EFFECT OF MODIFIED ATMOSPHERE PACKAGING AND STORAGE TIME ON PHYSICAL AND SENSORY PROPERTIES OF SLICED SALAMI

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ABSTRACT

The objective of this study was to investigate the quality properties of sliced and modified atmosphere-packaged salami during refrigerated storage. Salami was sliced and packaged under air and three modified atmosphere packaging (MAP) compositions (100% N_2; 50% CO_2, 50% N_2; 5% O_2, 25% CO_2, 70% N_2) in polypropylene trays sealed with polyethylene terepthalate/polyvinylidene chloride/oriented polypropylene. Headspace oxygen and carbon dioxide (%), physical (color and texture), chemical (pH) and sensory properties were analyzed for 20 days at 4C. The results showed that CO_2 concentration (%) decreased after 5 days of storage for MAP applications with high CO_2, which was attributed to the solubility of CO_2 in the salami. The pH did not significantly change during storage at all applications ($P > 0.05$*). While* L *values increased,* a *and* b *values decreased during storage. The MAP applications with no oxygen received higher panelist scores and provided better quality characteristics than air and 5% O_2, 25% CO_2, 70% N_2 for 15 days.*

PRACTICAL APPLICATIONS

Nowadays, consumers demand for safe, nutritious and ready-to-eat/use food products. The use of modified atmosphere packaging (MAP) for ready-to-eat/use meat products has considerably increased in recent years. Salami that are sliced and packaged in smaller portions could attract consumers interested in individual portions at supermarkets. Although optimization of gas

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composition is critical to ensure the product's quality and safety, only a few studies have focused on the preservation of meat products like salami. Atmospheres with no oxygen could be used for MAP of sliced salami as color, textural and sensory properties were preserved better than atmospheres with oxygen. Previous studies stated that vacuum packaging did not inhibit microbial growth; however, MAP with CO_2 was found effective on microorganisms due to its bacteriostatic effect. Therefore, MAP packaging of sliced salami would be a better option than vacuum packaging.

INTRODUCTION

In recent years, marketing sliced ready-to-eat meat products have gained popularity. Modified atmosphere packaging (MAP) is one of the preservation and packaging techniques that meet the increasing demand of consumers for safe, additive-free and high nutritional value food. The quality and shelf life of minimally processed products can be extended by MAP combined with cold storage (Huxsoll *et al.* 1989; Kader *et al.* 1989; Labuza and Breene 1989; Church 1994; Church and Parsons 1995; Farber *et al.* 2003). Therefore, using MAP and chill storage for meat products like salami may considerably preserve the quality and increase the shelf life. In addition to longer shelf life, attractive product qualities can be achieved by MAP. The visual appearance of meat products is of major importance when a consumer is evaluating the product quality.

Elias and Carrascosa (2000) suggested that refrigeration temperatures were necessary in order to extend the shelf life of vacuum-packaged dry-cured Iberian ham based on microbial and physicochemical aspects. Garcia-Esteban *et al.* (2004) found no clear differences in color, texture, sensory and microbiological quality between vacuum and gas (100% N_2; 20% N_2, 80% CO_2) packaging of dry-cured ham during cold storage. Similar results were found in "Cecina de Leon," a dry-cured beef, packaged under vacuum and 80% CO_2 and 20% N_2, but some sensory deterioration was observed for the samples packaged under 20% CO_2 and 80% N_2 (Rubio *et al.* 2006).

The objective of this study was to investigate the effects of MAP on the important quality characteristics by examining physical and sensory properties of sliced salami stored at 4C for 20 days.

MATERIALS AND METHODS

Materials

Salami (Economic Plump Salami; 75% veal, 25% turkey) samples having the same batch number and presenting the same shelf life were obtained from a local market. Chemicals were supplied from Merck (Darmstadt, Germany). Polypropylene (PP) trays (mono PP with the dimensions of 144 × 190 × 50 mm) were provided by Huhtamaki (Istanbul, Turkey). Polyethylene terephthalate/polyvinylidene chloride/oriented polypropylene (PET/PVDC/OPP) lidding film having oxygen permeability of 8.58 $cm^3/m^2/d/atm$ and carbon dioxide permeability of 36.77 $cm^3/m^2/d/atm$ at 75% relative humidity was provided by A-Pack (Istanbul, Turkey).

