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Quality assessment of cold dried chicken slices during storage in different packages and temperatures

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In this study, dried chicken slices were packaged in MAP (modified atmosphere packaging) and AP (atmospheric packaging), and stored at 4 °C and 25 °C. The CO_2 content of MAP packaged samples decreased as the storage temperature and time increased. The slices exhibited lower a_w values when they were packaged in AP at 25 °C. The pH increased from 6.1 to 6.2, 2-thiobarbituric acid reactive substances (TBARS) increased from 10.6 to 37.3 µmol MDA kg^{-1}, and non-protein nitrogen (NPN) increased from 4.9 to 5.3 g 100 g^{-1} in MAP for 90 days of storage. The microbiological quality of the samples was assessed by enumerating total aerobic mesophilic bacteria (TAMB), total psychrophilic bacteria (TPB), *Micrococcus*/ *Staphylococcus,* lactic acid bacteria (LAB), Enterobacteriaceae and yeast-mold, and was higher in the sample stored in MAP at 4 °C. Moreover, the sensory quality was determined by sensory evaluation with a 9-point hedonic scale. When the sensory and microbiological qualities were evaluated together, the shelf lives of the samples were determined to be 90 days at 4 °C and 75 days at 25 °C for MAP and 45 days at 4 °C and 30 days at 25 °C for AP. It could be concluded that the cold dried chicken slices can be stored in MAP for 90 days without much change in physicochemical, microbiological, and sensory quality.

Key words: chicken, dried meat, low temperature-vacuum drying, MAP, storage

Introduction

Chicken meat is the type of meat most preferred by consumers in Turkey due to its relatively low-price, low-fat content, and high nutritional value (Anonymous 2022). However, poultry meat can microbiologically deteriorate rapidly due to its high water content, water activity value ($a_w \approx 0.99$), rich nutrient content, and high pH value, which limits its shelf life (Cantalejo et al. 2016). The multiple hurdle concept, which includes factors such as heat treatment, reduction of water activity, use of salt and various preservatives, selection of packaging methods that extend shelf life, and lowering of storage temperature, is one of the most reliable methods for controlling microbial growth (Rodríguez-Calleja et al. 2012). Combining these factors well improves microbial safety and sensory quality and extends the shelf life of the product (Cantalejo et al. 2016). However, in recent years, consumers prefer meat products that are nutritionally healthier, microbiologically safe, less processed, and free from chemical preservatives.

Low temperature vacuum drying is a method based on the use of cold and dehumidified air in the drying process at pressures below atmospheric pressure. The sensory quality of meat products is adversely affected by dehydration to a moisture level < 10% (Modi et al. 2007). For this reason, the production of intermediate-moisture chicken meat (a_w: 0.6–0.9 and moisture content: 10–50%, Huang and Nip 2001) by this system is becoming increasingly important. A higher drying rate at a low temperature and a drying environment containing less oxygen can be achieved, and biochemical reactions such as lipid oxidation and protein denaturation in meat products can be minimized through the application of vacuum (Wu et al. 2007, Aykın-Dinçer et al. 2020). In addition, the combination of vacuum with other technologies allows the development of alternative methods to the traditional air drying method (Ran et al. 2019, Teng et al. 2020).

Even if the activities of microorganisms are inhibited and their counts are reduced, deterioration in dried chicken meat can easily occur through chemical and physical reactions during storage. MAP is the process of converting the gas atmosphere in the package to the desired gas composition and is usually applied together with cold storage (Azlin-Hasim et al. 2018). It can enhance the shelf life and safety of meat products in a similar way to pasteurization and also provide additional benefits such as high product quality and reducing the use of preservatives (Pérez-Rodríguez et al. 2014). While postmortem muscle mitochondria continue to metabolize O_2, active O_2 consumption and CO_2 formation decrease depending on the postmortem time (Faustman and Cassens 1990). Therefore, in the packaging of fresh meat, higher levels of O_2 are desired for the conversion of the myoglobin pigment to oxymyoglobin, while lower concentrations can be used in processed meat products. In particular, raw meat products are stored in modified atmosphere packages containing 70% O_2 and 30% CO_2, and processed meat

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products are stored in packages containing 70% N_2 and 30% CO_2 (Wani et al. 2015). In these packages, CO_2 gas (≥ 20%) is used to prolong the lag phase of aerobic bacterial growth and reduce the growth rate in the logarithmic phase. N_2, an inert gas, is used to prevent oxidation, flavor alteration, and also precipitation caused by CO_2 (Cutter et al. 2012).

The objective of this study was to investigate changes in quality properties of cold dried chicken slices at atmosphere condition or modified atmosphere condition at 4 °C and 25 °C. The different storage conditions as well as packaging type were determined by taking into account the dried meat products available in market. The shelf life of the slices was determined by assessing the physicochemical and microbiological quality characteristics together with the sensory evaluation.

