Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola
ISSN 1516-635X Jan - Mar 2018 / v.20 / n.1 / 091-098

http://dx.doi.org/10.1590/1806-9061-2017-0628

Effect of Storage in Display Cases on the Sensory Quality of Chicken Breast Meat (M. Pectoralis)

■Author(s)

Chmiel M[I]
Słowiński M[I]

[I] Warsaw University of Life Sciences–SGGW, Faculty of Food Sciences, Department of Food Technology, Division of Meat Technology, 166 Nowoursynowska Street, 02-787 Warsaw, Poland.

■Mail Address

Corresponding author e-mail address
Marta Chmiel
Warsaw University of Life Sciences–SGGW, Faculty of Food Sciences, Department of Food Technology, Division of Meat Technology, 166 Nowoursynowska Street, 02-787 Warsaw, Poland.
Tel: (48) 22 5937532
Email: marta_chmiel@sggw.pl

■Keywords

Chicken breast muscles, display case, MAP, sensory quality.

Submitted: 18/September/2017
Approved: 08/October/2017

ABSTRACT

This paper describes a study on the determination of sensory quality of chicken breast muscles packaged with a PVC overwrap and under high-oxygen modified atmosphere (MAP: 75% O_2 and 25% CO_2), and stored in the display case (exposure to light and temperature fluctuations). For a more complete characterization of the raw material, the volume of drip loss in the package, and meat pH, L*, a*, and b* color components were measured. For comparison purposes, the quality of meat maintained under dark cold storage was also evaluated (control samples). In total, 64 PVC overwrap and 64 MAP packages were evaluated. Chicken breast muscles stored in the display case on PVC overwrap and in MAP packaging presented acceptable, despite but not the highest sensory quality until days 7 and 8 of storage, respectively. The meat under dark cold storage maintained high quality until the end of the experiment. When stored in the display case, packaging in MAP allowed extending chicken breast meat shelf life by at least 1 day in comparison with PVC overwrap packaging.

INTRODUCTION

Food packaging facilitates the sales process of by improving the convenience of shopping. It also facilitates distribution activities, such as warehousing, transportation, and exhibition of products (Zhou *et al.,* 2010). The success of a particular meat packaging technology depends on many factors: package material quality, which includes its microbiological quality, type and properties, as well as the efficiency of the packaging devices, composition of the gas mixture in MAP packaging, and maintenance of appropriate temperature in the cold chain (Fraqueza *et al.,* 2008; Säde *et al.,* 2013). In the meat industry, the most frequently used methods of fresh meat packaging are packaging in Styrofoam trays, which are wrapped with PVC foil (called PVC overwrap), vacuum packaging, and packaging using modified/protective atmosphere or MAP (Patsias *et al.,* 2006; Latou *et al.,* 2014).

PVC overwrap is one of the easiest way to pack meats. The shelf life of a PVC-overwrapped product, however, is short, of only few days. Additionally, this method provides insufficient protection of the product against external factors, drip loss, and unfavorable changes in color (Fraqueza *et al.,* 2008; Byrd *et al.,* 2011). It is the most commonly method reported for poultry meat.

However, poultry meat has been increasingly packaged in MAP, using oxygen, nitrogen (N_2), and carbon dioxide mixtures (CO_2). In Europe, gas mixtures composed of CO_2 and $N_2$are recommended; however, meat processing plants often use mixtures with high oxygen content (McMillin, 2008; Ntzimani *et al.,* 2008; Nassu *et al.,* 2012; Herbert *et al.,* 2013).

There are some studies (Meredith *et al.,* 2014; Rossaint *et al.,* 2014) comparing the quality of poultry meat packaged using PVC overwrap and MAP in meat processing plants and stored under typical conditions of food retail networks.

This paper describes a study on the determination of the sensory quality of chicken breast meat packaged in PVC overwrap or under high-oxygen MAP (75% O_2 and 25% CO_2) and stored in a display case (simulating the conditions of display cases in food retail stores, which are frequently opened and closed, and which temperature requirements are often not complied with, in addition of the presence of light).

