Meat Science 186 (2022) 108737



Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci





Chemical, microbial, color, oxidative and sensory properties of clean-label pastırma produced with raspberry water extracts as a novel ingredient

Muhammet İrfan Aksu [a,*], Ebru Erdemir [b], Emre Turan [c], Fatih Öz [d]

[a] Eskişehir Osmangazi University, Faculty of Agriculture, Department of Food Engineering, 26160 Eskişehir, Turkey
[b] Agri Ibrahim Cecen University, Faculty of Health Sciences, Department of Nutrition and Dietetics, 04000 Agri, Turkey
[c] Ordu University, Faculty of Agriculture, Department of Food Engineering, 52200 Ordu, Turkey
[d] Atatürk University, Faculty of Agriculture, Department of Food Engineering, Erzurum, Turkey

ARTICLE INFO

Keywords:
Raspberry water extract
Pastırma
Protein and lipid oxidation
Redness
Microbial quality
Sensory acceptability
Storage

ABSTRACT

In recent years, plant extracts are used as colorant and antioxidant in meat products. Therefore, the effects of cemen pastes produced using different concentrations (0%, 3%, 4% and 5%) of raspberry water extract (RWE) on pastırma were investigated. RWE was tested to improve the color quality of pastırma and decrease lipid and pigment oxidation during production and storage at 4 °C for 150 days. Increasing RWE concentration in cemen paste reduced pH, TBARS ($P < 0.05$) and lactic acid bacteria counts ($P < 0.01$) of pastırma, while redness values ($P < 0.05$) increased compared to control sample without extract. The use of RWE contributed to improve sensory attributes of pastırma, and the groups with 4% and 5% RWE had the highest sensory scores. Also, the color and oxidative stabilities of the pastırma containing RWE were maintained better than control during storage period ($P < 0.01$). The overall results suggested that use of 4.0% or 5.0% RWE as a new additive in cemen paste can be considered an antioxidant and colorant for pastırma processing to prevent color and lipid oxidation.

1. Introduction

Pastırma, a dry-cured and dried meat product, is traditionally produced from buffalo and beef muscle or muscles (Aksu & Erdemir, 2022; Ceylan & Aksu, 2011). In traditional pastırma production, a large number of pastırma can be produced by using different muscles from a carcass (Cakici, Aksu, & Erdemir, 2015). Among these types of pastırma, "sırt" pastırma type produced from the loin section containing *Longissimus thoracis et lumborum* is considered to be first-class pastırma in terms of quality characteristics, and have an extensively intramuscular fat. The amounts of polyunsaturated and total unsaturated fatty acids are also high in muscles with high intramuscular fat (Aksu, Dogan, & Sirkecioglu, 2017; Cakici et al., 2015). For this reason, a significant oxidation problem occurs in pastırma during both production and storage period (Aksu & Erdemir, 2022).

The process of pastırma involves salting/curing, drying, pressing at certain stages of the drying of the large meat pieces, and then drying again after coating with a sauce called cemen paste at the cemening stage. In production of pastırma, salt, nitrite and nitrates are used for curing (Aksu, Erdemir, & Cakici, 2016). Nitrate and nitrites increase the color quality of pastırma as well as other advantages such as antioxidant and antimicrobial. Another process that affects the color quality in pastırma production is cemening. Cemening is a prominent phase in pastırma process as covering the pastırma with a mixture of cemen paste, which gives characteristic taste, color, aroma and flavor (Aksu, Erdemir, Turan, & Sat, 2020; Erdemir & Aksu, 2017). Cemen paste prevents oxidation and microbial contamination, and helps to prevent excessive drying of the pastırma. The color of cemen paste covering the external surface of the pastırma is the first sensory parameter that the consumer perceives for the decision to purchase pastırma, and it is very important to provide the desired color (Aksu, Turan, & Sat, 2020). Red pepper powder and paprika are mainly responsible for the color of the cemen paste. However, the use of poor quality and inadequate amount of the red pepper and paprika in the formulation prevents the formation of the desired cemen paste or pastırma color (Aksu, Erdemir, Turan and Sat, 2020). In other words, providing and maintaining the desired color formation (bright red in the sliced surface) in pastırma is an important problem. Therefore, insect-based carmine is used as a coloring agent in cemen paste to provide the desired color and to prevent discoloration during storage. Although used as a food additive, carmine is a dubious ingredient due to some personal or religious preferences of consumers (Nakyinsige, Man, & Sazili, 2012; Yetim et al., 2017). In addition,

* Corresponding author.
E-mail address: mirfan.aksu@ogu.edu.tr (M.İ. Aksu).

https://doi.org/10.1016/j.meatsci.2022.108737
Received 18 October 2021; Received in revised form 11 January 2022; Accepted 12 January 2022
Available online 19 January 2022
0309-1740/© 2022 Published by Elsevier Ltd.

carmine in food can initiate or promote allergic reactions in some people (Lim, Choi, Song, & Kim, 2014). Accordingly, researches on the use of natural extracts in pastırma production, especially in cemen paste formulation, are very important.

Raspberries (*Rubus idaeus* L.) are red fruits and these fruits with high free radical scavenging capacity are not only an excellent source of anthocyanin color pigments, but also contain a large number of bioactive compounds with potential health benefits (Summen & Erge, 2014). Anthocyanins are defined as functional foods and have great potential as food colorants to replace synthetic colorants due to their high pigment content and low toxicity (Laokuldilok & Kanha, 2015). These natural pigments are responsible for the bright colors of fruits and vegetables ranging from red to blue, depending on the pH and the molecular structure with an ionic nature (Assous, Abdel-Hady, & Medany, 2014; Cavalcanti, Santos, & Meireles, 2011). The flavylium cation (red hue) predominates at pH < 2, while purple or blue quinonoidal species are formed due to rapid deprotonation when pH rises from 2.0 to 4.0. Between pH 4–6, carbinol pseudobase (colorless) and chalcone (colorless/pale yellow) forms are observed. In addition, the flavylium cation, quinonoidal base, carbinol pseudobase, and chalcone forms can coexist in admixture at pH values in the range of 4.0 to 6.0, resulting in an integrated violet color. Equilibrium shifts towards quinoidal anhydrobase (purple) and ionized anhydrobase (deep blue) at $6 < \text{pH} < 8$. (Cavalcanti et al., 2011; Liu, Liu, Wu, Zheng, & Zhang, 2021; Tang et al., 2019). Anthocyanins contribute to the aesthetic value and quality properties of foods as well as to increase oxidative stability thanks to their high antiradical activities, and offer potential positive health effects that provide significant protection against certain diseases (Franceschinis, Salvatori, Sosa, & Schebor, 2014; Summen & Erge, 2014). In this regard, raspberry water extracts are a remarkable source of anthocyanin compounds (Aksu, Turan, Sat, & Erdemir, 2021; Sariburun, Sahin, Demir, Turkben, & Uylaser, 2010).

The use of additives that prevent oxidation and increase storage stability in pastırma production is important to overcome two important problems such as lipid oxidation and discoloration during storage of pastırma. In this context, red beet (Aksu, Erdemir, Turan and Sat, 2020) and red cabbage water extracts (Aksu, Erdemir, Turan and Sat, 2020) have been investigated in our previous studies. The addition of betalain-rich red beet extract significantly contributed to increase the color values of pastırma during storage and prevent lipid oxidation (Aksu, Erdemir, Turan and Sat, 2020). Similar results were also obtained from anthocyanin-containing red cabbage water extracts (Aksu et al., 2020).

In a recent study (Aksu et al., 2021), various properties of raspberry extract and its use as a natural colorant and antioxidant in the production of pastırma cemen paste were investigated. Accordingly, it was reported that raspberry extract had remarkable total anthocyanin content (1.096.71 ± 36.97 mg cyanidin 3-glucoside (cy3-G) / kg), total phenolic content (66.19 ± 9.46 μg gallic acid equivalent (GAE) / mg) and antiradical activity, and the inclusion of raspberry extract in the cemen paste formulation increased the antioxidant capacity as well as improving the desired redness (up to 38.79%). In addition, it was recommended to determine the effects of cemen pastes containing raspberry extract (3.0%, 4.0% and 5.0%) on pastırma quality. On the other hand, although the bioactive components of both raspberry and red cabbage water extracts are anthocyanins, raspberry water extract is considered to have a more promising potential to provide the desired color and stability in pastırma due to its low pH (3.36), high acidity (11.91% as citric acid) and high redness (a^*) values (46.91) (Aksu et al., 2021). Therefore, the objectives of this study were to provide a better quality and reliable pastırma production by using the most suitable freeze-dried raspberry water extract (RWE) concentrations for the production of cemen paste; to increase the shelf life of the pastırma; and to offer an alternative in favor of the consumer instead of synthetic or insect-based dyes by providing widespread use of natural color substances in cemen paste production. The usability of cemen paste produced with RWE as natural color substances in pastırma production, and its effects on pastırma quality during storage were determined in detail for the first time in this study.

