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Effect of storage temperatures and time on shelf-life of sliced and modified atmosphere packaged Pastırma, a dried meat product, produced from beef

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Abstract: The effects of modified atmosphere on some physical, chemical and microbiological properties of sliced pastırma made from beef *Longissimus dorsi* muscle were investigated. Sliced-pastırma samples (moisture 43.65 ± 0.15%, pH 5.71 ± 0.02) were stored in modified atmosphere packages (50% N_2 + 50% CO_2) at 4 and 10 °C for 150 days. The storage period had a significant effect ($p < 0.01$) on moisture, pH, thiobarbituric acid reactive substances, free fatty acid, non-protein nitrogen, water-soluble nitrogen, colour values and total aerobic bacteria, lactic acid bacteria and *Micrococcus/Staphylococcus* counts. The storage temperatures (4 and 10 °C) also had a significant effect ($p < 0.01$) on moisture, pH, thiobarbituric acid reactive subctances, free fatty acid, water soluble nitrogen, a^* values, total aerobic bacteria lactic acid bacteria, and *Micrococcus/Staphylococcus* counts. It was determined that the storage period × the storage temperature interactions had a significant ($p < 0.01$) effect on the values of pH, a^* and the counts of total aerobic bacteria, lactic acid bacteria, *Micrococcus/Staphylococcus*. It was also observed that the yeast and mold count was the highest in the first storage period and decreased throughout storage. Enterobacteriaceae count was also below the detectable level (<2.00 cfu g^{-1}) throughout the storage period.
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Keywords: sliced pastırma; dry-cured meat product; modified atmosphere packaged; shelf-life; chemical and microbiological quality

INTRODUCTION

Pastırma is a dry-cured meat product which is produced from whole muscle obtained from certain parts of beef and water buffalo carcasses. From a carcass, 16–20 different types of pastırma can be produced. Muscle is cured, dried, pressed, coated with a garlic-containing paste, and dried again. The production of pastırma takes about 25–30 days according to the size of muscles used, and pastırma can be protected for a long time at 10 °C if it is not sliced.[1–4]

Pastırma is a meat product consumed in slices.[4] For the preservation of quality characteristics of sliced pastırma it needs to be packaged and stored at low temperature. Microbiological contamination can occur in sliced pastırma, and the risk of spoilage is increased with slicing.[5] Variations such as color defect, rancidity and spoil due to inappropriate protection occur in sliced pastırma. Packaging, therefore, is a necessary measure to extend shelf-life and protect the quality properties of sliced pastırma. In some studies, modified atmosphere packaging has been used to delay oxidation and proteolytic activity in both fresh meat and processed meat products,[6,7] and to protect color.[8] For food packages, the gases and gas mixtures used depend on the property of the meat products. Different mixture of $CO_2 + N_2$ gases are often used for this type of meat product.[6,9–12]

The purpose of this study was to determine the effect of different storage temperatures (4 and 10 °C) and storage period (0, 30, 60, 90, 120 and 150 days) on the chemical, physical and microbiological properties of sliced–modified atmosphere packaged (50% CO_2 + 50% N_2) pastırma.

MATERIALS AND METHODS

Production, packaging and storage of sliced pastırma

Longissimus dorsi muscle from beef carcasses was used as the raw material. After removing fat and connective tissue from the surface, muscle tissue was cut vertically into two pieces. Four pastırma lots were produced from the carcass of a 3-year-old cow. One carcass was used for each replicate (total of two carcasses,

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two replicates). After removing fat and connective tissue from the surfaces (*Longissimus dorsi* muscle), the muscle tissue was cut vertically into two pieces.

The production process of pastırma was as follows:[13,14]

(1) Dry-curing and addition of a starter culture: 2 days, 6 °C, 80–90% relative humidity (RH), for 1 kg meat, 50 g curing mixture. The curing mixture contained 47.0 g NaCl, 0.75 g KNO_3, 1.0 g glucose and 1.0 g sucrose. In a treatment, commercial preparations of *Staphylococcus carnosus* + *Lactobacillus pentosus* (Bactoferm™ C-P-77 S) were used as starter cultures (CHR Hansen's, Pohlheim, Germany). Starter culture (25 g starter 100 kg^{-1} meat) was introduced into muscle with the curing mixture.
(2) First drying: 4 days, 15 °C, 80–85% RH.
(3) First pressing: 17 h, 7 °C, for each 1 kg of meat; a 25 kg weight was used.
(4) Second drying: 3 days, 20 °C, 70% RH.
(5) Second pressing: 7 h, 25 °C, for each 1 kg of meat; a 25 kg weight was used.
(6) Paste cemening: 4 days, 7 °C. The seasoning mixture (cemen) used in this research contained 500 g flour (*Trigonella foenum graecum*) ground from seed, 350 g smashed fresh garlic, 75 g paprika, 75 g red pepper and 1200 ml water. Then the dried meat surface was pasted to a depth of 3 mm in thickness with the seasoning mix.
(7) Final drying: 2 days, 15 °C, 70% RH; 2 days, 18 °C, 65% RH; 6 days, 20 °C, 60% RH.

