2(4): 189-198 (2016) doi: 10.3153/JFHS16020

Journal of Food and Health Science

E-ISSN 2149-0473

ORIGINAL ARTICLE/ORİJİNAL ÇALIŞMA

FULL PAPER TAM MAKALE

QUALITY OF 'MANTI' (MEAT-FILLED PASTA PRODUCT) AS AFFECTED BY MODIFIED ATMOSPHERE PACKAGING DURING REFRIGERATED STORAGE

Aysun Yücetepe, Gürbüz Güneş

Department of Food Engineering, Faculty of Chemical and Metallurgical Engineering, Istanbul Technical University, Istanbul, Turkey

Received:.17.06.2016

Accepted: 20.09.2016

Published online: 24.09.2016

Corresponding author:

Gürbüz GÜNEŞ, Department of Food Engineering, Faculty of Chemical and Metallurgical Engineering, Istanbul Technical University, Maslak, TR-34469, Istanbul, Turkey

E-mail: gunesg@itu.edu.tr

Abstract:

The fresh 'mantı' pieces were blanched in boiling water for 5 min and dehydrated in an oven at 125°C to adjust water activity to 0.91. The samples were packaged under different atmospheres (C: air as control, M1: 70% CO_2+30% N_2+0% O_2, M2: 70% CO_2+25% N_2+5% O_2, M3: 100% N_2). Packages have been stored in a refrigerator at +4 ± 1 °C for 35 days during which headspace gas composition, total aerobic meshophilic bacteria (TAMB), total yeast-mold, moisture, pH, lipid oxidation and sensory analyses were carried out. Yeast-mold and TAMB counts were 1.40 log cfu/g and 4.62 log cfu/g in samples packaged in air after 35 days, respectively. Yeast-mold and TAMB counts were below 2 log cfu/g in M1, M2 and M3 during 35 days. The 2-thiobarbituric acid reactive substances (TBARS) values of the samples in all modified atmosphere packaging (MAP) were lower than the samples in the control packages after 35 days. Sensory qualities of uncooked and cooked samples were significantly higher in M1 and M2 than C and M3 during 35-day storage. Overall, microbiological, chemical and sensory quality of the samples packaged with M1 and M2 were maintained successfully during 35-day storage.

Keywords: Lipid oxidation, Meat-filled pasta ('mantı'), Microbiological quality, Modified atmosphere packaging, Sensory quality

© 2015-2016 ScientificWebJournals (SWJ)

Introduction

'Mantı' is a traditional Turkish food in which a meat based filling material is wrapped with a thin sheet of dough in small pieces. It has been produced handmade and sold daily for long time, but nowadays special wrapping machines are available and used in large scale production. Although the fresh refrigerated product is considered as a premium, due to its very short shelf-life the product is released to the market as totally dehaydrated or frozen forms. Drying or freezing of 'mantı' extend the shelf-life but they adversely affect texture, overall flavor, and color of the product. Refrigerated 'mantı' with premium quality and an extended shelf-life is highly demanded by consumers and subject of interest in industry.

The shelf-life of refrigerated 'mantı' is limited mainly due to microbial spoilage and lipid oxidation. Traditionally, both the filling material and the dough in 'mantı' are raw with high water activity, resulting in high initial microbial (bacteria, yeast and mold) count. Lipid oxidation especially in the filling material is a major problem causing quality degradation in fresh 'mantı'. Modified atmosphere packaging (MAP) can be used to decrease the rate of quality degradations and thus, increase the shelf-life of refrigerated 'mantı'. MAP with reduced O_2 and elevated CO_2 in the package headspace would decrease the rate of microbial growth and lipid oxidation in 'mantı' as suggested in various meat and bakery products in literature (Pikul *et al*., 1989; Church & Parsons, 1995; Jakobsen & Bertelsen, 2000; Rasmussen & Hansen, 2001; Taniwaki *et al*., 2001; Kennedy *et al*. 2004; Aksu *et al*., 2005; Berruga *et al*. 2005; Gök *et al*. 2008; Zakrys *et al*. 2008; Bornez *et al*., 2009; Esmer *et al*., 2011; Fik *et al*., 2012; Khoshakhlagh *et al*., 2014; Santos *et al*., 2015; Shah *et al*., 2015). The objective of this study was to determine the effect of modified atmosphere packaging on microbial quality, lipid oxidation and sensory quality of 'mantı' during refrigerated storage.

