EFFECT OF MODIFIED ATMOSPHERE PACKAGING AND TEMPERATURE ON THE SHELF LIFE OF SLICED PASTIRMA PRODUCED FROM FROZEN/THAWED MEAT

MUHAMMET İRFAN AKSU[1] and MÜKERREM KAYA

Department of Food Engineering
College of Agriculture
Atatürk University
25240, Erzurum
Turkey

AND

HERBERT W. OCKERMAN

Department of Animal Sciences
Agriculture and Environmental Science
College of Food
The Ohio State University
Columbus, OH

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ABSTRACT

Pastirma is a dry-cured meat product and is categorized as an intermediate moisture food. Nonsliced pastirma can be stored without refrigeration. Pastirma is consumed sliced without cooking. For preservation of quality characteristics, sliced pastirma needs to be packaged and stored at fairly low temperatures (<10C). In this study, pastirma was made from frozen M. Longissimus dorsi *muscle stored at −18C for 240 days and then thawed at 10C for 24 h. Pastirma produced from frozen/thawed meat was sliced. The sliced pastirma samples were stored in modified atmosphere packaging (MAP) (50% N_2 + 50% CO_2) at 4C and 10C for 150 days and thiobarbutiric acid reactive substances, free fatty acids, nonprotein nitrogen, pH,* L*, a* *and* b* *values, total aerobic and lactic acid bacteria,* Micrococcus/Staphylococcus*, yeast-mold, and* Enterobacteriaceae *counts in sliced product were determined during storage (0, 30, 60, 90, 120 and 150 days). Results showed that sliced pastirma samples made from frozen/thawed meat and MAP can be stored at 4C and 10C for 150 days.*

[1] Corresponding author. TEL: +90-442-2312724; FAX: +90-442-2360958; EMAIL: miaksu@atauni.edu.tr

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INTRODUCTION

Pastirma is a traditional Turkish dry-cured meat product. Pastirma is made from whole muscle obtained from various parts of fresh beef and water buffalo carcasses. Pastirma is consumed sliced without cooking. Typical aromas from the pastirma seasoning and the high nutritional value have led to increased pastirma consumption (Kaya *et al.* 1996; Gökalp *et al.* 1999; Tekinsen and Dogruer 2000).

Modified atmosphere packaging (MAP) increases food safety and has recently seen more use in the food industry. It is applied to foods that are sensitive to O_2, because high O_2 levels decrease the quality and shelf life of most foods. It has been reported that MAP can maintain the quality of foods and prolong shelf life (Sullivan *et al.* 2003). Many reports indicate that MAP prevents lipid oxidation and proteolytic activity in raw and processed meat products (Wang *et al.* 1995; Wang 2001), maintains color (Sullivan *et al.* 2003) and decreases growth of pathogens as compared to vacuum packaging (Fernando *et al.* 1995). In MAP, different gases and gas combinations are used depending on the type and properties of the meat product. In processed meat products, N_2 and/or CO_2 combinations are the most common gases used (Davies 1995; Wang *et al.* 1995; Djenane *et al.* 2001; Wang 2001; Tewari *et al.* 2002; Sullivan *et al.* 2003).

Studies of whole muscle products have indicated that fresh or frozen meat could be used as the raw material for pastirma production. When the raw material used is frozen, it is necessary to reduce the salting period. While the salt penetrates more rapidly, this acceleration does not effect the sensory quality of hams (Kemp *et al.* 1982; Motilva *et al.* 1994; Banon *et al.* 1999). There has been some research on pastirma produced from fresh meat (El-Khateib *et al.* 1987; Askar *et al.* 1993; Katsaras *et al.* 1996; Aksu and Kaya 2001a,b, 2002a,b,c, 2004; Aksu *et al.* 2002), but there is no research on pastirma produced from frozen/thawed meat. The purpose of this study was to determine the effect of MAP and storage temperature and the use of frozen/thawed meat as a raw material on the chemical, physical and microbiological properties of sliced pastirma.

MATERIALS AND METHODS

Production of Pastirma

Frozen/thawed *M. Longissimus dorsi* muscle from beef carcasses was used as the raw material. Four pastirma production replications were produced from the carcasses of 3-year-old cows. One carcass was used for each replication. After removing fat and connective tissue from the surfaces, muscle

tissue was cut into two pieces across its center. Muscle tissue was frozen at −20C and stored at −18C for 240 days. The muscles were then thawed at 10C for 24 h.