Material and methods

Sliced chicken breast pieces (90 mm × 35 mm × 2 mm) were purchased from a well-known butcher (Veli Cengiz Et Ürünleri Ltd., Antalya, Turkey). The average weight of the slices after dry salting (0.75% salt) was determined to be 5.28 ± 0.55 g. Pasteurization and drying processes were applied to the chicken slices, which were hung in accordance with the low temperature vacuum drying system. For pasteurization, superheated steam was applied so that the core temperature of the slices was 72 °C. Then, the slices were dried in the same unit at a drying temperature of 10 °C and a pressure of 0.70 atm until they reached approximately 40% moisture content and 0.90 water activity.

Packaging and storage of dried chicken slices

Dried chicken slices were randomly grouped such that every group consisted of 5 pieces. Each of these groups was placed in polyvinyl chloride/ethylene vinyl alcohol/polyethylene (PVC/EVOH/PE) laminated plates (13.5 cm × 9 cm × 4 cm), and these plates were covered with a film consisting of layers of polyamide (15 µm) and polyethylene (65 µm) (Aykın-Dinçer and Erbaş 2020) using a packaging device (Lipovak KV-600, Adapazarı, Turkey). In the MAP type packaging, the gas mixture (70% N_2 + 30% CO_2) (Habaş, Istanbul, Turkey) was given to the plates placed in the device after vacuum was applied. In the AP type packaging, the plates were closed with the film in the atmosphere. Packaged chicken slices were stored at two different storage temperatures (4 °C and 25 °C), and their quality characteristics were investigated at 15-day intervals for 90 days.

Because the slices were analyzed on 7 different days (0, 15, 30, 45, 60, 75, and 90 days) during storage, they were divided into 7 groups and packed. For each storage temperature, 35 slices (7 packages × 5 slices) were used. For each packaging type, 70 slices (35 × 2 storage temperatures) and totaling in 140 slices (70 slices × 2 packaging types) were stored for each replication. Because the study was carried out in 2 replications, a total of 280 slices (140 × 2 replications) were analyzed.

Determination of gas composition

Before opening the package containing the dried chicken slices, the gas composition (%) in the headspace of the package was determined using a digital O_2 and CO_2 analyser (OXYBABY, Witt-Gasetechnik GmbH & Co. KG, Witton, Germany).

Determination of physicochemical properties

The a_w values of the dried chicken slices were measured at 25 °C using an a_w meter (Decagon Devices Inc., USA). The pH values were measured using a Hanna HI 2210 pH meter (Hanna Instruments, Woonsocket, RI, USA) (AOAC 2000). NPN (g 100 g^{-1} sample) was determined according to the method of Kaban (2009). TBARS (µmol malondialdehyde (MDA) kg^{-1} sample) was determined spectrophotometrically at a wavelength of 530 nm (Lemon 1975).

Determination of microbiological quality

The microbiological quality of the dried chicken slices was assessed by enumerating total aerobic mesophilic bacteria (TAMB), total psychrophilic bacteria (TPB), *Micrococcus* / *Staphylococcus,* lactic acid bacteria (LAB), Enterobacteriaceae, and yeast-mold.

TAMB and TPB were determined on plate count agar (Merck, Darmstadt, Germany) incubated at 30 °C for 48 h and at 7 °C for 10 days, respectively. *Micrococcus*/*Staphylococcus* were determined on mannitol salt phenol-red agar (Merck) incubated at 30 °C for 48 h. LAB and Enterobacteriaceae were determined on de Mann–Rogosa–Sharpe agar (Merck) and violet red bile dextrose agar (Merck), respectively, after incubation at 30 °C for 48 h in anaerobic conditions (Anaerocult A, Merck). Yeast-mold was determined on potato dextrose agar (Merck) incubated at 25 °C for 5 days (Aykın-Dinçer and Erbaş 2019). The criteria for shelf life was defined as the time when the TAMB count exceeded 7 log cfu g^{-1} in the microbiological analysis.

Determination of sensorial quality

In the sensory evaluation, eight panelists evaluated four samples in a single session for each storage time, and a total of seven sessions (0, 15, 30, 45, 60, 75, and 90 days) were conducted for one repetition. The appearance, color, odor, flavor, texture, and overall acceptability of the samples were determined according to a 9-point hedonic scale (1: did not like at all, 9: liked very much) (Huang et al. 2005). Panelists were Masters students in Department of Food Engineering in Akdeniz University. The samples were coded with three-digit numbers, and presented to the panelists in a random order. The responses were collected using paper in a laboratory. Panelists were asked to chew the samples in the mouth and clean their palate with water between samples, swallowing was optional. The criteria for shelf life was defined as the time when the overall acceptability score fell below 5 points out of 9 in the sensory evaluation. Only microbially acceptable samples were included in the sensory evaluation.

Statistical analysis

The packaging type (MAP and AP), storage temperature (4 °C and 25 °C), and storage times (0, 15, 30, 45, 60, 75, and 90 days) were taken as factors, and experiments were carried out in 2 replications according to a randomized complete block design. Variance analysis was performed using SAS version 7 (SAS Institute, Inc., Cary, NC, USA), and the significant means were compared using Duncan's multiple comparison test. The values were given as mean ± standard error.