The pastirma produced was sliced (2 mm thick) using a slicing machine at the end of the final drying. The sliced pastirma samples were packaged in 100 g portions in a moderately gas-impermeable bag OPAEVOH/PE (water vapor transmission rate 15 g m^{-2} 24 h^{-1} at 38 °C, 90% RH, 1 atm; O_2 transmission rate 5 cm^3 m^{-2} 24 h^{-1} at 23 °C, 50% RH, 1 atm; N_2 transmission rate 1 cm^3 m^{-2} 24 h^{-1} at 23 °C, 50% RH, 1 atm; CO_2 transmission rate 23 cm^3 m^{-2} 24 h^{-1} at 23 °C, 50% RH, 1 atm). Packages were evacuated, filled with a modified atmosphere (50% N_2 + 50% CO_2) and automatically heat-sealed with a Multivac packaging unit (Multivac A 300/16, Sepp Haggenmüller, Wolfertschwenden, Germany). The volume ratio of gas to sliced pastirma product was approximately 1:2.

The packaged pastirma samples were divided into two groups (replicate 1, 4 °C and replicate 1, 10 °C; replicate 2, 4 °C and replicate 2, 10 °C) and samples were stored at 4 or 10 °C for 150 days. In stored pastırma samples, the moisture, pH, thiobarbituric acid reactive substances (TBARS), free fatty acids (FFA), water-soluble nitrogen (WSN), non-protein nitrogen (NPN), L^*, a^*, b^*, total aerobic bacteria, lactic acid, *Micrococcus*/*Staphylococcus*, yeast-mold and Enterobactericeae counts were determined at 0, 30, 60, 90, 120 and 150 days of storage.

Chemical and physical analysis

Moisture, total fat, crude protein and pH contents in samples were determined according to the methods described by Ockerman.[15] TBARS value was determined according to Gökalp *et al*.[16] NPN content was determined according to the method reported previously.[17] WSN and FFA values were determined by the method of Wang.[7]

The surface color of raw materials and the sliced pastirma (2 mm thick) was measured on a white plate using a tristimulus colorimeter (Minolta Chroma Meter Measuring Head CR-200, Minolta, Osaka, Japan), which was used to objectively measure CIE Laboratory values (where L^* measures relative lightness, a^* relative redness and b^* relative yellowness). Before each measurement, the apparatus was standardized using a white tile.

Microbiological analysis

Sample solutions for microbiological analyses were prepared by homogenizing a 25 g sample with 225 ml physiological saline (NaCl 0.85%) in a Stomacher (Laboratory Blender Stomacher 400, Seward) for 1 min. Bacteria counts were expressed as log cfu g^{-1}. Incubation temperature and time for microbiological analyses were as follows: total aerobic bacteria count, Plate Count agar (Merck) at 30 °C for 3 days, aerobically; lactic acid bacteria count, De Man Rogosa Sharpe agar (Merck), at 30 °C for 3 days, anaerobically; *Micrococcus*/*Staphylococcus* count, Mannitol Salt Phenol-Red agar (Merck), at 30 °C for 2 days, aerobically; yeast and mold counts, potato dextrose agar (Merck) at 25 °C for 5 days, aerobically; Enterobacteriaceae count, Violet Red bile dextrose agar (Merck) at 30 °C for 2 days, anaerobically.

Statistical analysis

Data were analysed according to the t test for determination of differences for each period of time (0, 30, 60, 90, 120 and 150 days), and variance analyses for determination of differences between storage days (0, 30, 60, 90, 120 and 150 days) and between temperatures (4 and 10 °C) and interactions using SPSS Package Program (SPSS 10.01, 1996). The variance analyses model included storage temperature (4 and 10 °C) and storage period (0, 30, 60, 90, 120 and 150 days) as main effects (2 × 6 × 2) and all their interactions, but the only significant interactions were shown in figures. The differences among means were tested for significance ($p < 0.05$) by Duncan's multiple range test. Mean values ± standard deviation were shown in Tables 1–4.

RESULTS AND DISCUSSION

Results of raw material

The moisture, pH, protein, NPN, WSP, total fat, FFA, TBARS, L^*, a^* and b^* values of raw materials used in production of pastırma were

Table 1. The Moisture, pH, TBARS, FFA, NPN, WSN, L^*, a^* and b^* values and microbial counts of modified atmosphere packaged Pastırma stored at 4 and 10 °C