The production process of pastirma was as follows: (1) Dry-curing (2 days at 6C, 80–90% RH) using 1 kg of meat, 50 g of curing mixture (47.0 g NaCl, 0.75 g KNO_3, 1.0 g glucose, 1.0 g sucrose) per kg of meat applied to the surface of the muscle. A commercial preparation of *Staphylococcus carnosus* + *Lactobacillus pentosus* (Bactoferm C–P–77 S) was used as the starter culture (CHR Hansen, Rudolf Müller, Pohlheim, Germany). Starter culture (25 g starter culture per 100 kg meat) was introduced into the muscle with the curing mixture. (2) The muscles were then dried (4 days at 15C, 80–85% RH). (3) The muscle was pressed (17 h at 7C) using a 25-kg weight for each kilogram of meat. (4) The product was dried again (3 days at 20C, 70% RH). (5) The product was pressed again (7 h at 25C, using a 25-kg weight per kilogram of meat). (6) Tissue was paste-seasoned (cemening) on the surface of the muscle. The seasoning mixture (cemen) used in this research contained 500 g flour (*Trigonella foenum graecum*) ground from seed, 350 g mashed fresh garlic, 75 g paprika, 75 g red pepper and 1200 mL water. The dried meat surface was pasted to a depth of 3–4 mm with the seasoning mix and stored at 7C for 4 days. (7) The product was then dried again (2 days at 15C, 70% RH; 2 days at 18C, 65% RH; 6 days at 20C, 60% RH) as described by Aksu (1999).

Packaging of Sliced Pastirma and Storage

Pastirma produced from frozen/thawed meat was sliced (1–2 mm thick) using a slicing machine at the end of the last drying. The sliced pastirma samples were packaged in 120- to 130-g portions in a moderately gas-impermeable bag (made of oriented polyamide ethylene-vinyl alcohol copolymer polyethylene [OPAEVOH/PE]: transmission rate for water vapor, 15 g/m^2/24 h/38C, 90% RH, 1 atm; O_2, 5 cm^3/m^2/24 h/23C, 50% RH, 1 atm; N_2, 1 cm^3/m^2/24 h/23C, 50% RH, 1 atm; CO_2, 23 cm^3/m^2/24 h/23C, 50% RH, 1 atm). Packages were evacuated, filled with a modified atmosphere gas mixture (50% N_2 + 50% CO_2) and automatically heat-sealed with a Multivac packaging unit (Multivac A 300/16, Sepp Haggenmüller, D 87787 Wolfertschwenden, Germany). The volume ratio of gas to sliced pastirma product was approximately 1 : 2. The packaged pastirma samples were divided into two groups and samples were stored at 4C or 10C for 150 days.

Moisture, Fat, Thiobarbutiric Acid Reactive Substance (TBARS), Protein, Salt and pH Analysis

Moisture, total fat and protein content in raw material and sliced pastirma were determined according to the methods of the AOAC (1984). The pH value

was determined by homogenizing a 10-g sample with 100 mL distilled water, then measuring pH with a pH star probe (SCHOTT L 6880, Lab Star pH, Germany). The degree of rancidity in samples was measured using TBARS analysis (Tarladgis *et al.* 1960). TBARS values were calculated as milligrams malonaldehyde/kilogram (mg malonaldehyde/kg). Salt content was determined according to the Tauchmann (1987) method.

Nonprotein Nitrogen (NPN) Analysis

A 5 g sample was homogenized with 40 g of 20% trichloroacetic acid and 10 mL of dichloromethane, allowed to settle at room temperature (20C) for 15 min, centrifuged at 3500 × g at 4C for 10 min and filtered through Schleicher & Schuell 2095 filter paper (Scheicher & Schuell GmbH, Dassel, Germany). The nitrogen content of the filtrate was determined and then NPN values were calculated (Anonymous 1989).

Water-soluble Nitrogen (WSN) Analysis

A 10-g portion of the pastirma sample was homogenized four times with 50 mL of deionized water for each homogenization (a total of 200 mL of water) and centrifuged at 5000 × g at 4C for 10 min. The supernatant was filtered through Whatman No. 1 filter paper (Whatman International Ltd., Maidstene, England). The WSN in 25 mL of the filtrate was determined (AOAC 1984).

Free Fatty Acid (FFA) Analysis

Ground sample (10 g) was homogenized with 30 mL of chloroform containing 0.5 g of sodium sulfate and allowed to settle at room temperature (20C) for 5 min then filtered through Whatman No. 1 filter paper. The free fatty acid content in 25 mL of the filtrate was determined by titration with a potassium hydroxide solution (0.01 N). Results were expressed as grams of oleic acid/100 g of fat.

Color Measurement

The surface color of the sliced pastirma (2–3 mm thickness) and raw materials were measured using a tristimulus colorimeter (Minolta Chroma Meter Measuring Head CR–200, Minolta, Osaka, Japan), which was used to determine Commision International de l'Eclairage (CIE) L^*, a^* and b^* 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 pastirma sample with 225 mL physiological saline (NaCl 0.85%) in a Stomacher (Laboratory Blender Stomacher 400, Seward Medical, London, UK) for 1 min. Total aerobic bacteria were enumerated on Plate Count Agar (Merck, 1.05463; Merck, Darmstadt, Germany) at 30C for 3 days. Lactic acid bacteria and *Enterobacteriaceae* were incubated anaerobically on De Man Rogosa Sharpe Agar (Merck, 1.10660) and Violet Red Bile Dextrose Agar (Merck, 1.10275) at 30C for 2 days, respectively. *Micrococcus/Staphylococcus* and yeast and mold were incubated aerobically on Mannitol Salt Phenol–Red Agar (Merck, 1.05404) and Potato Dextrose Agar (Merck, 1.10130) at 30C for 2 days and 20C for 5 days, respectively. Bacterial counts were expressed as colony-forming units per gram of sample (cfu/g).