Materials and Methods

Materials

Fresh hand made 'mantı' was obtained from a local manufacturer (Pelin Food Company, Istanbul, Turkey). Peptone was purchased from Oxoid (Basingstoke, Hampshire, UK), plate count agar (PCA) and dichloran rose-bengal chloramphenicol (DRBC) agar were supplied by Merck (Darmstadt, Germany) and sodium chloride and trichloroacetic acid (TCA) was obtained from Riedel-de Haen (Germany). 3,5-di-tert-4-butylhydroxytoluene (BHT, SAFC, Germany), thiobarbituric acid (TBA) and 1,1,3,3,-Tetraetoksipropan (TEP) were obtained from Fluka (Buschs, Switzerland). Packaging materials were supplied by Korozo Packaging Industry and Trade Co. (Istanbul, Turkey).

Preparation of 'Fresh Mantı' Samples

'Fresh mantı' samples were prepared by a local manufacturer according to the method given in Figure 1. Dough, prepared from flour, water and salt, was rolled out by using a dough roller machine to get thin sheets (ca 2 mm). The sheets of dough were cut into pieces of 2.5 × 2.5 cm dimensions. The filling material contained ground meat, onion, salt and spices mixture (black pepper, chili powder and cumin). The filling material was cooked for 20 min in a cauldron and cooled to 4 ºC to decrease initial microbial load before used. A small amount of filling material (ca 1 cm^3) is wrapped by each pieces of the dough to obtain the final form of 'mantı'.

Pretreatments, Packaging and Storage of the 'Mantı' Samples

The fresh 'mantı' samples were taken to our laboratory under refrigerated condition and pretreatment and packaging were applied in our laboratory as shown in Figure 1. The samples were blanched in boiling water for 5 min to decrease initial microbial load. They were partially dehydrated in an oven at 125ºC for 70 min so that the individual pieces of 'mantı' do not stick to each other. Water activity of the 'mantı' samples were 0.91, after this treatment.

The 'mantı' samples were placed into disinfected polypropylene plates and packaged with LDPE bags (50 µm with OTR: 3800 cc $O_2/m^2 \cdot day \cdot atm$ at 23ºC and 0%RH) for the control treatment (air-packaging, C), or with bags of a high barrier multilayered film (62 µm PET/PE-EVOH-PE with OTR: 1.2 cc $O_2/m^2 \cdot day \cdot atm$ at 23ºC and 0%RH) for the modified atmosphere packaging treatments (M1: 70% CO_2 + 30% N_2 + 0% O_2, M2: 70% CO_2 + 25% N_2 + 5% O_2, M3: 100% N_2) using a packaging machine (Multivac C200, Multivac Sepp Haggenmüller GmbH & Co. KG, Wolfertschwenden, Germany). The gas mixtures were obtained through a gas mixer (PBI Dansensor Map Mix 9000, Ringsted, Denmark) and fed to the

packaging machine. All the packages were stored at 4 ±1°C during 35 days. The packaging treatments are independently repeated two times in the study.

Gas Analysis

The headspace gas composition (O_2 and CO_2) of packages were measured by a gas analyzer (PBI Dansensor Check-Mate 9900) at each sampling period before opening the packages for sample analyses. The gas analyzer had zirconia-based O_2 sensor and infrared CO_2 sensor with a detection limit of 0.1%.

Moisture and pH Measurements

Moisture content of 'mantı' samples were determined using a standart method in which 3 g sample were dried to constant weight in an oven (Schutzart DIN 40050-IP 20, Schwabach, Germany) at 125ºC (AOAC, 1996). The moisture content is calculated based on the amount of weight loss and expressed in percentage.

The pH analysis was performed according to the method of Jakobsen & Bertelsen (2000) using a pH meter (Testo 250, Testo AG, Lenzkirch, Germany). A 10 g 'mantı' was homogenized in 10 mL distilled water using a stomacher (AESAP1068-Easymix, AES Chemunex, Combourg, France) for 10 min. The probe of pH meter was inserted into this mixture and the pH value was recorded.

Microbiological Analysis

Total yeast/mold and TAMB were enumerated using the spread plate technique according to the International Commission on Microbiological Specifications for Foods (ICMSF, 1978), using PCA and DRBC agar, respectively. A 25 g sample was homogenised in 225 mL peptone water (0.1% w/v) using a stomacher for 10 minutes, and serial dilutions were prepared. A 100 µL diluted samples were spread onto the agar plates. The PCA plates were incubated at 37°C for 2 days, and the DRBC plates were incubated at 25°C for 3 days for yeast count and 5 days for mold counts. The microbial counts were expressed as log cfu/g.

