J Food Sci Technol (April 2022) 59(4):1288–1298
https://doi.org/10.1007/s13197-021-05137-x

ORIGINAL ARTICLE

# 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

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Revised: 30 March 2021 / Accepted: 6 May 2021 / Published online: 27 May 2021
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**Abstract** In this study, the effects of potassium lactate (PL, Potassium-L-2-hydroxy-propionate, Potassium-L-Lactate) usage (0%, 0.5%, 1.0%, 2.0% PL of curing mixture) in addition to NaCl and sodium nitrite as curing agent on the physico-chemical, microbiological and sensory properties of ready-to-eat pastırma were investigated. The usage of PL affected pastırma properties as pH ($P < 0.01$), TBARS ($P < 0.01$), salt ($P < 0.01$), residual nitrite content ($P < 0.01$), a* value ($P < 0.01$), microbial properties ($P < 0.01$) (total aerobic mesophylic bacteria, lactic acid bacteria, *Micrococcus*/*Staphylococcus*, yeast-mould count) and amino acid levels [lysine ($P < 0.01$), isoleucine ($P < 0.01$), leucine ($P < 0.01$), methionine ($P < 0.05$), phenylalanine ($P < 0.01$), valine ($P < 0.05$), threonine ($P < 0.01$), tryptophan ($P < 0.05$), aspartic acid ($P < 0.05$), glutamic acid ($P < 0.05$), asparagine ($P < 0.05$), serine ($P < 0.01$), histidine ($P < 0.01$), glycine ($P < 0.01$), alanine ($P < 0.01$), proline ($P < 0.01$), cystine ($P < 0.05$) and norvaline ($P < 0.01$)]. According to results of sensory analysis, the difference among pastırma samples including PL was not significant ($P > 0.05$).

**Keywords** Pastırma · Potassium lactate · Free amino acid · TEM · Oxidation

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## Introduction

Dry-salted meat products such as pastırma, dry-cured bacon, pastrami and dry-cured ham etc. are a type of processed meat products. The salting/curing is the main process in the production of salted meat products as it improves product quality such as texture, structure, flavor, microbial stability, sensory properties, lipid and protein oxidation, and also shelf life. The salt is the main ingredient in curing/salting process, however, there may be problems with products that use high amounts of salt, such as pastırma. Therefore, alternative ingredients should be used to improve the product quality and stability and also to increase the effect of salt and other curing agents. Some of these are Lactates (eg. Potassium lactate, PL). PL is a potential alternative compound which may be used for this aim. In previous studies PL is used for various purposes such as antimicrobial (Kim et al. 2010) and antioxidant (Mancini et al. 2010) activities, colour (Brewer et al. 1995; Kim et al. 2009; 2010), tenderness and texture (Fulladosa et al. 2009) improvement, increased cook yields (Papadopoulos et al. 1991), flavour development, proteolytic effect (Fik et al. 2008) and also improvement of shelf life (Brewer et al. 1995; Kim et al. 2009; 2010; Choi et al. 2014) of meat and meat products. However, the effects of PL on free amino acids and meat ultrastructure are not well known.

Pastırma is a traditional dry-cured meat product, and the maximum pH, moisture and salt content limits were specified 6.0, 50.0% and 10.0%, respectively in Turkish Food Codex (Anonymous, 2019). Also, the amount of nitrite allowed for pastırma production in Turkey is 150 ppm. In recent years, it has been observed that the salt and residual nitrite content of ready-to-eat pastırma samples is generally higher than acceptable limit. In previous studies,

the amounts of salt (sodium chloride) and residual nitrite were reported as 6.32 ± 1.00%—8.49 ± 1.57% and 1.34—48.89 ppm by Çakıcı et al. (2015), 2.74%—9.76% and 0.93—11.59 ppm by Aksu and Kaya (2001), respectively. Also, Zahran and Kassem (2011) determined residual nitrite content Egyptian pastırma samples as 51.99–251.60 ppm. On the other hand, it was found that *Pseudomonas* and *Enterobacteriacea* counts for ready-to-eat pastırma samples were < 2.0–5.69 log CFU/g and < 2.0–5.01 log CFU/g by Çakıcı et al. (2015), 4.38 log CFU/g and 5.69 log CFU/g by Gök et al. (2008), respectively. The growth of Gram(-) microorganisms including *Pseudomonas* and *Enterobacteriaceae* in pastırma is unacceptable. For improving safety and quality of final product, it is important to determine the effects of alternative curing agents which have potential for industrial practices. Due to their antimicrobial and antioxidant activities, effects on shelf-life of various meat product of lactates as curing agents has been reported previously. Lactates also improves the colour, flavor and texture characteristics of the meat products and reduce the amount of residual nitrite in cured meat products. However, to date, the effects of using lactate as curing agent in pastırma production on the final product quality have not been investigated in detail. The aim of this study was to evaluate the quality properties of read-to-eat pastırma containing PL together with salt and nitrite as curing component.

## Meterial and methods

### Material

For pastırma production, the *Longissimus thoracis et lumborum* muscles from carcasses of 3-year-olds male cattle (Brown Swiss crossbred) were used. The muscles were obtained from (after 24-h postmortem) ESK Slaughterhouse, Erzurum/Turkey. Potassium-L-Lactate (Potassium-L-2-hydroxy-propionate, 78%, GRAS, PURAC pure by nature, PURASAL HiPure P Plus, Density: 1.41–1.46 g/ml for 20 °C) was used as alternative partial replacement curing agent (Corbion Food Ingredients, Amsterdam, The Netherlands).

### Curing agent mixture and the pastırma process

The production of pastırma was performed according to the method used by Aksu et al. (2016) with some modifications in the curing compositions and drying time. The curing agent composition including PL and pastırma production method are given Fig. 1. For the last drying, the moisture value, stated in "Turkish Food Codex, Meat and Meat Products Notification", was considered (Anonymous 2019).