Production of Salami

The meat and additives used in the production of salami were very similar to a sausage. The detailed production scheme for salami can be seen in Fig. 1.

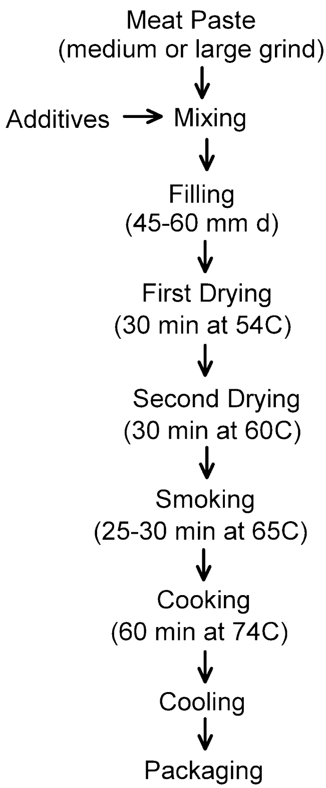

FIG. 1. SALAMI PRODUCTION SCHEME

Processing and Packaging Procedures

The salami was sliced at a thickness of 2.5 mm using an industrial cutting machine (Ersoz, Turkey), and 250 g sample was placed in PP trays previously sanitized with 3% hydrogen peroxide (H_2O_2). Four different gas compositions were used for packaging: air (MAP1); 100% N_2 (MAP2); 50% CO_2, 50% N_2 (MAP3); and 5% O_2, 25% CO_2, 70% N_2 (MAP4) as MAP applications. After applying vacuum, the trays were flushed with modified atmosphere and sealed with lidding film (PET/PVDC/OPP) at 170C using MAP machine (MECA 501, Champigny sur Marne, France) combined with triple gas mixer (KM60-3, Witt, Germany). Packaged samples were stored at 4C. Sampling was carried out on 0, 5, 10, 15 and 20 days of storage. The storage time was limited to 20 days based on sensory deterioration. Two packs were analyzed for each application on sampling days.

Analysis

Headspace Gas Analysis. The headspace contents of oxygen (%) and carbon dioxide (%) in the packs were determined using a gas analyzer (PBI Dansensor, Ringsted, Denmark) by a needle through an adhesive septum previously fixed on the lidding material. The average of four measurements was calculated (Ayhan *et al.* 2008).

pH. Ten grams of salami sample was thoroughly homogenized with 90 mL of distilled water. The pH value of the homogenates was recorded using a WTW-315i pH meter (Weilheim, Germany). The average of four measurements was calculated (AOAC 2003).

Color. Color measurements (L, a and b values) were made using a Minolta chromameter model CR-400 (Osaka, Japan). L, a and b values were measured on 20 slices from two packages (10 slices per package) for each application and the mean of 20 measurements was calculated.

Texture. Textural analysis was carried out using TA-XT Plus (Stable Micro System, Surrey, England). The firmness and toughness were measured using a blade set. A speed of 5 mm/s and penetration distance of 40 mm were used. The firmness was expressed as maximum cutting force (N), and the toughness was expressed as peak area (N/s). A total of 10 measurements were made for each application.

Sensory Evaluation

Sensory evaluation of sliced salami samples was performed during storage by a sensory panel consisting of eight trained judges. Panel members were either faculty members or graduate students of the Food Engineering department at the Mustafa Kemal University. Three whole slices from each treatment at room temperature were distributed to all panel members. Panelists were asked to evaluate visual appearance, color, odor, texture and taste intensities of the samples categorized as follows: 1 = slimy, 5 = acceptable, 9 = fresh; 1 = pale, 5 = acceptable, 9 = pink/red; 1 = strong off-odor, 5 = acceptable, 9 = no off-odor; 1 = hard/dry, 5 = acceptable, 9 = normal/typical texture; 1 = rancid/spoiled, 5 = acceptable, 9 = normal/typical taste, respectively. Overall product acceptability was scored on a 9-point hedonic scale where 9 corresponds to extremely liked and 1 corresponds to extremely disliked (Meilgaard *et al.* 1991).

