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Shelf-life Extension of Precooked Chicken Fillets by Modified Atmosphere Packaging

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ABSTRACT

The objective of this study was to determine the effects of modified atmosphere packaging (MAP) on qualities and shelf-life of chilled precooked chicken fillets. Precooked chicken fillets were packed in air (control) and under MAP conditions (20%CO_2+80%N_2, M1; 40%CO_2+60%N_2, M2 and 60%CO_2+40%N_2, M3). All treatments were stored under refrigeration at 4±1°C. The results indicated that MAP conditions and storage time had no effect on water activity, moisture content, pH and surface color of all samples ($P \geq 0.05$). The precooked samples kept under MAP conditions showed significantly lower thiobarbituric acid (TBA) value as compared to that of the control sample ($P<0.05$). MAP was effective for inhibiting growth of total viable counts (TVC), lactic acid bacteria (LAB), *Pseudomonas* sp., and yeasts and molds. The higher CO_2 concentration, the higher inhibition of microbial records. Counts of *E. coli* and coliform were less than 2 log cfu/g whereas no *Salmonella* sp. and *Listeria monocytogenes* was detected in all chicken samples, irrespective of the packaging conditions throughout the storage period. Sensory analysis revealed that the precooked products were better preserved under MAP conditions. Physicochemical, microbiological and sensorial data indicated that the shelf-life of aerobically packaged precooked chicken fillets was around 5 days. MAP could extend product shelf-life to 35 days under M1 and at least 65 days under M2 and M3.

Key words: precooked chicken fillet, shelf-life, modified atmosphere packaging, chilling

INTRODUCTION

Thailand was ranked the fourth in the world's frozen chicken meat exporters. Its major export markets are Japan and the European Union. The key success is the availability of supplies, the price competitiveness and the utilization of most advanced and hygenic method with close supervision and control management. However, in 2004-2005 the exports dramatically decreased, mainly due to Avian Influenza trade restrictions. This situation has forced Thai producers to export frozen cooked products instead to reduce the volatility of export markets. Though freezing is the practical way to store food**,** it does affect the texture, color, juiciness and flavor of the foods (Alarcon-Rojo, 2004). For this reason, combination of different preservation techniques i.e, chilling and gas packaging are used to achieve multi-target, mild but reliable preservation effects. Despite there are several studies available on the effects of modified atmospheric packaging (MAP) on fresh poultry meat (Sawaya *et al*., 1995; Kim and Marshall, 1999; Chouliara *et al*., 2007), the

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work on MAP of precooked chicken meat products is rather limited. The previous research mostly focused on fried chicken meat products (Marshal *et al*., 1992; Patsias *et al*., 2006). Therefore, the objective of the present study was to investigate the effect of MAP on qualities and shelf-life of precooked chicken meat product stored at 4±1°C.

MATERIALS AND METHODS

Sample preparation

Fresh chicken fillets without any food additives were prepared by a local poultry processing plant. The fillets were cooked in boiling water and hold until the internal temperature reached 73±2°C for 1 min. After cooling, the precooked samples (ca. 100 g) were placed on a polystyrene (PS) tray and packed in a nylon/LLDPE pouch (85 μm in thickness; oxygen transmission rate (OTR) of 101.4 cm^3/m^2 day atm at 0%RH 23°C; carbon dioxide transmission rate (CO_2TR) of 74.5 cm^3/m^2 day atm at 0%RH 23°C; and water vapor transmission rate of 1.64 g/m^2 day at 100%RH 23°C). Gas mixtures were prepared by using gas mixer (WITT MM-2G, Germany). The following MAP conditions were applied: 20% CO_2+80%N_2 (M1), 40% CO_2+60%N_2 (M2), and 60% CO_2+40%N_2 (M3). The gas concentrations in each package was monitored by gas analyzer (Servomex, Model 1450, UK). Pouches were heat-sealed using a vacuum sealer (Multivac C200, Germany) and kept at 4±1°C. For control, identical chicken samples were packed in air and kept in the same condition. Samples from each treatments were randomly taken at 5 day intervals for analysis of qualities and storage life.