### Moisture, pH, Thiobarbituric Acid Reactive Substances, Salt, Residual Nitrite and Colour Anaylsis

The moisture and pH values were determined according to the method used by Ockerman (1985). The thiobarbituric acid reactive substances (TBARS) values of raw material and ready-to-eat pastırma were analyzed according to the method described by Aksu et al. (2015), and the TBARS values were calculated as μmol MDA/kg tissue. The salt and residual nitrite values were determined according to the method described by Tauchmann (1987), and the salt and residual nitrite results were calculated as % and ppm $NaNO_2$, respectively. The L*, a* and b* values of samples were measured according to the method used by Çakıcı et al. (2015). Colour measurements were taken on the sliced surface (1–2 mm thickness) of the each ready-to-eat pastırma samples.

### Free amino acids and transmission electron microscopy (TEM) analysis

The amounts of free amino acid were determined according to the methods described by Henderson et al. (1999) and Ceylan and Aksu (2011), and calculated as mg/100 g of dry matter. The Transmission Electron Microscopy (TEM) analysis was determined by the method of used by Ikinci et al. (2016). For analysis, nearly 1 $mm^3$ of each pastırma samples were subjected to 1.5 h of prefixation in 2.5% glutaraldehyde containing phosphate buffer (pH 7.3). The postfixation was applied 1 h in 1% $OsO_4$ solution containing phosphate buffer (pH 7.3). Washing of the parts was performed by using phosphate buffer. Washed materials were dehydrated by passing through rising alcohol levels. Washes materials were dehydrated by passing through 50%, 70%, 80% and 96% ethyl alcohol and waiting 20 min in 100% ethyl alcohol (repeated 3 times). Blocks were embedded in propylene oxide and araldite (CY 212, Electron Microscopy Science). To determine the cutting areas of the blocks, semi-thin sections (LKB Nova-Sweden) were painted with toluidine blue, thin sections of 30–40 nm thickness were taken, and the sections were painted with uranyl acetate and lead citrate dyes to increase contrast. These sections were examined by electron microscope (Jeol 100SX- Japan) and the images were captured (Kodak 4048, UK).