Results

The O_2% and CO_2% values of the package under different storage conditions are given in Table 1. Temperature and storage time were found to have a significant effect on the O_2% value ($p < 0.01$) in the AP type and on the CO_2% value ($p < 0.05$, $p < 0.01$) in both packaging types (MAP and AP).

Table 1. O_2% and CO_2% amount in the packaging under different storage conditions

	O_2%		CO_2%	
	MAP	AP	MAP	AP
Temperature (°C, n=14)				
4	0.19 ± 0.05	15.24^{a} ± 2.11	25.61^{a} ± 1.25	4.19^{b} ± 1.40
25	0.39 ± 0.08	10.99^{b} ± 2.40	23.70^{b} ± 1.61	7.46^{a} ± 1.81
Significance	NS	**	*	**
Time (day, n=4)				
0	0.10 ± 0.06	20.85^{a} ± 0.03	32.95^{a} ± 0.47	0.05^{e} ± 0.03
15	0.10 ± 0.06	20.48^{a} ± 0.10	29.80^{b} ± 0.53	0.28^{e} ± 0.10
30	0.30 ± 0.11	19.63^{a} ± 0.58	26.50^{c} ± 0.67	1.33^{e} ± 0.81
45	0.25 ± 0.09	15.60^{b} ± 2.32	23.60^{cd} ± 0.81	4.85^{d} ± 1.63
60	0.43 ± 0.18	11.48^{c} ± 3.67	21.48^{de} ± 1.43	6.30^{c} ± 2.04
75	0.40 ± 0.17	3.78^{d} ± 2.26	19.83^{e} ± 1.60	12.53^{b} ± 1.45
90	0.45 ± 0.16	0.00^{e} ± 0.00	18.45^{e} ± 1.15	15.45^{a} ± 1.19
Significance	NS	**	**	**

MAP = Modified atmosphere packaging; AP = Atmospheric packaging. ^{a,b,c,d,e}Means with different letters within the column indicate differences. *NS* = Not Significant ($p > 0.05$); * $p < 0.05$; ** $p < 0.01$

It was determined that as the storage temperature and time of the AP type packaged chicken slices increased, the O_2% value decreased and the CO_2% value increased. It was evaluated that this change in the gas composition of the AP type was caused by aerobic microorganisms. Microorganism growth was more active at 25 °C than at 4 °C, and as the storage time increased, they performed aerobic respiration, that is, they consumed O_2 and formed CO_2 gas. It was determined that the CO_2% value of the MAP type packaged samples decreased as the storage temperature and time increased. During the storage period, the CO_2 value was reduced by about 15%.

The a_w and pH values of dried chicken slices under different storage conditions are given in Table 2. It was determined that the packaging type had a significant ($p < 0.01$) effect on the a_w value of the dried chicken slices. In addition, the storage temperature had an effect ($p < 0.01$) on the a_w value only in the AP type packaging, while the storage time had a significant ($p < 0.01$) effect on the a_w value for both packaging types.

Table 2. a_w and pH values of dried chicken slices under different storage conditions

	a_w		pH	
Packaging method (n=28)				
MAP	$0.896^{a} \pm 0.003$		$6.13^{b} \pm 0.01$	
AP	$0.836^{b} \pm 0.014$		$6.38^{a} \pm 0.05$	
Significance	**		**	
	MAP	AP	MAP	AP
Temperature (°C, n=14)				
4	0.897 ± 0.004	$0.882^{a} \pm 0.006$	6.10 ± 0.02	$6.32^{b} \pm 0.07$
25	0.894 ± 0.004	$0.791^{b} \pm 0.021$	6.15 ± 0.02	$6.44^{a} \pm 0.08$
Significance	NS	**	NS	**
Time (day, n=4)				
0	$0.910^{a} \pm 0.001$	$0.903^{a} \pm 0.010$	6.10 ± 0.04	$6.09^{e} \pm 0.03$
15	$0.906^{a} \pm 0.002$	$0.893^{a} \pm 0.004$	6.07 ± 0.04	$6.09^{e} \pm 0.03$
30	$0.906^{a} \pm 0.004$	$0.850^{b} \pm 0.027$	6.08 ± 0.02	$6.18^{d} \pm 0.02$
45	$0.901^{ab} \pm 0.005$	$0.840^{b} \pm 0.023$	6.11 ± 0.02	$6.39^{c} \pm 0.09$
60	$0.894^{b} \pm 0.003$	$0.805^{c} \pm 0.041$	6.17 ± 0.03	$6.54^{b} \pm 0.08$
75	$0.883^{c} \pm 0.002$	$0.791^{cd} \pm 0.046$	6.16 ± 0.04	$6.70^{a} \pm 0.03$
90	$0.870^{d} \pm 0.002$	$0.773^{d} \pm 0.044$	6.21 ± 0.04	$6.69^{a} \pm 0.04$
Significance	**	**	NS	**

MAP = Modified atmosphere packaging; AP = Atmospheric packaging. ^{a,b,c,d,e}Means with different letters within the column indicate differences. *NS* = Not Significant ($p > 0.05$); * $p < 0.05$; ** $p < 0.01$

It was determined that the packaging type had a significant ($p < 0.01$) effect on the pH value of the samples. Storage temperature and time had a significant ($p < 0.01$) effect only in the AP type packaging. The MAP type packaging caused lower pH values than the AP type. In addition, higher pH values were determined in the AP type at 25 °C and at the end of the storage period.

