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ORIGINAL ARTICLE

# Red raspberry (*Rubus ideaus* L.) extracts: A novel ingredient in cemen paste

Muhammet İrfan Aksu[1] | Emre Turan[2] | İhsan Güngör Şat[3] | Ebru Erdemir[4]

[1]Department of Food Engineering, Faculty of Agriculture, Eskişehir Osmangazi University, Eskişehir, Turkey

[2]Department of Food Engineering, Faculty of Agriculture, Ordu University, Ordu, Turkey

[3]Department of Food Engineering, Faculty of Agriculture, Atatürk University, Erzurum, Turkey

[4]Department of Nutrition and Dietetics, Health High School, Ağrı Ibrahim Çeçen University, Ağrı, Turkey

**Correspondence**
Muhammet İrfan Aksu, Department of Food Engineering, Faculty of Agriculture, Eskişehir Osmangazi University, 26160 Eskişehir, Turkey.
Email: mirfan.aksu@ogu.edu.tr; miaksu@hotmail.com

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## Abstract

Red raspberry (*Rubus ideaus* L.) has promising potential for the concept of "clean-label food" as a natural coloring and flavoring agent as well as its bioactive properties. The objective of this study was to determine some properties of lyophilized red raspberry water extract (LRWE) and its optimal levels contributing to the improvement of pastırma cemen paste (CP) quality. LRWE displayed high total phenolic and anthocyanin content, and strong antioxidant activity. Incorporating LRWE into CP improved the instrumental redness and sensory color scores between 10.52%–38.79% and 9.62%–71.55%, respectively, depending on the extract level. Compared to the control, the pH, lightness ($L^*$), and yellowness ($b^*$) values of CP decreased with the addition of LRWE, while the redness ($a^*$), titratable acidity, anthocyanin content, and metal chelating activity (MCA) increased. According to these results, 3%, 4%, and 5% LRWE levels can be recommended to enhance the color, sensory acceptability, and functional properties of CP.

**Novelty impact statement**

Although the formation and maintenance of the desired color in pastırma cemen paste is an important problem, studies to overcome this problem are quite limited. Natural plant extracts have been widely used in the food industry in recent years as colorant, antioxidant, and antimicrobial due to consumer health concerns. The results of this study showed that the anthocyanin-rich LRWE can be utilized as a natural alternative to synthetic and insect-based colorants in CP production. In this way, better quality and reliable pastırma production will be possible using clean-label natural colorants instead of synthetic dyes.

## 1 | INTRODUCTION

Pastırma is a dry-cured meat product that is processed in pieces, and the "cementing" stage defined as coating the meat surface with a spreadable paste called "cemen" significantly affects the quality of pastırma (Aksu et al., 2016; Aksu, Turan, & Şat, 2020). Cemening provides pastırma typical taste, flavor/aroma, and color, as well as a salt balance between meat and CP. In addition, the protective effect against excessive drying, mold formation, external factors and insects, the delay of oxidative reactions by cutting air contact, and the bactericidal effect thanks to the garlic in the formulation are other contributions of cemening process to pastırma (Aksu et al., 2006; Aksu, Erdemir, Oz, et al., 2020). CP is produced using fenugreek (*Trigonella foenum graecum* L.) seed flour, fresh garlic, paprika, red pepper, and sufficient amount of water (Aksu et al., 2006; Aksu, Erdemir, Turan, et al., 2020; Erdemir & Aksu, 2017). Although the usage rates vary in practical applications, the composition of CP contains 15% red pepper, 35% garlic, and 50% fenugreek seed flour according to the Pastırma Standard (Anonymous, 2002).

Color is one of the most remarkable indicators of pastırma quality, and the color of CP significantly affects the acceptance of pastırma as it is the first color that consumers perceive when purchasing pastırma. The color quality of CP is related to the quality and quantity of the red pepper and paprika. The use of inferior and

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insufficient ground red pepper and paprika negatively affects the color and flavor of CP (Aksu et al., 2020; Aksu, Turan, Sat, et al., 2020). In addition, it has been observed in many of our previous studies that although the $a^*$ value slightly increased with cementing (Aksu & Kaya, 2002), the desired color could not be achieved even if the materials in CP composition were used at the high quality. Therefore, synthetic dyes have been involved in CP to enhance the color characteristics of pastırma. The pale color of CP produced without synthetic dyes is not preferred by consumers because it reduces the attractiveness of pastırma.

In this regard, the Turkish Food Codex Food Additives Regulation (Anonymous, 2013) allowed the use of colorants such as carmines, riboflavins, and curcumin in edible outer coatings (i.e., cemen paste [CP]) of pastırma, and carmine is mostly used in pastırma production. However, carmine is an insect-based dye and is considered as doubtful by consumers due to its adverse health effects (Müller-Maatsch & Gras, 2016) and concerns about its religiously halal status (Karahalil, 2020). On the other hand, the demand for using natural colorants and antioxidants is increasing due to the safety and health concerns of synthetic ones (Sigurdson et al., 2017). Meat processors are looking for natural colorants and antioxidants that can overcome these problems and improve the quality of pastırma by providing the desired CP color. Recent studies have revealed that the color characteristics, color stability, antioxidant potential, and sensory acceptability of CP can be improved by using natural colorants and additives (Aksu, Erdemir, Turan, et al., 2020; Aksu et al., 2020; Aksu, Turan, Sat, et al., 2020; Yetim et al., 2017).