2. Material and methods

2.1. Materials

Beef *Longissimus thoracis et lumborum* muscle used as meat material (after 24-h postmortem, at 4 °C) in the production of pastırma was purchased from the Meat and Milk Board in Erzurum, Turkey, and stored at 4 °C until used (approximately 2–3 h). For three replicate trials, these muscles were sourced from the carcasses of 29–35 months old male cattle (Brown Swiss crossbred). In addition, ripe raspberries (*Rubus ideaus* L. cv. Heritage), salt, sodium nitrite, garlic, fenugreek (*Trigonella foenum graecum* L.) seed flour, paprika, red pepper powder were obtained from local markets in Erzurum, Turkey.

2.2. Methods

2.2.1. Preparation of freeze-dried raspberry water extract (RWE)

Following a pre-cleaning process, the raspberries that were crushed in a blender were homogenized with an Ultra-turrax (Nach Prof. P. Willem, Janke and Kunkel KG, IKA 25 Werk, Staufen im Breisgau, Germany) at 13,500 rpm for 3–4 min after addition of distilled water (1:20 *w/v*). The mixture was kept for 15 min on a magnetic stirrer at room temperature and filtration was carried out using Whatman No: 1 paper. Glass balloons containing 25 mL of filtrate were frozen at −38 °C and lyophilization was performed at −50 °C. The freeze-dried powders obtained were placed in amber glass jars and kept at refrigerator temperature until used.

2.2.2. Pastırma production and storage

Pastırma production was performed as shown in Fig. 1 according to the methods described by Aksu, Kaya, and Ockerman (2005). The slaughter days and hours of the animals were followed, and the muscles taken 24 h after slaughter were transferred to the laboratory under cold chain and strict hygienic conditions. After removing the fat layers and visible connective tissues on the surface of the muscles, each whole muscle was divided into two parts horizontally, and four groups of meat pieces were obtained from a carcass for different treatments. In this way, the differences that may arise from the raw material for different treatments in the same repetition were reduced. The same procedure was followed for all three replicates in pastırma production. Both curing and cemening processes were carried out individually for each treatment group in specially designed wooden cuvettes (15 × 10 × 60 cm). The one of the four meat pieces suitable for the production of pastırma belonging to a carcass for each repeat was evaluated as a control group (without RWE). Other muscles were used for treatment groups produced with cemen paste composition containing the three best RWE (freeze-dried raspberry water extracts) concentrations (3.0%, 4.0%, and 5.0%) determined by Aksu et al. (2021). According to the methods, dry curing was applied in production and curing was carried out at 6 °C. Cemening (coating with cemen paste; 500 g fenugreek seed flour, 350 g garlic, 75 g red pepper powder, 75 g paprika, 1200 mL water) was done at 7 °C for 4 days. The produced all pastırma groups were wrapped with a single layer of polyvinyl chloride film (Cook, Sedat Tahir Jsc) and stored at 4 ± 1 °C for 150 days. The characteristics of the packaging material were as follows: thickness 8 μ; WVTR (water vapor transmission rate) 169 g/m^2.24h.bar at 23 °C, 75% RH; OTR (oxygen transmission rate) 5000 cm^3/m^2.24 h.bar at 23 °C, 0% RH.

2.2.3. Sampling and analysis procedure

Color measurements of outer surface were made on the whole pastırma (without sliced), then the samples were sliced and other analysis were carried out. The pastırma samples were sliced about 2–3 mm thick under hygienic conditions and each sampling was done in twice.

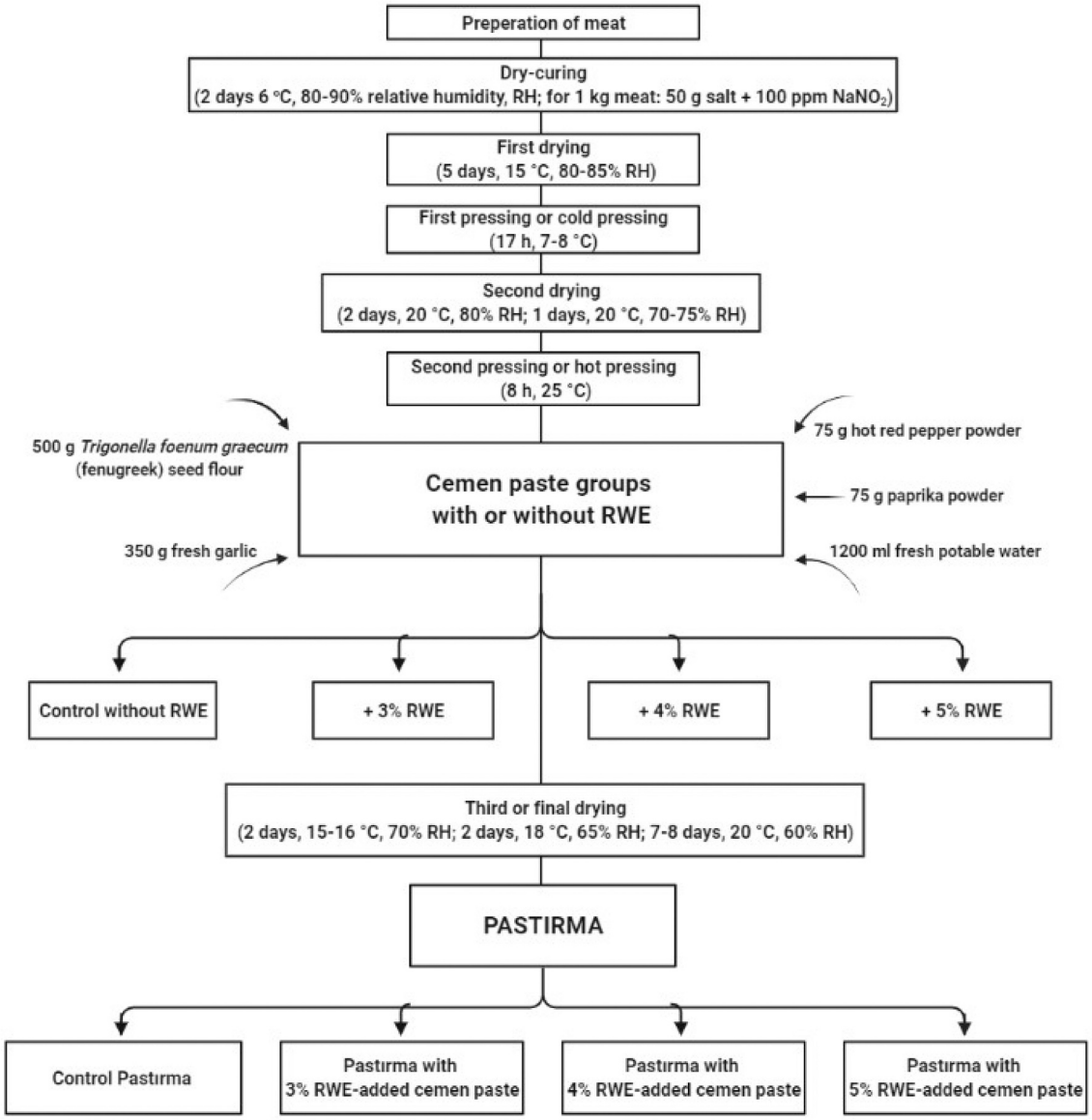

Fig. 1. Production process of pastırma with raspberry water extract (RWE).

Primarily, samples were randomly taken from sliced pastırma in aseptic conditions for microbiological analysis. Following color measurements of the sliced surface of pastırma, sliced pastırma samples were used by passing through a meat grinder for lipid oxidation, protein oxidation, moisture, pH, salt and residual nitrite analyses. Sensory evaluation was performed on sliced pastırma samples after microbiological analysis results were determined.

2.2.4. Chemical analyzes

Moisture contents of raw material and pastırma samples were determined by drying ten grams of sample weighed in nickel containers for 16–18 h in a drying cabinet at 100–102 °C until a constant weight was obtained. For pH analysis, ten grams of pastırma samples with cemen paste weighed in parallel were homogenized with an Ultra-Turrax after adding 100 mL of distilled water. Color measurements were performed on the outer surface of meat and pastırma samples (covered with cemen paste), and on the inner area of the sliced (thickness 2–3 mm) surface of each sample using a chromameter (CR-400, Minolta Co, Osaka, Japan) with a Ø11 mm, D65 illuminant source and 2° observer features. Lipid oxidation (thiobarbituric acid reactive substances, TBARS, as μmol MDA (malondialdehyde)/kg sample) was assessed using the method developed by Tarladgis, Pearson, and Dugan Jr (1962). Protein oxidation (nmol carbonyl/mg protein) was determined according to the DNPH procedure applied by Armenteros, Heinonen, Ollilainen, Toldrá, and Estevez (2009). The method described by Tauchmann (1987) was used to determine the residual nitrite (ppm) and salt (%) content of the pastırma samples. Color, lipid oxidation, protein oxidation, moisture, pH analyses were carried out during the pastırma production stages (raw material, before cemening, after cemening, and pastırma) at all storage periods (0th, 30th, 60th, 90th, 120th and 150th days). Salt and residual nitrite analyses were carried out only in pastırma.