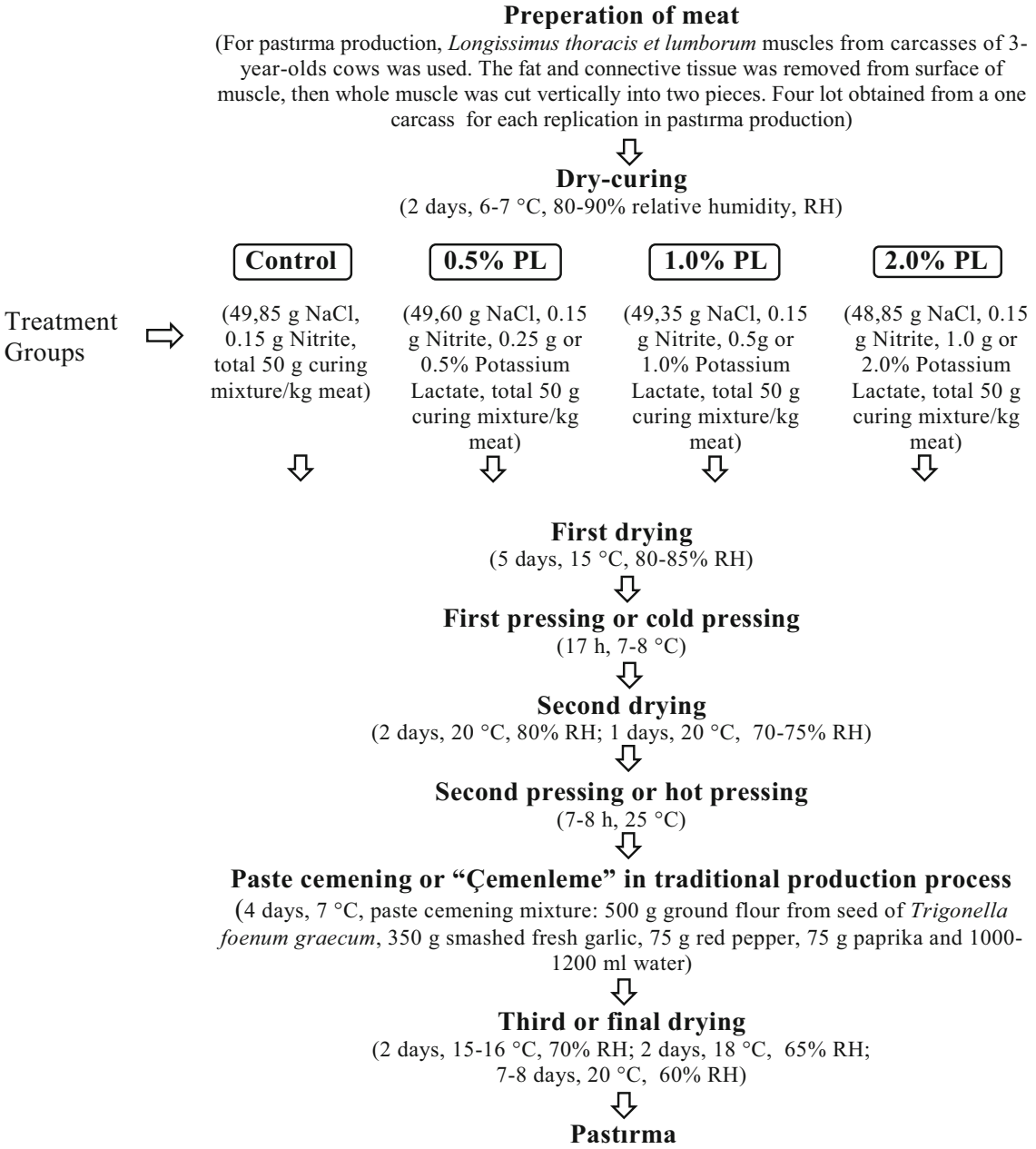


**Fig. 1** Production process of pastırma with potassium lactate

### Microbiological analysis

For microbiological analysis, a 25 g of the pastırma sample and 225 mL of physiological salt solution was homogenized in Stomacher. Then, dilutions were prepared by sterilized physiological salt solution and the analyses were performed. The plates were inoculated following spread plate method and transferred 0.1 ml from $10^{-2}$ solution. For determination of Total Aerobic Mesophilic Bacteria (TAMB), Plate Count Agar (PCA, Oxoid CMO325, England) was used. Samples were aerobically incubated at 30 °C for 48 h. For Lactic Acid Bacteria (LAB) analysis, MRS Agar (de Man Rogosa Sharpe, Oxoid CMO361, England) was used. The plates inoculated from the dilutions were incubated at anaerobic conditions at 30 °C for 48 h. The catalase (-) colonies were considered in determining the total LAB counts. For *Micrococcus/Staphylococcus* bacteria (M/S), mannitol salt phenol-red agar (Merck, KGaA, Germany) was used. The plates were aerobically incubated for 2 days at 30 °C. The catalase ( +) cocci were considered in determining the total M/S count. For yeast—mould counts, Potato Dextrose Agar (pH: 3.5) was used. Incubation was carried out for 4–5 days at 25 °C. For *Pseudomonas* count, *Pseudomonas* Agar Base (Oxoid CMO559,

England) prepared by adding Cetrimid-Fusidin-Cephaloridin (CFC) Selective Agar Supplement (Oxoid SR 0103, England) was used. For *Enterobacteriaceae* count, Violet Red Bile Glucose Agar (Oxoid CMO485, England) was used. The plates were incubated at 30 °C under anaerobic condition for 48 h and colonies with diameter > 1 mm were counted to determine count of *Enterobacteriaceae.* The results were calculated as log CFU/g (Colony forming units per gram of sample) (Baumgart et al. 1993).

### Sensory analysis

Sensory evaluation of pastima was carried out by 10 expert panelists from the meat and food science (60% females, 40% males, 23–46 years old) using a 9-point structured hedonic scale (1–3 = not acceptable, 4–5 = fairly acceptable, 6–7 = good, 8–9 = very good) for colour, brittleness, texture and structure, palatability and overall acceptability (Gök et al. 2008). For the salinity, 1–3 scores were regarded as extremely low salty, 4–7 moderate accebtable salty, 8 very salty and 9 extremely salty. Panellists were given all of four different pastırma groups sliced (Control, 0.5% PL, 1.0% PL and 2.0% PL) with randomized numbers for each sensory sessions. The sensory analyses of pastırma were done in two replicates for each pastırma. The sensory evaluation was done at room temperature in summer and at 11:00 in the daytime. Dirinking water and lavash bread were given to panelists for rinsing the mouth cavity between tests of each sample.

### Statistical analysis

Data were analysed as a completely randomized design procedure with SPSS using the General Linear Models in the analysis of variance (IBM SPSS Advanced Statistics 20.0, Program Number: 5725-A54), in two replicates. In this study, the model included only PL levels (control, 0.5% PL, 1.0% PL, and 2.0%PL) as main effects. Ten samples for sensory analysis (n = 10), four samples (n = 4) for other analysis were tested for each treatment group. ANOVA, analysis of variance was performed to determine if the differences between the corresponding quality parameter of the samples were statistically or not by using Duncan's method ($P < 0.05$). The results of the analysis were given as mean ± standard deviation and/or error in tables.

## Results and discussions

### Moisture contents and pH of pastirma samples

Use of PL in pastırma production had important effect on the moisture content ($P < 0.05$), the lowest moisture values were observed for ready-to-eat pastırma samples containing 0.5% and 2.0% PL as 44.09 ± 0.30% and 43.87 ± 0.46%, respectively (Table 1). The high amount of NaCl in the control pastırma caused it to have a higher moisture content than the pastırma with PL in the same conditions. Because salt increases the water holding capacity of proteins (Işıksal et al. 2009). Muñoz et al. (2009) found that the using K-lactate instead of NaCl to reduce sodium intake could reduce the excessive hardening at the surface of salted meat products. Thus, it will be easier for the product to dry, so the moisture of the product will fall more. These results are in line with our study. According to the Turkish Food Codex (TFC), the upper limit for moisture content for pastırma without cemen paste should be 50% (Anonymous 2019). Çakıcı et al. (2015) reported that the moisture contents of sırt type pastırma was as 47.56 ± 5.29%. The initial pH of raw meat used in production of pastirma was 5.59 ± 0.10; thereafter, it increased in all of the ready-to-eat pastırma depending on the used PL concentration. There were significant differences among treatments ($P < 0.01$), and the highest pH values were observed for the sample containing 2.0% PL as 5.95 ± 0.15 (Table 1). The pH is an important quality attribute of meat and meat product. During pastırma processing, the pH values tented to increase as a result of proteolysis and drying procedures. In particular, compounds formed as a result of proteolytic activity may cause a partial increase in pH. Nizamlıoğlu et al. (1998) reported that the pH values of pastırma were 5.56 – 6.16. In this study, similar changes were observed in control and 0.5% PL pastırma but it was thought that the increases in 1.0% and 2.0% PL groups were not a result of only proteolytic breakdown. Because, PL might have a role in increasing of the pH. The free amino acid results also supported this approach when considering the samples including PL, especially 2.0%, had lower free amino acid content than the control ($P < 0.05$) (Table 2). In studies related to dry-cured hams (Fulladosa et al. 2009) and model meat systems (McClure et al. 2011), it has been reported that the use of lactate increases the pH values.