MATERIAL AND METHODS

Materials and organization

The evaluated material consisted of chicken breast muscles (*m. pectoralis*) obtained under industrial conditions. The raw material was serially collected during four different processing days, and then packaged in accordance with the procedures applied in the meat processing plant as follows: (1) PVC overwrap – Styrofoam trays wrapped with PVC foil and (2) under modified atmosphere (MAP) with gas mixture of 75% O_2 and 25% CO_2. In each series, 16 trays with meat and MAP packages were prepared. A total of 64 PVC overwrap and 64 MAP packages were prepared, containing two single breast muscles, with a total mass of approximately 500 g.

Twenty-four hours after packaging, which is usually the period of time raw materials are supplied by the processing plant to the stores, half of the samples (32 PVC overwrap and 32 MAP packages) was placed in a closed, vertical display case (Paros 2/1.3DU, Igloo, Bochnia, Poland) with continuous (24 h/day) access to light (LED tube T8 type: LT90NM-TS-230 V 230 V/50 Hz/16.1W) and at an average temperature of 1.3°C (temperature of the respective shelves of the display case ranged between 1.0 and 3.5°C). The sensor of the display case was set for defrosting every 4h. Minimum defrost phase was 40min. Defrost end temperature was 8°C. During storage, the position of samples on the shelves of the display case was randomly changed to minimize variations in temperature and light intensity. The temperature was recorded every 5 min by using data loggers (EL-USB-2-LCD and EL-USB-2, Lascar Electronics Ltd. Erie, USA).

In order to compare the meat sensory quality, the other half part of the samples (32 PVC overwrap and 32 MAP packages) was maintained under cold storage at 0-2°C, in the dark. These were control samples.

The evaluation of sensory quality of breast muscles was performed on days 1, 3, 7, and 8 of storage. For a more complex characterization of raw material, the amount of drip loss into the packaging, and meat pH, L*, a*, b*color components were determined. On each day, for the purpose of analyses, two randomly chosen samples from both packaging systems and storage conditions were selected. Measurements of gas concentrations in the MAP packages were also performed.

Evaluation methods

Gas concentration in MAP packaging

In MAP packages, the concentrations of O_2 and CO_2 were measured using Check Point I gas analyzer (Dansensor, Poland; accuracy of the analyzer was 0.25%/2.0% for O_2/CO_2, respectively).

Sensory evaluation

Twenty pane lists scored the general appearance (including color and discoloration) and the meat odor 3 min after the MAP package was opened or the foil was removed from the tray according to five-point scale, from 1 (minimum) to 5 (maximum). Before the evaluation of the samples, all pane lists were trained on the meat attributes and the use of the scale, and were introduced to the samples and sensory analysis procedures.

Individual scores for general appearance were described as follows: 5 – fresh, bright pink color, no or very slight drip loss, no discoloration, glossy and smooth surface, juicy, white fat; 4 – bright pink color, pale, slight drip loss, slight discoloration, glossy, white fat; 3 – less fresh, pale, grayish to yellowish color, less glossy to dull, slight discoloration (especially at the sides and edges), visible drip loss, little or no glossiness, dry spots (at the sites), white to yellowish fat; 2 – gray or dirty brownish to yellowish color, obvious drip loss, dark dry spots, discoloration, soft and dull surface, forming threads, yellowish fat; 1 – yellowish to brownish color, strong drip loss, white colonies, sticky, slimy, dappled surface, yellowish to brownish fat. In turn, scores describing the odor included the following: 5 – fresh, characteristic of meat; 4 – characteristic of meat, neutral; 3 – no longer fresh, slightly changed (sweet, sour), atypical; 2 – fruity or musty, sour, sharp; 1 – old, musty, sweet, rancid, sharp, cheesy.

Drip loss into the package

The amount of drip loss into the package was determined as the difference between the gross weight of package and the weight of the empty, dry package

and the weight of meat. The amount of drip loss was determined as a percentage relative to the weight of the meat declared on the packages (500 g).

Color measurement

The color components L*, a*, and b* were measured on the surface of the muscles using a Minolta CR200 colorimeter (Konica Minolta, Poland). The following camera settings were used: illuminant D65, 2nd observer, hole size of measuring head – 8 mm. Prior to the measurements, the device was calibrated using the white balance (L* 97.81; a* –0.45; b* +1.88). Measurements were performed at five different locations on the surface of the each breast muscle sample, and the result is expressed as the average of the five measurements.