2.2.5. Sensory analysis

A nine-point hedonic scale (1–9) was used in the panel organized to determine the sensory attributes of pastırma. Sensory evaluation was performed by 10–12 expert panelists selected from the academic staff and researchers in the Department of Food Engineering, and panelists were informed in detail prior to sensory analysis. The selection of the panelists was carried out by paying attention to their sensory experience

on meat products and especially their familiarity with the consumption of pastırma. The panelists who agreed on the purpose of the study signed the consent form. The panelists were asked to evaluate randomly coded samples for each sensory criterion, including the color of sliced pastırma, the quality of cemen paste, flavor, texture-structure, and general acceptability level. The samples were presented to the panelists in white plates, water and bread was given for rinsing the mouth cavity between tests of each sample. The sensory evaluation of pastırma was performed in three replicates as sessions for each storage time, and the scores from the panelists for each sample and session were averaged.

2.2.6. Microbiological analyses

Briefly, 225 mL of sterile saline solution (0.85% NaCl, Merck) was transferred to 25 g sample weighed in sterile sample bags and the mixture was homogenized using a stomacher (120 s, paddle speed: 230/normal, Lab Stomacher Blender 400-BA 7021, UK) Then, serial dilutions were prepared with sterile saline solution and inoculated onto the surface of the appropriate medium with the spread plate technique. Plate Count Agar (PCA, Oxoid) was used for total aerobic mesophilic bacteria count. Colonies growing on petri plates incubated aerobically for 48 h at 30 °C were counted. MRS (de Man Rogosa Sharpe) and VRBD (Violet Red Bile Dextrose, Oxoid) Agars were used for lactic acid bacteria (LAB) and *Enterobacteriaceae* counts, respectively, both were incubated at 30 °C for 48 h under anaerobic conditions (Anaerocult A, Merck). Catalase test was applied to the growing colonies and the LAB counts were determined by considering the catalase (−) colonies. For *Enterobacteriaceae* colonies over 1 mm in diameter were enumerated. *Micrococcus/Staphylococcus* were enumerated on Mannitol Salt Agar (MSA, Merck) considering catalase (+) cocci after an aerobic incubation at 30 °C for 48 h. Mold-yeast counts on Potato Dextrose Agar (PDA, Merck) were determined following incubation at 25 °C for 4–5 days. The results were expressed as log colony forming units(CFU)/g. Microbiological analyses were determined in pastırma during the different storage periods (0th, 30th, 60th, 90th, 120th and 150th days).

2.3. Statistical analysis

The entire experiment was carried out in triplicate. A complete randomized design procedure with 4 × 10 factorial arrangement including treatments (extract levels in cemen paste; control without RWE, 3% RWE, 4% RWE, and 5% RWE) and production stages-storage periods (raw material, before addition of cemen, after addition of cemen, surface with cemen, pastırma, 30, 60, 90, 120, and 150 days) was applied for color, moisture, pH, TBARS and protein oxidation values. For these analysis, the treatments, production stages-storage periods and their interactions were considered as fixed factors, while replications was included in the model as a random factors.

The production stages were not included in the model for microbiological and sensory evaluation results and the experimental was a completely randomized design with 4 × 6 factorial arrangement including treatments and storage periods (pastırma, 30, 60, 90, 120, and 150 days) factors. For data from the microbiological and sensory analysis, the treatments, storage days, the interactions between these parameters and panelists (for sensory data) were considered as fixed effects and the replications as random effects. All data were subjected to General Linear Model (GLM) procedure using SPSS 22.0. Duncan's multiple comparison test was used to estimate significant differences ($P < 0.05$) between mean values. The results were presented as mean ± SE (standart error of the mean) in tables and figures.

3. Results and discussion

3.1. Color values (L*, a* and b*)

3.1.1. Outer surface color values

The outer surface color that enhances the appeal of pastırma is an important factor in consumers' preference of pastırma and depends on the cemen paste. This color of cemen paste is provided by red pepper. However, red pepper loses its vivid red color and becomes discolored (dull brown) due to unsuitable drying and storage conditions (Rhim & Hong, 2011). Furthermore, red pepper powder is adulterated with health-threatening Sudan dyes, sawdust and bran to mask the perception of quality and increase profits (Galvin-King, Haughey, & Elliott, 2018; Modupalli, Naik, Sunil, & Natarajan, 2021). If the impurities are high and the color is pale brown in red pepper, it is not possible to achieve the desired color. For this reason, synthetic colorants are usually added to the cemen paste composition. In studies conducted by various researchers, it has been suggested to use different components such as water extracts of red beet (Aksu, Erdemir, Turan and Sat, 2020) and red cabbage (Aksu, Erdemir, Oz, Turan, & Gurses, 2020; (Aksu et al., 2020)) instead of synthetic colorants in the production of pastırma and cemen paste. In the present study, the L^* color values of the outer surface did not change in the pastırma produced with RWE cemen paste ($P > 0.05$, Table 1). However, the production-storage stages ($P < 0.01$) had a significant effect on the L^* value (Table 2). It was observed that the change occurred mostly during the production. The treatment ($P < 0.01$), production-storage stages ($P < 0.01$), and the two-way interaction ($P < 0.01$) of these parameters had significant effects on the redness (a^*) values (Table 1; Table 2; Fig. 2a). The fact that this difference is approximately 3 units led to the conclusion that the extract increases the appeal of pastırma outer surface. As seen in Fig. 2a, a^* values in the

Table 1
Instrumental color, chemical, microbial and sensory mean values of pastırma produced using different levels of raspberry water extract (RWE).

Parameters	Extract level in cemen paste				*Standart Error*	*P*
	0%	3%	4%	5%		
Color values of the outer surface						
L^*	32.07	32.90	33.17	32.65	0.344	ns
a^*	7.36^{d}	8.88^{c}	9.64^{b}	10.40^{a}	0.186	**
b^*	9.37^{b}	10.79^{a}	11.25^{a}	11.02^{a}	0.277	**
Color values of the sliced surface						
L^*	40.32	40.60	39.90	39.28	0.431	ns
a^*	34.12^{c}	35.34^{b}	35.77^{ab}	36.40^{a}	0.293	**
b^*	17.95^{b}	19.23^{a}	19.20^{a}	19.38^{a}	0.345	**
Chemical properties						
Moisture (%)	47.44	47.26	46.52	47.03	0.280	ns
pH	5.59^{a}	5.50^{b}	5.41^{c}	5.38^{c}	0.015	**
TBARS[A]	22.65^{a}	14.84^{b}	12.20^{bc}	9.86^{c}	0.994	**
Protein oxidation[B]	3.31	3.01	3.17	2.98	0.164	ns
Residual nitrite (ppm)	2.30	2.06	1.67	1.05	0.603	ns
Salt (%)	4.72^{b}	4.81^{b}	4.95^{a}	4.60^{c}	0.451	**
Microbial changes (log cfu/g)						
Total aerobic mesophilic bacteria	6.78	6.43	6.28	6.22	0.171	ns
Micrococcus/ Staphylococcus	6.09	5.81	5.88	5.96	0.173	ns
Lactic acid bacteria	4.62^{a}	3.62^{b}	3.36^{b}	3.04^{b}	0.313	**
Yeast and moulds	4.58	4.03	4.53	3.94	0.295	ns
Sensory evaluation						
Color of sliced surface	6.67^{c}	7.00^{b}	7.37^{a}	7.54^{a}	0.095	**
Cemen quality	6.80^{c}	6.70^{c}	7.24^{b}	7.49^{a}	0.076	**
Flavor	6.84^{c}	6.99^{c}	7.30^{b}	7.58^{a}	0.089	**
Texture-structure	6.89^{d}	7.10^{c}	7.31^{b}	7.56^{a}	0.070	**
Overall acceptability	6.83^{c}	7.04^{c}	7.34^{b}	7.59^{a}	0.091	**

a-d: Any means in the same section and line having the same letters are not significantly different at $P < 0.05$.
±: Standard deviation, **: $P < 0.01$, ns: not significant.
[A] TBARS, Thiobarbituric acid-reactive substances, μmol malonaldehyde/kg.
[B] PO, Protein Oxidation, nm carbonyl/mg protein.

Table 2
Instrumental color, chemical, microbial and sensory values of pastırma samples produced using different levels of raspberry water extract (RWE) during the production and/or storage stages.