Statistical Analysis

Data were analyzed as a completely randomized design procedure using the GLM procedure of the SPSS package (SPSS 1996). The model included storage temperature (4C or 10C) and storage period (0, 30, 60, 90, 120 or 150 days) as main effects (2×6) and all their interactions. Only significant interactions are shown in figures. The differences among means were tested for significance ($P < 0.05$) by Duncan's multiple range test. The results of statistical analysis were shown as mean values ± SD.

RESULTS AND DISCUSSION

Results of Raw Material and Pastirma

Data in Table 1 show the analytical results for frozen/thawed meat and sliced pastirma. These values in pastirma are close to those reported in the literature and for the pastirma standard (TS 1071) (Anonymous 1983). According to TS 1071, the maximum moisture and salt levels are 40.0 and 6.0%, respectively, and the maximum pH value is 6.0. Aksu and Kaya (2001a, 2002a,b) reported similar results for color values (L^*, a^* and b^*) in their pastirma samples.

Results of Pastirma Stored in Modified Atmosphere

Data in Table 2 show the means and SD for pH, TBARS, free fatty acids and WSN for pastirma samples.

TABLE 1.
CHARACTERISTICS OF RAW MATERIAL (FROZEN/THAWED MEAT) AND SLICED PASTIRMA PRODUCED FROM FROZEN/THAWED MEAT

Properties	Raw material (Frozen/thawed meat)	Pastirma
Moisture (%)	74.33 ± 0.03	40.68 ± 0.29
pH	5.90 ± 0.06	5.93 ± 0.04
Total protein (%)	22.30 ± 1.20	42.87 ± 1.81
Nonprotein nitrogen (NPN) (%)	2.53 ± 0.02	5.12 ± 0.09
Water-soluble nitrogen (WSN) (%)	4.95 ± 0.09	10.42 ± 0.36
Total fat (%)	2.28 ± 0.26	3.42 ± 0.34
Free fatty acids (FFA)*	0.23 ± 0.07	0.48 ± 0.02
Thiobarbutiric acid reactive substance (TBARS)†	0.56 ± 0.04	0.64 ± 0.04
Salt (%)	Not detected	4.90 ± 0.15
*L** color value‡	38.08 ± 0.07	47.38 ± 1.59
*a** color value§	24.47 ± 0.39	36.38 ± 1.15
*b** color value¶	4.72 ± 0.38	21.75 ± 0.36
Total bacterial count††	5.02 ± 0.25	7.89 ± 0.16
Lactic acid bacterial count††	3.19 ± 0.58	5.89 ± 0.13
Micrococcus/*Staphylococcus* count††	4.16 ± 0.51	7.73 ± 0.06
Enterobacteriaceae count††	2.81 ± 0.60	<2.00
Yeast and mold count††	3.43 ± 0.72	6.08 ± 0.37

* g oleic acid/100 g fat.
† mg malonaldehyde/kg.
‡ Relative lightness ($L = 0$ darkness; $L = 100$ lightness).
§ Relative redness ($+a$ = redness; $-a$ = greenness).
¶ Relative yellowness ($+b$ = yellowness; $-b$ = blueness).
†† Log_{10} cfu/g.

pH values

Storage period had a significant effect ($P < 0.01$) on pH values. The maximum pH value occurred on day 90 (Table 2). Nitrogenous compounds formed by proteolysis during the storage period may explain this increase. Aksu and Kaya (2005) reported similar results for pastirma produced from fresh beef. Houben and van-Dijk (2001) found that pH values decreased in sliced hams in modified atmosphere (50% N_2 + 50% CO_2) at 8C for 28 days. Furthermore, Pexara *et al.* (2002) reported that pH values decreased in modified atmosphere in cured, cooked Turkey fillets. In the current research storage temperature had no significant effect ($P > 0.05$) on pH values.

TBARS Content

The effect of both storage period and storage temperature on TBARS was significant ($P < 0.01$). TBARS increased until 30 days, but after the said number of days it did not significantly change in samples stored in MAP.