TBARS and NPN values of dried chicken slices under different storage conditions are given in Table 3. The packaging type had a significant ($p < 0.01$) effect on the TBARS value of the dried chicken slices. In addition, the effect of storage temperature on the TBARS value was found to be significant only in the AP type, while the effect of storage time was significant at the $p < 0.01$ level in both packaging types. On the NPN value, the packaging type and storage temperature and time in both packaging types were found to be significant at the $p < 0.01$ level.

The TBARS value of the AP type packaged samples was determined to be approximately 2 times that of the MAP type samples. In addition, the increase in the storage temperature from 4 °C to 25 °C in the AP type packaged samples caused the TBARS value to increase from 51.38 µmol MDA kg^{-1} to 62.90 µmol MDA kg^{-1}. In addition, the TBARS value increased in both packaging types during the 90-day storage, and this was caused by O_2 in the AP type and carbonic acid formed from carbon dioxide dissolved in the sample water content in the MAP type.

Table 3. Thiobarbituric acid-reactive substances (TBARS) and non-protein nitrogen (NPN) values of dried chicken slices under different storage conditions

	TBARS (µmol MDA kg^{-1})		NPN (g 100 g^{-1})	
Packaging method (n=28)				
MAP	24.35^{b} ± 1.88		5.19^{b} ± 0.12	
AP	57.14^{a} ± 4.24		6.09^{a} ± 0.20	
Significance	**		**	
	MAP	AP	MAP	AP
Temperature (°C, n=14)				
4	23.64 ± 2.50	51.38^{b} ± 5.43	4.82^{b} ± 0.08	5.61^{b} ± 0.22
25	25.06 ± 2.90	62.90^{a} ± 6.34	5.55^{a} ± 0.18	6.57^{a} ± 0.30
Significance	*NS*	**	**	**
Time (day, n=4)				
0	10.62^{e} ± 0.40	10.69^{f} ± 0.79	4.88^{c} ± 0.14	5.03^{f} ± 0.14
15	16.31^{d} ± 0.64	48.68^{e} ± 2.79	4.72^{c} ± 0.09	5.22^{f} ± 0.10
30	19.75^{c} ± 1.34	57.38^{d} ± 8.49	5.19^{b} ± 0.49	5.48^{e} ± 0.50
45	20.22^{c} ± 0.68	65.75^{c} ± 3.04	4.89^{c} ± 0.07	7.48^{a} ± 0.47
60	30.96^{b} ± 1.59	69.82^{b} ± 2.55	5.61^{a} ± 0.49	5.71^{d} ± 0.30
75	35.29^{a} ± 2.79	70.74^{b} ± 4.49	5.69^{a} ± 0.32	6.70^{c} ± 0.21
90	37.32^{a} ± 1.49	76.93^{a} ± 2.16	5.33^{b} ± 0.08	7.00^{b} ± 0.36
Significance	**	**	**	**

MAP = Modified atmosphere packaging; AP = Atmospheric packaging. ^{a,b,c,d,e,f}Means with different letters within the column indicate differences. *NS* = Not Significant ($p > 0.05$); * $p < 0.05$; ** $p < 0.01$

It was determined that the NPN value was higher in AP type packaged slices and increased with increasing storage temperature from 4 °C to 25 °C in both packaging types. More nitrogenous compounds might have been released due to the more active proteolytic enzymes and natural microflora in the samples under atmospheric storage conditions and at room temperature. In addition, it was determined that the NPN value reached the highest level on the 75th day of storage in MAP type samples and on the 45th day of storage in AP type samples and then decreased slightly.

TAMB, TPB, *Micrococcus/Staphylococcus*, LAB, and yeast-mold counts of dried chicken meat slices at different storage conditions are given in Table 4. It was determined that the packaging type had a significant ($p < 0.01$) effect on TAMB, TPB, *Micrococcus/Staphylococcus*, LAB, and yeast-mold counts of dried chicken slices. The effect of storage temperature on all microorganism groups was found to be significant only in the AP type packaging, while the effect of storage time was significant in both packaging types ($p < 0.05$, $p < 0.01$).

When all the microorganism counts were taken into account, it was determined that the microbial quality of the MAP type packaged samples was higher than that of the AP type packaged samples. Depending on the increase in storage temperature, an increase in the counts of all microorganisms in the AP type packaged samples was determined. This might be due to the higher oxygen levels in the product atmosphere and the absence of antimicrobial agents, resulting in a greater growth of microorganisms at room temperature. In addition, as the storage time increased, an increase in the counts of all microorganisms in both packaged types was determined.

Meanwhile, the count of Enterobacteriaceae was below < 1 log cfu g^{-1} in dried chicken slices stored under different conditions. The reason for this might be that lactic acid bacteria suppressed the growth of Gram-negative bacteria by producing organic acids and various antibacterial metabolic products.