Storage temperature	Day 0[a]	Day 30	Day 60	Day 90	Day 120	Day 150	p
			Moisture (%)				
4 °C	43.65 ± 0.18a	42.48 ± 0.68ab	41.68 ± 0.59bc	41.88 ± 0.79b	41.54 ± 0.74bc	40.41 ± 0.55b	*
10 °C	43.65 ± 0.18a	41.18 ± 0.11b	40.89 ± 0.18b	41.04 ± 0.08b	41.64 ± 0.21b	39.25 ± 0.31c	**
			pH				
4 °C	5.71 ± 0.02c	5.84 ± 0.03b	5.81 ± 0.08b	5.91 ± 0.01a	5.90 ± 0.01a	5.94 ± 0.02a	**
10 °C	5.71 ± 0.01d	5.89 ± 0.03c	5.96 ± 0.10b	6.00 ± 0.09a	5.93 ± 0.03b	5.96 ± 0.02ab	**
			Thiobarbituric acid reactive substance (mg malonaldehyde kg^{-1})				
4 °C	0.48 ± 0.04e	1.12 ± 0.02d	1.48 ± 0.02c	1.61 ± 0.01a	1.59 ± 0.00a	1.53 ± 0.02b	**
10 °C	0.48 ± 0.03c	1.22 ± 0.10b	1.60 ± 0.02a	1.64 ± 0.03a	1.61 ± 0.16a	1.60 ± 0.04a	**
			Free fatty acids (g oleic acid 100 g^{-1} fat)				
4 °C	0.39 ± 0.06c	0.36 ± 0.02c	0.40 ± 0.07bc	0.43 ± 0.00b	0.53 ± 0.02a	0.54 ± 0.01a	**
10 °C	0.39 ± 0.06c	0.45 ± 0.20b	0.45 ± 0.01b	0.46 ± 0.04b	0.57 ± 0.02a	0.58 ± 0.03a	**
			Non-protein nitrogen (%)				
4 °C	4.77 ± 0.07b	5.03 ± 0.04ab	5.13 ± 0.02ab	5.23 ± 0.18ab	5.26 ± 0.16a	5.25 ± 0.08a	*
10 °C	4.77 ± 0.07b	5.04 ± 0.02ab	5.18 ± 0.16ab	5.24 ± 0.13ab	5.27 ± 0.04a	5.31 ± 0.13a	*
			Water-soluble nitrogen (%)				
4 °C	9.60 ± 0.09c	10.61 ± 0.13ab	10.91 ± 0.74a	11.18 ± 0.24a	9.78 ± 0.04bc	9.90 ± 0.09bc	**
10 °C	9.60 ± 0.09d	10.82 ± 0.17ab	11.35 ± 0.02a	11.29 ± 0.30a	10.10 ± 0.18cd	10.30 ± 0.39bc	**
			L value*				
4 °C	41.14 ± 0.23a	39.31 ± 1.17a	38.82 ± 1.17a	38.08 ± 1.00a	39.78 ± 1.20a	37.24 ± 3.30a	NS
10 °C	41.14 ± 0.23a	38.58 ± 0.26bc	39.42 ± 1.42ab	39.54 ± 0.79ab	36.54 ± 1.49c	39.20 ± 0.40ab	*
			a value*				
4 °C	40.96 ± 0.14a	40.08 ± 0.30a	39.30 ± 0.37a	29.30 ± 0.02b	28.30 ± 2.13bc	24.64 ± 1.41c	**
10 °C	40.96 ± 0.14a	37.59 ± 0.57ab	36.79 ± 1.75b	30.48 ± 0.38c	35.76 ± 0.39b	34.42 ± 0.19b	**
			b value*				
4 °C	19.23 ± 0.75a	14.51 ± 1.15b	11.58 ± 1.48b	8.36 ± 0.29c	7.79 ± 0.38c	8.44 ± 0.13b	**
10 °C	19.23 ± 0.75a	12.22 ± 0.48b	11.94 ± 0.94b	7.91 ± 0.04c	7.44 ± 0.40c	10.80 ± 0.99b	**
			Total aerobic bacteria count (log cfu g^{-1})				
4 °C	7.00 ± 0.02b	8.31 ± 0.21a	6.23 ± 0.11c	5.86 ± 0.01d	5.84 ± 0.04d	5.92 ± 0.03d	**
10 °C	7.00 ± 0.02a	7.34 ± 0.33a	6.08 ± 0.12b	5.84 ± 0.04b	6.00 ± 0.06b	5.69 ± 0.13b	**
			Lactic acid bacteria count (log cfu g^{-1})				
4 °C	4.38 ± 0.16a	3.02 ± 0.02b	2.39 ± 0.13c	2.24 ± 0.34c	4.26 ± 0.05a	3.25 ± 0.01b	**
10 °C	4.38 ± 0.16a	3.24 ± 0.34b	3.27 ± 0.01b	2.15 ± 0.21c	2.00 ± 0.00c	2.15 ± 0.21c	**
			Micrococcus/Staphylococcus count (log cfu g^{-1})				
4 °C	6.49 ± 0.04b	7.05 ± 0.11a	5.93 ± 0.04c	5.79 ± 0.13c	5.76 ± 0.13c	5.80 ± 0.07c	**
10 °C	6.49 ± 0.04a	6.27 ± 0.05b	6.19 ± 0.06b	5.75 ± 0.04c	5.73 ± 0.01cd	5.62 ± 0.13d	**

[a] Day of packaging and slicing of pastırma samples; *$p < 0.05$, **$p < 0.01$, NS, $p > 0.05$. p probability, ± standard deviation. (a–d) Any two means in the same line with the same letters at the same temperature are not significantly different at $p > 0.05$.

