste, decreased to an average of 25.35 ± 2.89 in cemen paste with 1.2% extract. This value has partially increased between 0 and 30 days of storage then decreased, but did not change between 60 and 90 days (Fig. 4). Similar changes were observed in the research carried out by Aksu et al., 2016, where the b* value decreased as the extract added to the cemen paste increased. The b* value of the cemen paste gradually decreased as the extract levels added in all cemen paste with

Table 5
The pH values and Duncan Multiple Comparison Test results ($p < 0.05$) of cemen pastes produced with different amounts of LRCWE and different pH values during the 90 days of storage at 4 ± 0.5 °C.

pH Values	LRCWE[a] Levels	Storage Times (days)			
		0	30	60	90
4.00	**Control**	3.99 ± 0.01^{qD}	4.06 ± 0.01^{rC}	4.16 ± 0.01^{tA}	4.13 ± 0.01^{rB}
	0.4%	4.02 ± 0.01^{pD}	4.08 ± 0.01^{qC}	4.20 ± 0.01^{sA}	4.16 ± 0.01^{qB}
	0.8%	4.11 ± 0.02^{nD}	4.17 ± 0.01^{pC}	4.26 ± 0.01^{rA}	4.20 ± 0.01^{pB}
	1.2%	4.08 ± 0.01^{oC}	4.21 ± 0.01^{oB}	4.28 ± 0.01^{qA}	4.21 ± 0.01^{oB}
4.50	**Control**	4.50 ± 0.01^{lD}	4.56 ± 0.01^{lB}	4.67 ± 0.01^{mA}	4.54 ± 0.01^{nC}
	0.4%	4.46 ± 0.01^{mD}	4.52 ± 0.01^{nC}	4.65 ± 0.00^{nA}	4.55 ± 0.01^{mB}
	0.8%	4.46 ± 0.01^{mD}	4.52 ± 0.01^{nC}	4.63 ± 0.00^{oA}	4.58 ± 0.01^{lB}
	1.2%	4.49 ± 0.01^{lD}	4.53 ± 0.01^{mC}	4.62 ± 0.01^{pA}	4.59 ± 0.01^{kB}
5.00	**Control**	4.96 ± 0.01^{iD}	5.07 ± 0.01^{iB}	5.20 ± 0.01^{iA}	5.03 ± 0.00^{hC}
	0.4%	4.93 ± 0.01^{jD}	5.05 ± 0.01^{jB}	5.17 ± 0.01^{jA}	5.01 ± 0.01^{iC}
	0.8%	4.92 ± 0.01^{kD}	5.04 ± 0.01^{jB}	5.14 ± 0.01^{kA}	4.98 ± 0.01^{jC}
	1.2%	4.91 ± 0.01^{kD}	5.02 ± 0.01^{kB}	5.11 ± 0.01^{lA}	4.98 ± 0.00^{jC}
5.50	**Control**	5.51 ± 0.01^{eD}	5.69 ± 0.01^{hA}	5.63 ± 0.01^{eB}	5.56 ± 0.01^{fC}
	0.4%	5.46 ± 0.01^{fD}	5.71 ± 0.01^{gA}	5.61 ± 0.01^{fB}	5.53 ± 0.01^{gC}
	0.8%	5.41 ± 0.01^{gC}	5.73 ± 0.01^{fA}	5.59 ± 0.01^{gB}	5.59 ± 0.01^{eB}
	1.2%	5.37 ± 0.01^{hC}	5.74 ± 0.01^{eA}	5.57 ± 0.01^{hB}	5.57 ± 0.01^{fB}
6.00	**Control**	5.98 ± 0.01^{aB}	6.03 ± 0.01^{aA}	5.99 ± 0.01^{aB}	5.92 ± 0.01^{aC}
	0.4%	5.84 ± 0.01^{bD}	5.92 ± 0.01^{bB}	5.96 ± 0.01^{bA}	5.89 ± 0.01^{bC}
	0.8%	5.79 ± 0.01^{cD}	5.88 ± 0.01^{cB}	5.95 ± 0.01^{cA}	5.87 ± 0.01^{cC}
	1.2%	5.77 ± 0.01^{dD}	5.86 ± 0.01^{dB}	5.93 ± 0.01^{dA}	5.84 ± 0.01^{dC}

a-t: Means with different lowercase letters in the same column compare the different pH and extract levels and show significant differences at $P < 0.05$.
A-D: Means with different capital letters in the same row compare the storage times and show significant differences at $P < 0.05$.
±: Standard deviation.
[a] LRCWE: Lyophilized red cabbage water extracts.