The appearance, color, odor, flavor, texture, and overall acceptability scores of dried chicken slices under different storage conditions are given in Table 5. While the packaging type significantly affected the appearance score of the samples ($p < 0.05$), the storage temperature significantly ($p < 0.01$) affected the odor score in the MAP type packaging and the flavor score in the AP type packaging. It was also determined that the storage time significantly affected all sensory scores of the samples ($p < 0.01$) in both packaging types.

Table 4. Microbial quality of dried chicken slices under different storage conditions

	TAMB		TPB		*Micrococcus/ Staphylococcus*		LAB		Yeast and mold	
Packaging method (n=28)										
MAP	$5.07^{b} \pm 0.31$		$3.92^{b} \pm 0.24$		$4.05^{b} \pm 0.27$		$3.54^{b} \pm 0.36$		$4.30^{b} \pm 0.31$	
AP	$6.53^{a} \pm 0.39$		$4.74^{a} \pm 0.32$		$5.98^{a} \pm 0.42$		$5.02^{a} \pm 0.49$		$5.54^{a} \pm 0.35$	
Significance	**		**		**		**		**	
	MAP	AP	MAP	AP	MAP	AP	MAP	AP	MAP	AP
Temperature (°C, n=14)										
4	4.80 ± 0.55	$5.97^{b} \pm 0.59$	4.09 ± 0.41	$4.15^{b} \pm 0.44$	3.76 ± 0.37	$5.29^{b} \pm 0.63$	3.68 ± 0.59	$4.09^{b} \pm 0.62$	4.18 ± 0.50	$5.19^{b} \pm 0.55$
25	5.34 ± 0.27	$7.08^{a} \pm 0.47$	3.75 ± 0.27	$5.32^{a} \pm 0.42$	4.34 ± 0.39	$6.67^{a} \pm 0.51$	3.39 ± 0.44	$5.95^{a} \pm 0.70$	4.41 ± 0.39	$5.90^{a} \pm 0.44$
Significance	*NS*	**	*NS*	**	*NS*	**	*NS*	**	*NS*	*
Time (day, n=4)										
0	$3.38^{d} \pm 0.61$	$2.90^{d} \pm 0.44$	$2.29^{d} \pm 0.11$	$2.17^{d} \pm 0.12$	$2.92^{c} \pm 0.55$	$1.96^{d} \pm 0.46$	$< 1^{d}$	$< 1^{c}$	$1.69^{e} \pm 0.33$	$2.08^{d} \pm 0.39$
15	$4.10^{cd} \pm 0.76$	$5.58^{c} \pm 1.12$	$2.88^{cd} \pm 0.37$	$3.72^{c} \pm 0.89$	$3.18^{bc} \pm 0.86$	$4.60^{c} \pm 0.93$	$2.80^{c} \pm 0.67$	$4.78^{b} \pm 1.49$	$3.30^{d} \pm 0.52$	$4.21^{c} \pm 0.70$
30	$4.03^{cd} \pm 0.88$	$6.10^{bc} \pm 0.69$	$3.14^{bc} \pm 0.23$	$5.23^{ab} \pm 1.08$	$3.17^{bc} \pm 0.49$	$5.96^{b} \pm 0.63$	$3.35^{bc} \pm 0.60$	$5.18^{b} \pm 0.68$	$3.98^{cd} \pm 0.78$	$5.65^{b} \pm 0.55$
45	$5.12^{bc} \pm 0.39$	$7.03^{ab} \pm 0.57$	$3.69^{b} \pm 0.33$	$4.98^{b} \pm 0.38$	$3.51^{bc} \pm 0.57$	$6.78^{ab} \pm 0.56$	$4.20^{ab} \pm 0.20$	$5.71^{ab} \pm 0.99$	$4.45^{bcd} \pm 0.32$	$6.04^{b} \pm 0.27$
60	$5.48^{b} \pm 0.32$	$7.64^{a} \pm 0.19$	$4.82^{a} \pm 0.39$	$4.96^{b} \pm 0.41$	$4.52^{ab} \pm 0.20$	$7.14^{ab} \pm 0.43$	$4.47^{ab} \pm 0.37$	$5.92^{ab} \pm 0.76$	$4.88^{abc} \pm 0.34$	$6.78^{ab} \pm 0.22$
75	$6.21^{ab} \pm 0.40$	$8.29^{a} \pm 0.13$	$5.12^{a} \pm 0.36$	$6.26^{a} \pm 0.37$	$5.20^{a} \pm 0.32$	$8.02^{a} \pm 0.20$	$4.64^{ab} \pm 0.59$	$6.64^{a} \pm 0.07$	$5.62^{ab} \pm 0.38$	$7.29^{a} \pm 0.18$
90	$7.21^{a} \pm 0.36$	$8.14^{a} \pm 0.17$	$5.50^{a} \pm 0.30$	$5.84^{ab} \pm 0.37$	$5.85^{a} \pm 0.51$	$7.42^{a} \pm 0.54$	$5.31^{a} \pm 0.80$	$6.92^{a} \pm 0.44$	$6.16^{a} \pm 0.51$	$6.77^{ab} \pm 0.31$
Significance	**	**	**	**	**	**	**	**	**	**