Anthocyanins are an important subclass of water-soluble natural pigments that impart red to blue color to plants, fruits, and vegetables and have various biological and antioxidant properties (Sigurdson et al., 2017). These compounds are easily incorporated into aqueous food systems due to their water solubility, and their structures undergo reversible pH-dependent changes (Giusti & Wrolstad, 2003). Therefore, anthocyanin-rich extracts can be an important alternative for consumers demanding clean-label foods without health-threatening synthetic additives.

Raspberry (*Rubus ideaus* L.), a member of the Rosaceae family, is a very popular fruit known not only for its distinctive taste, attractive color, and high nutritional value but also for health benefits. Apart from consumption as fresh or frozen fruit forms, raspberries are consumed by processing into fruit juices, wines, jams, and freeze-dried fruits (Chen et al., 2013; Si et al., 2016). Raspberries contain innumerable important bioactive compounds such as phenolics, organic acids, vitamins, and minerals, and exhibit strong antioxidant capacity resulting from high content of anthocyanin and other phenolics (Çekiç & Özgen, 2010; de Souza et al., 2014).

Although the formation and maintenance of the desired color in pastırma CP is an important problem, the studies to overcome this problem are quite limited. In this context, our previous studies investigating the effects of red cabbage (Aksu, Turan, & Şat, 2020; Aksu, Turan, Sat, et al., 2020) and red beet (Aksu, Erdemir, Turan, et al., 2020) extracts on the quality of pastırma CP revealed that natural colorants can be used as an alternative to synthetic dyes in the production of CP. In addition, these studies showed that the formation of the color of CP and its stability during storage depends on the level of the extract used, the initial $a^*$ value of the extract, and the pH. Considering its high anthocyanin content, low pH, high redness value, and bioactive properties, raspberry can be conceived as a possible source of natural colorants, and it is of great importance to investigate the application potential in providing the desired quality characteristics of pastırma CP. To the best of our knowledge, no published research has determined the effects of lyophilized raspberry water extract (LRWE) on CP quality. For this reason, the objectives of this study were: (1) to determine the various characteristics of LRWE, (2) to investigate the effects of different LRWE concentrations on the quality of pastırma CP, and (3) to determine the most suitable LRWE levels to be used in CP production for pastırma. In this way, it will be possible to produce better quality and reliable pastırma by spreading the use of natural colorants and reducing the use of synthetic dyes.

## 2 | MATERIALS AND METHODS

### 2.1 | Materials

Fresh raspberry (*Rubus idaeus* L.), fresh garlic, paprika, fenugreek seed flour, and red pepper powder used as materials in this study were obtained from local markets in Erzurum, Turkey. All chemicals used were of analytical grade scale.

### 2.2 | Methods

#### 2.2.1 | Preparation of LRWE

The production of lyophilized water extract from raspberry fruit was carried out following the method used by Aksu, Turan, and Şat (2020) with some modifications as given in Figure 1. Fresh raspberries were physically cleaned after being brought to the laboratory. Subsequently, they were immediately frozen and stored at −38°C until used. The extracts produced according to the scheme in Figure 1 were stored in dark-colored jars at 4°C until used. LRWE powder obtained is shown in Figure 2.

#### 2.2.2 | Production of CP

CP production was performed by combining appropriate quantities of fenugreek seed flour (500 g), fresh garlic (350 g), red pepper powder (75 g), paprika (75 g), and tap water (1,200 ml). The produced CP was partitioned into 6 equal parts, and incorporated with LRWE at 1.0%, 2.0%, 3.0%, 4.0%, and 5.0% levels. CP without LRWE was used for the control group. Each cemen group was produced as triplicate, kept in jars at 4°C for 24 hr, and then analyzed (Aksu et al., 2006; Aksu, Turan, Sat, et al., 2020).

