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EFFECT OF PACKAGING METHOD, STORAGE TIME AND CONDITIONS ON THE CHICKEN THIGHS QUALITY

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Summary. The aim of the study was to determine the effect of packaging method (PVC overwrap – in air, and under high-oxygen modified atmosphere – MAP), storage time and conditions (cooling room or display case) on the quality of chicken thighs. In MAP packages the gas mixture composition was measured. In all samples, the drip loss, pH of muscle tissue and L*, a*, b* color components of skin and muscle tissue were determined. It was found that along with the extension of storage time a tendency toward decreasing O_2 and an increasing in CO_2 content in MAP packages was observed. The amount of drip loss in MAP packaging for all days of storage was significantly higher ($p \leq 0.05$) in comparison to the PVC overwrap. Also the amount of drip loss systematically increased with the extension of storage time, regardless of the packaging method and storage conditions of raw material.

Key words: chicken thighs, MAP packaging, PVC overwrap packaging, quality

INTRODUCTION

Packing or dividing culinary meat into portions and further packing in individual or bulk packaging have become an essential step in the production process and commercial activity of meat plants [Kozačinski et al. 2012]. In meat industry, the most frequently used methods of fresh meat packing are as follows: packing in styrofoam trays that are wrapped with stretch-type film (PVC overwrap or in air), packing with the use of vacuum (VP), and packing under modified/protective atmosphere (MAP) [Latou et al. 2014]. In terms of culinary meat, the influence of applied technologies on packed raw material is diverse and refers to its many quality characteristics [Cortez-Vega et al. 2012, Säde et al. 2013]. In the case of cuts of chicken carcasses and poultry meat, they

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are rarely found as packed in vacuum. Still, the most common method of packing is placing culinary portions of meat in styrofoam trays, which are then wrapped with PVC foil. Stability of a product packed in such way, however, is short and lasts only few days [McMillin 2017]. The lack of an adequate barrier, hermetic seal, and the presence of leakage promote rapid changes in the quality of the product, its contamination, and mechanical damage, which limit its stability [Fraqueza et al. 2008, Byrd et al. 2011]. After a few hours of exposure in the display case, change in the color of the raw material is observed and its stability depends, inter alia, on temperature and characteristics of the light used [Keokamnerd et al. 2008]. Compared to other systems, the advantages of this packing system, however, cover low cost, easy application, and exposure in the display case [McMillin 2017]. For these reasons, this method is often preferred by commercial networks for packing culinary meat portions. Compared to packing in a PVC overwrap, MAP packaging provides longer time of storage, simultaneously maintaining appropriate quality. The disadvantage of products packed in MAP is that large packs occupy a larger storage space, which is associated with an increase in the cost of transport, storage, and in-store display [McMillin 2017]. Packaging using MAP technology involves a change in the composition of the atmosphere (or vacuum replacement) around the meat with appropriately chosen gas mixture. Most often, gasses used for this purpose are carbon dioxide (CO_2), nitrogen (N_2), and oxygen (O_2). The result of application of the above-mentioned gasses can be multidimensional, both positive and negative [Chouliara et al. 2007, Orkusz et al. 2017]. A properly selected composition of the gas mixture, depending on the type of packed meat, in combination with the influence of low temperatures, allows to extend its shelf-life [Rogers et al. 2014]. A critical condition to achieve this goal is a good initial quality of raw material and maintenance of hygienic conditions during the packaging process, as well as many other factors [Herbert et al. 2013]. Recently, in the market, there is an increasing proportion of poultry meat packed in MAP [Rossaint et al. 2014].

In the literature, there are only few papers on the comparison of the selected quality characteristics of chicken thighs (with skin and bone) packaged in PVC overwrap or using MAP and stored under different conditions. Therefore, the aim of this study was to determine the quality of chicken thighs with skin and bone, packed in PVC overwrap and in high-oxygen MAP (75% O_2 and 25% CO_2) and stored in the cooling room or in the display case (presence of light and temperature fluctuations and therefore simulating the conditions in commercial networks).

MATERIALS AND METHODS

Research material and organization

The study material consisted of chicken thighs (with skin and bone) obtained under industrial conditions, in accordance with applicable procedures, in a large-scale meat processing plant located in central Poland. The raw material was obtained in three experimental repetitions from three different slaughter days and further packed in accordance with the procedures of the meat processing plant. The chicken thighs were

packaged using the following two methods: PVC overwrap (in air) – meat was placed in polystyrene trays and overwrapped with an oxygen permeable polyvinyl chloride (PVC) film, and under high-oxygen modified atmosphere (MAP) consisting of 75% O_2 and 25% CO_2 – meat was placed in transparent semi-rigid trays made of PET/EVOH/PE (polyethylene terephtalate/ethylene vinyl alcohol/polyethylene), gas flushed and then, the trays were covered with a high barrier film made of PET/EVOH/PE (84 cm^3 m^{-2} 24 h^{-1} atm^{-1}, at 25°C and 70% RH). A total of 48 PVC overwrap and 48 MAP packages were prepared. Each packaging contained three or four chicken thighs with the total weight of approx. 500 g. The packing procedure was identical to that described by Chmiel et al. [2019].