Physicochemical analysis

Water activity was determined using a_w meter (Novasina, TH-500, Switzerland). Moisture content was determined by oven drying of 5 g of sample for 20-24 hr. according to AOAC (1990) until constant weight is reached. The pH value was measured using pH meter (Metrohm, Switzerland). Samples were thoroughly homogenized with 10 ml of distilled water and the homogenate was used for pH determination. TBA was determined according to the method proposed by Pearson (1976) and expressed as mg malonaldehyde/kg sample**.** Color determination was carried out on the surface of fillets using a color meter (Hunter Lab, Ultra Scan XE/IX7, USA)

Microbiological analysis

A sample (25 g) was drawn aseptically and transferred to 225 ml of sterile 0.1% peptone water solution. The sample was homogenized for 30 seconds. A 10-fold dilution was made of the peptone water as needed for plating. For microbial enumeration, 0.1 ml samples of serial dilution of chicken homogenates were spread on the surface of dry media.

Total plate count was performed on plate count agar (Merck, Germany). The samples were incubated at 30±2°C for 3 days. Lactic acid bacteria (LAB) were determined on de Man Rogosa Sharpe medium (Oxoid, UK) after incubation at 25±2°C for 5 days. *Pseudomonas* sp. was determined on cetrimide fusidin cephaloridine agar (Oxoid supplemented with selective supplement SR 103, Oxoid, UK) after incubation at 25±1°C for 2 days. Yeasts and molds were enumerated using acidified potato dextrose agar (Merck, Germany) after incubating at 30±2°C for 3 days. *E. coli*, coliform and *Listeria monocytogenes* were determined on Petrifilm™ E. coli count, Petrifilm™ rapid coliform count, and Petrifilm™ Environmental Listeria plates (3M, Germany), respectively after incubation at 35±2°C for 1 day. *Salmonella* sp. was determined by enriching in selenite-cystine broth (Difco, UK) and incubating at 35±2°C for 1 day. Isolations were performed on SS agar (Difco, UK), brilliant green agar (Difco, UK) and bismuth sulfite agar (Difco, UK) then incubated at 35±2°C. for 1 day.

Suspected colonies were tested biochemically by the methods as described in the Food and Drug Administration Bacteriological Analytical Manual (http://www.cfsan.fda.gov/~ebam/bam-5.html). Three replications of at least three appropriate dilutions were enumerated.

Sensory evaluation

The sensory qualities of precooked chicken fillets was evaluated at each sampling time by a ten member trained panel which was trained for a period of 1 month to familiarize with sensorial attributes of precooked chicken (i.e.,appearance, color, odor and texture). Each precooked chicken fillet was randomly drawn from each experimental code and reheated in a microwave oven at high power (700 W) for 4 min. Along with the test samples, the panelists were presented with a freshly precooked chicken sample, previously stored at -20°C throughout the experiment, this served as the reference sample. Panelists were asked to evaluate the sample in terms of appearance (0= poor to 5 = good/without any defects), color (0 = yellow to 5 = white), odor (0 = extremely rancid to 5 = cooked or natural), texture (0 = extremely tough or mushy to 5 = firm) and acceptability (0 = dislike very much and 5 = like very much). The acceptability score of 3.0 was taken as the lower limit of acceptability.

Statistical analysis

The experiment was performed using three replications. The collected data was analyzed using one-way analysis of variance (ANOVA) and presented as mean values with standard deviations. Differences between mean values were established using Duncan's multiple range test. Values were considered at 95% significant (P<0.05).

RESULTS AND DISCUSSION

Chemical analysis

Changes in water activity and moisture content during storage of precooked chicken fillets both in air and under MAP conditions at 4±1°C were not significantly different (P≥0.05). The water activity and moisture content (Figure 1) of all samples were in the range of 0.980-0.984 and 68.53-72.04%, respectively. Gas mixture conditions and storage time did not have significant effects on pH of the precooked chicken (P≥0.05). The pH of the samples was 6.53 ± 0.01