TABLE 2.
THE pH, THIOBARBUTIRIC ACID REACTIVE SUBSTANCE (TBARS), FREE FATTY ACIDS (FFA), NONPROTEIN NITROGEN (NPN) AND WATER-SOLUBLE NITROGEN (WSN) VALUES OF MODIFIED ATMOSPHERE PACKAGED SLICED PASTIRMA

	pH	TBARS[†]	FFA[‡]	NPN (%)	WSN (%)
Storage period (day)					
P	**	**	**	**	**
0	5.93 ± 0.04^{c}	0.64 ± 0.03^{b}	0.48 ± 0.02^{c}	5.11 ± 0.09^{e}	10.42 ± 0.37^{c}
30	6.03 ± 0.04^{b}	1.83 ± 0.23^{a}	0.50 ± 0.06^{bc}	5.62 ± 0.11^{d}	11.42 ± 0.34^{b}
60	6.04 ± 0.03^{b}	1.96 ± 0.23^{a}	0.52 ± 0.06^{bc}	5.74 ± 0.10^{c}	11.67 ± 0.27^{a}
90	6.11 ± 0.02^{a}	1.92 ± 0.14^{a}	0.54 ± 0.05^{b}	5.80 ± 0.10^{bc}	11.87 ± 0.33^{a}
120	6.07 ± 0.03^{b}	1.98 ± 0.19^{a}	0.64 ± 0.02^{a}	5.85 ± 0.14^{b}	10.53 ± 1.00^{c}
150	6.06 ± 0.01^{b}	1.91 ± 0.20^{a}	0.65 ± 0.03^{a}	6.12 ± 0.33^{a}	10.74 ± 0.43^{bc}
Storage temperature					
P	Ns	**	*	**	Ns
4C	6.03 ± 0.07^{a}	1.58 ± 0.45^{b}	0.53 ± 0.08^{b}	5.60 ± 0.25^{b}	10.92 ± 0.80^{a}
10C	6.05 ± 0.06^{a}	1.83 ± 0.57^{a}	0.58 ± 0.07^{a}	5.82 ± 0.40^{a}	11.29 ± 0.64^{a}

* $P < 0.05$; **$P < 0.01$; Ns, $P > 0.05$.
[†] mg malonaldehyde/kg.
[‡] g oleic acid/100 g fat.
[a–e] Any two means in the same column having the same letters in the same sections (time or temperature) are not significantly different at $P > 0.05$.
P, Probability.

Significantly higher TBARS were observed in samples stored at 10C compared to those stored at 4C (Table 2). Storage temperature × storage period interaction was not significant for TBARS ($P > 0.01$). TBARS of pastirma produced from frozen/thawed meat and stored in modified atmosphere for 150 days were close to those reported in the literature. For instance, several researchers reported that TBARS values of pastirma ranged from 0.16 to 2.46 mg malonaldehyde/kg (Askar *et al.* 1993; Yagli and Ertas 1998; Aksu 1999).

Free Fatty Acid (FFA) Content

There was a significant ($P < 0.01$) increase in FFA content in pastirma made with frozen/thawed meat between 0 and 150 days of storage. Storage temperature also caused a significant ($P < 0.01$) increase in FFA values (Table 2). The values for 120 and 150 days at 4C were not significantly different as shown in Fig. 1. Continuous lipolytic activity and increased quantity of fatty acids have been reported in dry-cured boneless ham during storage by Wang (2001). Occurrence of biochemical reactions such as lipolysis during the production of raw, dried meat products is important for aroma, color, texture and nutritive value of the final product. Lipids and phospholipids are

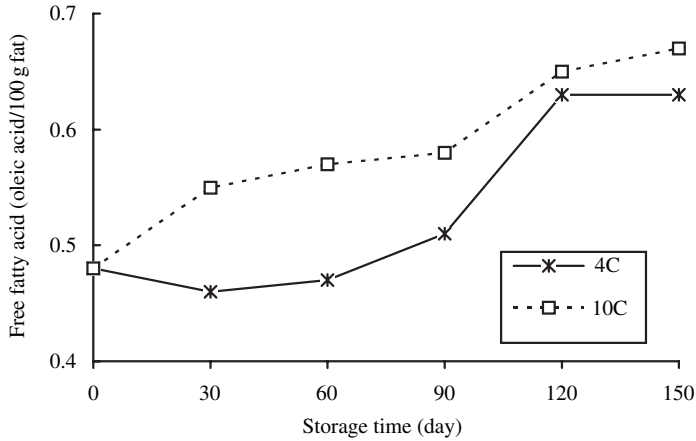

FIG. 1. EFFECT OF STORAGE TEMPERATURE AND STORAGE TIME ON THE FREE FATTY ACID CONTENT OF MODIFIED-ATMOSPHERE-PACKAGED PASTIRMA

hydrolyzed by lipase and phospholipase yielding free fatty acids, which are oxidized into peroxides (Toldra 1994). Lipid oxidation is quite important for the formation of the unique aroma in such products (Morrissey *et al.* 1998).

Nonprotein Nitrogen (NPN) Content

The NPN content increased significantly ($P < 0.01$) with storage, with the highest value occurring at the end of the storage period (Table 2). The amount of NPN has been reported to increase during the ripening process of pastirma and dry-cured ham. This increase confirms the breakdown of proteins during ripening (Martin *et al.* 1998; Aksu and Kaya 2001a,b). Toldra *et al.* (1993) reported that the muscle proteases remain active during the ripening process in this type of meat product and continue to break down peptides.