Lipid Oxidation Analysis

The 2-thiobarbituric acid reactive substances (TBARS) test was used to determine the extent of oxidative rancidity of samples according to the method of Pikul *et al*. (1989). A 10 g of 'mantı' sample was homogenized with 35 mL of trichloroacetic acid (TCA) and 1 mL 3,5-di-tert-4-butylhydroxytoluene (BHT, 7.2% w/v). The mixed solution was centrifuged at 1000 rpm for 6 min (Hettich Zentrifugen D-78532 Tuttlingen, Germany). The homogenate was filtered using Whatman No. 4 and the filtrate was completed to 50 mL with TCA (5%, w/v) in a volumetric flask. A 5 mL of 0.02 M thiobarbituric acid (TBA) was mixed with 5 mL of the filtrate-TCA solution in glass tubes. The tubes were kept in a water bath at 80°C for 20 min and the absorbance of each sample was read at 532 nm using a UV/VIS spectrophotometer (PG Instruments T80, Leicester, U.K.) Results were expressed as mg of malonaldehyde (MDA)/kg of 'mantı' samples from the standard curve using different concentration of TEP (1,1,3,3,-tetraethoxypropane).

Sensory Evaluations

Sensory analyses were carried out by 5 selected experienced panellists (ages of 22- 40 years old) among from graduate students and the members of Istanbul Technical University of Food Engineering Department at 7^{th}, 14^{th}, 21^{th}, 28^{th} and 35^{th} storage days. Fresh 'mantı', and 'mantı' samples packed with air and modified atmosphere were served to the panellists as uncooked and cooked. Uncooked samples were evaluated by the panellists for odor, general structure and colour. Then, cooked samples prepared by boiling for 1 min in boiling water were served to the panellists, and they were evaluated as odor, general structure, colour, texture and taste. The sensory quality was scored from 1 to 5 for each category, Where 1: Unacceptable, 2: Hardly Acceptable, 3: Acceptable, 4: Good, 5: Perfect. All samples were analyzed in duplicate.

Statistical Analysis

The data were analyzed using the general linear model procedure to determine the treatment and interaction effects using a statistical software (Minitab, Version 17, Minitab Inc., State College, PA). The differences between mean values of the treatments were compared using Tukey test.