After 24 h (day 1) since packing (after such time the raw material is usually supplied by the meat processing plant to retail stores), half of packages with chicken thighs (8 PVC overwrap and 8 MAP packages in each experimental serie) were placed in a closed, vertical display case (PAROS 2/1.3 DU, Igloo, Bochnia, Poland) under continuous light access – 24 h/day (LEDTUBE T8 Type: LT90NM-T-S-230 V 230 V/50 Hz/16.1 W) at an average temperature of 1.3°C (temperature in particular shelves of the display case ranged from 1.0 to 3.5°C). During storage, the samples on the display case shelves were randomly changed to minimize differences in temperature and light intensity. The temperature was recorded every 5 min using data loggers (EL-USB-2-LCD and EL-USB-2 models, Lascar Electronics Ltd., Erie, USA). The second half of packages with chicken thighs (8 PVC overwrap and 8 MAP packages in each experimental serie) was stored in a cooling room (0–2°C) without access to the light. Evaluation of the quality (drip loss, pH, L*, a*, b* color components) of chicken thighs stored in a cooling room or exposed in the display case was performed on days 1, 3, 7, and 8 of storage. On each day, two randomly chosen PVC overwrap and MAP packages from both storage conditions were selected for the analysis. In MAP packages the gas mixture composition was also measured.

Methods

Package headspace gas mixture composition. In MAP packages concentration of O_2 and CO_2 was measured using Check Point I portable gas analyzer (Dansensor, Poland). The accuracy of the analyzer was 0.25/2.0% for O_2/CO_2, respectively. Headspace gas mixture composition was measured by penetration with a syringe needle the lidding film using septum. A volume of 15 ml of the packaging atmosphere was taken twice until the readings were determined.

pH measurement. The pH was measured by punching the glass calomel electrode of pH meter (CP-411, Elmetron, Zabrze, Poland) directly into the tested chicken thighs (muscle tissue). Before the measurement, the device was calibrated using buffers of pH 4 and 7.

Drip loss. The amount of drip loss was determined according to Chmiel et al. [2018].

L*, a*, b* color components. Minolta CR200 colorimeter (Konica Minolta, Poland) was used for L*, a*, and b* color components measurement. Color components were

determined on the skin and muscle tissue of chicken thighs. The following device settings were used: illuminant D65, 10º observer, measuring head hole with size of 8 mm. Before measurements, the device was calibrated using white standard (L* 97.81; a* −0,45; b* +1.88). Each time, the measurement was made at five different locations on the surface of the skin or visible muscle tissue, taking the mean as a result of the measurement.

Statistical analysis

The obtained results were subjected to the statistical analysis using the STATISTICA software ver. 10 PL (StatSoft Inc., Tulsa, USA). The one-way ANOVA was conducted to determine the effect of storage time or storage conditions or packaging method on the selected chicken thighs quality characteristics. The detailed testing was conducted using Tukey's HSD test (significance level $\alpha = 0.05$).

RESULTS AND DISCUSSION

Gas mixture composition in MAP packages

Changes in the content of gas mixture composition in the MAP packages are presented in Table 1. Gas mixture composition in empty packages consisted of 73.0% O_2 and 24.3% CO_2. During the first day of storage of chicken thighs, the CO_2 content in MAP packages stored in the cooling room or display case was at a lower level (approximately 19%), and remained at similar level till day 7 (Table 1). According to Meredith et al. [2014], the initial decrease in CO_2 content in MAP packages in relation to empty packages may be caused due to the dissolving of some gas volume portion in the muscle and fat tissues of raw material. The CO_2 content in MAP packages with chicken thighs in the initial days of storage, both in cooling room or display case, however, remained below 20%. According to the literature [Rotabakk et al. 2006, Al-Nehlawi et al. 2013], an effective growth-inhibiting effect against microorganisms in the MAP method is achieved with CO_2 concentration 20–30% throughout the whole meat storage time, therefore, extending the shelf-life of meat. At the end of storage time (day 8), both in cooling room or display case CO_2 content was >20% and significantly ($p \leq 0.05$) higher in comparison with days 1–7 (Table 1), possibly as a result of microorganism growth and activity [Rossaint et al. 2015].