Table 2. Moisture, TBARS, NPN, WSN and b^* values of modified atmosphere packaged pastırma stored at 4 and 10 °C

Properties	4 °C	10 °C	p
Moisture (%)	41.94 ± 1.12a	41.10 ± 1.37b	**
TBARS[a]	1.30 ± 0.42b	1.36 ± 0.44a	**
NPN[b] (%)	5.11 ± 0.20a	5.13 ± 0.21a	NS
WSN[c] (%)	10.34 ± 0.66b	10.58 ± 0.67a	*
b^* value	11.65 ± 4.34a	11.59 ± 4.08a	NS

[a] Thiobarbituric acid reactive substance, mg malonaldehyde kg^{-1}.
[b] Non-protein nitrogen.
[c] Water soluble nitrogen. *$p < 0.05$, **$p < 0.01$, NS, $p > 0.05$. p, probability, ± standard deviation. (a, b) Means with the same letters in a line of the same section are not significantly different ($p < 0.05$).

76.25 ± 0.02%, 5.70 ± 0.05, 20.63 ± 0.42%, 2.41 ± 0.02%, 5.38 ± 0.04%, 2.72 ± 0.53%, 0.19 ± 0.06 g oleic acid 100 g^{-1}, 0.07 ± 0.02 mg malonaldehyde kg^{-1}, 39.56 ± 1.16, 26.08 ± 0.24 and 4.86 ± 0.18, respectively. The total aerobic bacteria, lactic acid bacteria and *Micrococcus*/*Staphylococcus* counts of raw materials were determined as 5.06 ± 0.06, 3.28 ± 0.13 and 3.39 ± 0.10 log cfu g^{-1}, respectively.

Results of sliced pastırma stored in modified atmosphere

Moisture, pH, TBARS, FFA, NPN and WSN results

The results of sliced and packaged pastırma in modified atmosphere samples stored at 4 and 10 °C during storage are shown in Table 1. The mean values of both temperature are shown in Table 2. The results at both temperatures for each period of time also are shown in Table 3. The storage period and the storage temperature had a significant effect ($p < 0.01$)

Table 3. Moisture, pH, TBARS, FFA, NPN, WSN, L^*, a^* and b^* values and microbial counts of modified atmosphere packaged pastırma for each period of time stored at 4 and 10 °C