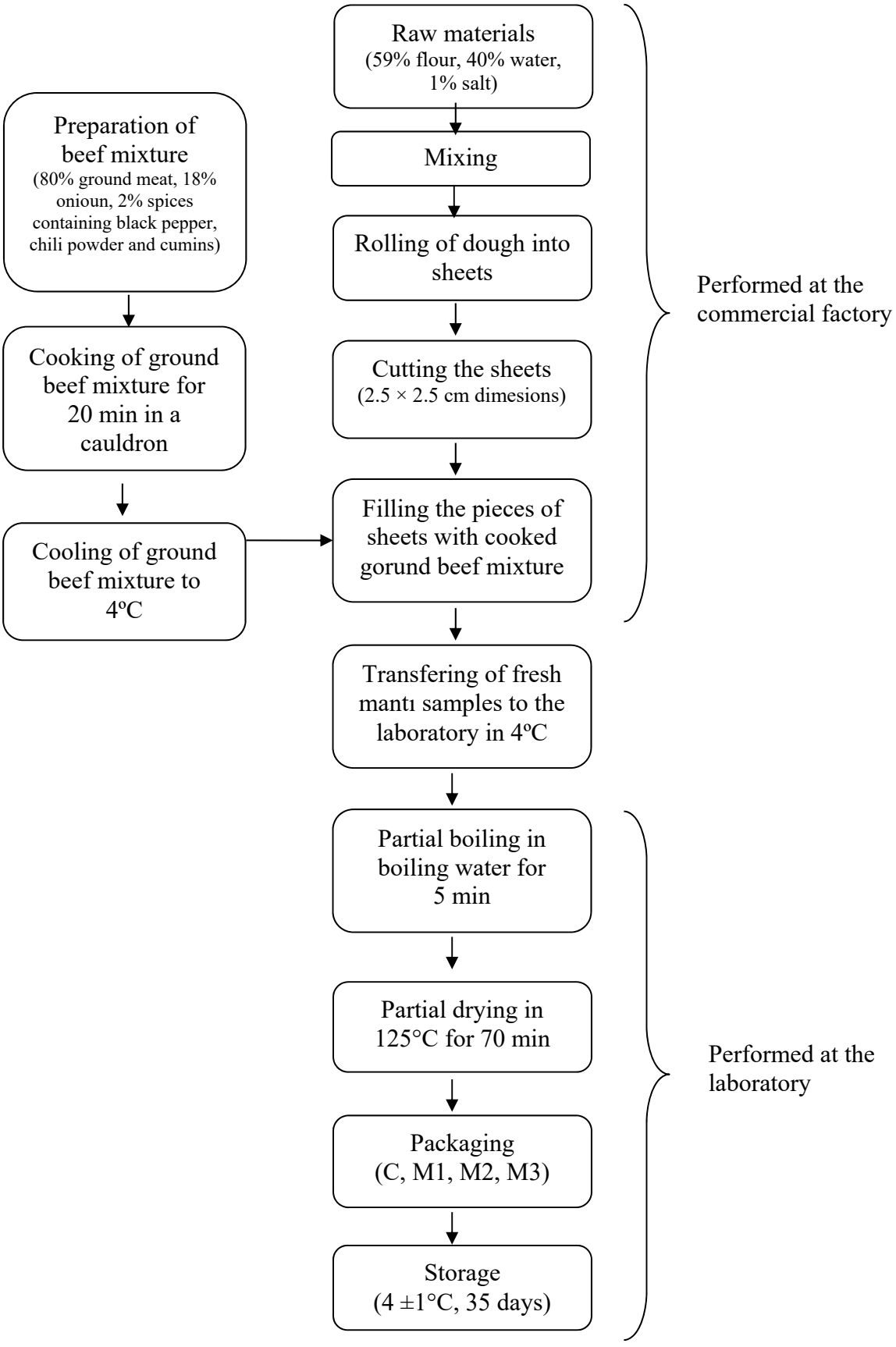

Figure 1. Preparation and packaging of 'mantı' samples

Results and Discussion

Headspace Gas Compositions

Concentrations of CO_2 and O_2 in the headspace of packages were showed in Table 1. The CO_2 and O_2 contents of all packages remained fairly stable at the initial levels during 35-day storage. This was associated with lack of microbial growth in the samples.

pH and Moisture Contents

Initial pH value of the samples was 5.87 and it did not changed during storage in C and M3 ($p > 0.05$, Table 2). The pH increased gradually in M1 and M2 packages during 35 days ($p < 0.05$). These packages contained elevated CO_2 (70%) which could result in slight reduction in pH due to dissolution of CO_2 in the product. However, there was slight increase in the pH during storage which may be associated with formation of nitrogenous compound through proteolysis as reported in some meat products in elsewhere (Aksu *et al*., 2005). Gök *et al*. (2008) also reported an increase in pH of Turkish pastırma packaged in modified atmosphere during storage. Similar observation was reported by Shah *et al*. (2015) in modified atmosphere packaged raw beef.

Moisture content of samples, which ranged from 41.20 to 44.8%, was not affected by storage time and packaging treatments ($p > 0.05$, data not shown). This was mainly due to high moisture barrier properties of the packgaging materials.

Microbiological Evaluations

The TAMB count of the samples was 5.46 log cfu/g prior to the pretreatments of blanching and partial drying. The TAMB count decreased to below 2 log cfu/g after the pretreatments, and this level was maintained in all packages (C, M1, M2 and M3) during 35-day storage (data not shown).

Total yeast-mold count of samples prior to the pretreatments was 3.91 log cfu/g. The pretreatments decreased the total yeast/mold counts below 2 log cfu/g. The total yeast-mold count was maintained below 2 log cfu/g in M1, M2, and M3 packages during 35-day storage, but increased to 4.62 log cfu/g in C after 35 days (data not shown). This can be explained by exclusion of O_2 and/or presence of CO_2 in the MAP treatments (M1, M2, M3) which have an inhibitory effect on growth of the microorganisms. Inhibitory effects of elevated CO_2 in packages of bread on TAMB and mold-yeast growth have also been reported in various studies (Patsias *et al*., 2006; Fik *et al*., 2012; Khoshakhlagh *et al., 2014).*

Oxidation

Lipid oxidation in the samples was assessed by measuring the TBARS values and reported in Table 3. Initial TBARS value of samples (3.63 mg MDA/kg) increased in the control packages (C) beyond day 21 of storage ($p < 0.05$) whereas it did not change in M1, M2, M3 packages during 35-day storage (Table 3). Lipid oxidation increased with concentration of O_2 in package headspace. The MAP treatments have residual O_2 (in M1 and M3) or low levels of O_2 (5% in M2) resulting in lower TBARS values compared to the control packages (C) which have about 20% O_2 in their headspace during the storage. A significant increase in TBARS value of meat in MA packages with higher O_2 during storage have been reported in several studies (Kennedy *et al*., 2004; Berruga *et al*. 2005; Zakrys *et al*., 2008; Bornez *et al*., 2009; Esmer *et al*., 2011; Santos *et al*., 2015, Messina *et al*., 2015).

Sensory Evaluations

The uncooked samples in M1, M2, and M3 samples had acceptable sensory quality which was similar to F (fresh samples) during 35-day storage (Table 4). However, the sensory quality of the uncooked samples in C dropped below the acceptable limit (score 3) on day 21 and further during storage (Table 4).