different pH values increased (Table 4). During storage, different changes in the b* values of cemen paste with different pH values were observed. The b* value which increased partially on day 0 in cemen paste with pH 4.0, 4.5 and 5.0 decreased in the cemen paste with pH 5.5 and 6.0 (Table 4). The b* value increased partially during storage in cemen paste with 0.8% and 1.2% LRCWE. This value decreased in the control group cemen paste during storage. The highest b* values were found in the groups without extracts from all cemen paste groups with different pH values (Table 4).

One of the parameters examined in terms of determining the effectiveness of anthocyanin on the quality of cemen paste in this study is pH value. Although the pH value of the cemen paste was adjusted to pH 4.0, 4.5, 5.0, 5.5 and 6.0 in this study, there were changes in the average pH values. These differences were caused by extracts added and storage time. In this context, the pH values were determined as averages ± standard deviations of 4.15 ± 0.08, 4.55 ± 0.06, 5.03 ± 0.09, 5.58 ± 0.11 and 5.90 ± 0.07 in cemen paste with pH 4.0, 4.5, 5.0, 5.5 and 6.0, respectively. Therefore, differences in the pH value were to be found significant ($P < 0.01$) (Table 1). The average pH values of cemen paste with high extract levels were partly lower than the control group. The pH value, which was determined as an average of 4.95 ± 0.65 at the beginning of storage, reached the highest level on the 60th day of storage (5.12 ± 0.63), and then decreased again on the 90th day (5.04 ± 0.63; Table 1). The addition of extracts to cemen paste with pH 4.0 increased the pH by about 0.1 units. The addition of extracts partially decreased the pH value of cemen paste with pH 5.0, 5.5 and 6.0. These decreases were 0.06, 0.04 and 0.13 units, respectively (Table 5). The pH values increased during storage both in the cemen paste with different amounts of extract and in the cemen paste with different pH values. The lowest pH values were found in the groups with extracts (Table 5). The pH value of control cemen paste produced in the study conducted by Aksu et al. (2020) was determined as 5.99 ± 0.12, these values were 5.75 ± 0.02 and 5.71 ± 0.05 for cemen paste with 0.8% and 1.2% LRCWE, respectively. Although the extracts used in the present research are similar to the extracts used previously, the low pH value in cemen paste is thought to result from differences in the red cabbage used in the extract production. This is because the extracts used by Aksu et al. (2020) have a lower pH value (5.52 ± 0.02) and higher titratable acidity value (1.96 ± 1.16% citric acid) compared to our extracts.

The pH values of cemen paste had a significant effect ($P < 0.01$) on the moisture value of cemen paste, and the moisture value increased due to the pH values increase ($P < 0.05$) (Table 1). It is thought that this increase was due to the increase of water retention capacity of cemen paste at high pH. The addition of extract and storage time had no effect on cemen paste moisture content ($P > 0.05$). While cemen paste with pH 4.0 and pH 5.0 had a higher moisture content than cemen paste with extract (data not shown), it was higher in the control group with pH 6.0 than other groups.

4. Conclusions

In this study, it was determined that the effect of the color compounds in extracts was increased by lowering the pH values of cemen pastes, and therefore the quality of cemen paste was improved. The best results regarding the desired red color for cemen paste value were obtained in the groups containing 1.2% extract and pH 4.0 and 4.5. Also, in terms of color properties (especially a* value), these cemen paste groups had the highest storage stability compared to other groups. As a result, LRCWE can be used as a natural colorant for pastırma cemen paste and can improve product quality and extend shelf life. Considering the results of this research, the effects of low pH cemen paste with 1.2% LRCWE on pastırma quality should be determined in detail and technologically.

CRediT authorship contribution statement

Muhammet İrfan Aksu: Conceptualization, Project administration, Methodology, Data curation, Visualization, Writing - review & editing. **Emre Turan:** Methodology, Formal analysis, Visualization, Investigation, Writing - original draft. **İhsan Güngör Şat:** Funding acquisition, Investigation, Resources.

Declaration of competing interest

The authors declare that they have no known competing interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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