### TBARS values

The lipid oxidation is another important quality parameter for pastırma as well as other cured meat products. The effect of lipid oxidation is important in the formation the

**Table 1** The properties of raw material and the pastırma produced with different potassium lactate levels (n = 4)

| Properties | Raw Metarial (Beef Meat) | Potassium Lactate Levels | | | | *P* |
|---|---|---|---|---|---|---|
| | | Control (0%) | 0.5% | 1.0% | 2.0% | |
| Moisture (%) | 75.26 ± 0.36 | 45.45 ± 1.21$^{a}$ | 44.09 ± 0.30$^{b}$ | 44.82 ± 0.38$^{ab}$ | 43.87 ± 0.46$^{b}$ | < 0.05 |
| pH | 5.59 ± 0.10 | 5.83 ± 0.20$^{c}$ | 5.85 ± 0.13$^{c}$ | 5.89 ± 0.10$^{b}$ | 5.95 ± 0.15$^{a}$ | < 0.01 |
| TBARS[1] | 7.31 ± 0.76 | 60.11 ± 15.78$^{a}$ | 47.27 ± 10.94$^{ab}$ | 49.87 ± 6.09$^{ab}$ | 39.08 ± 4.18$^{b}$ | < 0.01 |
| Salt (%) | – | 5.98 ± 0.16$^{a}$ | 6.07 ± 0.43 $^{a}$ | 5.42 ± 0.20$^{b}$ | 5.20 ± 0.07$^{b}$ | < 0.01 |
| Residual Nitrite (ppm) | – | 9.51 ± 0.80$^{a}$ | 6.37 ± 1.50$^{b}$ | 4.21 ± 0.88$^{c}$ | 4.32 ± 1.06$^{c}$ | < 0.01 |
| *Colour Values* | | | | | | |
| L* | 39.86 ± 3.20 | 38.83 ± 0.80$^{b}$ | 38.37 ± 0.42$^{b}$ | 40.24 ± 0.53$^{a}$ | 38.30 ± 0.75$^{b}$ | < 0.01 |
| a* | 29.86 ± 4.07 | 34.98 ± 0.93$^{c}$ | 38.25 ± 0.60$^{b}$ | 38.76 ± 0.28$^{b}$ | 39.97 ± 0.25$^{a}$ | < 0.01 |
| b* | 16.58 ± 2.54 | 19.37 ± 0.41$^{c}$ | 21.21 ± 0.42$^{b}$ | 22.50 ± 0.32$^{a}$ | 21.47 ± 0.58$^{b}$ | < 0.01 |
| *Microbiological Counts (Log CFU/g)* | | | | | | |
| Total aerobic mesophylic bacteria | 4.39 ± 0.14 | 7.93 ± 0.88$^{b}$ | 7.97 ± 0.89$^{b}$ | 7.66 ± 0.46$^{c}$ | 8.21 ± 0,18$^{a}$ | < 0.01 |
| *Micrococcus/Staphylococcus* | 3.07 ± 0.37 | 7.90 ± 0.96$^{b}$ | 8.12 ± 0.16$^{a}$ | 7.71 ± 0.94$^{c}$ | 7.46 ± 0.17$^{d}$ | < 0.01 |
| Lactic acid bacteria | 2.87 ± 0.13 | 4.40 ± 0.14$^{c}$ | 3.79 ± 0.23$^{d}$ | 5.55 ± 0.07$^{b}$ | 6.39 ± 0.15$^{a}$ | < 0.01 |
| Yeast and mould | 2.40 ± 0.22 | 5.16 ± 0.71$^{b}$ | 4.82 ± 0.87$^{d}$ | 4.98 ± 0.12$^{c}$ | 5.72 ± 0,74$^{a}$ | < 0.01 |
| *Pseudomonas* | 2.72 ± 0.22 | < 2.00 | < 2.00 | < 2.00 | < 2.00 | |
| *Enterobacteriaceae* | < 2.00 | < 2.00 | < 2.00 | < 2.00 | < 2.00 | |

[1]Thiobarbituric acid reactive substance, µmol malondialdehyde/kg

a-c Any means in the same line with the same letters for potassium lactate levels are not significantly different at $P < 0.05$

± Standard deviation

quality of pastırma during production, especially in the formation of flavour, but it is also undesirable to be above the desired level. So, it is important to use antioxidant compounds in pastırma production. In this study, the antioxidant effect of PL on pastırma was determined ($P < 0.01$). TBARS value, which is a measure of lipid oxidation, was affected by the use of PL in pastırma production ($P < 0.01$), and the lowest values were determined for samples containing 2.0% PL (Table 1). Similar findings were observed for samples containing 2.5% PL as beef fillet (Kim et al. 2009), beef muscles with 2.5% PL (Kim et al. 2010) and minced beef (Mancini et al. 2010).

## Salt and residual nitrite contents

Although pastırma is a traditional meat product preferred by consumers, the high amount of salt restricts it's consumption. In the production of pastırma, despite the recommendations made by various researchers to reduce the amount of salt content in end product, producers generally use the traditional method of dry curing. Therefore, the salt and Na contents of pastırma were high (Aksu and Erdemir 2014). The salt content of pastırma was determined in different studies and generally found to be above the desired levels (Çakıcı et al. 2015; Aksu and Kaya 2001). In this study, the use of PL for reducing salt and sodium in pastırma had important effects ($P < 0.01$), and lower values were found in samples including 1.0% and 2.0% PL ($P < 0.05$) (Table 1). As expected, the addition of PL to curing agents mixture of pastırma affected ($P < 0.01$) the residual nitrite levels, and the residual nitrite amounts decreased depending on the used PL amount ($P < 0.05$) (Table 1). Nitrite is an important curing ingredient used especially in meat products. It improves the color properties of products and also has antimicrobial and antioxidant activities. However, it is undesirable to have high amount of residual nitrite in the products. In this respect, the use of lactate have an advantage to reduce residual nitrite in the pastırma production. In model meat systems produced with the addition of lactate in different proportion and 150 ppm nitrite, it was found that lactate decreased the amount of residual nitrite as a result of acceleration of the curing reactions (McClure et al. 2011).