The cooked samples in M1 and M2 had acceptable sensory quality attributes on day 35 (scores were higher or close to the acceptable limit). These samples had similar sensory scores to F (Table 5). Cooked samples in M3 and C were not evaluated for their taste and texture on the 28th and the 35th day of storage because visible spots of green-white molds on the samples were detected in the packages. The sensory scores of cooked samples from M1 and M2 on the 21st day was higher than C and M3. Overall, the packaging treatments of M1 and M2 resulted in best and acceptable sensory quality for both cooked and uncooked samples during 35-day storage.

Table 1. Mean concentration of CO_2 and O_2 in the headspace of packages during storage

Packages	Gas	Storage time (day)					
		0	**7**	**14**	**21**	**28**	**35**
C (21%O_2+0% CO_2)	CO_2 (%)	0.65	0.50	0.48	0.45	0.50	0.58
	O_2(%)	20.45	20.40	20.43	20.40	20.48	20.40
M1 (70%CO_2+0% O_2)	CO_2 (%)	71.05	66.25	66.58	65.88	63.03	65.73
	O_2(%)	0.14	0.14	0.16	0.12	0.89	0.11
M2 (70%CO_2+5% O_2)	CO_2 (%)	71.55	67.43	68.08	66.08	68.13	66.80
	O_2(%)	5.53	6.39	5.87	5.97	5.24	5.14
M3 (100%N_2)	CO_2 (%)	0.50	0.55	0.70	0.85	1.43	1.48
	O_2(%)	0.77	0.67	0.71	0.50	0.44	0.37

Table 2. Change in pH value of mantı samples packed with different packaging conditions (C, M1, M2 and M3) during 35 days.

	Storage time (day)					
Packages*	**0**	**7**	**14**	**21**	**28**	**35**
C	$5.87^{a,x}$	$5.97^{a,x}$	$5.95^{a,x}$	$5.89^{a,x}$	$5.85^{a,x}$	$5.92^{a,y}$
M1	$5.87^{c,x}$	$5.98^{b,x}$	$5.93^{bc,x}$	$5.93^{bc,x}$	$5.98^{b,x}$	$6.07^{a,xy}$
M2	$5.87^{c,x}$	$6.01^{b,x}$	$6.04^{ab,x}$	$6.00^{b,x}$	$5.98^{b,x}$	$6.09^{a,x}$
M3	$5.87^{a,x}$	$5.95^{a,x}$	$5.97^{a,x}$	$5.97^{a,x}$	$5.91^{a,x}$	$5.96^{a,xy}$

* C: 21%O_2+0% CO_2; M1: 70% CO_2+0% O_2; M2: 70% CO_2+5% O_2; M3: 100% N_2,
Means with the same letter within a line (a,b,c) and column (x,y,z) are significantly different ($p < 0.05$).

Table 3. Change in TBARS (mg MDA/kg) value of mantı samples packed with different packaging conditions (C, M1, M2 and M3) during 35 days.

	Storage time (day)					
Packages*	**0**	**7**	**14**	**21**	**28**	**35**
C	$3.63^{a,x}$	$3.18^{a,x}$	$3.49^{a,x}$	$4.61^{b,x}$	$4.13^{b,x}$	$5.50^{b,x}$
M1	$3.63^{a,x}$	$2.79^{b,x}$	$3.29^{a,x}$	$3.90^{a,x}$	$3.89^{a,x}$	$4.81^{a,xy}$
M2	$3.63^{a,x}$	$2.28^{b,x}$	$3.01^{ab,x}$	$3.59^{a,x}$	$3.33^{a,x}$	$3.81^{a,y}$
M3	$3.63^{a,x}$	$3.26^{a,x}$	$3.23^{a,x}$	$3.31^{a,x}$	$3.06^{a,x}$	$4.08^{a,y}$

* C: 21%O_2+0% CO_2; M1: 70% CO_2+0% O_2; M2: 70% CO_2+5% O_2; M3: 100% N_2,
Means with the same letter within a line (a,b,c) and column (x,y,z) are significantly different ($p < 0.05$).

Sensory Evaluations

The uncooked samples in M1, M2, and M3 samples had acceptable sensory quality which was similar to F (fresh samples) during 35-day storage (Table 4). However, the sensory quality of the uncooked samples in C dropped below the acceptable limit (score 3) on day 21 and further during storage (Table 4).

The cooked samples in M1 and M2 had acceptable sensory quality attributes on day 35 (scores were higher or close to the acceptable limit). These samples had similar sensory scores to F (Table 5). Cooked samples in M3 and C were not evaluated for their taste and texture on the 28th and the 35th day of storage because visible spots of green-white molds on the samples were detected in the packages. The sensory scores of cooked samples from M1 and M2 on the 21st day was higher than C and M3. Overall, the packaging treatments of M1 and M2 resulted in best and acceptable sensory quality for both cooked and uncooked samples during 35-day storage.