Storage temperature	Day 0[a]	Day 30	Day 60	Day 90	Day 120	Day 150
			Moisture (%)			
p	NS	NS	NS	NS	NS	NS
4 °C	43.52 ± 0.64a	42.46 ± 0.65a	41.64 ± 0.48a	41.88 ± 0.11a	41.54 ± 0.65a	40.41 ± 0.30a
10 °C	43.52 ± 0.64a	41.18 ± 0.25a	40.85 ± 0.18a	41.04 ± 0.08a	41.65 ± 0.21a	39.25 ± 0.36a
			pH			
p	NS	*	**	*	NS	NS
4 °C	5.71 ± 0.02a	5.84 ± 0.03b	5.81 ± 0.08b	5.91 ± 0.01b	5.90 ± 0.01a	5.94 ± 0.02a
10 °C	5.71 ± 0.01a	5.89 ± 0.03a	5.96 ± 0.10a	6.00 ± 0.09a	5.93 ± 0.03a	5.96 ± 0.02a
			Thiobarbituric acid reactive substance (mg malonaldehyde kg^{-1})			
p	NS	*	**	NS	NS	*
4 °C	0.48 ± 0.04a	1.12 ± 0.02b	1.48 ± 0.02b	1.61 ± 0.01a	1.59 ± 0.00a	1.53 ± 0.02b
10 °C	0.48 ± 0.03a	1.22 ± 0.10a	1.60 ± 0.02a	1.64 ± 0.03a	1.61 ± 0.16a	1.61 ± 0.04a
			Free fatty acids (g oleic acid 100 g^{-1} fat)			
p	NS	*	*	*	*	NS
4 °C	0.39 ± 0.06a	0.36 ± 0.02b	0.40 ± 0.07b	0.43 ± 0.00b	0.54 ± 0.02b	0.54 ± 0.01a
10 °C	0.39 ± 0.06a	0.45 ± 0.20a	0.45 ± 0.01a	0.46 ± 0.04a	0.57 ± 0.02a	0.58 ± 0.03a
			Non-protein nitrogen (%)			
p	NS	NS	NS	NS	NS	NS
4 °C	4.77 ± 0.07a	5.03 ± 0.04a	5.13 ± 0.18a	5.22 ± 0.16a	5.26 ± 0.08a	5.25 ± 0.35a
10 °C	4.77 ± 0.07a	5.04 ± 0.06a	5.18 ± 0.25a	5.24 ± 0.06a	5.27 ± 0.16a	5.31 ± 0.30a
			Water-soluble nitrogen (%)			
p	NS	NS	NS	NS	NS	NS
4 °C	9.60 ± 0.10a	10.61 ± 0.10a	10.91 ± 0.74a	11.18 ± 0.25a	9.78 ± 0.17a	9.90 ± 0.21a
10 °C	9.60 ± 0.10a	10.82 ± 0.10a	11.35 ± 0.22a	11.29 ± 0.41a	10.10 ± 0.14a	10.30 ± 0.38a
			L value*			
p	NS	NS	NS	NS	NS	NS
4 °C	41.15 ± 0.21a	39.31 ± 1.17a	38.82 ± 2.36a	38.08 ± 1.00a	39.78 ± 1.20a	37.24 ± 3.30a
10 °C	41.15 ± 0.21a	38.58 ± 0.26a	39.42 ± 1.42a	39.54 ± 0.79a	36.54 ± 1.49a	39.20 ± 0.40a
			a value*			
p	NS	*	NS	*	*	**
4 °C	40.96 ± 0.14a	40.08 ± 0.30a	39.30 ± 0.37a	29.30 ± 0.02b	28.30 ± 2.13b	24.64 ± 1.41b
10 °C	40.96 ± 0.14a	37.59 ± 0.57b	36.79 ± 1.75a	30.48 ± 0.38a	35.76 ± 0.39a	34.42 ± 0.19a
			b value*			
p	NS	NS	NS	NS	NS	NS
4 °C	19.23 ± 0.75a	14.51 ± 1.15a	11.58 ± 1.48a	8.36 ± 0.29a	7.79 ± 0.38a	8.44 ± 0.13a
10 °C	19.23 ± 0.75a	12.22 ± 0.50a	11.94 ± 0.94a	7.91 ± 0.04a	7.44 ± 0.40a	10.80 ± 0.99a
			Total aerobic bacteria count (log cfu g^{-1})			
p	NS	NS	NS	NS	NS	NS
4 °C	7.01 ± 0.02a	8.31 ± 0.21a	6.23 ± 0.11a	5.86 ± 0.01a	5.84 ± 0.04a	5.92 ± 0.03a
10 °C	7.01 ± 0.02a	7.34 ± 0.33a	6.08 ± 0.11a	5.84 ± 0.04a	6.00 ± 0.06a	5.69 ± 0.13a
			Lactic acid bacteria count (log cfu g^{-1})			
p	NS	NS	**	NS	**	*
4 °C	4.38 ± 0.16a	3.02 ± 0.02a	2.39 ± 0.13b	2.24 ± 0.34a	4.26 ± 0.05a	3.25 ± 0.01a
10 °C	4.38 ± 0.16a	3.24 ± 0.34a	3.27 ± 0.01a	2.15 ± 0.21a	2.00 ± 0.00b	2.15 ± 0.21b
			Micrococcus/Staphylococcus count (log cfu g^{-1})			
p	NS	**	*	NS	NS	**
4 °C	6.49 ± 0.03a	7.05 ± 0.11a	5.93 ± 0.04b	5.79 ± 0.13a	5.76 ± 0.13a	5.80 ± 0.07a
10 °C	6.49 ± 0.04a	6.27 ± 0.05b	6.19 ± 0.06a	5.75 ± 0.04a	5.73 ± 0.01a	5.62 ± 0.13b

[a] Day of packaging and slicing of pastırma samples. $^*p < 0.05$, $^{**}p < 0.01$, NS, $p > 0.05$. p, probability, ± standard deviation. (a, b) Any two means in the same column having the same letters in the same section (time) are not significantly different at $p > 0.05$.

on moisture values. The highest moisture value was determined on day 0 (packaging day) and decreased during the storage period at both 4 and 10 °C. The moisture values had the highest decrease in maximum levels between 0 and 30 days at 10 °C (2.47%). A significant decrease was observed in sliced pastırma stored at 4 and 10 °C at 150 days of storage of 3.24 and 4.40% decrease compared with day 0 (Table 1). However, higher moisture values were observed in samples stored at 4 °C (Table 2). The moisture value of pastırma is below ≤ 40%, so pastırma is categorized as an intermediate-moisture food.[18] Aksu

Table 4. The yeast–mold and Enterobacteriaceae counts (log cfu g^{-1}) of modified atmosphere packaged pastırma stored at 4 and 10 °C

Day			Yeast–mold count	Entero-bacteriaceae count
Raw material (meat)			3.45 ± 0.68	3.27 ± 0.36
Pastırma (day 0[a])			5.57 ± 0.92	<2.00
Storage period (days)	30	4 °C	4.11 ± 0.07	<2.00
		10 °C	3.47 ± 0.17	
	60	4 °C	3.50 ± 0.50	<2.00
		10 °C	2.98 ± 0.59	
	90	4 °C	2.15 ± 0.83	<2.00
		10 °C	2.00 ± 0.14	
	120	4 °C	<2.00	<2.00
		10 °C	2.70 ± 0.12	
	150	4 °C	<2.00	<2.00
		10 °C	2.15 ± 0.65	

[a] Day of packaging and slicing of pastırma samples, ± standard deviation.

and Kaya[19,20] reported that the moisture value in Turkish pastırma ranged from 36.28 to 38.03%, and that the moisture value in pastırma found in the market place in Erzurum was 38.92–51.81%.