Parameters	Production-Storage Stages (PSS)												Statistical results
	Production stages					Storage stages (days)					*Standart Error*	*P*	Interactions
	Raw metarial	Before cemening	After cemening	Surface with cemen	Pastırma (Day 0)	30	60	90	120	150			*T x PSS*
Color values of the outer surface of pastırma													
*L**	40.64^{a}	28.59^{d}	29.85^{cd}	39.48^{a}	30.69^{bc}	31.97^{b}	31.74^{b}	31.42^{bc}	31.65^{b}	30.95^{bc}	0.544	**	ns
*a**	19.87^{a}	3.04^{e}	7.35^{cd}	14.70^{b}	8.10^{c}	8.13^{c}	7.81^{cd}	7.28^{cd}	7.38^{cd}	7.03^{d}	0.294	**	**
*b**	10.01^{de}	2.85^{g}	7.20^{f}	21.81^{a}	9.30^{e}	11.81^{b}	11.58^{bc}	10.54^{bcde}	10.72^{bcd}	10.26^{cde}	0.468	**	ns
Color values of the sliced surface of pastırma													
*L**	41.45	39.14	41.11		40.06	40.15	39.07	40.12	39.94	39.29	0.647	ns	ns
*a**	20.72^{e}	34.46^{c}	35.78^{b}		37.94^{a}	37.80^{a}	38.02^{a}	38.30^{a}	37.96^{a}	37.64^{a}	0.439	**	**
*b**	7.95^{d}	17.67^{c}	20.79^{ab}		21.35^{a}	19.56^{b}	20.45^{ab}	21.48^{a}	20.67^{ab}	20.59^{ab}	0.518	**	ns
Chemical properties of pastırma													
Moisture (%)	74.61^{a}	44.70^{c}	56.12^{b}		43.09^{d}	42.14^{d}	42.24^{d}	40.85^{e}	40.26^{ef}	39.54^{f}	0.420	**	ns
pH	5.48^{bc}	5.67^{a}	5.38^{c}		5.38^{c}	5.40^{c}	5.43^{cd}	5.49^{bc}	5.50^{b}	5.52^{b}	0.022	**	**
TBARS[A]	2.65^{c}	7.97^{b}	12.09^{b}		18.17^{a}	16.95^{a}	19.87^{a}	19.30^{a}	19.89^{a}	17.08^{a}	1.490	**	*
PO[B]	2.12^{c}	2.19^{c}	2.21^{c}		3.08^{b}	3.55^{ab}	4.03^{a}	4.01^{a}	3.46^{ab}	3.41^{ab}	0.246	**	ns
Microbial counts of pastırma													
Total aerobic mesophilic bacteria (log cfu/g)					6.66	6.37	6.57	6.61	6.44	5.92	0.209	ns	ns
Micrococcus/Staphylococcus (log cfu/g)					6.25	5.76	6.21	6.14	5.77	5.46	0.212	ns	ns
Lactic acid bacteria (log cfu/g)					3.85	3.38	3.44	3.56	3.70	4.03	0.383	ns	ns
Yeast and moulds (log cfu/g)					4.87^{a}	4.81^{a}	4.30^{a}	4.31^{a}	4.39^{a}	2.95^{b}	0.362	**	ns
Sensory evaluation of pastırma													
Color of sliced surface					6.92	7.44	7.09	7.11	7.16	7.14	0.116	ns	ns
Cemen quality					7.01	7.18	7.08	6.99	7.22	7.32	0.093	ns	ns
Flavor					7.21	7.21	6.97	7.24	7.17	7.26	0.109	ns	ns
Texture-structure					7.32^{ab}	7.26^{abc}	7.02^{c}	7.08^{bc}	7.26^{abc}	7.36^{a}	0.173	*	ns
Overall acceptability					7.25	7.24	7.07	7.21	7.15	7.28	0.183	ns	ns

a-g: Any means in the same section and line having the same letters are not significantly different at $P < 0.05$.
±: Standard deviation, **: $P < 0.01$, *: $P < 0.05$, ns: not significant.
[A] TBARS, Thiobarbituric acid-reactive substances, μmol malonaldehyde/kg.
[B] PO, Protein Oxidation, nm carbonyl/mg protein.

treatment groups with extract were higher than the control after the cemening stage. Similarly, the *a** values of the RWE containing samples during storage were higher than the control and the outer color of the pastırma was more stable. Because redness (*a**) values were connected with anthocyanins values of RWE (Aksu et al., 2021). In addition, an effective factor in increasing the color of cemen paste is the pH value. As can be seen in Table 1 and Fig. 3a, the pH values of pastırma produced with extract-added cemen paste were lower in the control samples. This is effective in increasing the *a** values due to the behavior of anthocyanins at low pH (Aksu, Turan and Sat, 2020). In the research conducted by Aksu et al. (2021), the pH values of cemen pastes with 5.0% RWE decreased from 6.07 (control cemen paste) to 4.72. Therefore, the outer surface *a** values improved with the increase of the effect of anthocyanins at low pH. The treatment and the production-storage stages parameters had a significant ($P < 0.01$) effect on the outer surface *b** values of the pastırma produced by adding RWE to the cemen paste (Table 1, Table 2). With the addition of raspberry extract to cemen paste, the pastırma outer *b** values increased ($P < 0.05$). In many studies, it was reported that there was a linear relationship between the *b** and *a** color values of pastırma (Cakici et al., 2015; Uguz, Soyer, & Dalmis, 2011).

3.1.2. Sliced pastırma surface color values

The *a** values of the sliced samples of pastırma produced by adding RWE to cemen paste were found higher than the control samples, and the addition of the extract contributed to the increase of redness ($P < 0.01$, Table 1). The detection of this color difference during the storage period, which had a significant ($P < 0.01$) effect on redness, is an important finding both in terms of preserving the quality of the pastırma and the effect of raspberry-induced color substances. In extract-added samples, the color remained more stable during storage, and the discoloration was less (Table 2, Fig. 2b). Production conditions and duration, curing form and duration, methods, curing agents (nitrite, nitrate, salt and ascorbic acid), storage time, storage conditions and microbiological properties in sliced pastırma samples may affect the redness value (Uguz et al., 2011). In the current study, the redness values in the pastırma produced using cemen paste containing RWE were higher than the values determined between 21.45 and 35.40 for the "sırt" pastırma type in the market research conducted by Cakici et al. (2015). As can be seen in Fig. 2b, there was no significant difference in *a** values for cured meats before the cemening stage (BC), while differences were observed between treatments after the cemening stage (AC). This difference is due to the use of different cemen paste compositions in production, and depending on the usage levels of anthocyanin-containing extracts, the *a** value increased and the difference was preserved during storage period. This situation can be explained as follows: Compound/substance transition occurs between cured meat and cemen paste in cemening stage. At this stage, although the salt balance is mainly provided between cemen paste and salted meat, other substances such as amino acids also pass into the meat. Erdemir and Aksu (2017) emphasized that the increase in the amount of free amino acids in pastırma was caused by the transition of free amino acids in the cemen paste to meat during the cemening stage. Treatment ($P < 0.01$, Table 1) and production-storage stages ($P < 0.01$, Table 2) had a very important