Meat pH measurement

Meat pH was measured by punching the glass calomelelectrode of the pH meter (CP-411, Elmetron, Zabrze, Poland) directly into the breast muscle. The device was previously calibrated using pH 4 and 7 buffers.

Statistical analysis

The obtained results were subjected to statistical analyses using the STATISTICA 12PL (Stat Soft Kraków, Poland) program. One-way analysis of variance was applied and multiple comparison of the means were performed using Tukey's HSD test were used (significance level $\alpha = 0.05$). The influence of the packaging method (MAP or PVC overwrap) and storage time on selected quality factors of the breast muscles were evaluated.

RESULTS AND DISCUSSION

Gas concentration in MAP package

Half of the breast muscles was packaged under modified atmosphere composed of 75% O_2 and 25% CO_2. The O_2 levels in the MAP packages were not affected by storage time when samples were maintained in dark cold storage, but when in display case storage, O_2 levels were significantly reduced ($p \leq 0.05$) to approximately 72.9% on day 8 of storage (Table 1). According to Rossaint *et al.* (2015), this may be a result of O_2 consumption by microorganisms, depletion of meat enzymes, and exchange of gases between the package and the environment. A significant influence of storage conditions ($p \leq 0.05$) on the oxygen levels in MAP packages was also determined (Table 1), with significantly lower levels determined on day 8 in the packages stored in the display case compared with dark cold storage.

Compared with the composition of the gas mixture of the empty packaging, the packages with the chicken breast muscles stored in the display case presented a slight decrease in CO_2 content on day 1 (Table 1). That may be caused by dissolution of a portion of this gas in the meat (McMillin, 2008, Meredith *et al.,* 2014). Storage time significantly influenced CO_2 levels ($p \leq 0.05$) when the samples were stored in the display case, but not under dark cold storage. The highest CO_2 level was determined at the end of the storage period (day 8), possibly as a result of microorganism growth and activity (Rossaint *et al.,* 2015). Significantly higher ($p \leq 0.05$) CO_2 level was also observed in MAP packages stored for 8 days in display case in comparison with packages under dark cold storage, which remained at the level of approx. 25% (Table 1). According to Zakrys-Waliwander *et al.* (2011) and Rotabakk *et al.* (2006), the maintenance of constant carbon dioxide levels at 20-30% throughout meat storage time prevents the development of microorganisms, particularly of putrefactive bacteria, therefore, extending the shelf life of the product.

Sensory quality of chicken breast muscles

A sensory evaluation of chicken breast muscles packaged in PVC overwrap or MAP, and stored in the display case or in dark cold storage, was performed on days 1, 3, 7, and 8 of storage. The obtained results

Table 1 - Gas concentration in MAP packagings (mean ± standard deviation)

Gas content [%]	Empty package	Day 1	Day 3	Day 7	Day 8
			Dark cold store		
O_2	74.9±0.9	74.5aA±1.3	74.6aA±1.4	74.7aA±1.9	75.2aA±0.8
CO_2	25.0±0.8	25.2aA±0.5	25.1aA±0.9	25.2aA±2.1	24.7aA±1.7
			Display case		
O_2		75.9aA±2.6	75.8aA±2.6	74.5aA±1.5	72.9bB±1.7
CO_2		23.9bA±1.9	24.1aAB±2.5	25.3aAB±0.4	26.8bB±0.8

a, b - average values in the column marked with different letters, for particular features, are significantly different at $\alpha \leq 0.05$. The letters refer to the differences between storage conditions.

A, B - average values in the row marked with different letters are significantly different at $\alpha \leq 0.05$. The letters refer to the differences between particular days of storage.

are summarized in Table 2. On day 1 of storage, PVC overwrap and MAP meat, both in the display case and in dark cold storage, presented characteristic bright pink color and no discoloration on the surface of the meat was observed. Odor was typical for fresh poultry meat (Table 2). Moreover, the meat was characterized by a small amount of drip loss (0.2-0.1% and 0.9-0.7% for the PCV overwrap and MAP meat, respectively; Table 3).