Both storage temperature and storage period had significant ($p < 0.01$) effects on pH values (Table 1). The interaction of the storage period × storage temperature also resulted in a significant ($p < 0.01$) effect on these value. The pH values increased in pastırma samples by 90 days (Table 1). Therefore, higher pH values were determined in samples stored at 10 °C (Fig 1), and maximum pH values were observed between 30 and 90 days at 10 °C rather than 4 °C (Table 3). This can be explain by higher proteolytic enzyme activity at higher temperatures. Similar results were reported in pastırma produced from frozen/thawed beef meat.[4] There has been some research on the pH value of pastırma produced in Turkey, and the pH values were reported as 5.64–6.11.[14,19–21]

The effects of both storage time ($p < 0.01$) and storage temperature ($p < 0.05$) on TBARS were significant (Table 1 and 2). Maximum TBARS values were observed after 90 days at 4 °C and after 60 days at 10 °C. After 60 days, it did not change in samples stored in MAP at 10 °C (Table 1). Maximum differences between temperatures were observed in 60 days (Table 3). As a mean value, higher TBARS values were determined in samples stored at 10 °C (Table 2). Many researchers have reported similar results in TBARS values of pastırma.[4,22,23] The FFA values of samples stored at 4 and 10 °C were greatly affected by the storage period ($p < 0.01$) (Table 1). Figure 2 shows the effect of storage temperature × storage period ($p < 0.01$). FFA values started to increase during the storage period and higher percentages of free fatty acids were obtained at 10 °C compared with 4 °C (Fig 2). Lipid oxidation is quite important for formation of unique aroma in such products.[24] Occurrence of biochemical reactions such as lipolysis during the production of raw-dried meat products is of importance with respect to the aroma, color and texture of the final product. Lipids and phospholipids are hydrolyzed by lipase and phospholipase, yielding free fatty acids, which are oxidized to peroxides.[25] Therefore, the forming of lipid oxidation is prevented by nitrogen in the modified atmosphere.[9]

The NPN significantly ($p < 0.05$) increased with storage both at 4 and 10 °C. The NPN contents of pastırma samples started to increase during storage and reached a maximum value after 120 days at storage temperatures (Table 1). No significant ($p > 0.05$) effect of storage temperature on NPN value was determined (Table 2). Aksu, *et al*[4] reported that NPN values increased in sliced pastırma in modified atmosphere. Muscle protein breakdown during storage has been reported during the ripening process of pastırma.[4,14] Aksu, *et al*[26] also reported that the effect of each starter culture on myofibrillar proteins in pastırma was different. The major effect on myofibrillar proteins of pastırma was determined using *S carnosus* + *L pentosus*. It was also reported that pastırma samples with *S carnosus* + *L pentosus* had the

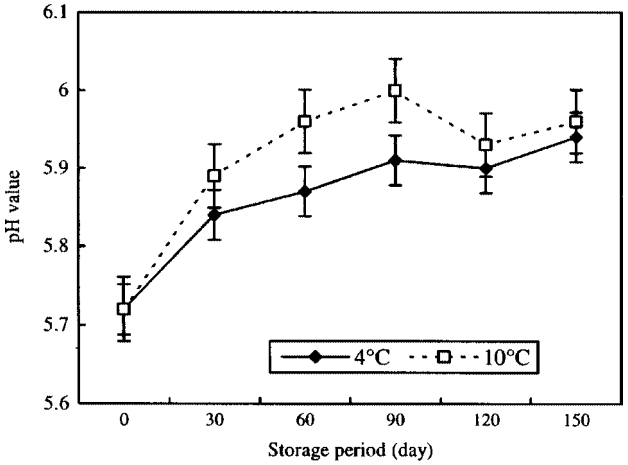

Figure 1. Effect of the interaction of storage temperature × storage period on the pH value.

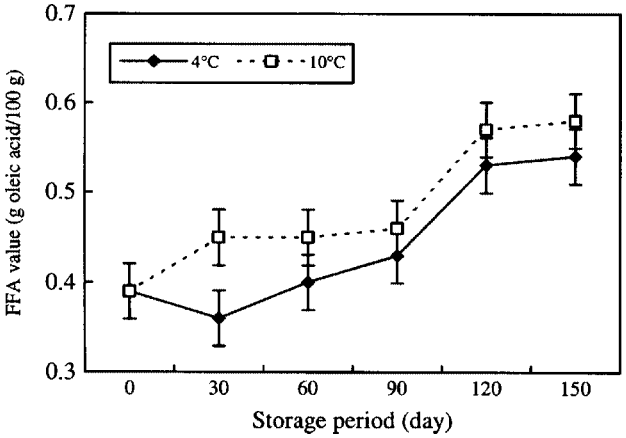

Figure 2. Effect of the interaction of storage period × storage temperature on the free fatty acid content of pastırma with modified-atmosphere packaging.

maximum general acceptability score in the sensory test, and the myofibrillar fragmentation was higher in pastırma with *S carnosus*. Aksu and Kaya[14] reported that the NPN value in Turkish pastirma ranged from 4.03 to 5.25%.