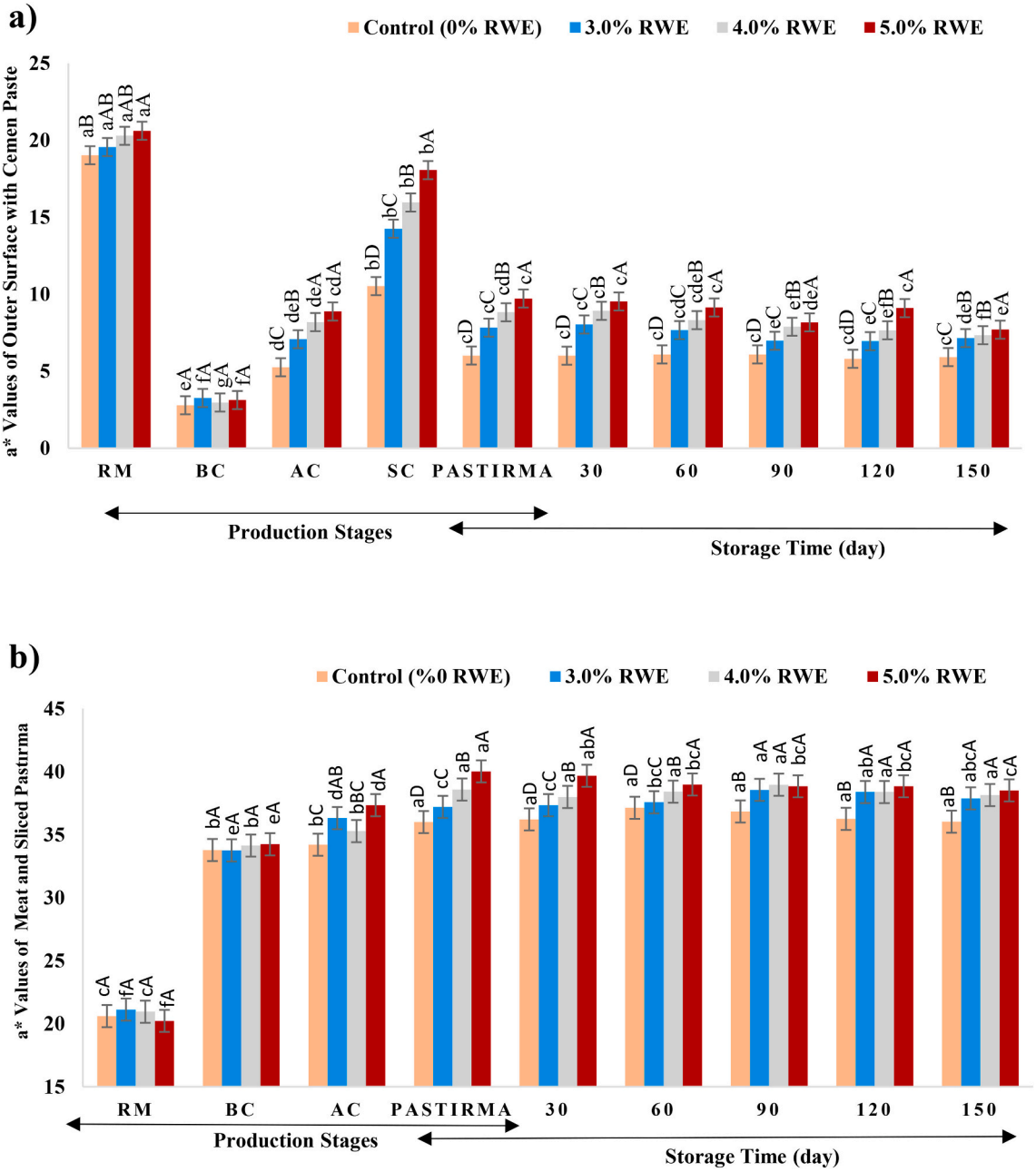

Fig. 2. Effect of the treatment x production-storage stages interaction on the outer surface (a) and the sliced section surface (b) a* values of pastırma.
RWE: Raspberry water extract; RM: Raw material; BC: Before cemening; AC: After cemening; SC: Surface with cemen paste).
The different letters in the bar graph show significant differences ($P < 0.05$) between the production-storage stages (a–f) in each treatment, or treatments (A–D) on each production-storage stage.

effect on the b^* values of sliced pastırma produced using different levels of RWE. Higher b^* values were determined in samples with extract ($P < 0.05$). The redness (a^*) values decrease depending on drying, storage time, temperature, packaging, and whether it is sliced (Aksu et al., 2005). However, in the present study, the use of LBWE in pastırma production prevented discoloration by maintaining the a^* values during storage.

3.2. Oxidation values

3.2.1. Lipid oxidation (TBARS) values

The stage defined as "second drying" or "terleme = sweating" in pastırma production is very important in terms of quality formation. At this stage, the fat on the surface of the meat pieces partially melts under the effect of the temperature (3–4 days, 20 °C) and fat droplets are formed on the surface of the meat. In addition, significant changes occur in the fat during the sweating stage and this change is desirable in terms of the sensory properties of pastırma. The process defined as "second pressing" or "sıcak denkleme" in pastırma production is applied immediately after the "second drying" stage (Aksu, Erdemir, Turan and Sat, 2020) and two important events that affect the pastırma quality occur in this process. Firstly, the meat partially loses water and easily takes its final shape. Secondly, in the "second drying" phase, the fat droplets formed on the outer surface of the meat penetrate into the meat with the effect of pressing, and the pastırma gains a better flavor and texture. If an appropriate cemening process (or paste seasoning) is not applied after "second pressing" stage, it creates important problems in later production stages and especially during storage in terms of lipid

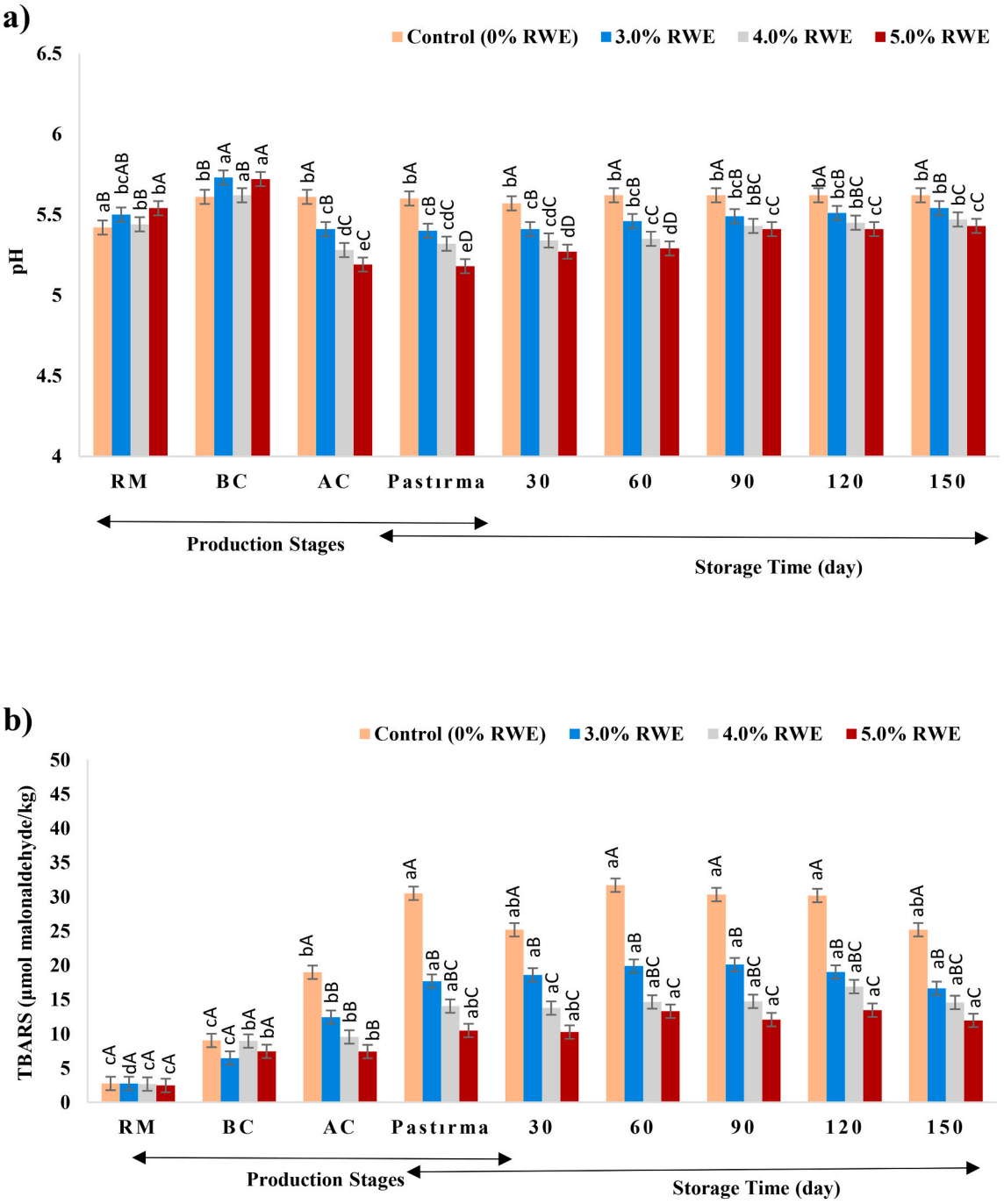

Fig. 3. Effect of the treatment x production-storage stages interaction on pH (a) and TBARS (b) values of pastırma.
RWE: Raspberry water extract; RM: Raw material; BC: Before cemening; AC: After cemening).
The different letters in the bar graph show significant differences ($P < 0.05$) between the production- storage stages (a–d) in each treatment, or treatments (A–C) on each production-storage stage.

oxidation. Aksu & Erdemir (2022) determined that the average TBARS value was 7.31 ± 0.76 µmol MDA/kg in beef *Longissimus thoracis et lumbarum* used in pastırma production. Similarly, Aksu et al. (2016) observed that the average TBARS value, which was 5.25 µmol MDA/kg in beef L. *dorsi* muscle used in pastırma production, increased up to 12.72, 28.67 and 36.51 µmol MDA/kg at the end of curing, second drying and final product stages, respectively. Briefly, it is not possible to prevent lipid oxidation under conventional and controlled conditions during pastırma production since significant changes occur in fats depending on the production conditions. These changes especially in fats directly affect the sensory properties and are undesirable as they are considered as an indicator of deterioration. In this regard, the present findings showed that RWE makes a remarkable contribution to the reduction of lipid oxidation in pastırma. The use of antioxidants or plant extracts with antioxidant properties is an important issue to maintain quality and product stability in pastırma production. However, two points should be considered in their use. Firstly, antioxidants in pastırma should be added at cemen paste or cemening stage. Thus, the formation of fat-based flavor and aroma is enabled in second drying and second pressing. Secondly, the use of plant extracts instead of synthetic antioxidants in the cemening stage provides an advantage in terms of preventing discoloration in addition to delaying oxidation in the product.

For these reasons, RWE was added to cemen paste and its antioxidant effects were also investigated in this research.