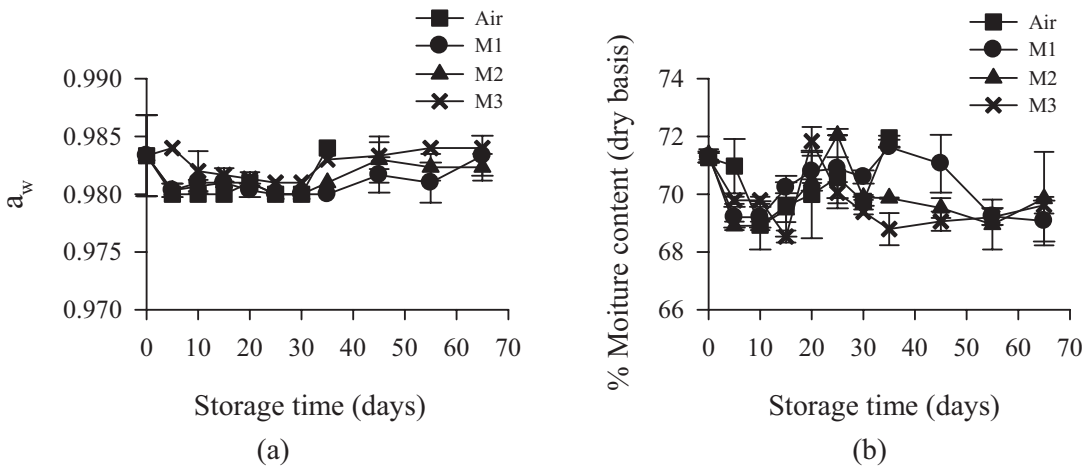

Figure 1 Changes in water activity (a) and moisture content (b) of chilled precooked chicken fillets packed in air and under MAP conditions stored at 4±1°C (M1 = 20%CO_2 + 80%N_2, M2 = 40%CO_2 + 60% N_2 and M3 = 60%CO_2 + 40% N_2).

at the beginning and was 6.36-6.58 after 65 days of storage (results not shown).

TBA values of precooked chicken fillet are present in Figure 2. The TBA values of precooked chicken samples increased as storage time progressed. TBA values of precooked chicken fillets in air packages were significantly higher than those of the sample under MAP condition packages (P<0.05). The sample in air condition had TBA value of 11.48±0.61 mg malonaldehyde/kg sample after 35 days of storage whereas those packed under MAP conditions showed TBA values within the range of 3.93-4.78 mg malonaldehyde/kg sample. This was because the air packages contained O_2 (ca. 21%) which was the determining factor for lipid oxidation (Ordonez and Ledward, 1977), resulting in higher TBA values of the samples. However, the increment of CO_2 from 20% (M1) to 60% (M3) slightly affected this parameter. At the end of the experiment, TBA values of these samples ranged from 5.44-6.75 mg malonaldehyde/kg sample. The gradual increase of TBA values of the samples packed under MAP

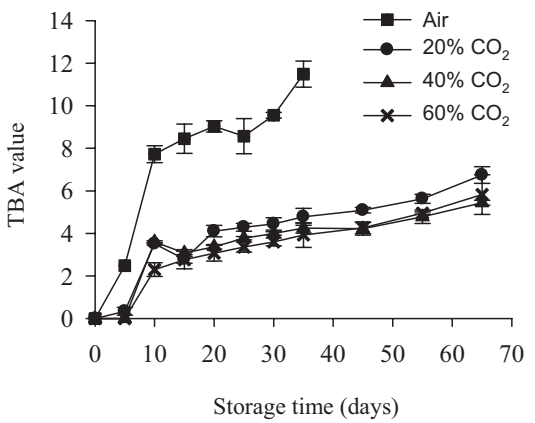

Figure 2 Changes in thiobarbituric acid (TBA value) (mg of malonaldehyde/kg) of chilled precooked chicken fillets packed in air and under MAP conditions stored at 4±1°C (M1 = 20%CO_2 + 80% N_2, M2 = 40%CO_2 + 60% N_2 and M3 = 60%CO_2 + 40% N_2).

conditions resulted from O_2 which permeated through packaging materials.

The color values of all precooked chicken treatments are given in Table 1. During storage, L^* and a^* of samples packed in air slightly decreased from 78.40±1.31 and 2.65±0.17 to 74.37±0.92 and 0.94±0.26, respectively. In contrast, the reverse trend was recorded for b^* values which gradually increased from 11.58±0.07 to 14.64±0.54. The results indicated that the color of the product became darker, less red and more yellow. However, MAP had no significant effect on the color of the precooked chicken fillets (P≥0.05).