There was a significant ($p < 0.01$) difference in WSN of pastırma samples stored at 4 and 10 °C over the storage period and the highest values were observed at 60 and 90 days (Table 1). There was no significant differences in WSN content for each period of time (0, 30, 60, 90, 120 and 150 days; Table 3). The WSN content significantly ($p < 0.05$) changed with storage temperature and the highest values was determined at 10 °C (Table 2). Aksu *et al*[4] recorded similar results in sliced and stored pastırma produced from frozen/thawed meat (50% N_2 + 50% CO_2, for 150 days). Wang[7] also found that WSN values of this kind of meat products with MAP increased gradually during storage.

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

The color stability of meat products is influenced by a large number of factors. These factors were processing, packaging and storage conditions.[27] The color values determined in samples stored in MAP and at 4 and 10 °C for 150 days were shown in Tables 1–3. The storage period had a significant effect on L^*, a^* and b^*($p < 0.01$) values (except for L^* values at 4 °C). There was a decrease in a^* values of sliced pastırma during the storage period both 4 and 10 °C (Table 1). On the other hand, the storage temperature had an effect on only a^* values ($p < 0.01$; Table 2). The a^* values were retained better at 10 than at 4 °C (Fig 3). The a^* values were higher at 10 °C than at 4 °C on days 30, 90, 120 and 150 (Table 3) Similar results were reported in sliced pastırma produced from frozen/thawed beef meat with MAP at 10 °C.[4] It was reported that a^* values in sliced pastırma ranged from 13.66 to 40.07.[14,20] Also, the color values (L^*, a^* and b^*) were preserved in sliced-pasteurized hams stored at 8 °C in MAP (50% CO_2 + 50% N_2) for 28 days.[28]

Microbiological properties

Both the storage period and storage temperature in modified atmosphere had a significant effect ($p < 0.01$) on total aerobic bacteria, lactic acid bacteria and *Micrococcus/Staphylococcus* counts (Tables 1 and 3). The total aerobic bacteria count in samples stored at 4 °C increased until the day 30 of the storage period (Table 1). After day 30 at 4 °C, total aerobic bacteria count decreased. The total aerobic bacteria count of sliced pastırma stored at 10 °C was lower than that of sliced pastırma stored at 4 °C (Fig 4). It has been reported that meat spoilage does not occur until the total bacterial count reaches a level of 10^{6-8} organism g^{-1}.[29] The highest lactic acid bacteria count in samples stored at 4 °C was determined at 0 and 120 days (Table 1). At the end of storage period (120 and 150 days), the count of lactic acid bacteria in samples stored at 4 °C was higher than of samples stored at 10 °C (Fig 5, Table 3). The *Micrococcus/Staphylococcus* count decreased in modified atmosphere during the storage period in samples stored at 10 °C. The maximum *Micrococcus/Staphylococcus* count was determined at day 30 at 4 °C, and at day 0 at 10 °C (Fig 6). The total aerobic bacteria, lactic acid bacteria and *Micrococcus/Staphylococcus* counts of pastırma stored at 4 and 10 °C in MAP were reported as 7.03 ± 0.76, 6.92 ± 0.70, 3.54 ± 1.34, 3.22 ± 1.45 and 7.11 ± 0.65, 7.10 ± 0.53 log cfu g^{-1}, respectively.[4] Similar microbiological results in sliced pastırma were also indicated by several researchers.[3,14,30] The inhibition of the tested modified atmospheres was higher when the gaseous mixture contained 50% CO_2, while higher concentrations of carbon dioxide had no retarding effect on microbial growth. It is well known that elevated levels of carbon dioxide inhibit microbial growth. The effectiveness of modified atmosphere storage is obtained on meat or on complex media by increasing the CO_2 concentration well above 25%.[31,32]

The count of yeast and mold was maximum at day 0 (5.57 ± 0.92 log cfu g^{-1}) and decreased during the storage period. The lowest count of yeast and mold (<2.00 cfu g^{-1}) was observed at

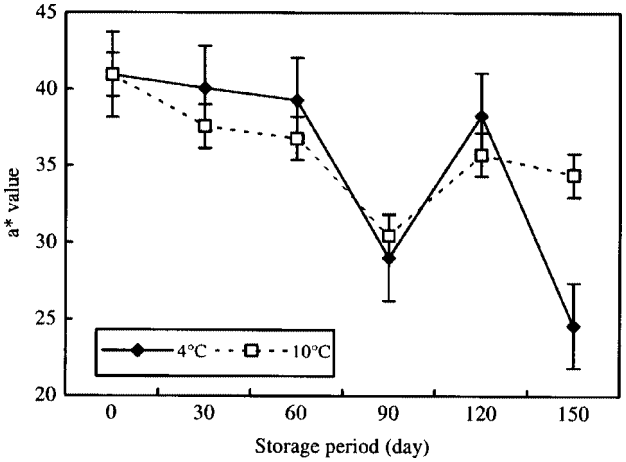

Figure 3. Effect of the interaction of storage period × storage temperature on the a^* value.