MAP = Modified atmosphere packaging; AP = Atmospheric packaging; TAMB = Total aerobic mesophilic bacteria; TPB = Total psychrophilic bacteria; LAB = Lactic acid bacteria. ^{a,b,c,d,e}Means with different letters within the column indicate differences. *NS* = Not Significant ($p > 0.05$); * $p < 0.05$; ** $p < 0.01$

Table 5. Sensory scores of dried chicken slices under different storage conditions

	Appearance		Color		Odor		Flavor		Texture		Overall acceptability	
Packaging method												
MAP (n=26)	6.69^{b} ± 0.21		5.78 ± 0.27		6.51 ± 0.22		6.15 ± 0.21		5.63 ± 0.22		5.91 ± 0.21	
AP (n=14)	7.14^{a} ± 0.22		6.39 ± 0.28		7.14 ± 0.18		6.59 ± 0.24		6.46 ± 0.24		6.52 ± 0.25	
Significance	*		*NS*		*NS*		NS		NS		NS	
	MAP	AP	MAP	AP	MAP	AP	MAP	AP	MAP	AP	MAP	AP
Temperature (°C)												
4	6.80 ± 0.25	7.19 ± 0.25	5.96 ± 0.35	6.41 ± 0.38	6.68^{a} ± 0.26	7.19 ± 0.23	6.20 ± 0.26	6.88^{a} ± 0.32	5.75 ± 0.27	6.59 ± 0.34	5.91 ± 0.27	6.56 ± 0.35
25	6.56 ± 0.36	7.08 ± 0.41	5.56 ± 0.42	6.38 ± 0.46	6.31^{b} ± 0.36	7.08 ± 0.30	6.10 ± 0.35	6.21^{b} ± 0.31	5.48 ± 0.37	6.29 ± 0.35	5.92 ± 0.35	6.46 ± 0.36
Significance	*NS*	*NS*	*NS*	*NS*	**	*NS*	*NS*	**	*NS*	*NS*	*NS*	*NS*
Time (day)												
0	8.00^{a} ± 0.20	8.06^{a} ± 0.06	8.00^{a} ± 0.23	7.44^{a} ± 0.12	7.88^{a} ± 0.26	7.81^{a} ± 0.06	7.81^{a} ± 0.31	7.50^{a} ± 0.34	7.56^{a} ± 0.26	7.50^{a} ± 0.18	7.69^{a} ± 0.26	7.56^{a} ± 0.19
15	7.44^{ab} ± 0.12	7.31^{b} ± 0.12	6.38^{b} ± 0.22	6.75^{a} ± 0.25	7.38^{ab} ± 0.22	7.38^{b} ± 0.16	6.50^{b} ± 0.10	6.19^{b} ± 0.34	5.88^{b} ± 0.22	6.38^{b} ± 0.36	6.69^{b} ± 0.12	6.50^{b} ± 0.27
30	7.19^{b} ± 0.16	6.50^{c} ± 0.37	6.25^{bc} ± 0.42	5.69^{b} ± 0.34	7.13^{b} ± 0.13	6.69^{c} ± 0.26	6.44^{b} ± 0.28	6.50^{b} ± 0.40	5.75^{b} ± 0.10	6.13^{b} ± 0.26	6.19^{b} ± 0.12	6.13^{b} ± 0.33
45	6.56^{c} ± 0.19	6.25^{c} ± 0.25	5.50^{cd} ± 0.18	5.00^{b} ± 0.75	6.25^{c} ± 0.31	6.25^{d} ± 0.25	5.94^{b} ± 0.12	5.75^{b} ± 0.25	5.63^{b} ± 0.16	5.25^{c} ± 0.25	5.63^{c} ± 0.07	5.25^{c} ± 0.25
60	6.56^{c} ± 0.21		5.19^{d} ± 0.34		6.00^{c} ± 0.18		6.13^{b} ± 0.16		5.25^{b} ± 0.27		5.25^{cd} ± 0.18	
75	5.19^{d} ± 0.48		4.19^{e} ± 0.37		5.19^{d} ± 0.48		4.88^{c} ± 0.46		4.25^{c} ± 0.43		4.75^{de} ± 0.31	
90	5.13^{d} ± 0.38		4.13^{e} ± 0.13		5.00^{d} ± 0.25		4.63^{c} ± 0.13		4.50^{c} ± 0.50		4.50^{e} ± 0.25	
Significance	**	**	**	**	**	**	**	**	**	**	**	**

MAP = Modified atmosphere packaging; AP = Atmospheric packaging. ^{a,b,c,d,e}Means with different letters within the column indicate differences. *NS* = Not Significant ($p > 0.05$); * $p < 0.05$; ** $p < 0.01$

Because the microbiological quality of the AP type packaged samples exceeded the acceptable level of 7 log cfu g^{-1}, sensory analysis was not performed after the 45th day at 4 °C and the 30th day at 25 °C. In the MAP type, sensory analysis was not performed on the samples stored at 25 °C after the 75th day.