Microbiological analysis

The present study focused on the monitoring of the following species of micro-organisms: TVC, LAB, *Pseudomonas* sp., yeasts and molds, *E. coli*, coliform, *Listeria monocytogenes* and *Salmonella* sp. At the beginning, TVC of precooked chicken fillets was 1.59±0.11 log cfu/g and the number of total count increased as the storage time increased (Figure 3a). TVC of the samples packed in air and M1 reached the value of 6 log cfu/g, which is considered as the upper acceptability limit for precooked poultry meat as defined by International Commission on Microbiological Specifications for Foods (ICMSF, 2002) on days 30 and 65 of storage, respectively. The M2 and M3 gas mixture package samples did not reach this value throughout the 65 days of storage period under refrigeration (4±1°C). Lactic acid bacteria (LAB) counts increased progressingly with storage time and attained final counts of 4.24-4.82 log cfu/g at day 35 and day 65 for the samples packed in air and M1, respectively. LAB counts in the samples packed under M2 and M3 slightly increased to 2.90-3.21 log cfu/g after storing for 65 days (Figure 3b). The number of *Pseudomonas* sp. counts of precooked chicken samples stored in air and under M1 increased to 6.82±0.04 on day 35 and to 5.02±0.02 on day 65,

respectively whereas the microbial counts of the samples packed under M2 and M3 were not statistically significant ($P \geq 0.05$) and within the range of 2.65-2.73 (log cfu/g) on 65 days of storage period (Figure 3c). The similar trend was observed for yeasts and molds which also were strictly aerobic microorganisms. The microbial counts kept in air package reached 5.5±0.05 log cfu/g after

Table 1 Changes in color properties of precooked chicken fillets in different atmosphere conditions during storage at 4±1°C

Color attributes	Storage time (days)	Packaging conditions**, ns			
		Air	M1	M2	M3
*L** (Lightness)	0	78.40±1.31	76.01±0.66	76.76±0.92	76.70±0.82
	5	77.16±0.74	77.07±2.48	76.46±0.61	76.49±0.95
	10	76.96±0.85	75.64±0.72	75.50±0.31	77.38±1.28
	15	76.17±0.10	75.66±1.69	74.72±0.62	78.84±1.42
	20	76.11±4.36	76.40±1.30	76.46±1.01	75.56±0.08
	25	74.37±0.75	73.34±0.02	75.35±0.34	74.84±0.75
	30	74.37±0.92	75.54±2.80	78.09±0.25	74.59±1.61
	35	74.37±0.92	73.34±0.02	74.35±1.53	74.17±0.56
	45		76.54±3.24	78.09±0.25	75.92±1.25
	55		76.54±3.24	78.09±0.25	76.92±1.25
	65		77.71±0.46	75.76±0.77	75.77±0.04
*a** (Redness)	0	2.65±0.17	2.71±0.34	2.52±0.07	2.63±0.05
	5	1.48±0.27	1.91±0.53	2.64±0.15	2.29±0.31
	10	1.10±0.20	2.86±0.14	2.81±0.12	2.30±0.20
	15	1.12±0.06	2.22±0.21	2.25±0.11	2.36±0.06
	20	1.17±0.08	2.14±0.21	2.89±0.19	2.59±0.47
	25	1.07±0.03	2.35±0.08	2.25±0.15	2.12±0.16
	30	1.07±0.03	1.90±0.67	2.90±0.10	2.41±0.09
	35	0.94±0.26	2.35±0.08	2.25±0.15	2.12±0.16
	45		2.23±0.16	2.90±0.10	2.41±0.09
	55		2.03±0.16	2.88±0.08	2.41±0.07
	65		1.92±0.06	2.42±0.07	2.44±0.13
*b** (Yellowness)	0	11.58±0.07	11.56±0.35	11.50±0.23	11.37±0.12
	5	12.98±0.13	12.86±0.16	12.52±0.20	12.24±0.33
	10	12.97±0.22	13.27±0.40	13.34±0.50	12.99±0.22
	15	13.21±0.83	12.57±0.06	13.31±0.13	13.00±0.15
	20	13.58±0.20	12.65±0.14	13.15±0.50	12.35±0.96
	25	13.65±0.09	12.47±0.23	11.76±0.67	11.17±0.68
	30	14.17±0.13	12.03±0.52	13.18±0.47	12.89±0.14
	35	14.64±0.54	12.47±0.23	11.76±0.67	11.17±0.68
	45		12.36±0.14	13.42±0.53	12.89±0.14
	55		12.33±0.11	12.98±0.43	12.89±0.11
	65		13.13±0.08	12.96±0.38	12.98±0.51

**M1 = 20%CO_2 + 80% N_2, M2 = 40%CO_2 + 60% N_2, and M3 = 60%CO_2 + 40%N_2

ns means in the same column are not significantly different ($P \geq 0.05$)

30 days of storage while those packed under M1, M2 and M3 reached 3.88±0.03, 3.19±0.06 and 2.69±0.09 log cfu/g after 65 days of storage, respectively (Figure 3d). The results above indicate that MAP could inhibit microbial growth by extending the lag phase of microorganisms (Faber, 1991). The higher CO_2 concentration in the MAP gas mixture, the higher the inhibition records. This observation was in agreement with the previous reports by Layrisse and Matches (1984), who found that CO_2 showed a spoilage delay of spotted shrimps by inhibiting psychotrophic, aerobic and Gram negative bacteria.