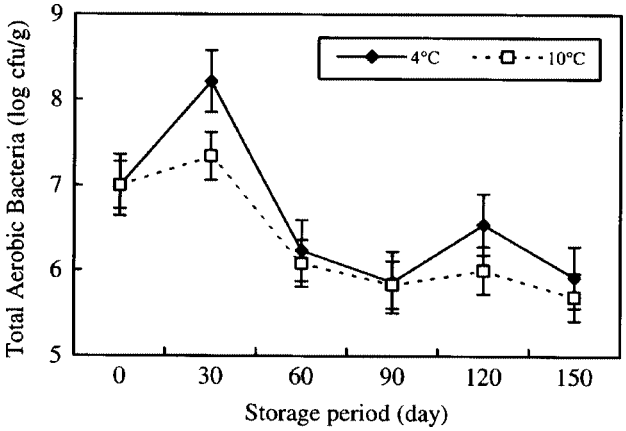

Figure 4. Effect of the interaction of storage period × storage temperature on the total bacteria count.

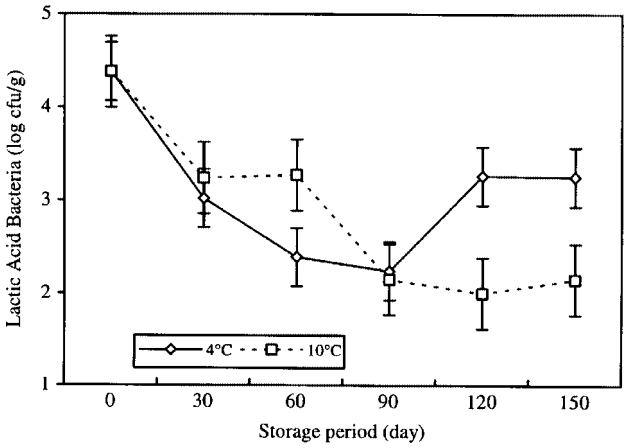

Figure 5. Effect of the interaction of storage period × storage temperature on the lactic acid bacteria count.

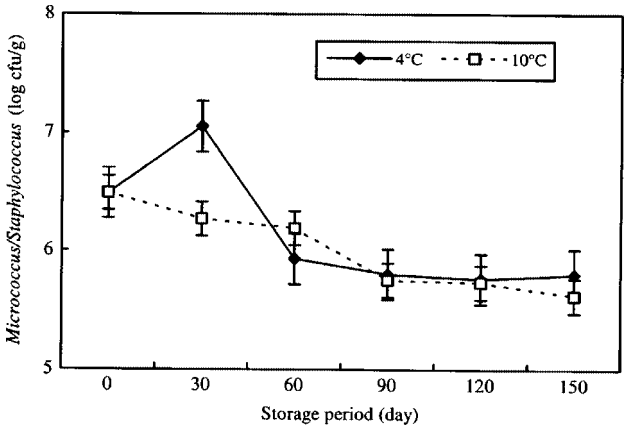

Figure 6. Effect of the interaction of storage period × storage temperature on the *Micrococcus/Staphylococcus* count.

120 and 150 days of storage at 4 °C (Table 4). The growth of yeast is greatly affected by the gaseous atmosphere ($CO_2 + N_2$), being restricted in an anaerobic atmosphere.[33] Furthermore, yeast was the dominant flora during whole storage period in sliced pastırma. Aksu and Kaya[14,20] both reported similar results in pastırma.

The Enterobacteriaceae count in all day of storage period was determined as under the detectable level ($<2.00 \log \text{cfu g}^{-1}$; Table 4). The storage temperature should be kept as low as possible for the maximum antimicrobial effect, because the solubility of CO_2 decreases dramatically with increasing temperature.[31,34] Modified-atmosphere packaging is a better method than aerobic/vacuum to achieve no growth of food pathogens.[10] Therefore, the growth of Enterobacteriaceae is restricted in a modified atmosphere ($CO_2 + N_2$).[32] The CO_2 in MAP had an antibacterial effect on Gram-negative bacteria[35] and the Enterobacteriaceae counts in the high CO_2 atmospheres were reduced significantly compared with vacuum packs and modified-atmosphere packaging, and the effect of temperature was significant in vacuum and 50% CO_2 + 50% N_2.[36]

CONCLUSIONS

This study indicated that pastırma can be stored for 150 days under modified atmosphere packaging (50% CO_2 + 50% N_2). However, 10 °C was more effective than 4 °C in maintaining the color characteristics (a^* value) of pastırma at the end of the storage period according to results of this research. It was also determined that values found in sliced pastırma during storage were acceptable.

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