Table 4. The effect of different packaging conditions (C, M1, M2 and M3) on sensory quality attributes of uncooked samples during 35 days. The sensory scores are: 1: unacceptable, 2: hardly acceptable, 3: acceptable, 4: good and 5: perfect.

		Storage time (day)				
Packages*	**Quality attribute**	**7**	**14**	**21**	**28**	**35**
C	Odor	$4.4^{a,x}$	$4.0^{a,x}$	$3.4^{ab,x}$	$2.3^{b,y}$	$2.7^{b,y}$
	General structure	$4.1^{a,x}$	$4.4^{a,x}$	$3.7^{ab,x}$	$3.4^{ab,y}$	$2.8^{b,x}$
	Colour	$4.2^{a,x}$	$4.1^{a,x}$	$3.5^{ab,x}$	$3.0^{b,y}$	$2.8^{b,x}$
M1	Odor	$4.5^{a,x}$	$4.1^{ab,x}$	$3.8^{ab,x}$	$3.5^{b,y}$	$3.6^{ab,xy}$
	General structure	$4.1^{a,x}$	$4.3^{a,x}$	$3.7^{ab,x}$	$2.7^{b,y}$	$3.8^{ab,x}$
	Colour	$3.9^{a,x}$	$4.1^{a,x}$	$3.7^{a,x}$	$3.5^{a,x}$	$3.7^{a,x}$
M2	Odor	$4.5^{a,x}$	$4.4^{a,x}$	$3.7^{ab,x}$	$2.7^{c,xy}$	$3.0^{bc,xy}$
	General structure	$4.3^{a,x}$	$4.3^{a,x}$	$3.8^{a,x}$	$3.4^{a,x}$	$3.2^{a,x}$
	Colour	$3.8^{ab,x}$	$4.2^{a,x}$	$3.7^{ab,x}$	$3.3^{b,x}$	$3.2^{b,x}$
M3	Odor	$4.4^{a,x}$	$4.4^{a,x}$	$3.9^{ab,x}$	$2.7^{c,xy}$	$3.3^{bc,xy}$
	General structure	$4.0^{ab,x}$	$4.4^{a,x}$	$3.9^{ab,x}$	$3.2^{b,x}$	$3.1^{b,x}$
	Colour	$3.9^{a,x}$	$4.2^{a,x}$	$4.3^{a,x}$	$2.3^{a,x}$	$3.5^{a,x}$
F	Odor	$4.3^{a,x}$	$3.6^{a,x}$	$3.0^{a,x}$	$3.2^{a,xy}$	$4.0^{a,x}$
	General structure	$3.6^{a,x}$	$4.4^{a,x}$	$3.4^{a,x}$	$3.6^{a,x}$	$3.1^{a,x}$
	Colour	$4.0^{ab,x}$	$4.2^{a,x}$	$3.8^{ab,x}$	$2.3^{b,x}$	$3.5^{ab,x}$

* C: 21%O_2+0% CO_2; M1: 70% CO_2+0% O_2; M2: 70% CO_2+5% O_2; M3: 100% N_2, F: Fresh (freshly prepared sample taken from the manufacturer at the time of evaluation, no pretreatments were applied).
Means with the same letter within a line (a,b,c) and column (x,y,z) are significantly different ($p < 0.05$).

Table 5. The effect of different packaging conditions (C, M1, M2 and M3) on sensory quality attributes of cooked samples during 35 days. The sensory scores are: 1: unacceptable, 2: hardly acceptable, 3: acceptable, 4: good and 5: perfect.