The quality of the meat in PVC overwrap meat and stored the display case deteriorated as storage time increased, as shown by the significantly ($p \leq 0.05$) lower scores for general appearance on days 7 and 8 of storage. On those days, the meat was characterized by grayish to yellowish color, discoloration, especially on the edges, and obvious drip loss (Table 2). In contrast, the general appearance of the meat maintained under dark cold storage did not under go such dramatic changes (scores were > 4.5 points on the day 8; Table 2). The lower general appearance scores obtained at the end of storage time by the PVC overwrap meat were determined by a continuous increase in the amount of drip loss (Table 3). Drip loss significantly increased ($p \leq 0.05$) on day 7 of storage in the display case and remained unchanged (1.8-2.1%) till the end of the experiment. High and increasing drip loss over time, particularly when exceeding the hygroscopic (water absorption) capacity of meat, deteriorates the appearance of packaged meat and limits its shelf life.

A significant ($p \leq 0.05$) and continuous disappearance of the specific odor of poultry meat was reported for the PVC overwrap meat stored in the display case as storage time compared with samples under dark cold storage (Table 2). At the end of storage period, the odor of the PVC overwrap meat stored in the display case was atypical, slightly sour, unpleasant, and sharp, and the meat showed signs of deterioration (most scores were approx. 2.0 points, Table 2). On the other hand, no significant differences in odor scores of the PVC overwrap meat under dark cold storage were detected during storage time (Table 2), with scores of ≥ 4.5 points. Storage conditions of PVC overwrap meat influenced its general appearance and odor starting from days 3 and 7, respectively (Table 2). PVC overwrap meat stored in display case (light exposure and temperature fluctuations) was characterized by significantly ($p \leq 0.05$) lower scores for both general appearance and odor on days 3, 7, and 8, and on days 7 and 8, respectively. Therefore, in comparison with the sensory quality of the meat stored in the display case, the meat under dark cold storage was characterized by high sensory quality until the end of the experiment (Table 2).

In case of breast muscles in MAP packages stored in the display case, the loss of fresh pink color (appearance of gray-pink color), and high drip loss were recorded. In addition, significantly ($p \leq 0.05$) lower general appearance scores were given on day 7 of storage, in comparison with days 1 and 3; however, these scores were not indicative of poor product quality (Table 2). On the last day of storage (day 8) MAP meat in the display case was still characterized by acceptable quality (scores >2.5 points). On the other hand, MAP meat under dark cold storage presented high quality throughout storage time (on the last day of storage, the general appearance average score was 4.7 points; Table 2).

The odor of the MAP meat in the display case significantly ($p \leq 0.05$) deteriorated with storage time, starting on day 7. Such changes were not detected in the MAP samples maintained in dark cold storage; however, lower odor score was obtained on day 8 compared with day 1 of storage (Table 2).

PVC overwrap meat stored in the display case presented lower general appearance scores at the end of the storage time due to continuous increase in drip loss (Table 3), reaching 3.4% on the last day of storage (day 8; Table 3). It should be noted that drip

Table 2 - Sensory quality of chicken breast muscles (mean ± standard deviation)

Characteristics [points]	Display case				Dark cold store			
	Day 1	Day 3	Day 7	Day 8	Day 1	Day 3	Day 7	Day 8
	PVC overwrap							
General appearance	4.8aA±0.3	4.3aAB*±0.3	2.9aB*±0.5	2.2aC*±0.2	4.9aA±0.1	4.8aA*±0.1	4.8aA*±0.1	4.6aA*±0.3
Odor	4.9aA±0.1	4.4aAB±0.2	3.0aB*±0.6	2.0aC*±0.1	4.8aA±0.2	4.6aA±0.2	4.5aA*±0.3	4.5aA*±0.4
	MAP packaging							
General appearance	4.9aA±0.2	4.6aA±0.3	3.5bB*±0.4	2.8bC*±0.4	4.9aA±0.2	4.8aA±0.2	4.8aA*±0.1	4.7aA*±0.1
Odor	4.8aA±0.2	4.3aAB±0.2	3.2aB*±0.6	2.7bC*±0.2	4.9aA±0.1	4.5aA±0.1	4.4aAB*±0.4	4.2aB*±0.5

a, b - average values in the column, for particular characteristics, marked with different letters are significantly different at $\alpha \leq 0.05$. The letters refer to the differences between particular methods of packaging.