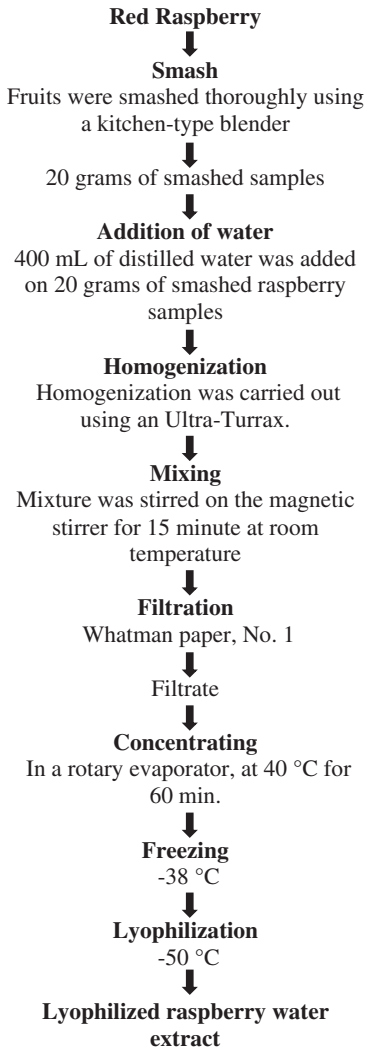



**FIGURE 1** Lyophilized raspberry water extract (LRWE) production procedure

## 2.3 | Analyzes

### 2.3.1 | Titratable acidity and pH analysis

Titratable acidity (in percent citric acid) and pH values of the CP and extract were detected by using the procedures in Cemeroğlu (2010). pH measurements were carried out using a benchtop pH meter (Orion 3-Star, Thermo Scientific, Singapore) calibrated with appropriate buffer (pH 4.0 and 7.0) solutions.

### 2.3.2 | Color measurement

A Minolta chromometer (CR-400, Osaka, Japan) with an 11 mm measuring head was used for measurements of $L^*$, $a^*$, and $b^*$ color values, which express lightness, redness, and yellowness, respectively. Before the color readings, the device with D65 illuminant and 2° standard observer features was calibrated with a white ceramic standard.

### 2.3.3 | Total phenolic content

The determination of total phenolic content was carried out following the procedure developed by Singleton et al. (1999) and reported by Aksu, Turan, Sat, et al. (2020). Briefly, 0.5 ml of Folin-Ciocalteu reagent and 0.25 ml of $Na_2CO_3$ solution (20%) were mixed with 1 ml of the sample extract in a test tube, and the total volume was adjusted to 10 ml by adding distilled water. Absorbance readings of the mixtures incubated in the dark for 30 min at room temperature were performed using a spectrophotometer at 760 nm against control. The results are expressed in mg GAE (gallic acid equivalent) per gram of sample using a standard curve prepared daily.

### 2.3.4 | DPPH radical scavenging activity

DPPH free radical (2,2′-diphenyl-1-picrylhydrazyl) scavenging activity analysis was performed according to the procedure described by Blois (1958), and the results were calculated as percentage inhibition. Briefly, sample extracts of different concentrations were transferred to test tubes precisely and the total volume of mixture was made up to 3 ml with ethanol. Subsequently, these mixtures were vortexed following incorporation with the DPPH solution and incubated in the dark for 30 min at room temperature. The absorbance values against control were measured at 517 nm with a spectrophotometer.

### 2.3.5 | Ferric reducing antioxidant power

Ferric reducing antioxidant power (FRAP) activities of the LRWE and CP samples were determined using the procedure described by Gao et al. (2000) with minor modifications, and expressed in μmol TE (Trolox equivalent) per gram of sample. Briefly, an aliquot of the sample extracts in the test tube was mixed with the FRAP stock solution containing acetate buffer (pH 3.6, 0.3 M), TPTZ (2,4,6-Tris(2-pyridyl)-s-triazine, 10 mM) and $FeCl_3 \cdot 6H_2O$ at ratios of 10:1:1, respectively. The absorbance readings against the control were performed at 593 nm.

### 2.3.6 | Total antioxidant activity

The total antioxidant activities of LRWE and CP were analyzed according to Yen and Chen (1995), and the results were calculated as percent inhibition. An aliquot (100 μl) of the sample extracts was mixed with phosphate buffer (2.4 ml) and linoleic acid emulsion (2.5 ml). The mixture was colored by reaction with $Fe^{2+}$ and thiocyanate anion ($SCN^-$) at certain periods of incubation at 37°C in the dark, and the absorbance values were read at 500 nm.

### 2.3.7 | Metal chelating activity

Metal chelating activity (MCA) analysis of LRWE and CP was performed following the method described by Bursal and Gülçin (2011).



FIGURE 2 Lyophilized raspberry water extract (LRWE)

In the analysis, after the sample extracts were mixed with 125 μl of $FeSO_4.7H_2O$ (0.2 mM), the reaction was initiated by adding 0.5 ml Tris–HCl buffer (pH 7.4) and 0.5 ml 2,2′-bipyridine solution. The final volumes of the reaction mixtures were made up to 3 ml, and incubated at room temperature for 10 min in the dark. The absorbance of values the mixtures were read at 522 nm, and MCA results were calculated as percent inhibition.

### 2.3.8 | Total anthocyanin content

Total anthocyanin content of all samples was detected using the pH-differential procedure. An aliquot of the sample extracts was mixed with the appropriate ratios of KCl (potassium chloride, pH 1.0, 0.025 M) and $NaCO_2CH_3{\cdot}3H_2O$ (sodium acetate, pH 4.5, 0.4 M) buffers. The absorbance measurements of the mixtures were carried out at both 520 and 700 nm. The results were expressed as cyanidin 3-glucoside (cy3-G) per kg (Lee et al., 2005).