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) and the least significant difference (LSD) test at 95% confidence level using SAS statistical program. The effects of applications, storage time and their interactions on the quality parameters were investigated.

RESULTS AND DISCUSSION

Headspace Gas Composition

The headspace gas concentrations of packs are shown in Figs. 2 and 3, representing O_2% and CO_2%, respectively. The oxygen concentration did not change much for MAP applications except MAP1 during the 20-day storage (Fig. 2). The decrease in O_2 concentration for MAP1 might be attributed to oxidative reactions. The CO_2 concentrations decreased in 5 days for the MAP applications high in CO_2 (MAP2 and MAP3). This decrease might be attributed to CO_2 solubility in the salami slices and the film permeability as reported by Doherty *et al.* (1995) and Sorheim *et al.* (1996). The increase in CO_2 concentration for MAP1 after 15 days of storage was probably due to microbial spoilage. Jo *et al.* (2003) reported that the amount of residual nitrite of sausage samples packaged with CO_2 was lower than with vacuum or aerobic packaging.

pH. The pH of salami samples during storage is shown in Table 1. There was no significant effect of MAP and storage time on the pH of salami slices ($P > 0.05$). pH tended to increase slightly at all MAP applications until the 10th day of storage. Proteolysis may have produced nitrogenous compounds, which in turn, may have caused increase in the pH values (Aksu *et al.* 2005).

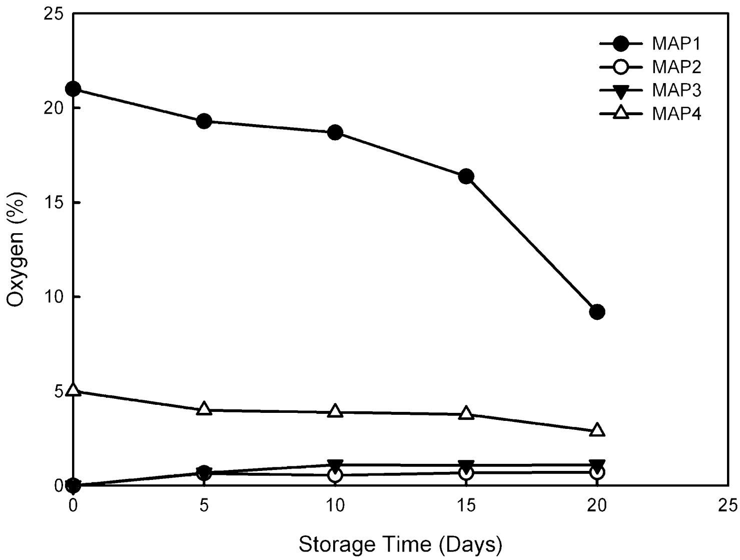

FIG. 2. EFFECTS OF MODIFIED ATMOSPHERE PACKAGING (MAP) ON THE HEADSPACE OXYGEN CONCENTRATION (%) DURING STORAGE (MAP1: 21% O_2, 79% N_2; MAP2: 100% N_2; MAP3: 50% CO_2, 50% N_2; MAP4: 5% O_2, 25% CO_2, 70% N_2)

After 10 days of storage, pH values slightly decreased which could be attributed to acid formation by microorganisms. In general, the changes in pH were statistically insignificant ($P > 0.05$).

Color. Results of the color measurements are shown in Table 1. The ANOVA revealed significant effects of MAP applications, storage days and interaction for lightness (L) values ($P \leq 0.05$). In general, L values did not change much until the 15th day of storage and tended to increase after that day at all treatments. On the 20th day of storage, L values at MAP1 (air) and MAP4 (low oxygen) were significantly higher than that of MAP2 treatment ($P \leq 0.05$). Increase in lightness (L) was also observed on vacuum-packaged ham slices (Garcia-Esteban *et al.* 2004) and on vacuum- and gas-packaged "Cecina de Leon" (Rubio *et al.* 2006) due to a whitening surface.