A, B - average values in the row marked with different letters are significantly different at $\alpha \leq 0.05$. The letters refer to the differences between particular days of storage.

* - average values in the row, for particular days of storage, marked with * are significantly different at $\alpha \leq 0.05$. The letters refer to the differences between storage conditions.

loss in MAP packages on most of the analyzed days of storage was significantly higher ($p \leq 0.05$) compared with PVC overwrap. According to Arvanitoyannis & Stratakos (2012), the high free meat drip loss in MAP packaging maybe caused by the high oxygen levels. Storage conditions of MAP meat significantly ($p \leq 0.05$) influenced its general appearance and odor starting from day 7 (Table 2). MAP meat under dark cold storage was characterized by high sensory quality until the end of the experiment.

In the initial stages of storage in the display case (days 1, 3), MAP meat presented similar sensory quality as the PVC overwrap meat (Table 2). However, on days 7 and 8, significantly higher general appearance and odor scores ($p \leq 0.05$) were obtained for the MAP meat in comparison with PVC overwrap meat. Such differences were not observed between package types when the meat was maintained under dark cold storage.

Meat pH did not affect the observed changes in the sensory quality of PVC overwrap or MAP meat stored in the display case or under dark cold storage (Table 3). No differences ($p > 0.05$) in meat pH were detected between package types or storage days, and was maintained between 5.8 and 6.0 (Table 3). Similar results were obtained by Rossaint *et al.* (2015), who measured the pH of chicken breast muscles stored for 20 days under modified atmosphere consisting of 70% oxygen and 30% carbon dioxide. The initial pH of the breast muscles was typical for fresh poultry meat, which was within the range of 5.8 and 6.4 and did not change significantly throughout the whole storage period.

The instrumental color measurements did not match the changes in the color of the PVC overwrap and MAP meat samples during storage in the display case as assessed in the sensory evaluation. When stored in the display case, both PVC overwrap and MAP meat samples presented a slight, but significant ($p \leq 0.05$) decrease in lightness (L*) as storage time increased, with the lowest value determined on day 8 (Table 3). However, no significant ($p > 0.05$) differences in L*, a* and b*values were determined in meat packaged by both methods were maintained under dark cold storage (Table 3). Moreover, a* and b* values were not influenced ($p > 0.05$) by storage conditions or storage times. Rotabakk *et al.* (2006) and Chouliara *et al.* (2007) observed a similar effect when evaluating the color of breast muscles stored under atmospheric air. Those authors did not observe any significant differences in mean L* and b* values components during storage periods of 7 and 12 days, respectively. Cortez-Vega *et al.* (2012) also observed a reduction in the lightness of breast chicken muscles stored for 9 days under atmospheric air and during storage in a modified atmosphere composed of 50% O_2 and 50% CO_2. This shows that high-oxygen packaging is not required to preserve the color of white meat (Rossaint *et al.,* 2015). However, individual differences between the samples were noticeable because the color of poultry is influenced by several factors other than packaging conditions.

The obtained results are consistent with literature data. According to Rotabakk *et al.* (2006), samples stored in air developed unacceptable strong off-odors after 5 days of storage. Rossaint *et al.* (2015) reported,

Table 3 - Quality characteristics of analyzed chicken breast muscles (mean ± standard deviation)