### 2.3.9 | Sensory evaluation

Sensory analysis of the CP samples was performed by 10–12 panelists who are experts in food science and technology. The aim of the study was explained to the panelists in an information letter. The panelists who agreed on the purpose of the study signed the consent form. Six different CPs (Control, 1.0%, 2.0%, 3.0%, 4.0%, and 5.0% LRWE) coded with random numbers for each sensory session were presented to the panelists. The panelists were asked to evaluate color, consistency, smell, taste, and overall acceptability using a 9-point structured hedonic scale (8–9 = very good, 6–7 = good, 4–5 = fairly acceptable, and 1–3 = not acceptable). The samples were mixed homogeneously before analysis. Bread and water were offered to the panelists to neutralize the palate left by the samples.

### 2.3.10 | Statistical evaluation

All tests were performed in triplicate, and all results were analyzed using the SPSS 20.0 package program. Data were evaluated in a completely random design by analysis of variance (ANOVA) considering the treatments (0.0%, 1.0%, 2.0%, 3.0%, 4.0%, and 5.0% LRWE) as a fixed factor and replicates as a random factor. Duncan test was applied for multiple comparisons of significant ($p < .05$) differences of means between the treatments. For sensory analysis, the effects of extract levels and panelists were considered as fixed and random factors, respectively. The data are indicated in tables as mean ± standard deviation and standard error of means (*SEM*).

## 3 | RESULTS AND DISCUSSION

### 3.1 | Physicochemical properties, bioactive compounds and antioxidant capacity of LRWE

LRWE had higher total phenolic content (Table 1) than the content (5.83–26.66 mg GAE/g) reported for lyophilized aqueous extracts of raspberry by Gülçin et al. (2011). Total anthocyanin content of LRWE was 1,096.71 ± 36.97 mg cy3-G/kg. Our findings were higher than the phenolic and anthocyanin content reported for fresh raspberry extracts in several previous studies (Çekiç & Özgen, 2010; Sarıburun et al., 2010). Kähkönen et al. (2001) found that the total phenolic amounts in the water extract of raspberry as 1,574 ± 300 mg GAE/g dry weight (dw). Dobson et al. (2012) reported the phenolic content of fresh red raspberry between 129.4 and 184.6 mg/100 g. These differences can be attributed to genetic variations, agricultural conditions, environment, maturation, processing, and extraction methods (Kähkönen et al., 2001; Skrovankova et al., 2015). Si et al. (2016) stated that the total anthocyanin contents in fresh raspberry fruit and freeze-dried raspberry powders were 0.54 g cy3-G/kg dw and 0.33 g cy3-G/kg dw,

**TABLE 1** Physicochemical properties, bioactive compound contents and antioxidant capacity of lyophilized raspberry water extract (LRWE)

| Properties | Mean ± *SD* |
|---|---|
| Total antioxidant activity (%) | 49.67 ± 3.67 |
| DPPH radical scavenging activity (%) | 71.17 ± 6.15 |
| Ferric reducing antioxidant power (FRAP) (μmol TE/g) | 96.89 ± 16.92 |
| Metal chelating activity (%) | 69.73 ± 3.80 |
| Total phenolic content (μg GAE/mg) | 66.19 ± 9.46 |
| Total anthocyanin content (mg cy3-G/kg) | 1,096.71 ± 36.97 |
| pH | 3.36 ± 0.01 |
| Titratable acidity (% citric acid) | 11.91 ± 0.60 |
| Color values | |
| $L^*$ | 36.77 ± 3.13 |
| $a^*$ | 46.91 ± 2.05 |
| $b^*$ | 18.23 ± 2.17 |

*Note:* ±, Standard deviation.
Abbreviations: cy3-G, cyanidin 3-glucoside; GAE, gallic acid equivalent; TE, Trolox equivalent.

respectively, and freeze-drying is a suitable method for the preservation of anthocyanins. Sarıburun et al. (2010) found that raspberry water extracts contained significantly higher anthocyanins than methanol extracts, and therefore stated that water is a more suitable solvent for anthocyanin extraction in berries. The prime anthocyanins present in raspberries are cyanidin-3 (cy3)-sophoroside, cy3-glucosylrutinoside, cy3-glucoside, and cy3-rutinoside (Chen et al., 2013; Mullen et al., 2002). The color pigments of many fruits and vegetables with specific natural colors from purple to red are anthocyanins (Giusti & Wrolstad, 2003). The high anthocyanin content in LRWE in the present study showed that water is a suitable solvent for anthocyanin extraction and that the anthocyanin-rich LRWE has a natural colorant potential as a substitute for synthetic dyes in the food industry.