Packages*	Quality attribute	Storage time (day) 7	14	21	28	35
C	Odor	$4.5^{a,x}$	$4.1^{a,x}$	$3.0^{b,x}$	$1.9^{b,y}$	$2.4^{b,x}$
	General structure	$4.0^{a,x}$	$4.1^{a,x}$	$4.0^{a,x}$	$2.6^{a,yz}$	$3.0^{ab,x}$
	Colour	$3.8^{a,y}$	$4.4^{ab,x}$	$3.7^{ab,x}$	$3.2^{b,z}$	$2.9^{b,x}$
	Texture	$4.0^{a,x}$	$3.7^{a,x}$	$3.0^{a,x}$	NA	NA
	Taste	$4.0^{a,x}$	$3.5^{ab,x}$	$2.8^{b,x}$	NA	NA
M1	Odor	$4.6^{a,x}$	$4.1^{ab,x}$	$3.6^{b,x}$	$3.3^{b,x}$	$3.4^{b,x}$
	General structure	$4.5^{a,x}$	$4.0^{ab,x}$	$3.6^{b,x}$	$3.9^{ab,x}$	$3.4^{b,x}$
	Colour	$4.8^{a,xy}$	$4.3^{a,x}$	$3.2^{b,x}$	$3.3^{ab,x}$	$3.4^{ab,x}$
	Texture	$4.3^{a,x}$	$3.8^{ab,x}$	$3.2^{bc,x}$	$3.4^{abc,x}$	$2.9^{c,x}$
	Taste	$4.0^{a,x}$	$3.6^{a,x}$	$3.4^{a,x}$	$3.2^{a,x}$	$3.1^{a,x}$
M2	Odor	$4.4^{a,x}$	$3.9^{ab,x}$	$3.3^{bc,x}$	$3.2^{bc,x}$	$2.7^{c,x}$
	General structure	$4.4^{a,x}$	$3.9^{a,x}$	$3.7^{a,x}$	$3.3^{a,xyz}$	$3.5^{a,x}$
	Colour	$4.5^{a,xy}$	$3.8^{a,x}$	$3.4^{a,x}$	$3.3^{a,x}$	$3.2^{a,x}$
	Texture	$4.1^{a,x}$	$3.6^{ab,x}$	$3.0^{b,x}$	$3.2^{ab,x}$	$3.4^{ab,x}$
	Taste	$4.2^{a,x}$	$3.4^{ab,x}$	$3.2^{ab,x}$	$2.7^{b,x}$	$3.0^{ab,x}$
M3	Odor	$4.7^{a,x}$	$4.1^{ab,x}$	$3.7^{bc,x}$	$2.9^{c,xy}$	$2.9^{c,x}$
	General structure	$4.3^{a,x}$	$3.9^{a,x}$	$2.6^{ab,x}$	$2.4^{b,z}$	$3.2^{ab,x}$
	Colour	$3.8^{a,y}$	$3.9^{a,x}$	$3.7^{a,x}$	$3.1^{a,x}$	$2.9^{a,x}$
	Texture	$4.1^{a,x}$	$3.7^{a,x}$	$3.6^{a,x}$	NA	NA
	Taste	$4.1^{a,x}$	$3.5^{a,x}$	$3.8^{a,x}$	NA	NA
F	Odor	$4.8^{a,x}$	$4.1^{ab,x}$	$2.7^{c,x}$	$3.9^{b,x}$	$3.5^{b,x}$
	General structure	$4.5^{a,x}$	$3.6^{ab,x}$	$3.6^{b,x}$	$3.6^{ab,xy}$	$2.7^{b,x}$
	Colour	$4.6^{a,x}$	$4.4^{ab,x}$	$3.8^{ab,x}$	$3.8^{ab,x}$	$3.3^{b,x}$
	Texture	$4.7^{a,x}$	$3.8^{ab,x}$	$3.9^{ab,x}$	$4.0^{ab,x}$	$3.4^{b,x}$
	Taste	$4.7^{a,x}$	$3.4^{ab,x}$	$3.3^{b,x}$	$3.3^{b,x}$	$3.1^{b,x}$

* C: 21%O_2+0% CO_2; M1: 70% CO_2+0% O_2; M2: 70% CO_2+5% O_2; M3: 100% N_2, F: Fresh (freshly prepared sample taken from the manufacturer at the time of evaluation, no pretreatments were applied).
Means with the same letter within a line (a,b,c) and column (x,y,z) are significantly different ($p < 0.05$).
NA: Not analyzed due to spots of visible mold in samples

Conclusions

The present study showed that microbiological, chemical and sensory quality of 'mantı' samples packaged with M1 and M2 were significantly higher than the the samples packaged with C and M3. Total yeast/mold and TAMB counts were below 2 log cfu/g in all MA packages after 35 days. MAP (M1, M2, M3) had significant inhibitory effect on lipid oxidation compared to C. Samples in both M1 and M2 with elevated CO_2 had higher sensory qualities than packages with air (C) and N_2-packages (M3). Inclusion of 5% O_2 in packages with elevated CO_2 (M2) did not affect microbial quality, TBARS values, and the sensory qualities. Overall, MAP containing 70% CO_2 with or without 5% O_2 (M1 and M2) resulted in better quality maintenance and extended shelf-life of the refrigerated 'mantı' up to 35 days.

Acknowledgements

This research was supported by Istanbul Technical University Scientific Research Projects Department (Project No: 34170).

References

Agata, N., Ohta, M. & Yokoyama, K. (2002). AOAC. (1996). Official methods of analysis. 16th ed. Association of Official Analytical Chemists, Arlington, VA.