The use of RWE (Table 1) and production-storage stages (Table 2) had a significant ($P < 0.01$) effect on TBARS values. TBARS values of pastırma samples decreased due to the increase in total phenolic content and antioxidant activity of cemen pastes produced with RWE, this decrease was depend on RWE concentration. The highest reduction was observed in the group produced with 5% RWE-added cemen paste. This difference was approximately 13 units relative to the control (Table 1). Sariburun et al. (2010) reported that there was a linear correlation between total phenolic content and antioxidant activity of raspberry. Total phenolic content, total anthocyanin content and total antioxidant activity of RWE were 66.19 ± 9.46 μg GAE/mg, 1096.71 ± 36.97 mg cy3-G/kg, and 49.67 ± 3.67%, respectively. RWE has high FRAP, free radical scavenging and metal chelating activities (Aksu et al., 2021). Anthocyanins also increase the oxidative stability of foods due to their high antiradical activities (Franceschinis et al., 2014; Turan & Şimşek, 2021). Recent studies have indicated that lipid oxidation can be prevented by applying different processes for pastırma production (Aksu, Erdemir, Oz, Turan, & Gurses, 2020; Aksu, Erdemir, Turan and Sat, 2020).

TBARS values of pastırma samples produced with or without RWE changed significantly during the production stages ($P < 0.05$), but the change during the storage period including the final product (day 0) phase was statistically insignificant ($P < 0.05$, Table 2). In addition, treatment x production-storage stages interaction ($P < 0.05$) was observed on the TBARS values of pastırma. TBARS values increased during the production stages decreased especially after day 60, but the greatest decrease was observed in the control samples on day 150 (Fig. 3b). This reduction is thought to be due to inhibition of formation of malonaldehyde(MDA) as a result of binding of oxidized compounds with amino groups. The fluctuations of TBARS values during the storage period can be attributed to the reaction of MDA with amino acids, proteins, phospholipids containing amine and the decomposition of MDA into other organic by-products that do not react with TBA (Karpińska-Tymoszczyk & Draszanowska, 2019). Also, the reason for the decrease in TBARS values towards the end of storage may be considered that the MDA loss rate during storage is predominant compared to the production rate through lipid oxidation and that low molecular weight volatile oxidation products are lost during long-term storage (Maqsood, Benjakul, & Balange, 2012). Furthermore, there are several limitations to the use of the TBARS method, which is widely used to determine lipid oxidation, in dry-cured products. The presence of residual nitrite in cured products can lead to nitrosation of MDA even at room temperature. This can result in the determination of lower values than expected TBA numbers by limiting the reaction of MDA with TBA. Although it is recommended to add sulfanilamide during analysis to prevent nitrosation of MDA, the addition of sulfanilamide is also not sufficient to prevent underestimation of TBARS in case of low nitrite concentration (Fernández, Pérez-Álvarez, & Fernández-López, 1997; Ventanas, Estevez, Tejeda, & Ruiz, 2006). A similar downward trend in TBARS after reaching its maximum values during the production and storage periods was previously determined by Harkouss et al. (2015) in dry-cured ham, reported by Lorenzo and Carballo (2015) in dry-cured foal loin, and shown by Guo et al. (2019) in dry-cured mutton ham.

3.2.2. Protein oxidation values

Protein oxidation can occur during food processing and storage and can affect meat processing quality. Studies have shown that salting and/or curing technology widely used in meat processing increases protein oxidation oxidation (Estevez, 2011; Soladoye, Juarez, Aalhus, Shand, & Estevez, 2015). In this context, it has been reported that oxidation is higher in meats cured with methods such as high pressure and power ultrasound, in which the effect of curing is increased (Kang et al., 2016). Pastırma is a dry cured meat product, but as noted by the researchers, there is no effective protein oxidation to in the curing stage (stages before cemening) (Table 1). In other studies, it was determined that there was a partial increase in protein oxidation values until cemening stage (Aksu, Erdemir, Oz, Turan, & Gurses, 2020; Aksu, Erdemir, Turan and Sat, 2020). It has been emphasized that the most change in proteins in the production of pastırma occurs in the second drying stage, where microbiological and enzymatic activities are higher. During the production and storage stages of pastırma, important changes occur in proteins, and proteins undergo structural changes as a result of various enzymatic and microbiological changes.

In the current study, considering the average protein oxidation values of the treatment groups, the values of the extract-added samples are slightly lower, but the results were statistically insignificant ($P > 0.05$). Contrary to the current study results, it has been reported that pomegranate peel extract prevent protein oxidation in meatballs during refrigerated (Turgut, Soyer, & Işıkçı, 2016). The protein oxidation values were significantly affected by the production-storage stages ($P < 0.01$). The relatively low protein oxidation values during the production stages increased until the 60th day of storage, and slightly decreased in the following storage days (Table 2).

3.3. Moisture content

Moisture content was not affected ($P > 0.05$, Table 1) by the treatment, but the effect of the production-storage stages was significant ($P > 0.01$, Table 2). The moisture values of all samples decreased during storage, and the lowest values were determined on day 150 (Table 2). Moisture content is an important criterion in the formation of the quality properties of pastırma. The moisture content of the raw material, which is about 75%, decreases up to 50% by curing, 1st, 2nd and 3rd drying processes and rises again with cemening. The water in the composition of the cemen paste passes into meat and causes an increase of about 10%. After the cemening stage, the pastırma is dried until it reaches the appropriate moisture content. In accordance with our findings, in a study conducted on pastırma produced from different animal meats, the moisture content of 73.4% in fresh beef muscle was determined as 42.6% in the final product (Ren et al., 2015). The moisture content of the final product, pastırma is affected by the quality of meat used in production, the method of salting and the amount of salt, the durations of drying, cemening and the drying with cemen paste. In addition, the moisture content of the pastırma is also affected by the storage conditions and decreases depending on the storage temperature. In the current study, approximately 3% moisture loss occurred in 150 days of storage (Table 2).

3.4. pH values

The pH values of the pastırma decreased compared to the control depending on the extract level (Table 1). This gradual decline in pH can be attributed to high titration acidity (11.91% citric acid) of RWE and low pH values (3.36) of extract-added cemen pastes determined in our previous study (Aksu et al., 2021). In the same study, the pH values of cemen pastes produced by adding 0%, 3%, 4% and 5% RWE were determined as 6.07, 5.03, 4.83 and 4.72, respectively. Therefore, pH values of samples decreased depending on the added extract level after from the cemening stage of pastırma production, and this difference between control samples and samples with extract was maintained during storage (Table 2). However, the pH values increased partially during storage (Fig. 3a). This increase is thought to result from the proteolytic changes and drying that occurred during this process. The pH value in ready-to-consumption pastırma increases compared to meat used as raw material due to proteolytic activities and drying process during production (Ren et al., 2015; Uguz et al., 2011). Similarly, in the current research, the pH changes of the control pastırma samples without extract are consistent with the values determined by the researchers during both production and storage stages.

3.5. Residual nitrite and salt values

During pastırma production, nitrite breaks down and residual nitrite amount decreases in the final product. Aksu et al. (2016) reported that the residual nitrite content of the pastırma, which was significantly affected by the nitrite level and production stages, gradually decreased in the stages after curing and was 4.38 ppm in the final product. In this study, the residual nitrite content was found higher in control pastırma than the other groups produced with cemen pastes containing RWE (Table 1), but this difference was statistically insignificant ($P > 0.05$). The low residual nitrite content in samples with RWE is thought to be due to lower of their pastırma pH. The decrease in the pH of these pastırma caused the nitrite to break down more. In pastırma, salt amounts significantly affected ($P > 0.01$) by the treatment, and the highest salt amount was determined as 4.95 ± 1.16% in the 4.0% RWE treatment group (Table 1).

3.6. Microbiological results

The treatment had a significant effect only on lactic acid bacteria ($P > 0.01$). The effect of storage period parameter only on yeast-mold counts was significant ($P > 0.01$, Table 1). Treatment x storage time interaction was insignificant for all bacterial counts ($P > 0.05$, Table 2). The decrease in LAB counts of pastırma samples was dependent on the increasing RWE level in cemen paste formulation, the lowest counts were in the pastırma group treated with 5% RWE-added cemen paste ($P > 0.05$, Table 1). However, the difference between the LAB counts of the extract-containing treatment groups was insignificant ($P > 0.05$). Total aerobic mesophilic bacteria and *Micrococcus/Staphylococcus* counts were partially reduced with prolonged storage time, but the difference between the mean values of the counts determined during storage times was insignificant. The yeast-mold counts decreased in general during storage, and the lowest values were determined at day 150 ($P > 0.05$, Table 2). Our data for mold-yeast counts were supported by Aksu, Erdemir, Oz, Turan, and Gurses (2020), Aksu, Erdemir, Turan and Sat (2020)'s previous observations. It was found that the mold-yeast count of pastırma produced using cemen paste with red beet extract decreased from 4.65 to 2.86 log cfu/g during storage (Aksu, Erdemir, Oz, Turan, & Gurses, 2020). The current study findings were similar to studies indicating that LAB and *Micrococcus/Staphylococcus* were dominate in the pastırma flora (Aksu et al., 2016; Cakici et al., 2015; Karabiyikli, Oncul, & Cevahiroglu, 2015). Öz, Kaban, Barış, and Kaya (2017) reported that the dominant lactic acid bacteria in pastırma is *Lactobacillus sakei*. The counts of *Enterobacteriaecea* were below the detectable limit (<2.00 log cfu/g) during storage in all pastırma groups. Due to phytochemical composition of major anthocyanins present in raspberries, raspberries offer potential bioactivities such as antimicrobial (Aly, Ali, & Eliwa, 2019). The change in the microbial counts of pastırma during storage mainly depends on the preservation method and the initial quality characteristics of the product (moisture, a_w, pH etc.). In the current study, lower aerobic mesophilic bacteria counts at the end of storage compared to initial values were similar to Aksu et al. (2005), they reported that these bacteria decreased with increasing storage time. Abd-Elghany, El-Makhzangy, El-Shawaf, El-Mougy, and Sallam (2020) reported that *Enterobacteriacea* and yeast-mold counts were not detected in pastırma samples stored for 60 days.