Redness (a), which is used as an indicator of color stability in meat and meat products, decreased during storage. There were significant effects of MAP application, storage day and interaction between MAP application and storage day ($P \leq 0.05$). The redness of salami slices decreased at all MAP applications with increase in storage time; however, decrease in redness value at MAP1 (air) especially at the end of the storage was more obvious, possibly due to oxidative reaction caused by oxygen. Pexara *et al.* (2002) reported that

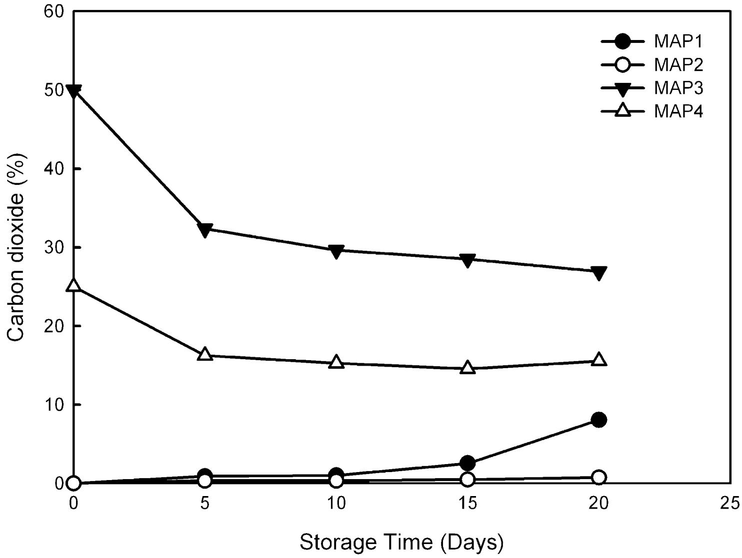

FIG. 3. EFFECTS OF MODIFIED ATMOSPHERE PACKAGING (MAP) ON THE HEADSPACE CARBON DIOXIDE CONCENTRATION (%) DURING STORAGE (MAP1: 21% O_2, 79% N_2; MAP2: 100% N_2; MAP3: 50% CO_2, 50% N_2; MAP4: 5% O_2, 25% CO_2, 70% N_2)

redness of piroski sausages packed in high O_2 concentration was less than that of other gas mixtures, and discoloration was significantly greater at 10C than at 4C. The red color of pork saveloys did not change during storage at 5C for up to 28 days, possibly because of a low amount of residual oxygen combined with the low oxygen permeability of packaging material (Juncher *et al.* 2000).

The b values tended to increase at the beginning of storage, then to decrease at the end of storage at all treatments. The effects of MAP application, storage day and interactions between MAP and storage day were significant ($P \leq 0.05$) for b (Table 1).

Higher oxygen levels in combination with residual oxygen in the package causes severe discoloration of nitrite-cured meat products (Moller *et al.* 2000). Thus, MAP with no oxygen could be suggested to preserve the color of salami slices. MAP applications preserved product color better than vacuum packaging or air packaging for pastirma (Gok *et al.* 2008) and dry-cured ham (Garcia-Esteban *et al.* 2004).

Texture. The texture measurements of salami slices are shown in Table 2. In general, there were minor differences in the firmness of salami slices during storage. The salami slices packaged with MAP3 and MAP4 appeared to be slightly firmer than the ones packaged with air (MAP1) after 10 days of storage.

TABLE 1.
THE EFFECTS OF MODIFIED ATMOSPHERE PACKAGING (MAP) AND STORAGE TIME ON THE pH AND COLOR VALUES OF SLICED SALAMI

	Application‡	pH ($n = 4$) and color values† ($n = 20$)*				
		Day 0	Day 5	Day 10	Day 15	Day 20
pH	MAP1	6.42bcde	6.56ab	6.62a	6.43bcde	6.27e
	MAP2	6.42bcde	6.47abcd	6.53abcd	6.38cde	6.44bcd
	MAP3	6.42bcde	6.53abc	6.58ab	6.54abc	6.41bcde
	MAP4	6.42bcde	6.49abcd	6.61a	6.51abcd	6.36de
L	MAP1	50.00gh	50.60efg	50.13fgh	49.92h	54.21ab
	MAP2	50.00gh	49.91h	52.44d	50.38fgh	53.31c
	MAP3	50.00gh	50.05gh	50.73ef	52.60d	53.65bc
	MAP4	50.00gh	51.05e	50.45fgh	50.66ef	54.46a
a	MAP1	17.00a	16.14b	15.56c	15.55c	12.23g
	MAP2	17.00a	16.94a	14.92d	16.22b	13.55f
	MAP3	17.00a	17.11b	16.38b	15.08d	14.03e
	MAP4	17.00a	16.31c	16.17b	15.74c	13.28f
b	MAP1	6.10ef	6.50a	6.20bcde	6.39ab	5.24gh
	MAP2	6.10ef	6.30bcd	5.37g	6.11def	4.93i
	MAP3	6.10ef	6.32abc	5.91f	5.44g	5.11hi
	MAP4	6.10ef	6.04ef	6.16cde	6.16cde	5.09hi