In this study, the number of *E. coli* and coliform was less than 2 log cfu/g in all precooked chicken fillet samples irrespective of the air or under MAP conditions packages throughout the storage period (results not shown). According to Holzapfel (1998), Enterobacteriaceae is sensitive to extrinsic factors such as heat. Therefore, heating the chicken fillets until its internal temperature reached 75°C for 1 min. might be sufficient to

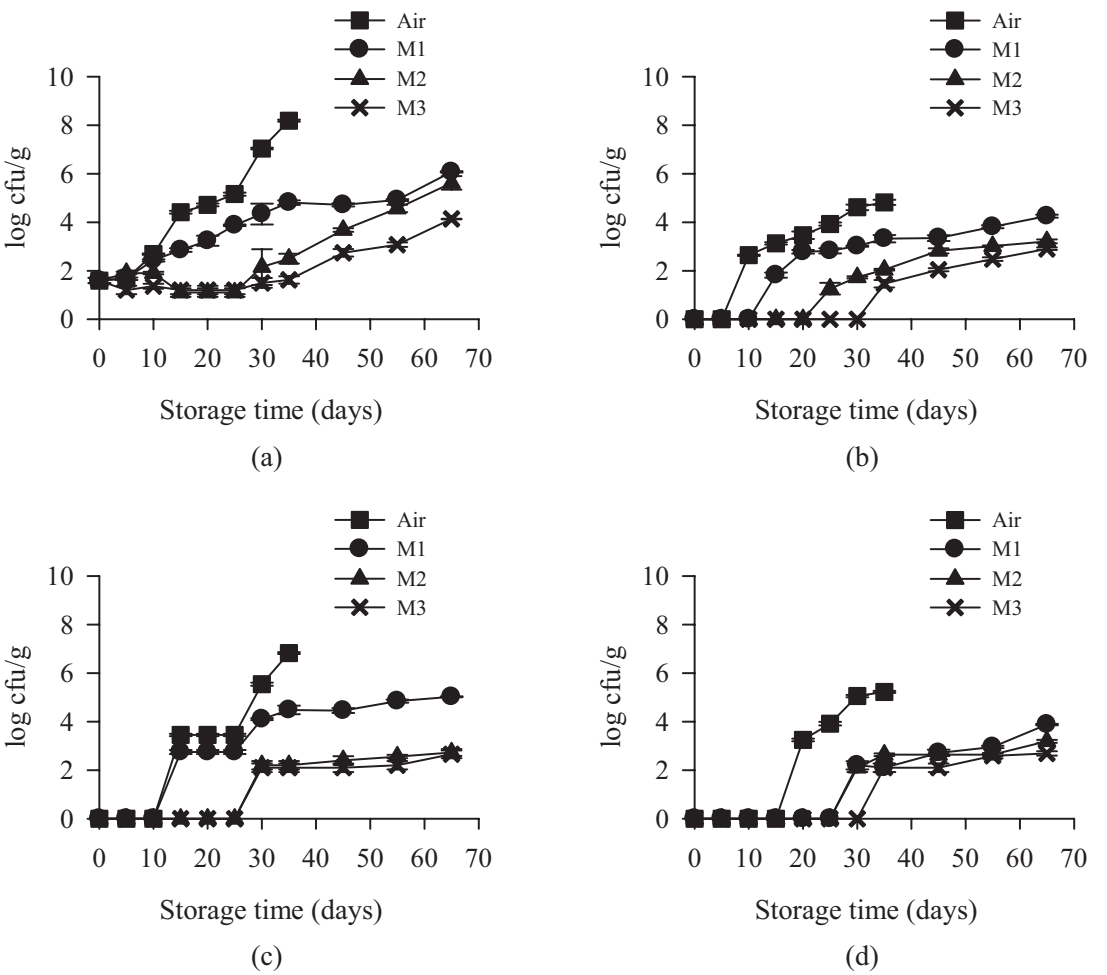

Figure 3 Changes (log cfu/g) in total viable count (a); lactic acid bacteria (b); Pseudomonas sp.(c); and yeast and molds (d) of chilled precooked chicken fillets packed in air and under MAP conditions stored at 4±1°C (M1 = 20%CO_2 + 80%N_2, M2 = 40%CO_2 + 60%N_2 and M3 = 60%CO_2 + 40%N_2).