3.7. Sensory evaluation

Organoleptically, the appearance of the pastırma is closely related to the quality of cemen paste, but the composition and properties of cemen paste are also effective (Aksu et al., 2020). On the other hand, the sensory attributes of sliced pastırma are also affected by the production conditions and curing composition. In the current study, the sliced section surface color, cemen paste quality, flavor, texture-structure and general appreciation level of the pastırma samples were significantly ($P < 0.01$) affected by the use of RWE. All sensory parameter scores increased depending on the concentration of extract incorporated to cemen paste ($P > 0.05$). The highest sliced section surface color scores were determined in 4.0% and 5.0% extract-added samples, while 5.0% extract-added pastırma samples had the highest scores for other parameters (Table 1). These results clearly showed that sensory evaluation scores determined for cemen paste treated with RWE in the previous study (Aksu et al., 2021) were reflected in the pastırma sensory results in this study. The storage period also had a significant effect only on the texture-structure feature among these parameters ($P > 0.05$, Table 2). As a result, the quality of cemen paste was improved with the addition of RWE, and the flavor, sliced section surface color and general appreciation level of the pastırma increased. It is possible to state that the color scores are compatible with instrumental color measurements especially for the external and sliced section surfaces redness values of the pastırma. In some studies conducted in recent years, it has been determined that the sensory properties of pastırma produced with lyophilized red beet (Aksu, Erdemir, Turan and Sat, 2020) and red cabbage water extract (Aksu, Erdemir, Oz, Turan and Gurses, 2020) were improved.

4. Conclusion

RWE contributed to the prevention of color and lipid oxidation during the storage period of the pastırma. The redness values of the outer and sliced section surfaces of the pastırma enhanced with increasing extract concentration. On the other hand, the use of RWE improved the sensory attributes without remerkable alteration of pastırma microbial quality. These results clearly showed that RWE can be considered as an extremely suitable additive for use in pastırma production as they contribute to the sensory attributes as well as improve the physical and chemical quality properties of the pastırma. In conclusion, it is recommended to use 4.0% or 5.0% RWE levels as an alternative to synthetic and health-threatening colorant and antioxidant additives in pastırma and pastırma cemen paste production. In the light of this, it will be interesting for future studies to determine the effect of incorporating freeze-dried raspberry water extract in the curing phase on the overall quality of pastırma and to evaluate the interactions of these extracts with the curing components.

Author Statement

Muhammet İrfan AKSU: Conceptualization, Data Curation, Methodology, Investigation, Funding Acquisition, Project Administration, Writing – Review & Editing; **Ebru ERDEMİR**: Data Curation, Methodology, Resources, Visualization, Writing – Original Draft; **Emre TURAN**: Data Curation, Methodology, Resources, Visualization, Writing – Review & Editing; **Fatih ÖZ**: Methodology, Visualization, Writing – Orijinal Draft

Declaration of Competing Interest

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

Acknowledgments

This work was funded by the Scientific and Technological Research Council of Turkey (TUBITAK), Project No. TOVAG-1001-213O244.

References

Abd-Elghany, S. M., El-Makhzangy, A. M., El-Shawaf, A. E. M., El-Mougy, R. M., & Sallam, K. I. (2020). Ensuring the best storage temperature of Egyptian pastrami based on microbiological, physico-chemical and sensory evaluation. *Journal of Stored Products Research, 87*, Article 101626. https://doi.org/10.1016/j.jspr.2020.101626

Aksu, M. I., Dogan, M., & Sirkecioglu, A. N. (2017). Changes in the total lipid, neutral lipid, phospholipid and fatty acid composition of phospholipid fractions during pastırma processing, a dry-cured meat product. *Korean Journal for Food Science of Animal Resources, 37*(1), 18–28. https://doi.org/10.5851/kosfa.2017.37.1.18

Aksu, M. I., & Erdemir, E. (2022). The effect of potassium lactate on the free amino acid composition, lipid oxidation, colour, microbiological, and sensory properties of ready-to-eat pastırma, a dry-cured and dried meat product. *Journal of Food Science and Technology*.. https://doi.org/10.1007/s13197-021-05137-x

Aksu, M. I., Erdemir, E., & Cakici, N. (2016). Changes in the physico-chemical and microbial quality during the production of pastırma cured with different levels of sodium nitrite. *Korean Journal for Food Science of Animal Resources, 36*(5), 617. https://doi.org/10.5851/kosfa.2016.36.5.617

Aksu, M. I., Erdemir, E., Oz, F., Turan, E., & Gurses, M. (2020). Effects of cemen paste with lyophilized red cabbage water extract on the quality characteristics of beef pastırma during processing and storage. *Journal of Food Processing and Preservation, 44*(11), Article e14897. https://doi.org/10.1111/jfpp.14897

Aksu, M. I., Erdemir, E., Turan, E., & Sat, I. G. (2020). Effects of red beet extracts on protein and lipid oxidation, colour, microbial, sensory properties and storage stability of Turkish pastırma. *Journal of Stored Products Research, 89*, Article 101721. https://doi.org/10.1016/j.jspr.2020.101721

Aksu, M. I., Kaya, M., & Ockerman, H. W. (2005). Effect of modified atmosphere packaging and temperature on the shelf life of sliced pastirma produced from frozen/thawed meat. *Journal of Muscle Foods, 16*(3), 192–206. https://doi.org/10.1111/j.1745-4573.2005.08404.x

Aksu, M. I., Turan, E., & Sat, I. G. (2020). Effects of lyophilized red cabbage water extract and pH levels on the quality properties of pastırma cemen paste during chilled storage. *Journal of Stored Products Research, 89*, Article 101696. https://doi.org/10.1016/j.jspr.2020.101696

Aksu, M. I., Turan, E., Sat, I. G., & Erdemir, E. (2021). Red raspberry (*Rubus ideaus* L.) extracts: A novel ingredient in cemen paste. *Journal of Food Processing and Preservation., e15930*. https://doi.org/10.1111/jfpp.15930

Aksu, M. I., Turan, E., Sat, I. G., Erdemir, E., Oz, F., & Gurses, M. (2020). Improvement of quality properties of cemen paste of pastirma by lyophilized red cabbage water extract. *Journal of Food Processing and Preservation, 44*, Article e14714. https://doi.org/10.1111/jfpp.14714

Aly, A. A., Ali, H. G., & Eliwa, N. E. (2019). Phytochemical screening, anthocyanins and antimicrobial activities in some berries fruits. *Journal of Food Measurement and Characterization, 13*(2), 911–920. https://doi.org/10.1007/s11694-018-0005-0

Armenteros, M., Heinonen, M., Ollilainen, V., Toldrá, F., & Estevez, M. (2009). Analysis of protein carbonyls in meat products by using the DNPH-method, fluorescence spectroscopy and liquid chromatography–electrospray ionisation–mass spectrometry (LC–ESI–MS). *Meat Science, 83*(1), 104–112. https://doi.org/10.1016/j.meatsci.2009.04.007

Assous, M. T. M., Abdel-Hady, M. M., & Medany, G. M. (2014). Evaluation of red pigment extracted from purple carrots and its utilization as antioxidant and natural food colorants. *Annals of Agricultural Sciences, 59*(1), 1–7. https://doi.org/10.1016/j.aoas.2014.06.001

Cakici, N., Aksu, M. I., & Erdemir, E. (2015). A survey of the physico-chemical and microbiological quality of different pastırma types: A dry-cured meat product. *CyTA-Journal of Food, 13*(2), 196–203. https://doi.org/10.1080/19476337.2014.938123

Cavalcanti, R. N., Santos, D. T., & Meireles, M. A. A. (2011). Non-thermal stabilization mechanisms of anthocyanins in model and food systems-an overview. *Food Research International, 44*(2), 499–509. https://doi.org/10.1016/j.foodres.2010.12.007