* Means with different letters in the same column are significantly different ($P \leq 0.05$); means with different letters in the same row are significantly different ($P \leq 0.05$).
† *L*, lightness; *a*, redness; *b*, yellowness.
‡ MAP1: 21% O_2, 79% N_2; MAP2: 100% N_2; MAP3: 50% CO_2, 50% N_2; MAP4: 5%O_2, 25% CO_2, 70% N_2.

In terms of toughness, MAP1 and MAP4 had significantly higher values on the 5th days of storage. The toughness of salami slices packaged with 100% N_2 (MAP2) and air was significantly higher than that of other two applications on the 20th day of storage. Changes in firmness and toughness could be due to changes in water content during the storage period. Garcia-Esteban *et al.* (2004) reported that moisture content of the dry-cured ham decreased significantly in samples vacuum packaged and with N_2 at 3 weeks; however, no decrease was observed in samples packaged with $CO_2 + N_2$. Hardness values of the dry-cured ham samples were highest in samples vacuum packaged, followed by samples packaged with $CO_2 + N_2$ and finally, in samples packaged with N_2, suggesting that MAP preserved textural properties more efficiently than vacuum packaging (Virgili *et al.* 1995; Garcia-Esteban *et al.* 2004).

Sensory Evaluation

Panelist scores for sensory evaluation of sliced salami packaged under four different MAP are presented in Table 3. In terms of visual quality and

TABLE 2.
THE EFFECTS OF MODIFIED ATMOSPHERE PACKAGING (MAP) AND STORAGE TIME ON THE FIRMNESS AND TOUGHNESS OF SLICED SALAMI

	Application†	Texture values (n = 10)*				
		Day 0	Day 5	Day 10	Day 15	Day 20
Firmness‡	MAP1	9.89cdef	7.98g	9.86def	9.64def	9.85def
	MAP2	9.89cdef	9.14f	10.18bcd	10.92ab	9.94cdef
	MAP3	9.89cdef	9.25ef	10.12bcde	11.24a	10.77abc
	MAP4	9.89cdef	10.33abcd	9.87cdef	10.91ab	11.21a
Toughness§	MAP1	9.50def	12.40ab	10.54cde	9.11efg	11.90abc
	MAP2	9.50def	7.57g	9.04efg	9.85def	13.25a
	MAP3	9.50def	8.68fg	9.19ef	9.86def	9.36ef
	MAP4	9.50def	11.09bcd	13.16a	10.49cde	9.72def

* Means with different letters in the same column are significantly different ($P \leq 0.05$); means with different letters in the same row are significantly different ($P \leq 0.05$).

† MAP1: 21% O_2, 79% N_2; MAP2: 100% N_2; MAP3: 50% CO_2, 50% N_2; MAP4: 5%O_2, 25% CO_2, 70% N_2.

‡ Maximum force, N.