Considering the classification stated by Hassimotto et al. (2005) as low (<40% inhibition), medium (40%–70% inhibition), and high (>70% inhibition) for antioxidant activity values, LRWE can be categorized as a natural source with high antioxidant activity in regard to scavenging DPPH radical (Table 1). According to these results, LRWE has important antioxidant properties such as MCA and free radical scavenging. Previous studies have also shown that raspberries have high antioxidant activity (Çekiç & Özgen, 2010; Chen et al., 2013; de Souza et al., 2014). Similarly, Gülçin et al. (2011) stated that lyophilized aqueous extracts of raspberries exhibited strong $Fe^{+2}$ chelating activity. These antioxidant properties of LRWE can be attributed to its high phenolic and anthocyanin contents. A strong correlation between the total phenolic content, anthocyanin levels and antioxidant capacity of raspberries was observed in previous studies (Çekiç & Özgen, 2010; Chen et al., 2013; Sarıburun et al., 2010). Flavonoids such as anthocyanins, flavonols, flavanols, phenolic acids, hydrolyzable tannins such as ellagitannins, and ascorbic acid act as important bioactive compounds that contribute to the antioxidant properties and health benefits of berries (Skrovankova et al., 2015). Polyphenols exhibit antioxidative properties due to high reactivity as hydrogen or electron-donating agents, the power of antioxidant-derived radicals to stabilize and displace unpaired electrons, the ability to react with other antioxidants, and the potential to chelate transition metal ions (Rice-Evans et al., 1997).

The pH and acidity properties of extracts are notably important for the stability and effects of color pigments. The pH value (3.36 ± 0.01) of LRWE was compatible with the literature data varying from 2.86 to 3.70 (Gülçin et al., 2011; de Souza et al., 2014), but the titratable acidity (11.91 ± 0.60%) value was higher. Anthocyanins undergo reversible structural transformations that result in color changes depending on pH (Aksu, Turan, & Şat, 2020; Giusti & Wrolstad, 2003). In the present study, the acidic pH of LRWE may have contributed to the increase in the redness value. On the other hand, the redness ($a^*$) value of LRWE was higher than the values determined for raspberry in the literature (Çekiç & Özgen, 2010; Si et al., 2016), while the $L^*$ and $b^*$ color values were similar.

## 3.2 | Quality properties of CPs including LRWE

### 3.2.1 | pH and titration acidity of CP

The pH values of CP showed a statistically significant difference ($p < .01$). Depending on the LRWE concentration used, pH values in all CP decreased compared to the control group (6.07 ± 0.10, Table 2), and this reduction was 20.43% and 22.24% in the CP samples containing 4% and 5% extract, respectively. Similar pH values for control samples were also determined by Aksu et al. (2006). There were significant differences among the LRWE groups ($p < .01$), and the lowest pH values were determined for the CP including 4.0% and 5.0% LRWE (Table 2). The pH is an important quality characteristic of CP. During CP production processing, the pH values tend to increase as a result of the typical CP composition. In particular, basic compounds found naturally in the structure of fresh garlic cause an increase in pH (Aksu et al., 2006). The findings in our previous studies have shown that the decrease in the pH value of CP provides

**TABLE 2** Mean values and Duncan multiple comparison results of pH, titratable acidity, color ($L^*$, $a^*$, $b^*$) parameters determined in cemen pastes produced with different levels of LRWE ($p < .05$)

| Properties | Extract levels | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | 1% | 2% | 3% | 4% | 5% | *SEM* | *p* |
| pH | 6.07 ± 0.10a | 5.70 ± 0.07b (−6.10%) | 5.35 ± 0.10c (−11.86%) | 5.03 ± 0.11d (−17.13%) | 4.83 ± 0.12e (−20.43%) | 4.72 ± 0.12e (−22.24%) | 0.060 | ** |
| Titratable Acidity (%) | 0.83 ± 0.08c | 0.87 ± 0.05c (+4.82%) | 0.91 ± 0.12c (+9.64%) | 1.09 ± 0.05b (+31.33%) | 1.17 ± 0.07ab (+40.96%) | 1.32 ± 0.15a (+59.04%) | 0.055 | ** |
| Color values | | | | | | | | |
| $L^*$ | 48.35 ± 2.26 | 46.86 ± 2.09 | 43.92 ± 5.61 | 45.91 ± 1.44 | 44.91 ± 1.43 | 41.78 ± 1.79 | 1.637 | NS |
| $a^*$ | 15.88 ± 0.48c | 17.55 ± 0.06b (+10.52%) | 17.73 ± 0.42b (+11.65%) | 18.45 ± 0.08b (+15.18%) | 20.81 ± 1.19a (+31.05%) | 22.04 ± 1.34a (+38.79%) | 0.445 | ** |
| $b^*$ | 32.66 ± 2.81a | 32.48 ± 1.84a (−0.55%) | 30.46 ± 3.21ab (−6.74%) | 29.21 ± 3.28ab (−10.56%) | 29.16 ± 1.11ab (−10.72%) | 26.77 ± 0.66b (−18.03%) | 1.374 | * |

*Note:* a–e: Any means in the same column with the same letters are not significantly different at $p < (0.05)$. ±, Standard deviation.