Ceylan, S., & Aksu, M. I. (2011). Free amino acids profile in sırt, bohca, sekerpare pastirma, dry cured meat products. *Journal of the Science of Food and Agriculture, 91*, 956–962. https://doi.org/10.1002/jsfa.4273

Erdemir, E., & Aksu, M. I. (2017). Changes in the composition of free amino acid during production of pastirma cured with different levels of sodium nitrite. *Journal of Food Processing and Preservation, 41*(2), Article e12801. https://doi.org/10.1111/jfpp.12801

Estevez, M. (2011). Protein carbonyls in meat systems: A review. *Meat Science, 89*(3), 259–279. https://doi.org/10.1016/j.meatsci.2011.04.025

Fernández, J., Pérez-Álvarez, J. A., & Fernández-López, J. A. (1997). Thiobarbituric acid test for monitoring lipid oxidation in meat. *Food Chemistry, 59*(3), 345–353. https://doi.org/10.1016/S0308-8146(96)00114-8

Franceschinis, L., Salvatori, D. M., Sosa, N., & Schebor, C. (2014). Physical and functional properties of blackberry freeze-and spray-dried powders. *Drying Technology, 32*(2), 197–207. https://doi.org/10.1080/07373937.2013.814664

Galvin-King, P., Haughey, S. A., & Elliott, C. T. (2018). Herb and spice fraud; the drivers, challenges and detection. *Food Control, 88*, 85–97. https://doi.org/10.1016/j.foodcont.2017.12.031

Guo, X., Lu, S., Wang, Y., Dong, J., Ji, H., & Wang, Q. (2019). Correlations among flavor compounds, lipid oxidation indices, and endogenous enzyme activity during the processing of Xinjiang dry-cured mutton ham. *Journal of Food Processing and Preservation, 43*(11), Article e14199. https://doi.org/10.1111/jfpp.14199

Harkouss, R., Astruc, T., Lebert, A., Gatellier, P., Loison, O., Safa, H., & Mirade, P. S. (2015). Quantitative study of the relationships among proteolysis, lipid oxidation, structure and texture throughout the dry-cured ham process. *Food Chemistry, 166*, 522–530. https://doi.org/10.1016/j.foodchem.2014.06.013

Kang, D. C., Zou, Y. H., Cheng, Y. P., Xing, L. J., Zhou, G. H., & Zhang, W. G. (2016). Effects of power ultrasound on oxidation and structure of beef proteins during curing processing. *Ultrasonics Sonochemistry, 33*, 47. https://doi.org/10.1016/j.ultsonch.2016.04.024

Karabiyikli, S., Oncul, N., & Cevahiroglu, H. (2015). Microbiological safety of pastrami: A traditional meat product. *LWT-Food Science and Technology, 64*(1), 1–5. https://doi.org/10.1016/j.lwt.2015.05.006

Karpińska-Tymoszczyk, M., & Draszanowska, A. (2019). The effect of natural and synthetic antioxidants and packaging type on the quality of cooked poultry products during frozen storage. *Food Science and Technology International, 25*(5), 429–439. https://doi.org/10.1177/1082013219830196

Laokuldilok, T., & Kanha, N. (2015). Effects of processing conditions on powder properties of black glutinous rice (*Oryza sativa* L.) bran anthocyanins produced by spray drying and freeze drying. *LWT-Food Science and Technology, 64*(1), 405–411. https://doi.org/10.1016/j.lwt.2015.05.015

Lim, H. S., Choi, J. C., Song, S. B., & Kim, M. (2014). Quantitative determination of carmine in foods by high-performance liquid chromatography. *Food Chemistry, 158*, 521–526. https://doi.org/10.1016/j.foodchem.2014.02.122

Liu, H., Liu, Z., Wu, Y., Zheng, L., & Zhang, G. (2021). Regulatory mechanisms of anthocyanin biosynthesis in apple and pear. *International Journal of Molecular Sciences, 22*(16), 8441. https://doi.org/10.3390/ijms22168441

Lorenzo, J. M., & Carballo, J. (2015). Changes in physico-chemical properties and volatile compounds throughout the manufacturing process of dry-cured foal loin. *Meat Science, 99*, 44–51. https://doi.org/10.1016/j.meatsci.2014.08.013

Maqsood, S., Benjakul, S., & Balange, A. K. (2012). Effect of tannic acid and kiam wood extract on lipid oxidation and textural properties of fish emulsion sausages during refrigerated storage. *Food Chemistry, 130*(2), 408–416. https://doi.org/10.1016/j.foodchem.2011.07.065

Modupalli, N., Naik, M., Sunil, C. K., & Natarajan, V. (2021). Emerging non-destructive methods for quality and safety monitoring of spices. *Trends in Food Science & Technology, 108*, 133–147. https://doi.org/10.1016/j.tifs.2020.12.021

Nakyinsige, K., Man, Y. B. C., & Sazili, A. Q. (2012). Halal authenticity issues in meat and meat products. *Meat Science, 91*(3), 207–214. https://doi.org/10.1016/j.meatsci.2012.02.015

Öz, E., Kaban, G., Barış, Ö., & Kaya, M. (2017). Isolation and identification of lactic acid bacteria from pastırma. *Food Control, 77*, 158–162. https://doi.org/10.1016/j.foodcont.2017.02.017

Ren, W. W., Bekhit, A. E. D. A., Li, F., Yang, H. Y., Jiang, X. F., Zhang, W., & Kong, L. M. (2015). Physicochemical properties of pastirma from horse meat, beef, mutton and pork. *Journal of Food Quality, 38*(5), 369–376. https://doi.org/10.1111/jfq.12152

Rhim, J. W., & Hong, S. I. (2011). Effect of water activity and temperature on the color change of red pepper (*Capsicum annuum* L.) powder. *Food Science and Biotechnology, 20*(1), 215–222. https://doi.org/10.1007/s10068-011-0029-2

Sariburun, E., Sahin, S., Demir, C., Turkben, C., & Uylaser, V. (2010). Phenolic content and antioxidant activity of raspberry and blackberry cultivars. *Journal of Food Science, 75*(4), C328–C335. https://doi.org/10.1111/j.1750-3841.2010.01571.x

Soladoye, O. P., Juarez, M. L., Aalhus, J. L., Shand, P., & Estevez, M. (2015). Protein oxidation in processed meat: Mechanisms and potential ımplications on human health. *Comprehensive Reviews in Food Science and Food Safety, 14*, 106–122. https://doi.org/10.1111/1541-4337.12127

Summen, M. A., & Erge, H. S. (2014). Thermal degradation kinetics of bioactive compounds and visual color in raspberry pulp. *Journal of Food Processing and Preservation, 38*(1), 551–557. https://doi.org/10.1111/jfpp.12002

Tang, B., He, Y., Liu, J., Zhang, J., Li, J., Zhou, J., & Wang, X. (2019). Kinetic investigation into pH-dependent color of anthocyanin and its sensing performance. *Dyes and Pigments, 170*, Article 107643. https://doi.org/10.1016/j.dyepig.2019.107643

Tarladgis, B. G., Pearson, A. M., & Dugan, L. R., Jr. (1962). The chemistry of the 2-thiobarbituric acid test for the determination of oxidative rancidity in foods. I. Some important side reactions. *Journal of the American Oil Chemists' Society, 39*(1), 34–39. https://doi.org/10.1007/BF02633347

Tauchmann, F. (1987). *Methoden der chemischen Analytik von Fleisch und Fleischwaren* (p. 80). Kulmbach: Bundensanstalt für Fleischforschung.

Turan, E., & Şimşek, A. (2021). Effects of lyophilized black mulberry water extract on lipid oxidation, metmyoglobin formation, color stability, microbial quality and sensory properties of beef patties stored under aerobic and vacuum packaging conditions. *Meat Science, 178*, Article 108522. https://doi.org/10.1016/j.meatsci.2021.108522

Turgut, S. S., Soyer, A., & Işıkçı, F. (2016). Effect of pomegranate peel extract on lipid and protein oxidation in beef meatballs during refrigerated storage. *Meat Science, 116*, 126–132. https://doi.org/10.1016/j.meatsci.2016.02.011

Uguz, S., Soyer, A., & Dalmis, U. (2011). Effects of different salt contents on some quality characteristics during processing of dry-cured Turkish pastirma. *Journal of Food Quality, 34*(3), 204–211. https://doi.org/10.1111/j.1745-4557.2011.00382.x

Ventanas, S., Estevez, M., Tejeda, J. F., & Ruiz, J. (2006). Protein and lipid oxidation in Longissimus dorsi and dry cured loin from Iberian pigs as affected by crossbreeding and diet. *Meat Science, 72*(4), 647–655. https://doi.org/10.1016/j.meatsci.2005.09.011

Yetim, H., Ekici, L., Ozcan, C., Ozturk, I., Tornuk, F., & Karaman, S. (2017). Effects of some food juices and additives on some physicochemical, textural, color, microbiological and sensory properties of cemen paste. *Journal of Food Processing and Preservation, 41*(3), Article e12950. https://doi.org/10.1111/jfpp.12950