## Colour properties

Usage of PL in pastırma production affected sample colour values significantly ($P < 0.01$). The L* values were determined among 38.37 ± 0.42–40.24 ± 0.53 in the pastırma produced, and the highest values were in the 1.0%

**Table 2** The free amino acids contents of pastırma with different potassium lactate levels (mg/100 g dry matter) (n = 4)

| Free Amino Acids | Potassium Lactate Levels | | | | *P* |
|---|---|---|---|---|---|
| | Control (0%) | 0.5% | 1.0% | 2.0% | |
| *Essential Amino Acids (EAAS)* | | | | | |
| Lysine (Lys) | 265.64 ± 1.49$^{a}$ | 188.92 ± 28.38$^{b}$ | 186.22 ± 16.47$^{b}$ | 124.06 ± 6.87$^{c}$ | < 0.01 |
| Isoleucine (Ile) | 41.35 ± 1.50$^{a}$ | 23.66 ± 3.57$^{b}$ | 21.86 ± 1.04$^{b}$ | 14.68 ± 0.06$^{c}$ | < 0.01 |
| Leucine (Leu | 553.34 ± 2.62$^{a}$ | 385.55 ± 50.18$^{b}$ | 382.01 ± 22.70$^{b}$ | 261.51 ± 12.32$^{c}$ | < 0.01 |
| Methionine (Met) | 321.48 ± 0.67$^{a}$ | 235.34 ± 22.44$^{b}$ | 233.60 ± 7.56$^{b}$ | 144.78 ± 8.25$^{c}$ | < 0.01 |
| Phenylalanine (Phe) | 194.29 ± 1.22$^{a}$ | 138.73 ± 21.90$^{b}$ | 134.04 ± 11.68$^{b}$ | 88.10 ± 4.32$^{c}$ | < 0.01 |
| Valine (Val) | 7.57 ± 0.88$^{a}$ | 6.01 ± 0.17$^{b}$ | 5.81 ± 0.61$^{b}$ | 3.82 ± 0.15$^{c}$ | < 0.05 |
| Threonine (Thr) | 146.96 ± 2.05$^{a}$ | 109.14 ± 13.72$^{b}$ | 108.87 ± 5.36$^{b}$ | 75.56 ± 4.16$^{c}$ | < 0.01 |
| Tryptophan (Trp) | 81.56 ± 3.98$^{a}$ | 71.24 ± 3.80$^{a}$ | 73.26 ± 6.84$^{a}$ | 54.21 ± 3.49$^{b}$ | < 0.05 |
| *Non Essential Amino Acids (NEAAS)* | | | | | |
| Aspartic acid (Asp) | 58.11 ± 1.13$^{a}$ | 35.97 ± 12.59$^{b}$ | 34.05 ± 8.69$^{bc}$ | 13.30 ± 1.61$^{c}$ | < 0.05 |
| Glutamic acid (Glu) | 544.92 ± 5.10$^{a}$ | 431.19 ± 46.42$^{b}$ | 425.93 ± 14.78$^{b}$ | 312.35 ± 16.96$^{c}$ | < 0.01 |
| Asparagine (Asn) | 12.92 ± 0.59$^{a}$ | 9.23 ± 1.01$^{b}$ | 12.44 ± 0.57$^{a}$ | 11.46 ± 0.89$^{a}$ | < 0.05 |
| Glutamine (Gln) | 26.43 ± 1.12 | 20.38 ± 7.01 | 23.38 ± 1.10 | 15.67 ± 0.83 | > 0.05 |
| Serine (Ser) | 165.70 ± 0.88$^{a}$ | 120.03 ± 11.52$^{b}$ | 122.52 ± 1.02$^{b}$ | 86.39 ± 4.97$^{c}$ | < 0.01 |
| Histidine (His) | 107.98 ± 0.58$^{a}$ | 65.17 ± 11.12$^{b}$ | 70.90 ± 3.50$^{b}$ | 45.19 ± 2.27$^{c}$ | < 0.01 |
| Glycine (Gly) | 106.86 ± 0.05$^{a}$ | 68.54 ± 1.96$^{b}$ | 70.12 ± 3.60$^{b}$ | 46.68 ± 2.80$^{c}$ | < 0.01 |
| Arginine (Arg) | 329.59 ± 0.38 | 349.41 ± 40.18 | 351.71 ± 18.73 | 294.87 ± 15.99 | > 0.05 |
| Alanine (Ala) | 748.62 ± 1.70$^{a}$ | 648.81 ± 21.61$^{b}$ | 655.56 ± 14.62$^{b}$ | 602.00 ± 29.75$^{b}$ | < 0.01 |
| Tyrosine (Tyr) | 241.55 ± 1.04 | 257.74 ± 17.38 | 258.79 ± 0.65 | 251.36 ± 14.24 | > 0.05 |
| Proline (Pro) | 50.58 ± 1.06$^{a}$ | 44.04 ± 0.97$^{b}$ | 43.91 ± 0.03$^{b}$ | 38.14 ± 0.75$^{c}$ | < 0.01 |
| Norvaline (Nva) | 41.90 ± 0.13$^{a}$ | 33.04 ± 3.21$^{b}$ | 32.82 ± 0.92$^{b}$ | 25.95 ± 0.92$^{c}$ | < 0.01 |
| Cystine (cys) | 93.44 ± 0.38$^{a}$ | 73.23 ± 11.85$^{b}$ | 74.37 ± 6.70$^{ab}$ | 48.03 ± 3.72$^{c}$ | < 0.05 |