Abbreviations: LRWE, lyophilized raspberry water extract; *SEM*, standard error of means; (+/− ..%), percentage of increase or decrease according to control sample.

$^{**}p < .01$; $^{*}p < .05$; NS: Non-significant ($p > .05$).

significant advantages in terms of color quality and stability. Aksu, Turan, and Şat (2020) determined pH levels below 5.0 as the threshold for the efficiency of red cabbage extracts in CP. The researchers also reported that the quality of the CP improved as a result of the increase in the effect of the color substances in the anthocyanin-rich extracts by reducing the pH values of CP.

The effect of extracts on the pH value of the pastırma CP is also different, as the pH value changes depending on the characteristics of the fruit and vegetables. A previous study determined that the addition of 0.4%, 0.8%, and 1.2% lyophilized red cabbage water extract gradually reduced the pH of CP from 5.99 in the control group to 5.88, 5.75, and 5.71, respectively (Aksu, Turan, Sat, et al., 2020). Contrary to this research, red beet extracts did not significantly change the pH of CP due to the low acidity (0.42% citric acid) and high pH (6.67) values of the extract (Aksu, Erdemir, Turan, et al., 2020). As expected, the acidity value of the CP increased partially ($p < .01$), and the highest values were found in the CP containing 4.0% and 5.0% LRWE ($p < .05$) (Table 2), which can be attributed to the high acidity values of the extract (Table 1). The acidity values of these groups increased by 40.96% and 59.04%.

### 3.2.2 | Instrumental color values of CP

The means of $L^*$, $a^*$, and $b^*$ instrumental color values detected in CP treated with different levels of LRWE, and the Duncan multiple comparison test results are given in Table 2. The incorporation of LRWE into CP significantly ($p < .01$) affected the $a^*$ and $b^*$ color values, the $b^*$ values decreased and the $a^*$ values increased ($p < .05$). The $L^*$ values decreased with the extract supplement, but this decline was statistically insignificant ($p > .05$). The redness values of CP samples gradually increased depending on the increasing level of LRWE. As shown in Table 2, the lowest $a^*$ values were in the control group without LRWE, the highest values were determined in CP containing 5.0% LRWE. In other words, the redness of the CP was enhanced by about 10%–38% with the LRWE treatment.

As can be seen from the present results, it was not possible to achieve the desired color quality of CP with the typical composition. In addition, even if suitable/high-quality materials are used in the composition, the necessity of using colorants in the production of CP was revealed. Both paprika and red peppers used in CP contain carotenoids as colorants. Since carotenoids are generally fat-soluble compounds that give foods of vegetable and animal origin varying from red to yellow, their effects are naturally limited. Since the predominant color compounds in raspberries are anthocyanins with water-soluble properties, the addition of LRWE significantly increased the color characteristics of the CP, especially the $a^*$ value. As seen in Table 2, the $a^*$ values of 3%, 4% and 5% extract-added CP increased by 15.18%, 31.05% and 38.79%, respectively. Our results are consistent with previous studies reporting that the color quality of CP can be improved using natural colorants (Aksu, Erdemir, Turan, et al., 2020; Aksu, Turan, & Şat, 2020; Aksu, Turan, Sat, et al., 2020; Yetim et al., 2010). The main reasons for the high $a^*$ values in the samples with LRWE compared to the control are: (1) the high amount of anthocyanin in LRWE, (2) the high $a^*$ value of LRWE, and (3) the decrease in the pH value of CP including LRWE.

As stated in the discussion of pH results, pH is an important factor in the effectiveness of anthocyanins in CP, and below pH 5.0, their effect on color is greater. In the present study, the pH values of CP were reduced below 5.0 with the addition of 4% and 5% LRWE, and the $a^*$ value increased as a result of the increase in the effectiveness of anthocyanins. Aksu, Turan, and Şat (2020) emphasized that pH is also effective in providing the desired color in CP produced

**TABLE 3** Mean values and Duncan multiple comparison test results of total phenolic content, total antioxidant activity, FRAP, DPPH radical scavenging activity, and metal chelating activity determined in cemen pastes treated with different levels of LRWE ($p < .05$)