The appearance score of the MAP type packaged samples was lower than that of the AP type packaged samples. As the storage temperature increased, the odor score of the MAP type samples and the taste score of the AP type samples decreased. The reason for the decrease in the odor score might be that more CO_2 dissolves in the chicken meat as the temperature increases (Table 1). The reason why AP type samples were perceived as less palatable as the storage temperature increased might be that the samples lost some water (Table 2, a_w value) and the amount of lipid oxidation products and nitrogenous compounds increased (Table 3). Additionally, the overall acceptability scores of dried chicken slices decreased significantly as the storage time increased.

Discussion

CO_2 content within package was significantly ($p < 0.01$ and $p < 0.05$) affected (Table 1) by temperature, time and packaging type. Consistent with the results of the present study, it was determined that the sliced dry fermented sausage packs stored at 22 °C contained a higher percentage of CO_2 than the packs stored at 4 °C (Ščetar et al. 2013). Esturk and Ayhan (2009) also reported that the CO_2 content of the package increased significantly after 15 days of storage at 4 °C in salami slices packaged with 100% N_2 gas, and the reason for this was microbial deterioration. In another study on the storage of Iberian ham slices, it was reported that 5% O_2 in the packages was depleted within 18 days and the CO_2% value increased as a result of the growth and metabolic activity of microorganisms (Andrés et al. 2006).

The decrease of CO_2 might have resulted from the absorption of some of the CO_2, a gas highly soluble in water and oil, by the samples. Similarly, in a study by Zouaghi and Cantalejo (2016) in which freeze-dried chicken meat was packaged in different CO_2 concentrations (20, 30, 40, and 50%) and stored at 21 °C for 28 days, the CO_2% value decreased significantly at the end of storage, and the highest reduction was determined to be 5% for packages containing 50% CO_2. Parra et al. (2010) also reported that as the storage time of MAP type packaged dry-cured *Iberian* ham slices increased, the amount of O_2 did not change, while the amount of CO_2 decreased significantly.

The following conditions caused the slices to have lower a_w values: i) AP type packaging compared to MAP type, ii) 25 °C storage temperature in the AP type compared to 4 °C, and iii) prolonged storage time in both packaging types. This might be due to the fact that the AP type packaged samples lose more water vapor during storage at room temperature.

Lower pH value in MAP has been explained in many studies by the penetration of CO_2 gas in the packaging into the meat and its conversion to carbonic acid during storage (Cilla et al. 2006, Kim et al. 2014). The AP type packaging, 25 °C storage temperature, and long storage time might have supported microorganism activities, and accordingly, the protein in the meat structure might have been reduced to more nitrogenous compounds. Zouaghi and Cantalejo (2016) reported that the pH values of freeze-dried chicken meat stored at different gas atmospheres were higher in packages containing more oxygen after the 15th day. Rubio et al. (2007a) reported that the pH value of the vacuum packed cecina slices increased from 5.94 to 6.05 and the a_w value decreased from 0.90 to 0.87 after 210 days of storage at 6 °C. Kim et al. (2014) found that the pH value increased from 5.54 to 5.61 and the a_w value decreased from 0.88 to 0.82 in MAP type (25% CO_2 + 75% N_2) packaged pork samples after 90 days of storage at 10 °C. On the other hand, Parra et al. (2012) reported that the packaging type had no effect on the pH value in *Iberian* ham samples packaged with different atmospheric gases (vacuum, 70% N_2 + 30% CO_2, and 70% Ar + 30% CO_2) and stored at 4 °C for 60 days.

Lower TBARS value might be due to the delay of lipid oxidation by the MAP type packaging. Similarly, Aykın-Dinçer and Erbaş (2020) reported that the TBARS value (42.96 µmol MDA kg^{-1}) of AP type packaged cold-dried beef slices was higher than that of the MAP type. In a study in which atmospheric packaged chicken charqui samples were stored at 25 °C for 120 days, it was reported that the TBARS value reached the highest value (1.6 mg MA kg^{-1}) on the 90th day and then decreased at the end of storage (Silva et al. 2018). In a study by Modi et al. (2007) in which the atmospheric packaged dried chicken kebab mix was stored at 27 °C for 6 months, it was also reported that the TBARS value increased from 2.9 mg MA kg^{-1} to 5.3 mg MA kg^{-1}. Aksu and Kaya (2005) reported that the TBARS values of pastırma slices in MAP type packaging and stored at 10 °C were higher than the samples stored at 4 °C. Uysal et al. (2022) noted that TBARS values for sausage chips with AP stored at 4 °C were lower compared to 25 °C.

In another study comparing different packaging types (vacuum, AP, and MAP), the TBARS value was found to be the highest (2.80 mg MA kg^{-1}) in AP type packaged pastırma slices after 120 days of storage at 4 °C (Gök et al. 2008).

Consistent with the NPN results in the present study, Aykın-Dinçer and Erbaş (2020) found that the NPN value was higher (5.84 g 100 g^{-1}) in AP type packaged dried beef slices and increased from 5.40 to 5.75 g 100 g^{-1} with the increase in storage temperature from 4 °C to 25 °C. Aksu and Kaya (2005) also reported that the NPN value in pastırma samples in MAP type packaging and stored at 2 different temperatures (4 °C and 10 °C) increased during storage, reached the highest value on the 120th day of storage, and was not affected by the storage temperature.