Storage temperature also had a significant effect ($P < 0.01$) on NPN values, with the highest ones occurring at 10C. However, there was a further difference in the NPN after 120 days in samples stored at 10C (Fig. 2). Wang (2001) also reported a significant increase in NPN values in dry-cured boneless hams, which were produced from frozen/thawed meat and stored in 75% N_2 + 25% CO_2 for 20 weeks. Aksu *et al.* (2002) also reported less NPN values in fresh meat compared to frozen/thawed meat that was processed under these same storage conditions (50% N_2 + 50% CO_2 for 150 days). This can be explained by higher proteolytic enzyme activity at higher temperatures. However, there has been no reported difference in the enzyme profile between fresh meat and frozen/thawed samples prior to processing (Ellerbroek *et al.* 1995).

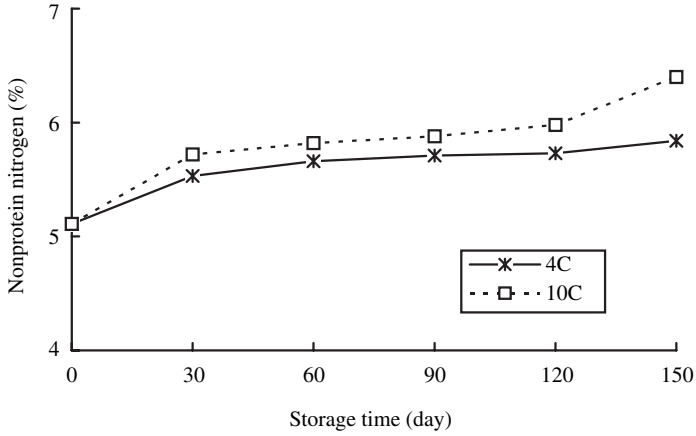

FIG. 2. EFFECT OF STORE TEMPERATURE AND STORAGE TIME ON THE NONPROTEIN NITROGEN CONTENT OF MODIFIED-ATMOSPHERE-PACKAGED PASTIRMA

WSN Content

The WSN content changed significantly ($P < 0.01$) with storage with the highest values occurring after 60 and 90 days (Table 2), then decreasing. Frozen/thawed meat has less WSN than fresh meat because of drip losses. Wang (2001) found that WSN values in MAP meat products increased gradually during storage and that higher WSN values were observed in frozen/thawed meat than in fresh meat. Storage temperature effects on WSN were insignificant ($P > 0.05$) (Table 2).

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

There were significant changes ($P < 0.01$) in L^*, a^* and b^* values of sliced pastirma during storage. While storage temperature had no effect on L^* values ($P > 0.05$), it did affect a^* values ($P < 0.01$, Table 3). The a^* values were maintained at higher levels in pastirma held at 10C compared to that held at 4C (Fig. 3). Similar results have been reported by Aksu and Kaya (2005) in sliced pastirma in MAP (50% N_2 + 50% CO_2) at 4C and 10C. Banon *et al.* (1999) also reported no significant changes in L^* values in dry-cured hams produced from precure freezing and frozen/thawed hams. However, a^* and b^* values decreased in hams produced from frozen/thawed meat. Houben and van-Dijk (2001) reported that color values (L^*, a^* and b^*) were retained in sliced, pasteurized hams stored at 8C in MAP (50% N_2 + 50% CO_2) for 28 days. Aksu and Kaya (2001a,b) reported that L^*, a^* and b^* color values in pastirma were 30.24–42.30, 13.66–40.07 and 6.67–20.54, respectively.

TABLE 3.
*L**, *a** AND *b** VALUES OF MODIFIED ATMOSPHERE PACKAGED SLICED PASTIRMA

	*L** value[†]	*a** value[‡]	*b** value[§]
Storage period (day)			
P	*	*	*
0	47.38 ± 1.59[a]	36.38 ± 1.15[a]	21.75 ± 0.36[a]
30	44.33 ± 0.91[b]	35.55 ± 0.50[a]	14.87 ± 0.38[b]
60	41,07 ± 1.24[c]	34.84 ± 1.18[a]	13.70 ± 0.82[b]
90	42.54 ± 2.45[bc]	31.34 ± 3.28[b]	12.45 ± 1.91[b]
120	43.04 ± 1.87[bc]	30.34 ± 3.69[b]	12.55 ± 2.38[b]
150	41.42 ± 1.14[bc]	30.06 ± 3.77[b]	13.50 ± 1.22[b]
Storage temperature	Ns	*	Ns
P	Ns	*	Ns
4C	42.93 ± 2.69[a]	31.74 ± 4.46[b]	14.60 ± 3.74[a]
10C	42.60 ± 2.53[a]	34.42 ± 1.42[a]	15.08 ± 3.41[a]

* $P < 0.01$; Ns, $P > 0.05$.
† Relative lightness ($L = 0$ darkness; $L = 100$ lightness).
‡ Relative redness ($+a$ = redness; $-a$ = greenness).
§ Relative yellowness ($+b$ = yellowness; $-b$ = blueness).
[a–c] Any two means in the same column having the same letters in the same sections (time or temperature) are not significantly different at $P > 0.05$.
P, Probability.