| Properties | Extract levels | | | | | | SEM | P |
|---|---|---|---|---|---|---|---|---|
| | Control | 1% | 2% | 3% | 4% | 5% | | |
| Total antioxidant activity (%) | 33.11 ± 10.03 | 42.22 ± 2.77 | 43.11 ± 4.07 | 36.78 ± 4.55 | 37.56 ± 1.02 | 45.33 ± 9.62 | 3.645 | NS |
| Total phenolic content (μg GAE/mg) | 3.15 ± 0.10 | 3.32 ± 0.30 | 3.44 ± 0.41 | 3.51 ± 0.36 | 3.51 ± 0.32 | 3.77 ± 0.38 | 0.189 | NS |
| Total anthocyanin content (mg cy3-G /kg) | 146.17 ± 1.92c | 184.04 ± 12.71ab (+25.91%) | 181.35 ± 22.02b (+24.07%) | 199.24 ± 12.31ab (+36.31%) | 207.13 ± 3.35a (+41.70%) | 209.13 ± 16.44a (+43.07%) | 7.757 | ** |
| FRAP activity (μmol TE/g) | 175.75 ± 43.30 | 182.97 ± 43.03 | 209.50 ± 44.31 | 208.81 ± 42.71 | 224.77 ± 47.33 | 228.58 ± 30.19 | 24.342 | NS |
| DPPH radical scavenging activity (% inhibition) | 37.41 ± 4.56 | 39.52 ± 7.65 | 44.57 ± 11.22 | 46.16 ± 13.20 | 46.67 ± 8.87 | 55.21 ± 20.45 | 6.977 | NS |
| Metal chelating activity (%) | 11.24 ± 0.60d | 25.77 ± 0.77c (+129.27%) | 30.72 ± 2.25bc (+173.31%) | 32.56 ± 0.07b (+189.68%) | 38.54 ± 4.22a (+242.88%) | 40.42 ± 5.51a (+259.61%) | 1.734 | ** |

*Note:* a–d: Any means in the same column with the same letters are not significantly different at $p < .05$. ±, Standard deviation

Abbreviations: cy3-G, cyanidin 3-glucoside; GAE, gallic acid equivalent; LRWE, lyophilized raspberry water extract; *SEM*, standard error of means; TE, Trolox equivalent; (.%), Percentage of increase according to control sample.

**$p < .01$; NS: Non-significant ($p > .05$).

using extracts. Similarly, Yetim et al. (2017) stated that some acidic additives improved the redness of CP.

### 3.2.3 | Anthocyanin content of CP

The addition of LRWE significantly affected the amounts of cyanidin 3-glucoside (cy3-G) ($p < .01$), the highest values were found in CP including 4.0% and 5.0% LRWE ($p < .05$) (Table 3). The LRWE treatment increased the anthocyanin content of the pastırma CP by about 23.76%–43.07% depending on the extract level. Red pepper and paprika species in the CP composition also contain anthocyanin compounds (Lightbourn et al., 2008). Therefore, the presence of anthocyanin compounds in red pepper and paprika is responsible for the anthocyanin content determined as 146.17 ± 1.92 cy3-G/kg in control CP samples. The high anthocyanin content of LRWE (Table 1) was also reflected in the CP and improved its quality properties. Moreover, the high content of these compounds increased the antioxidant and color-forming properties of CP. The anthocyanin content in the current study was found to be approximately 100 mg/kg lower than that of CP produced by using the same CP composition and adding 1.2% anthocyanin-rich red cabbage water extract in our previous study (Aksu, Turan, Sat, et al., 2020). However, the $a^*$ values of the LRWE-added CP in the present study were higher. This may be attributed to the LRWE extracts being more effective in reducing the pH of CP and forming the red visibility of anthocyanins.

### 3.2.4 | MCA, total phenolic content, total antioxidant activity, FRAP, and DPPH radical scavenging activity of CP

MCA of CP was significantly affected by the addition of LRWE ($p < .01$), and the average value in control CP was lower compared to the LRWE added groups ($p < .05$). These values were 189.68%, 242.88%, and 259.61% higher in CP containing 3%, 4%, and 5% LRWE compared to the control group, respectively (Table 3).

The effect of LRWE addition on total antioxidant activity, FRAP, and DPPH radical scavenging activity of CP samples was not significant ($p > .05$). In all antioxidant activity assays, the lowest activities were in the control CP, while the highest activities were determined in the groups containing 4% and 5% LRWE. Although the FRAP, total antioxidant, and DPPH radical scavenging activities of the LRWE-added groups increased up to approximately 30% (53 units), 37% (12 units), and 47% (18 units), respectively, the difference between treatment groups was insignificant ($p > .05$).

Regarding total phenolic content, the addition of LRWE into the pastırma CP did not significantly affect the amount of phenolic compounds ($p > .05$) (Table 3). Raspberry is an important source of polyphenols among the frequently consumed fruits with its rich polyphenol composition, especially anthocyanin and ellagitannins (Dobson et al., 2012; Kähkönen et al., 2001). The total polyphenol

contents and anthocyanins (especially ellagitannins) in the red raspberry were positively correlated with antioxidant activities measured as total antioxidant, DPPH radical scavenging, FRAP, and metal chelating. Although the antioxidant properties of LRWE were found to be high in both the literature studies and the current study (Table 1), its effect on the antioxidant properties of CP was statistically insignificant. However, the total antioxidant activity, total phenolic content, FRAP, and DPPH radical scavenging activity values of LRWE-added CPs were higher than those of the control group (Table 3). Therefore, it can be stated that the inclusion of LRWE positively affects the antioxidant potential of CP.