CO_2 gas in the MAP type packaging might have suppressed the growth of microorganisms by creating an anaerobic environment and turning into carbonic acid, reducing the pH value (Table 4.9). Gök et al. (2008) found that MAP type samples had lower TAMB (6.07 log cfu g^{-1}), yeast-mold (3.43 log cfu g^{-1}), and LAB (4.00 log cfu g^{-1}) counts compared to AP type packaged pastırma samples stored for 120 days. Rubio et al. (2007b) reported that the yeast-mold count of the MAP type (20% CO_2 + 80% N_2) packaged samples was lower than the vacuum-packed samples, and the packaging type did not have a significant effect on the counts of TAMB, TPB, LAB, and Micrococcaceae. In another study, consistent with the results of the present study, the storage temperature (4 and 10 °C) did not have a significant effect on TAMB, *Micrococcus/Staphylococcus*, and LAB counts of MAP type packaged pastırma slices stored for 150 days (Aksu et al. 2005).

AP and MAP type packaged samples exceeded the microbial acceptability limit (TAMB count 7 log cfu g^{-1}) determined for poultry meat on the 45th day (7.03 log cfu g^{-1}) and 90th day (7.21 log cfu g^{-1}), respectively. Cantalejo et al. (2016) reported that the TAMB count of freeze-dried chicken meat was less than 5 log cfu g^{-1} during 8 months of storage. In a study in which dried chicken rings were aerobically packaged and stored at 30 °C for 45 days, it was reported that the TAMB count reached 5.18 log cfu g^{-1} and the yeast-mold count reached 2.04 log cfu g^{-1} at the end of storage (Mishra et al. 2015).

It was determined that storage at room temperature negatively affected the sensory quality of the samples. Similarly, Aykın-Dinçer and Erbaş (2020) determined that the flavor score of cold-dried beef slices (5.51) stored at 25 °C was lower than the samples stored at 4 °C (6.20). As the storage time increased, a similar decrease was determined in all sensory scores of dried chicken slices. Mishra et al. (2015) associated the decrease in the flavor score during storage under aerobic conditions with an increase in the TBARS value in meat products. Modi et al. (2007) reported all sensory scores in the range of 7.7–8.1 in the chicken kebab mix at the beginning of storage, while the scores were determined to be in the range of 7.4–7.8 after 6 months storage at 27 °C in atmospheric conditions. Rubio et al. (2007b) reported that the packaging type did not have a significant effect on the color, odor, and flavor properties of dry fermented sausages, but the scores of these sensory properties decreased gradually as the storage time increased. In another study, all sensory scores of MAP-type packaged chicken meat were found to be above the acceptable limit of 4 points during the 28-day storage period (Zouaghi and Cantalejo 2016).

The decrease of overall acceptability scores might be due to increased biochemical reactions such as lipid oxidation, pigment oxidation, and degradation of proteins and lipids in dried chicken slices during storage. Shelf life is defined as the time when the overall acceptability score falls below 5 points on a 9-point hedonic scale (Capita et al. 2018). According to this definition, the shelf life of the MAP type packaged samples was 90 days at 4 °C and 75 days at 25 °C. Because the overall acceptability score did not fall below 5, the shelf life of the AP type packaged samples was considered as the time when they were microbiologically safe and was determined to be 45 days at 4 °C and 30 days at 25 °C. In a study in which sugar-sweetened chicken jerky samples were stored under vacuum and aerobic (33% and 75% relative humidity) conditions, it was reported that samples stored aerobically had lower sensory scores and could not be consumed because their overall acceptability scores were below 5 on the 15–30th day of storage (Wongwiwat and Wattanachant 2015).

The limitation of this study is that the panelists consisted of university students with similar education levels. Therefore, sensory evaluation results might not be a true reflection of general public consumers in terms of age, education level and employment status. Another limitation is that the quality of the products can be improved by the inclusion of another gas, not just nitrogen (N_2) and carbon dioxide (CO_2).

Conclusions

In this study, cold dried chicken slices were packaged in two different types as MAP and AP and stored at 4 and 25°C for 90 days to determine the effect of different storage conditions. It was determined that as the storage temperature and time increased, the CO_2% value decreased in the headspace of MAP type packaged samples, while the CO_2% value increased and O_2% value decreased in the headspace of AP type samples. The increase in the storage temperature in the AP type and the prolongation of the storage time in both packaging types caused lower a_w values in the samples. On the other hand, the pH and TBARS values of dried chicken slices were higher in AP type packaging at 25 °C. The microbiological quality of MAP type packaged samples was higher, and this quality decreased due to the prolonged storage period in both packaging types. The shelf life of AP type samples was determined to be 45 days at 4 °C and 30 days at 25 °C, where they are microbiologically safe. As a result of the sensory evaluation, it was determined that the shelf life of the MAP type packaged samples was 90 days at 4 °C and 75 days at 25 °C.

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