$^{a-c}$: Means followed by different superscript alphabets in each line for potassium lactate levels are significantly different ($P < 0.05$). ± : Standard Deviation

groups (Table1). Aksu et al. (2016) opined that the L* value was 41.24 ± 1.40 for 150 ppm nitrite added pastırma. They did not determine an effect of using nitrite on pastırma L* values. In another study, L* values for raw material and pastırma were reported as 35.77 ± 2.59 and 38.86 ± 2.04 by Aksu et al. (2017), respectively. Similar findings were reported in the sırt pastırma type (27.37–50.08, mean:40.47) by Çakıcı et al. (2015) and in pastırma produced by adding different amounts of NaCl and KCl (42.35–50.21) by Hastaoglu and Vural (2018). As expected, the most obvious colour change in the pastırma produced was the a* value ($P < 0.01$), which indicates redness. The a* value of the raw material (29.86 ± 4.07) increased to 39.97 ± 0.25 during pastirma production. There was a statistical difference in the a* values between conrol and treatment groups ($P < 0.01$), but there was no different ($P > 0.05$) between samples containing 0.5% PL (38.25 ± 0.60) and samples containing 1.0% PL (38.76 ± 0.28). The a* values of the pastırma samples increased with PL level, the highest and the lowest a* values were obtained for sample including 2.0% PL (39.97 ± 0.25) and control (34.98 ± 0.93), respectively (Table 1). Aksu et al. (2016) reported that the a* value for 150 ppm nitrite added pastırma was 39.16 ± 0.99. Aksu et al. (2020) reported that the a* value was 34.00 ± 5.09 for 100 ppm nitrite added pastırma. In previous studies, colour improvement effect of low amounts of lactate added in water and sodium chloride was reported in the meat product (Brewer et al., 1995; Kim et al. 2009 and 2010). Mancini and Ramanathan (2008) stated that the colour stability in the beef with lactate improves but, the mechanism is unclear. However, researcehes remarked that the effect of lactate on myoglobin redox stability could be partially responsible for the improved color stability in the beef products with lactate. Kim et al. (2010) stated in their study that lactate / phosphate addition to three different bovine muscles (*M. Longissimus lumborum*, *Bemimembranosus* and *Adductor*) provides color stability by reducing myoglobin and lipid oxidation during storage and marketing. The researchers noted that the potassium lactate samples had a more stable colour, as the addition of potassium lactate reduced the formation of metmyoglobin

(Mancini and Ramanathan 2008; Kim et al. 2010). Kim et al. (2010) also reported that lactate can consistendly shown to improve fresh meat colour as a result of providing a strong antioxidant activity. In our current study, the lactate addition increased pH of the pastırma ($P < 0.01$), which may explain elevated colour stability of the injected pastırma in part, because pH plays a significant role in maintaining colour stability of postmortem muscle (Kim et al. 2010). In terms of the effect of lactate on colour changes, our findings were in agreement with results of McClure et al. (2011) studied a cured meat system using ground beef. They proposed that lactate increased more complete reduction of nitrite to nitric oxide and increased cured colour development. Additionaly in our study, it was determined that the addition of lactate, increased the effect of nitrite and improved the product colour in meat products processed in muscle form (pastırma) similar like the meat system produced using minced meat.

## Microbiological properties

Results of microbiological analysis are given in Table 1. The initial total aerobic mesophylic bacteria (TAMB) counts of raw meats used in pastırma production were 4.39 ± 0.14 log CFU/g. TAMB counts were determined as; 7.93 ± 0.88 log CFU/g for control and 7.97 ± 0.89 log CFU/g, 7.66 ± 0.46 log CFU/g, and 8.21 ± 0.18 log CFU/g for pastırma samples containing 0.5%, 1.0% and 2.0% PL, respectively. Using PL concentration affected TAMB count significantly ($P < 0.01$). The highest counts of TAMB were observed for ready-to-eat pastırma containing 2.0% PL. Also, using PL in curing mixture of pastırma affected the *Micrococcus/Staphylococcus* ($P < 0.01$), lactic acid bacteria ($P < 0.01$) and yeast – mould counts ($P < 0.01$), as expected. But the effects on each microorganism group were different depending on the added PL level ($P < 0.05$) (Table 1). While the highest *Micrococcus/Staphylococcus* counts were observed for the ready-to-eat pastırma samples containing 0.5% PL, the highest lactic acid bacteria and yeast-mould counts were determined for samples containing 2.0% PL. The majör member of microbiota in pastırma is *Micrococcus/Staphylococcus* (Gram positive, catalase positive cocci) (Aksu et al. 2016). Both *Micrococcus/Staphylococcus* and lactic acid bacteria are effective in the formation of pastırma quality due to their lipolytic and proteolytic activities. In a previous study, it was observed that the counts of lactic acid bacteria in the ready-to-eat pastırma produced by adding nitrite in different ratios ranged from 4.85 ± 0.33 log cfu/g to 4.14 ± 0.49 log cfu/g whereas, the counts of *Micrococcus/Staphylococcus* were ranged from 6.62 ± 0.26 log cfu/g to 7.48 ± 0.25 log cfu/g. In this study, pastırma with 150 ppm nitrite had the lowest *Micrococcus/Staphylococcus* counts (Aksu et al. 2016). According to previous results and findings, we may state that the counts of *Micrococcus/Staphylococcus* in the 2.0% PL group decreased not only due to lactate addition, but also as a result nitrite addition. The *Micrococcus/Staphylococcus* and lactic acid bacteria counts in sırt pastırma were 7.18 ± 1.03 (4.70–8.56) and 6.81 ± 1.32 (3.78–8.83) log CFU/g, respectively (Çakıcı et al. (2015). The yeast- mould counts of pastırma were 3.43–5.91 log CFU/g by Gök et al. (2008), < 2.00–5.76 log CFU/g by Aksu and Kaya (2001) and < 2.0–7.24 log CFU/g by Çakıcı et al. (2015). In this study, the initial *Pseudomonas* count was 2.72 ± 0.22 log CFU/g, it was < 2.0 log CFU/g for all of the pastırma samples. Also, the counts of *Enterobacteriaceae* were < 2.0 log CFU/g in both raw materials and pastırma. During the production of pastırma, the water activity of the final product decreases due to salting/curing, drying, cemening and re-drying applications and microorganisms belonging to the *Enterobacteriaceae* family toxin-producing and pathogenic in the normal intestinal flora of cattle are inactivated. Gök et al. (2008) reported that the counts of *Pseudomonas* were between 4.42 and 1.14 log CFU/g in the pastırma stored at aerobic, modified atmosphere and vacuum packaged for 120 days at the 4 °C. In another study, Çakıcı et al. (2015) reported that the counts of *Pseudomonas* bacteria were < 2.00 log CFU/g for investigated 32 of the 62 pastırma samples whereas it ranged from 2.30 to 5.69 log CFU/g for other samples. The growth of *Pseudomonas* in the pastırma production is undesirable. In this study, in the inhibition of the growth of *Pseudomonas* in pastırma, lactate and the moisture content of pastırma were probably effective together. As a result, PL had no adverse effect on pastırma microbiological quality (*Micrococcus/Staphylococcus*, lactic acid bacteria) and usage of PL prevented the growth of Gram (-) bacteria (*Pseudomonas* and *Enterobacteriaceae*) as a result of its antimicrobial activity (Brewer et al. 1995; Kim et al. 2010). Also, De Wit and Rombout (1990) highlighted that lactates could be used for inhibition of the growth of pathogens and spoilage microorganisms in meat and meat products.