eliminate this microorganism. No *Salmonella* sp. and *Listeria monocytogenes* was found in all samples (results not shown). This findings coincided with the work of Gill and Reichel (1989) who reported that cold tolerant pathogens did not grow on high pH meat in oxygen free carbon dioxide packaging atmospheres.

Sensory evaluation

Sensory qualities of precooked chicken fillets are given in Figure 4 and Table 2. The acceptable samples were described as having good appearance, firm texture and a cooked or natural odor without any sign of rancidity. In comparison with control, all MAP samples showed significantly delayed decrease in sensory scores in terms of appearance, color, odor and texture (Figure 4). The precooked chicken fillet packed in air quickly lost its qualities (especially appearance and odor) during 10 days of storage period while MAP samples could maintain their sensorial qualities up to at least 45 days regardless of CO_2 concentration. The acceptability results from Table 2 indicated that storage time and MAP conditions had significant impacts on panel acceptability. The lower acceptability score of 3.0

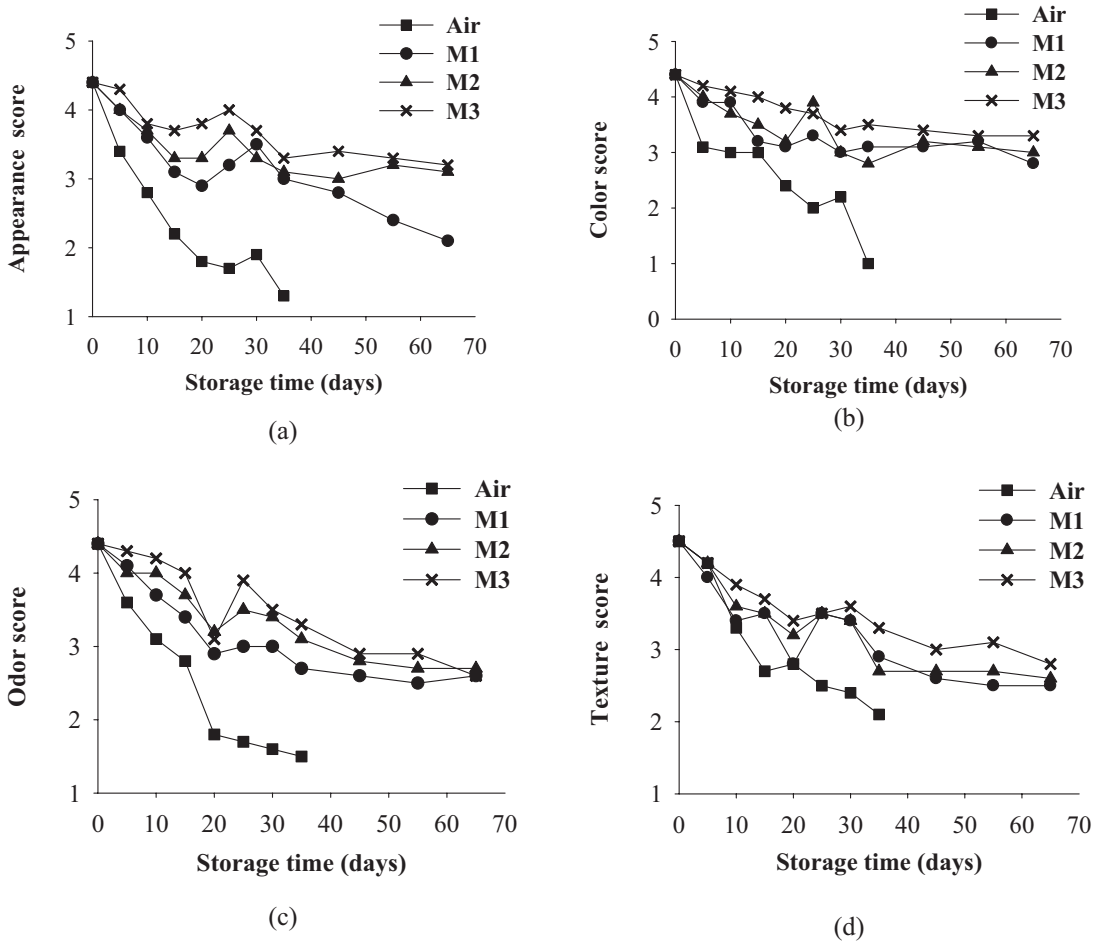

Figure 4 Changes in appearance score (a); color score (b); odor score (c); and texture score (d) of chilled precooked chicken fillets packed in air and under MAP conditions stored at 4±1°C (M1 = 20%CO_2 + 80%N_2, M2 = 40%CO_2 + 60%N_2 and M3 = 60%CO_2 + 40%N_2).

Table 2 Acceptability score of precooked chicken fillets stores at 4±1°C.

Storage time (days)	Packaging conditions*/**			
	Air	M1	M2	M3
0	4.40^{A} ± 0.70	4.40^{A} ±0.70	4.40^{A} ±0.70	4.40^{A} ±0.70
5	$3.40^{b,B}$ ±0.84	$4.00^{ab,AB}$±0.67	$4.00^{ab,AB}$±0.67	$4.30^{a,AB}$ ±0.67
10	$2.80^{b,C}$ ±0.79	$3.60^{a,BC}$ ±0.52	$3.70^{a,BC}$ ±0.48	$3.80^{a,BC}$ ±0.42
15	$2.20^{b,D}$ ±0.63	$3.50^{a,BC}$ ±0.71	$3.30^{a,CD}$ ±0.82	$3.70^{a,CD}$ ±0.48
20	$1.80^{c,DE}$ ±0.42	$3.20^{b,C}$ ±0.42	$3.30^{b,CD}$ ±0.67	$3.80^{a,BC}$ ±0.42