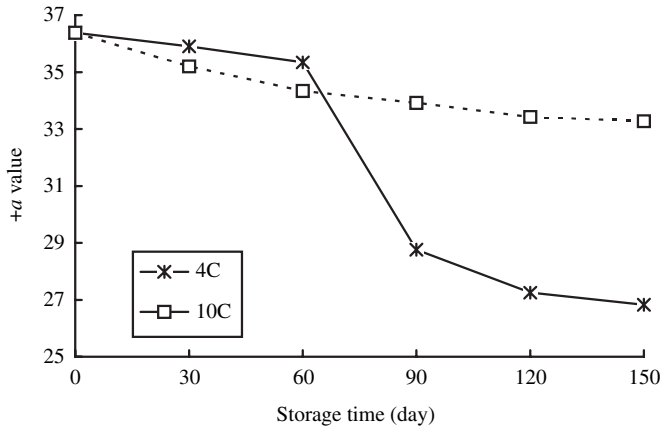

FIG. 3. EFFECT OF STORAGE TEMPERATURE AND STORAGE TIME ON THE *a** VALUE OF MODIFIED-ATMOSPHERE-PACKAGED PASTIRMA

These values and our values are acceptable to consumers' values for sliced pastirma.

An interaction ($P < 0.01$) between storage period and storage temperature occurred for a^* values (Fig. 3). The a^* values decreased after 60 days of storage at 4C.

Microbiological Properties

The use of modified atmosphere with a high concentration of CO_2 – either alone or in combination with up to 70% N_2 – has been reported to increase the microbiological shelf life of cured meat compared with that of meat in MAP with a high O_2 concentration (Sorheim *et al.* 1997). Storage in modified atmosphere caused a significant decrease ($P < 0.01$) in total aerobic and lactic acid bacteria and *Micrococcus*/*Staphylococcus* counts (Table 4). The highest numbers for lactic acid bacteria and *Micrococcus*/*Staphylococcus* occurred on day 0, while the highest total aerobic bacterial counts occurred in the early days of storage (0 and 30 days) (Table 4). Aksu and Kaya (2001a,b, 2002b,c) reported similar results. Storage temperature had no significant effect ($P > 0.05$) on total aerobic and lactic acid bacteria and *Micrococcus*/*Staphylococcus* counts. The growth rate of some lactic acid bacteria is reduced in CO_2 atmospheres compared to aerobic conditions (Blickstad and Molin 1984),

TABLE 4.
MICROBIAL COUNTS ($\log_{10}$ cfu/g) OF STORED MODIFIED ATMOSPHERE PACKAGED SLICED PASTIRMA

	Total aerobic bacterial counts[†]	Lactic acid bacterial counts[†]	*Micrococcus/Staphylococcus* counts[†]
Storage period (day)			
P	*	*	*
0	7.89 ± 0.16^{a}	5.89 ± 0.13^{a}	7.72 ± 0.06^{a}
30	7.80 ± 0.18^{a}	4.16 ± 0.49^{b}	7.74 ± 0.16^{a}
60	7.09 ± 0.38^{b}	3.16 ± 0.56^{c}	7.30 ± 0.24^{b}
90	6.32 ± 0.13^{c}	2.29 ± 0.36^{d}	6.70 ± 0.46^{cd}
120	6.49 ± 0.23^{c}	2.59 ± 0.52^{cd}	6.81 ± 0.25^{c}
150	6.24 ± 0.09^{c}	2.19 ± 0.14^{d}	6.36 ± 0.09^{d}
Storage temperature	Ns	Ns	Ns
P	Ns	Ns	Ns
4C	7.03 ± 0.76^{a}	3.54 ± 1.34^{a}	7.11 ± 0.65^{a}
10C	6.20 ± 0.70^{a}	3.22 ± 1.45^{a}	7.10 ± 0.53^{a}

* $P < 0.01$; Ns, $P > 0.05$.

[†] $\log_{10}$ cfu/g.

[a–d] Any two means in the same column having the same letters in the same sections (time or temperature) are not significantly different at $P > 0.05$.

P, Probability.

which may explain the prolonged reduction in these bacterial counts in this research. Ogihara *et al.* (1993) reported that the concentration of CO_2 did not affect the growth of *Lactobacillus* in food packaged in a modified atmosphere.

With modified atmosphere, yeast and mold counts were highest on day 0 (6.07 ± 0.50 log cfu/g), decreasing thereafter. The lowest count (<2.00 cfu/g) was observed after 90–150 days of storage at 4 and 10C. Furthermore, yeast was more dominant than mold during the entire storage period. The growth of yeast is greatly affected by the gaseous atmosphere ($CO_2 + N_2$), with O_2 being restricted in an anaerobic atmosphere (Borch *et al.* 1996).