## Free amino acids content

Proteolysis is very important in the development of desired quality and sensory properties of pastırma. Factors such as raw material properties ($a_w$, pH and enzymes), curing agents and usage rates, curing time, drying temperatures, fenugreek and microbial flora affect the proteolytic degradation that occurs during production. Increases in free amino acids (FAA) of pastırma were explained as indicators of proteolysis(Ceylan and Aksu 2011; Aksu et al. 2002; Erdemir and Aksu 2017). In our study, 21 FAAs (8 essential and 13 non-essential) were detected in pastırma samples. The total amounts of FAAs in the control group

were higher than the samples containing PL, and as the amount of PL increased, the total amount of FAA in pastırma decreased significantly (Table 2). The decrease in total FAA level as a result of use of PL in curing agent mixture, may indicate that protein degradation decreases. Nnanna et al. (1994) stated that this may be due to the fact that lactates are chelating. Previously, Erdemir (2017) opined that using PL as a curing agent reduces the amount of salt in the pastırma production and further reported that PL addition reduces protein oxidation and total amount of FAA. As seen in Table 1, the pH value increased as PL levels increased. It is thought that low pH value increases degradation of proteins. In addition, except 1.0% PL containing sample, the counts of LAB were higher in PL containing samples compared to control (Table 1). Previous studies found that the use of sodium and potassium lactate increased the pH values of the samples (Askar et al. 1993; Kim et al. 2009; McClure et al. 2011). The highest essential and non-essential amino acid amounts (excluding arginine and tyrosine) were observed in the control group (Table 2). Leucine, methionine and lysine were the most abundant essential FAAs in pastırma samples, while alanine, glutamic acid, arginine and trosine, respectively, were the majör non-essential FAAs (Table 2). The addition of PL did not affect glutamine and tyrosine content. Results of this study are compatible with previous ones (Ceylan and Aksu 2011; Deniz et al. 2016; Erdemir and Aksu 2017; Erdemir 2017). Differences with previous studies might be due to variation in raw materials used. Also, *Trigonella foenum graceum* L. seed flours used in fenugreek composition might affect the amount of lysine, leucine, glutamic acid and arginine in the pastırma samples (El-Mahdy and El-Sebaiy 1985; Deniz et al. 2016).

## Micro-structure of pastirma samples

Electron micrographs of the sections of PL treated and control pastırma samples investigated with transmission electron microscopy (TEM) are shown in Fig. 2. The A bands and I bands weren't clearly visible, the Z lines were intact and M lines were distinguishable in the samples. Also, some ultra-structural changes occurred at the whole samples with PL according to the control group. The visual changes in myofibrils appeared depending on the PL treatment, but in particular, the Z lines showed the prominent changes in the all samples containing PL. It was observed that Z lines became clearer as PL addition increased (Fig. 2). The disordered A bands and distorted Z lines were observed in the control samples. For control sample, M lines were the partly clearer. This might be due to the degration at the Z line which had an effect on the tenderization of the meat. This changes were also observed in the sensory analysis of the samples by panelists. The A band, I band, Z line and M line can been clearly due to increased distance between myofibrils (Kim et al. 2012).

## Sensory properties

The sensory analysis was performed to assess the sensory parameters as brittleness, colour, texture and structure, palatability, salinity and overall acceptability The sensory properties of pastırma were not affected by use of PL in curing agent mixure ($P > 0.05$) (Table 3). Similarly, Askar et al. (1993) found that the use of KCl and K-lactate (40%) at the same amount instead of 40% NaCl in the curing of pastırma were not affect the sensory characteristics of end product. The a* values of sliced pastırma were shown to be significantly different among control and treatment group (Table 1), the panellists were not able to distinguish a difference in colour likings among the samples ($P > 0.05$) (Table 3). A similar result was observed in the study contucted by Choi et al. (2014). For brittleness and texture and structure evoluation, the samples containing 1.0% PL and 2.0% PL had liking rates lower than samples containing 0.5% PL. Howewer the difference were not significant. The PL may form a gummy/tight structure in pastırma. In other words, instead of the typical texture of pastırma, a less brittle structure was formed for samples containing 2.0% PL. This effect was also confirmed by the results for the FAA, TEM and *Staphylococcus/Micrococcus* counts. A decreasing effect on FAAs content depending on used PL concentration in samples was determined (Table 2). The counts of *Staphylococcus/Micrococcus* with proteolytic activity were also lower in these groups (Table 1). During the processing of pastırma, degradative changes occurs in meat, including changes in proteins (Aksu et al. 2002), and this changes have a higly positive effect to the development of texture and structure in pastırma. This also affected palatability and overall acceptability scores of pastırma samples including 2.0% PL which was scored lower than others. Also Gimeno et al. (2001) reported that excessive additions of PL in the meat products may caused an acidic taste.