§ Area, N/s.

color, sliced salami was acceptable until day 15, except MAP1. The color scores were in good correlation with the color measurements. The color scores decreased during storage, indicating the loss of desirable pink color. The odor and taste of salami slices packaged with air received scores below 5, which was considered under acceptability limit on the 5th day of storage. However, the other three applications (MAP2, MAP3 and MAP4) were acceptable in terms of odor and taste at 15th day of storage. On the 20th day, the product was not tasted due to noticeable off odor at all treatments. The species of lactic acid bacteria are mainly responsible for the spoilage of refrigerated vacuum or MA-packaged cooked meat products (Holley 1997; Samelis and Georgiadou 2000). Lactic acid bacteria spoil refrigerated meat products by causing off-flavors, discoloration and slime production which could be detected by sensory analysis. Panelist's scores showed that sliced salami was acceptable for all MAP applications in terms of texture after 20 days of storage, except MAP1. The texture measurements by TA-XT Plus were in agreement with the sensory scores. While the sliced salami packaged with air (21% oxygen) was not acceptable after 5 days of storage, MAP4 with low oxygen was acceptable during 10 days of storage, and the applications with no oxygen (100% nitrogen and 50% nitrogen–50% carbon dioxide) were acceptable during 15 days of storage.

TABLE 3.
THE EFFECTS OF MODIFIED ATMOSPHERE PACKAGING (MAP) AND STORAGE TIME ON THE SENSORY QUALITY OF SLICED SALAMI

	Application†	Panelist scores ($n = 8$)*				
		Day 0	Day 5	Day 10	Day 15	Day 20
Visual quality	MAP1	8.1a	7.0abcd	6.0cdefg	4.3hi	2.8i
	MAP2	6.4bcde	6.3bcdefg	6.3bcdefg	6.8abcde	5.6efgh
	MAP3	7.5abc	7.9ab	6.4bcdef	5.5defgh	4.6gh
	MAP4	7.1abcd	7.4abc	5.9cdefg	6.0cdefg	4.9fgh
Color	MAP1	7.3ab	7.0abc	6.5abcd	4.8de	3.4e
	MAP2	6.8abc	6.3abcd	5.5bcd	6.0abcd	5.8abcd
	MAP3	7.3a	7.5a	6.3abcd	6.0abcd	5.3cd
	MAP4	7.0abc	6.9abc	6.6abc	5.9abcd	5.5bcd
Odor	MAP1	7.9a	6.9abcdef	4.6ghi	4.3hi	3.1i
	MAP2	7.1abcd	5.8bcdefgh	5.6cdefg	6.4abcdefg	4.9fghi
	MAP3	7.8ab	7.5abc	5.1defghi	5.9abcdefg	5.9abcdefgh
	MAP4	7.0abcde	6.8abcdef	6.0abcdefgh	5.0efghi	4.5ghi
Texture	MAP1	7.8a	7.0abcde	5.6cdefg	4.8gh	3.0h
	MAP2	7.6ab	6.9abcdef	6.4abcdefg	6.6abcdefg	5.0fg
	MAP3	7.6ab	8.1a	5.1efg	5.5cdefg	5.5cdefg
	MAP4	7.1abcd	7.4abc	6.9abcdef	5.8bcdefg	5.4defg
Taste	MAP1	7.8a	7.6ab	4.6ef	3.9f	NT‡
	MAP2	7.6ab	6.3bcd	4.8ef	7.0abc	NT
	MAP3	7.4ab	7.5ab	5.5de	5.9dec	NT
	MAP4	7.0abc	7.6ab	5.1def	5.0def	NT
Overall acceptance	MAP1	7.8a	7.4ab	4.4fg	3.5gh	2.5h
	MAP2	6.8abcd	5.9bcdef	4.9efg	6.8abcd	5.8bcdef
	MAP3	7.4ab	7.5ab	5.0defg	5.1defg	4.9efg
	MAP4	6.4abcde	7.1abc	5.5cdef	4.6efg	5.0defg

* Means with different letters in the same column are significantly different ($P \leq 0.05$); means with different letters in the same row are significantly different ($P \leq 0.05$).

† MAP1, 21% O_2, 79% N_2; MAP2, 100% N_2; MAP3, 50% CO_2, 50% N_2; MAP4, 5%O_2, 25% CO_2, 70% N_2.

‡ Not tasted.

CONCLUSIONS

MAP with high CO_2 (50%) and nitrogen (100%) was more suitable for the preservation of sliced salami as the color and taste were preserved better than air or low-oxygen (5%) atmospheres. Packaging film with low permeability of oxygen, carbon dioxide and water, low storage temperature (0–4C) and good sanitation practices should be considered together in order to maintain the quality, while increasing the shelf life of meat products like salami.

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