25	$1.70^{b,D}$ ±0.48	$3.40^{a,BC}$ ±0.52	$3.70^{a,BC}$ ±0.48	$4.00^{a,BC}$ ±0.00
30	$1.90^{b,D}$ ±0.32	$3.50^{a,BC}$ ±0.53	$3.30^{a,CD}$ ±0.48	$3.70^{a,CD}$ ±0.48
35	$1.30^{b,E}$ ±0.48	$3.00^{a,CD}$ ±0.82	$3.10^{a,CD}$ ±0.88	$3.30^{a,CD}$ ±0.48
45		$2.60^{b,DE}$ ±0.84	$3.00^{ab,D}$ ±0.67	$3.40^{a,CD}$ ±0.52
55		$2.40^{b,DE}$ ±0.53	$3.20^{a,CD}$ ±0.63	$3.30^{a,CD}$ ±0.67
65		$2.00^{b,E}$ ±0.42	$3.10^{a,CD}$ ±0.32	$3.20^{a,D}$ ±0.42

*M1 = 20%CO_2 ± 80% N_2, M2 = 40%CO_2 ± 60% N_2 and M3 = 60%CO_2 ± 40% N_2

** means with different lower case letters (a,b,...) in the same row are significantly different ($p<0.05$)
means with different upper case letters (A,B,...) in the same column are significantly different ($p<0.05$)

was reached after 5 days for the air packaged samples, 35 days for M1 and at least 65 days for M2 and M3. Sensory data were in agreement with microbiological data for the samples packed under MAP conditions (Table 2). On the other hand, the limit of overall acceptability of precooked chicken fillets packed in air packages was clearly due to rancid odor which showed TBA values more than 7 mg malonaldehyde/kg sample after 5 days of storage (Figure 2). This results was in agreement with Tims and Watts (1958) who stated that loss of flavor in cooked meat during storage would produce a warm-over flavor (WOF) thus increasing TBA values of the products.

CONCLUSION

Obviously, the limiting factor for the samples packed in air packaging was lipid oxidation whereas that for those in modified atmospheric packaging was microbial spoilage. Based on physicochemical, microbiological and sensorial data, the shelf-life of precooked chicken fillets in air packaging stored at 4±1°C was around 5 days. Modified atmospheric packaging could extend product shelf-life at 4±1°C to 35 days under M1 and at least 65 days under M2 and M3.

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