Characteristics	Display case				Dark cold store			
	Day 1	Day 3	Day 7	Day 8	Day 1	Day 3	Day 7	Day 8
	PVC overwrap							
Drip loss [%]	0.2aA±0.4	1.0aAB±0.7	1.8aB±1.1	2.1aB±1.1	0.1aA±0.5	0.8aAB±0.3	1.6aB±1.0	1.9aB±0.9
L*	53.1aA±1.6	52.3aA±2.0	50.0aA±2.6	49.9aB±1.5	51.3aA±2.0	50.6aA±1.9	50.4aA±1.9	49.8aA±3.3
a*	3.5aA±0.8	3.5aA±0.9	3.2aA±1.0	3.0aA±1.0	2.9aA±0.5	3.3aA±0.9	2.4aA±1.2	2.6aA±1.1
b*	2.7aA±1.2	2.5aA±1.1	2.5aA±1.3	2.5aA±1.0	2.9aA±1.2	2.2aA±0.7	2.7aA±1.1	3.0aA±1.7
pH	5.9aA±0.1	5.8aA±0.2	5.8aA±0.1	5.9aA±0.1	5.9aA±0.1	5.9aA±0.1	5.9aA±0.1	6.0aA±0.2
	MAP packaging							
Drip loss [%]	0.9bA±0.2	2.3bB±0.3	3.3bBC±0.9	3.4bC±0.7	0.7bA±0.2	1.9bB±0.5	3.0bBC±0.7	3.2bC±0.5
L*	52.9aA±1.5	50.4aAB±1.5	50.4aAB±3.0	48.9aB±2.4	51.4aA±1.5	50.1aA±1.3	49.6aA±2.5	50.4aA±2.0
a*	4.2aA±1.4	3.7aA±0.8	3.3aA±1.2	3.2aA±1.3	3.4aA±1.1	3.5aA±0.9	2.5aA±1.1	3.1aA±0.9
b*	3.2aA±1.1	2.7aA±1.6	3.3aA±1.3	3.2aA±1.0	3.0aA±0.9	2.1aA±0.7	3.5aA±0.9	2.8aA±1.2
pH	5.9aA±0.1	5.8aA±0.1	5.8aA±0.1	5.9aA±0.1	5.8aA ±0.1	5.9aA ±0.1	6.0aA ±0.2	5.9aA ±0.1

a, b - average values in the column, for particular characteristics, marked with different letters are significantly different at $\alpha \leq 0.05$. The letters refer to the differences between particular methods of packaging.

A, B - average values in the row marked with different letters are significantly different at $\alpha \leq 0.05$. The letters refer to the differences between particular days of storage.

* - average values in the row, for particular days of storage, marked with * are significantly different at $\alpha \leq 0.05$. The letters refer to the differences between storage conditions.

that based on sensory assessment, the shelf life of MAP poultry meat was approximately 10 days. Also, Jongberg *et al.* (2014), evaluating the sensory quality of chicken breast muscles stored under modified atmosphere composed of 80% O_2 and 20% CO_2, observed a significant deterioration in the quality of sensory characteristics of meat after approximately 10 days of storage

CONCLUSIONS

The sensory characteristics of PVC overwrap meat stored in the display case were at the limit of acceptability on day 7 of storage, and presented unacceptable sensory quality on the last day of the evaluated storage period. Meat packaged in MAP and stored in the display case was characterized by acceptable, despite not the highest sensory quality, until the end of the experiment, or day 8 of storage. Therefore, based on the sensory quality, the meat packaged in MAP and stored in the display case allowed for the extension of its shelf life by at least 1 day compared with that packaged in PVC overwrap. Drip loss was significantly influenced by storage time and packaging method.

The results obtained in the present study confirm the crucial impact of storage conditions on meat quality. The meat packaged in MAP and stored in the display case was characterized by acceptable, despite not the highest sensory quality during the entire experiment, in comparison with the meat packaged in PVC overwrap, which showed signs of deterioration at the end of storage time. The meat maintained under dark cold storage presented high quality until the end of the experiment. The results indicate the need to monitor the operation of refrigerating appliances and storage conditions in wholesale and retail trade units, which are the final link in the production chain. This condition should be fulfilled to provide consumers with products of the desired quality and within the shelf life declared. However, in commercial practice, when possible, the display case should be constantly replenished with raw materials previously maintained under cold storage (warehouse) in order to reduce their exposure time. In addition, the number of meat portions should be limited in order to be sold after a relatively short time of exposure in the display cases. Furthermore, manufacturers specifying the shelf life should assume that the product offered to be sold will be exposed to extreme storage conditions, which may significantly affect its quality.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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