## Conclusion

In this study, the usage possibility of PL in the different amounts in curing agent mixures of pastırma was investigated. It was observed that PL affected the some quality parameters of pastırma. The lipid oxidation was prevented with the use of PL in pastırma and the redness values increased. Additionally, the amount of residual nitrite and FAAs decreased in the ready-to-eat pastırma. PL also

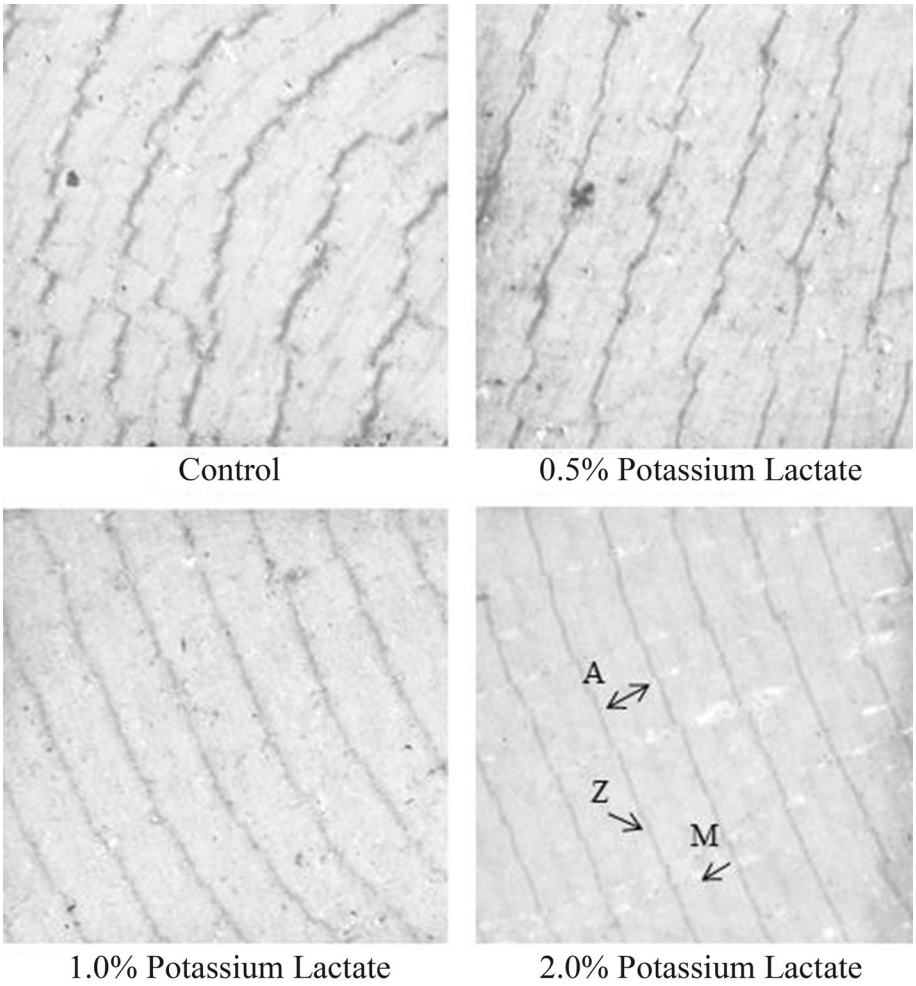


**Fig. 2** TEM images of pastırma groups

**Table 3** The mean scores of sensory properties of pastırma with different potassium lactate levels (n = 10)

| Potassium Lactate levels | Colour of Sliced Pastırma | Brittleness | Texture and Structure | Palatability | Salinity | Overall Acceptability |
|---|---|---|---|---|---|---|
| Control (0%) | 7.25 ± 1.75 | 7.50 ± 1.41 | 7.50 ± 1.41 | 7.00 ± 1.51 | 6.56 ± 1.12 | 7.25 ± 1.39 |
| 0.5% | 7.88 ± 1.25 | 7.50 ± 1.07 | 7.12 ± 1.25 | 7.00 ± 1.07 | 6.38 ± 0.92 | 7.10 ± 0.84 |
| 1.0% | 7.25 ± 1.28 | 6.88 ± 1.55 | 7.13 ± 1.55 | 7.50 ± 0.76 | 6.25 ± 1.28 | 7.13 ± 1.13 |
| 2.0% | 7.38 ± 1.92 | 7.00 ± 2.27 | 6.88 ± 2.10 | 6.75 ± 2.12 | 5.94 ± 1.61 | 6.53 ± 2.08 |
| *P* | > 0.05 | > 0.05 | > 0.05 | > 0.05 | > 0.05 | > 0.05 |

± Standard deviation

inhibited the growth of Gram(-) bacteria. Using 2.0% PL in curing agent caused a gummy/tight structure in pastırma samples. In other words, instead of the typical texture of pastırma, a less brittle structure was observed in pastirma containing 2.0% PL. Therefore, it was concluded that suggested concentration for PL in pastırma production is 0.5% or 1.0%.

**Acknowledgements** This study was supported by the Atatürk University Research Center as financial (BAP Project Number: 2012/260). Thus, authors would like to thank the Atatürk University in making this study possible and TUBITAK (2211-E) for giving scholarship to Ebru ERDEMIR.

**Author contributions** Conceptualization: Aksu MI. Data curation: Aksu MI. Formal analysis: Aksu MI, Erdemir E. Methodology: Aksu MI, Erdemir E. Validation: Aksu MI. Investigation: Aksu MI.

Writing—original draft: Aksu MI. Writing—review & editing: Aksu MI, Erdemir E.

**Declarations**

**Conflict of ınterest** The authors declare no potential conflict of interest.

**Ethics approval** This article does not require IRB/IACUC approval because there are no human and animal participants.

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