The current results are inconsistent with the results of a study conducted by Aksu, Turan, Sat, et al. (2020) that reported the significant effect of red cabbage extracts on the total phenolic, FRAP, and total antioxidant activity values of pastırma CPs, while they are similar to the changes reported for DPPH radical scavenging activity and MCA. In another study investigating the effects of lyophilized red beet water extract on the quality characteristics of CP, it was found that total phenolic content, FRAP, DPPH radical scavenging activity, total antioxidant activity, and MCA values increased depending on the extract level (Aksu, Erdemir, Turan, et al., 2020).

### 3.2.5 | Sensory evaluation of CP

The high redness ($a^*$) value in LRWE had a positive effect on the sensory color scores of CP ($p < .01$, Figure 3). CPs containing 4% and 5% LRWE were the most notable groups for the sensory color parameter, with 59.83% and 71.55% higher color scores compared to the control, respectively. There was also a parallel relationship between these scores and instrumental color measurements (Table 2). Considering both data groups, it was concluded that adding LRWE to pastırma CP improved color values. Sensory properties of CP such as consistency, smell, and taste were not significantly affected by the addition of the extract to CP ($p > .05$) (Figure 3). On the other hand, the overall acceptability of CP increased with the addition of extract ($p < .01$), and the highest values were detected at 4% and 5% levels. The inclusion of 4% and 5% LRWE in the CP increased the overall acceptability by 20.88% and 22.51%, respectively. These results showed that the use of particularly high levels of LRWE improved the quality properties and sensory acceptability of pastırma CP.

## 4 | CONCLUSION

This study showed that LRWE from fresh raspberries is an important source of anthocyanins, which contribute to the coloration and antioxidant properties in foods. The inclusion of LRWE in the CP formulation improved the desired redness between 10.52% and 38.79%. The increase in redness ($a^*$) of CP depending on the extract levels indicated that this extract was adapted to the CP composition. Also, the addition of LRWE, especially at the level of 4% and 5%, resulted in a significant improvement (up to 71.55%) in the sensory color values of the CP. According to these results, LRWE can be used as a natural colorant and antioxidant instead of synthetic dyes in the production of CP. Consequently, the use of CPs prepared by including 3.0%, 4.0%, and 5.0% LRWE can be recommended for pastırma production. Further studies are needed to investigate the effects of CP containing these recommended levels of LRWE on pastırma quality, and to determine the behavior, color, and storage stability of LRWE anthocyanins in CP with different pH. Moreover, a comparative study investigating the use of natural extracts and carmine in pastırma production and their storage stability will be useful for further studies.

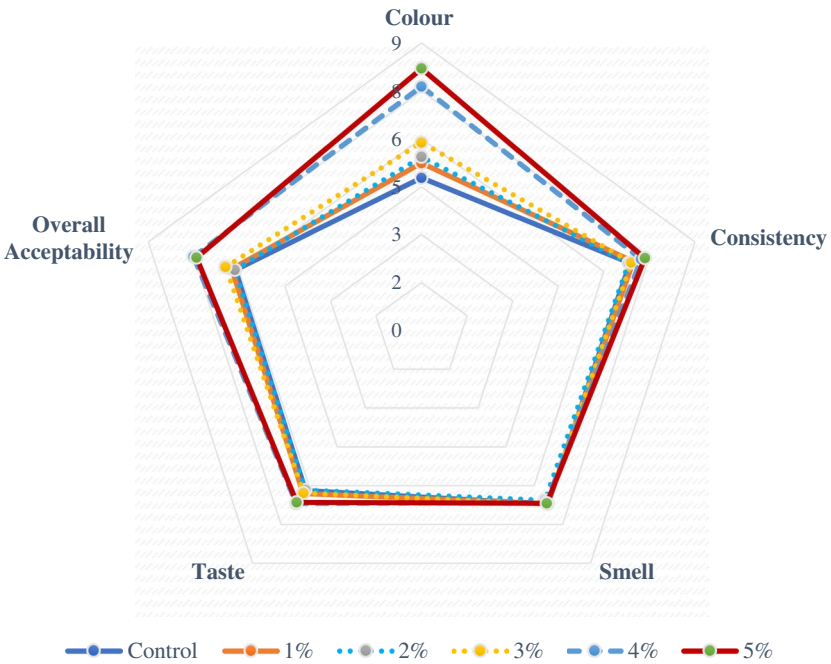



FIGURE 3 Sensory evaluation of cemen pastes containing different levels of LRWE

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## CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

## AUTHOR CONTRIBUTIONS

**Muhammet Irfan Aksu:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Writing-original draft; Writing-review & editing. **Emre TURAN:** Investigation; Resources; Writing-original draft; Writing-review & editing. **İhsan Güngör SAT:** Methodology; Resources. **Ebru Erdemir:** Formal analysis; Investigation.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## ORCID

*Muhammet İrfan Aksu* https://orcid.org/0000-0001-9391-6955
*Emre Turan* https://orcid.org/0000-0002-4289-0107
*Ebru Erdemir* https://orcid.org/0000-0001-5001-8151

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