The *Enterobacteriaceae* counts were below the limit of detection (<2.00 cfu/g) on all days of storage. Davies (1995) indicated that MAP is better than aerobic/vacuum methods in preventing growth of food pathogens. Fernando *et al.* (1995) also reported that Gram-negative bacteria (aerobic-psychrotrophic) were inhibited more in MAP and pathogen growth was less in MAP than in vacuum packaging.

CONCLUSION

Results of this research indicated that:

(1) Pastirma can be made from frozen/thawed meat and results are acceptable for the parameters examined.
(2) Sliced pastirma can be stored for 150 days in 50% N_2 + 50% CO_2.
(3) Although a^* values of sliced pastirma determined at both 4 and 10C were acceptable, this value can be better maintained at 10 versus 4C.

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REFERENCES

AKSU, M.I. 1999. *Pastırma Uretiminde Starter Kultur Kullanim Imkanlari* (*Research on the possibility of starter culture use in pastirma production*). PhD Thesis, Atatürk University Graduate Institute of Science, Erzurum, Turkey.

AKSU, M.I. and KAYA, M. 2001a. Some microbiological, chemical and physical characteristics of pastirma marketed in Erzurum. Turk. J. Vet. Anim. Sci. *25*, 319–326.

AKSU, M.I. and KAYA, M. 2001b. The effect of starter culture use in pastirma production on the properties of end product. Turk. J. Vet. Anim. Sci. *25*, 847–854.

AKSU, M.I. and KAYA, M. 2002a. Production of pastirma with different curing methods and using starter culture. Turk. J. Vet. Anim. Sci. *26*, 909–916.

AKSU, M.I. and KAYA, M. 2002b. The possibilities for the use of commercial starter cultures in pastirma production. Turk. J. Vet. Anim. Sci. *26*, 917–923.

AKSU, M.I. and KAYA, M. 2002c. Effect of commercial starter cultures on the fatty acid composition of pastirma (Turkish dry meat product). J. Food Sci. *67*, 2342–2345.

AKSU, M.I. and KAYA, M. 2005. Effect of storage temperatures and time on shelf-life of sliced and modified atmosphere packaged Pastirma, a dried meat product, produced from beef. J. Sci. Food Agric. *85*, 1305–1312.

AKSU, M.I., AKTAS, N. and KAYA, M. 2002. Effect of commercial starter cultures on the myofibrillar protein of pastirma. J. Food Sci. *67*, 2548–2551.

ANONYMOUS. 1983. PASTIRMA. TS 1071. Institute of Turkish Standards. (Türk Standardlari Enstitüsü) Necatibey Cad. 112, Bakanliklar, Ankara, Turkey.

ANONYMOUS. 1989. Amtliche Sammlung von Untersuchungsverfahren nach § 35 LMBG. Untersuchung von Lebensmitteln, Bestimmung des Gehaltes an Nichtprotein-Stickstoffsubstanz in Fleischerzeugnissen.

AOAC. 1984. *Official Methods of Analysis*, 14th Ed., Association of Official Analytical Chemists, Washington, DC.

ASKAR, A., EL-SAMAHY, S.K., SHEHATA, H.A. and TAWFIK, M. 1993. Pasterma and beef bouillon. The effect of substituting KCl and K-lactate for sodium chloride. Fleischwirtschaft *73*, 289–292.

BANON, S., CAYUELA, J.M., GRANADOS, M.V. and GARRIDO, M.D. 1999. Precure freezing affects proteolysis in dry-cured hams. Meat Sci. *51*, 11–16.

BLICKSTAD, E. and MOLIN, G. 1984. Growth and end-product formation in fermenter cultures of *Brochotrix thermosphacta* ATCC 11509^{T} and two psychrotrophic *Lactobacillus* spp. in different gaseous atmospheres. J. Appl. Bacteriol. *57*, 213–220.

BORCH, E., KANT-MUERMANS, M.L. and BLIXT, Y. 1996. Bacterial spoilage of meat and cured meat products. Int. J. Food Microbiol. *33*, 103–120.

DAVIES, A.R. 1995. Fate of foodborne pathogens on modified-atmosphere packaged meat and fish. Int. Biodeter. Biodegr. *36*, 407–410.

DJENANE, D., SANCHEZ-ESCALANTE, A., BELTRAN, J.A. and RONCALES, P. 2001. Extension of retail display life of fresh beef packaged in modified atmosphere by varying lighting conditions. J. Food Sci. *66*, 181–186.

EL-KHATEIB, T., SCHMIDT, U. and LEISTNER, L. 1987. Microbiological stability of Turkish pastirma. Fleicshwirtschaft *67*, 101–105.

ELLERBROEK, L.I., LICHTENBERG, G. and WEISE, E. 1995. Differentiation between fresh and thawed meat by an enzyme profile test. Meat Sci. *40*, 203–209.

FERNANDO, G.D., MANO, S.B., LOPEZ, D. and ORDONEZ, J.A. 1995. Effectiveness of modified atmospheres against psychrotrophic pathogenic microorganisms in proteinaceous food. Microbiologia (Madrid, Spain) *11*, 7–22.