Aksu, M.I., Kaya, M., & Ockerman, H.W. (2005). Effect of modified atmosphere packaging and temperature on the shelf life of sliced pastirma produced from frozen/thawed meat. *Journal of Muscle Foods*, 16, 192-206.

Berruga, M.I., Vergara, H. & Gallego, L. (2005). Influence of packaging conditions on microbial and lipid oxidation in lamb meat. *Small Ruminant Research*, 57, 257-264.

Bornez, R., Linares, M.B. & Vergara, H. (2009). Microbial quality and lipid oxidation of Manchega breed suckling lamb meat: effect of stunning method and modified atmosphere packaging. *Meat Science*, *83*, 383-389.

Church, J.I. & Parsons, A. L. (1995). Modified atmosphere packing technology: a review. *Journal of The Science of Food and Agriculture*, 67(2), 143 – 152.

Esmer, Ö.K., Irkin, R., Degirmencioğlu, N. & Degirmencioğlu, A. (2011). The effects of modified atmosphere gas composition on microbiological criteria, color and oxidation values of minced beef meat. *Meat Science*, *88,* 221-226.

Fik, M., Surówka, K., Maciejaszek, I., Macura, M., Michalczyk, M. (2012). Quality and shelf life of calcium-enriched wholemeal bread stored in a modified atmosphere. *Journal of Cereal Science*, 56, 418-424.

Gök, V., Obuz, E. & Akkaya, L. (2008). Effect of packaging method and storage time on the chemical, microbiological, and sensory properties of Turkish pastirma-A dry cured beef product. *Meat Science*, 80, 335-344.

ICMSF (1978). International commission for microbiological specifications for foods. Microorganisms in foods. 1: Their significance and methods of enumeration. 2nd ed. University of Toronto Press., Toronto, Canada.

Jakobsen, M. & Bertelsen, G. (2000). Colour stability and lipid oxidation of fresh beef. Development of a response surface model for predicting the effects of temperature, storage time, and modified atmosphere composition. *Meat Science*, 54, 49-57

Kennedy, C., Buckley, D.J. & Kerry, J.P. (2004). Display life of sheep meats retail packaged under atmospheres of various volumes and compositions. *Meat Science*, 68, 649-658.

Khoshakhlagh, K., Hamdami, N., Shahedi, M. & Le-Bail, A. (2014). Quality and microbial characteristics of part-baked Sangak bread packaged in modified atmosphere during storage. *Journal of Cereal Science*, 60, 42-47

Messina, C., M., Bono, G., Renda, G., Barbera, L., L. & Santulli, A. (2015). Effect of natural antioxidants and modified atmosphere packaging in preventing lipid oxidation and increasing the shelf-life of common dolphinfish (Coryphaena hippurus) fillets. *LWT - Food Science and Technology*, 62, 271-277.

Patsias, A., Chouliara, I., Badeka, A., Savvaidis, I.N. & Kontominas, M.G. (2006). Shelf-life of chilled precooked chicken product stored in air and under modified atmospheres: mlcrobiological, chemical, sensory attributes. *Food Microbiology*, 23, 423-429.

Pikul, J., Leszczynski, D.E. & Kummerow, F.A. (1989). Evaluation of three modified TBA methods for measuring lipid oxidation in chicken meat. *Journal of Agricultural and Food Chemistry,* 37(5), 1309-1313

Rasmussen, P.H. & Hansen, A. (2001). Staling of wheat bread store in modified atmosphere, *LWT-Food Science and Technology,* 34, 487-491.

Santos, P.R., Donado-Pestana, C.M., Delgado, E.F., Tanaka, F.O. & Contreras-Castillo, C.J. (2015). Tenderness and oxidative stability of Nellore bull's steaks packaged under vacuum or modified atmosphere during storage at 2 °C. *Food Packaging and Shelf Life*, 4, 10-18.

Shah, M.A., Bosco, S J.D. & Mir, S.A. (2015). Effect of Moringa oleifera leaf extract on the physicochemical properties of modified atmosphere packaged raw beef. *Food Packaging and Shelf Life*., 3, 31-38.

Taniwaki, M.H., Hocking, A.D., Pitt, I.J. & Fleet., G.H. (2001). Growth of fungi and mycotoxin production on cheese under modified atmospheres. *International Journal of Food Microbiology*, 68, 125-133.

Zakrys, P.I., Hogan, S.I., O'Sullivan, M.G., Allen, P. & Kerry, J.P. (2008). Effect of oxygen concentration on the sensory evaluation and quality indicators of beef muscle packed under modified atmosphere. *Meat Science*, 79, 648−655.