GÖKALP, H.Y., KAYA, M. and ZORBA, O. 1999. *Technology of Pastirma and Some Other Dried Products. Engineering of Meat Products Processing*, 3rd Press, pp. 309–339, Atatürk Univ. Publ. no. 786, Faculty of Agric. no. 320, Atatürk University, Erzurum, Turkey.

HOUBEN, J.H. and VAN-DIJK, A. 2001. Effect of dietary vitamin E supplementation and packaging on the colour stability of sliced pasteurized beef ham. Meat Sci. *58*, 403–407.

KATSARAS, K., LAUNTENSCHLAGER, R. and BOSCHKOVA, K. 1996. Physikalisch-chemische vorgänge bei der herstellung von pasterma. Fleischwirtsch *76*, 136–142.

KAYA, M., AKSU, M.I. and GOKALP, H.Y. 1996. Dry-curing raw meat products. *Symposium of Meat and Meat Products '96*, pp. 26–34, Istanbul Univ. Vet. Fac., Istanbul, Turkey.

KEMP, J.D., LANGLOIS, B.E. and JOHNSON, A.E. 1982. Effect of pre-cure freezing and thawing on the microflora, fat characteristics and palatability of dry-cured ham. J. Food Prot. *45*, 244–248.

MARTIN, L., CORDOBA, J.J., ANTEGUERA, T., TIMON, M.L. and VENTANAS, J. 1998. Effects of temperature on proteolysis during ripening of Iberian ham. Meat Sci. *49*, 145–153.

MORRISSEY, P.A., SHEEHY, P.J.A., GALVIN, K., KEERY, J.P. and BUCKLEY, D.J. 1998. Lipid stability in meat and meat products. Meat Sci. *49*, S73–S86.

MOTILVA, M.J., TOLDRA, F., NADAL, M.I. and FLORES, J. 1994. Prefreezing hams affects lipolysis during dry-curing. J. Food Sci. *59*, 303–305.

OGIHARA, H., KANIE, M., YANO, N. and HARUTA, M. 1993. Effect of carbon dioxide, oxygen, and their gas mixture on the growth of some

foodborne pathogens and spoilage bacteria in modified atmosphere package of food. J. Food Hyg. Soc. Jpn *34*(4), 283–288.

PEXARA, E.S., METAXOPOULOS, J. and DROSINOS, E.H. 2002. Evaluation of shelf life of cured, cooked, sliced turkey fillets and cooked pork sausages – "piroski" – stored under vacuum and modified atmospheres at +4 and +10C. Meat Sci. *62*, 33–43.

SORHEIM, O., AUNE, T. and NESBAKKEN, T. 1997. Technological, hygienic and toxicological aspects of carbon monoksit use in modified-atmosphere packaging of meat. Trends Food Sci. Technol. *8*, 307–312.

SPSS. 1996. SPSS users guide. Windows Release 10.01, SPSS Inc.

SULLIVAN, A.O., GALVIN, K., MONOLEY, A.P., TROY, D.J., SULLIVAN, K.O. and KERRY, J.P. 2003. Effect of pre-slaughter rations of forage and/or concentrates on composition and quality of retail packaged beef. Meat Sci. *63*, 279–286.

TARLADGIS, B.G., WATTS, B.M., YOUNATHAN, M.T. and DUGAN, L.R.J. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J. Am. Oil Chem. Soc. *37*, 44–46.

TAUCHMANN, F. 1987. *Methoden der Chemischen Analytic von Fleisch und Fleischwaren*, p. 80, Bundensanstalt für Fleischforschung, Kulmbach, Germany.

TEKINSEN, O.C. and DOGRUER, Y. 2000. *Pastirma. From Every Aspects*, Selcuk University Press, Konya, Turkey.

TEWARI, G., JEREMIAH, L.E., DIGVIR, S.J. and HOLLEY, R.A. 2002. Improved use of oxygen scavengers to stabilize the colour of retail-ready cuts stored in modified atmospheres. Int. J. Food Sci. Technol. *37*, 199–207.

TOLDRA, F. 1994. Proteolysis and lipolysis in flavor development or dry-cured meat products. Meat Sci. *49*, S101–S110.

TOLDRA, F., RICO, E. and FLORES, J. 1993. Cathepsin B, D, H and L activities in the processing of dry-cured ham. J. Food Sci. Agric. *62*, 157–161.

WANG, F.S. 2001. Lipolytic and proteolytic properties of dry-cured boneless hams ripened in modified atmospheres. Meat Sci. *59*, 15–22.

WANG, F.S., JIANG, Y.N. and LIN, C.W. 1995. Lipid and cholesterol oxidation in Chinese-style sausage using vacuum and modified atmosphere packaging. Meat Sci. *40*, 93–101.

YAGLI (GUR), H. and ERTAS, A.H. 1998. Effect of sodium ascorbate on some quality characteristics of Turkish pastirma. Turk. J. Agric. Forr. *22*, 515–520.