Along with the extension of storage time of chicken thighs, both in cooling room or display case, a tendency toward decreasing O_2 and an increasing in CO_2 content in MAP packages was observed. At the end of storage time (day 7 in cooling room and days 7 and 8 in display case) O_2 content was significantly ($p \leq 0.05$) lower in comparison with other days of storage. It was also found that in MAP packages stored for 8 days in display case CO_2 level was significantly ($p \leq 0.05$) higher in comparison with packages from the cooling room (Table 1). The successive reduction in the O_2 content and increase in CO_2 content could be caused by, i.e. microorganisms that used O_2 during their life processes and produced CO_2, by O_2 consumption through own meat enzymes, heme pigments, and the exchange of gasses between the packaging and the

Table 1. Gas mixture composition in MAP packages (mean ±standard deviation)

Tabela 1. Skład mieszaniny gazów w opakowaniach MAP (średnia ±odchylenie standardowe)

Gas content [%] Zawartość gazu [%]	Empty package Puste opakowanie	Cooling room / Chłodnia				Display case/Regał chłodniczy			
		day 1 dzień 1	day 3 dzień 3	day 7 dzień 7	day 8 dzień 8	day 1 dzień 1	day 3 dzień 3	day 7 dzień 7	day 8 dzień 8
O_2	73.0 ±0.9	76.1^{a} ±1.3	75.6^{a} ±2.0	72.7^{a} ±1.4	71.2^{b} ±0.5	75.8^{a} ±3.2	75.2^{a} ±1.8	71.4^{b} ±1.6	70.4^{b} ±1.7
CO_2	24.3 ±1.1	19.2^{a} ±0.5	19.0^{a} ±1.1	20.2^{a} ±2.1	21.9^{b*} ±0.6	18.8^{a} ±1.1	19.3^{a} ±0.9	22.3^{a} ±1.9	24.8^{b*} ±1.4

a, b, c – mean values in the row marked with different letters are significantly different at $p \leq 0.05$. The letters refer to the effect of storage time on the changes in gas mixture composition, for particular storage conditions. * – average values in the row, for particular days of storage, marked with * are significantly different at $p \leq 0.05$. The letters refer to the effect of storage conditions on the changes in gas mixture composition.

a, b, c – średnie wartości w wierszu oznaczone różnymi literami różnią się istotnie przy $p \leq 0{,}05$. Litery odnoszą się do wpływu czasu przechowywania na zmiany w składzie mieszaniny gazów, dla poszczególnych warunków przechowywania. * – średnie wartości w wierszu, dla poszczególnych dni przechowywania, oznaczone * różnią się istotnie przy $p \leq 0{,}05$. Litery odnoszą się do wpływu warunków przechowywania na zmiany w składzie mieszaniny gazów.

environment [Rossaint et al. 2015]. Similar tendencies obtained in this study were also observed by Chmiel and Słowiński [2018] and Chmiel et al. [2019] during storage of chicken breast meat in MAP packages.

Quality characteristics

Changes in the selected quality characteristics of chicken thighs are presented in Table 2. No differences in muscle tissue pH were detected between raw material packaged in a PVC overwrap or in MAP packages and during storage, both in cooling room or display case. The muscle tissue pH remained at the level of 6.1–6.3. A small differences observed in pH resulted from inter-individual variability between chickens from which the thighs were collected. Similar results were obtained by Dogu-Baykut and Gunes [2014]. In their studies, the storage time and the packaging method (under vacuum or in MAP) also had no effect on pH of chicken thighs.

At the beginning of storage (day 1), chicken thighs were characterized by a small amount of drip loss. In case of PVC overwrap it was 0.1 and 0.1% for meat stored in a cooling room or display case, respectively. For chicken thighs packed in MAP drip loss on day 1 amounted to 0.9 and 1.1% for raw material stored in a cooling room and in a display case, respectively (Table 2).

With extension of storage time steadily increasing amount of drip loss in the PVC overwrap and MAP packages was observed. The amount of drip loss in PVC overwrap significantly ($p \leq 0.05$) increased, in comparison to day 1, on days 7 and 8 (both in cooling room and display case) of storage, reaching 1.5% on day 8 in display case (Table 2). For raw material in MAP packages, a significant increase in the amount of drip loss was observed on day 8 (cooling room) and days 3–8 (display case). At the

Table 2. Selected quality characteristics of chicken thighs (mean ±standard deviation)

Tabela 2. Wybrane wyróżniki jakości ud kurcząt (średnia ±odchylenie standardowe)

Characteristics Wyróżnik	Cooling room / Chłodnia				Display case / Regał chłodniczy			
	day 1 / dzień 1	day 3 / dzień 3	day 7 / dzień 7	day 8 / dzień 8	day 1 / dzień 1	day 3 / dzień 3	day 7 / dzień 7	day 8 / dzień 8
PVC overwrap / Tacka								
pH	6.1aA ±0.2	6.1aA ±0.1	6.2aA ±0.1	6.3aA ±0.2	6.2aA ±0.1	6.2aA ±0.1	6.2aA ±0.1	6.3aA ±0.2
Drip loss [%] Ilość wycieku do opakowania [%]	0.1aA ±0.1	0.3aA ±0.1	1.0bA ±0.3	1.1bA ±0.2	0.1aA ±0.1	0.4aA ±0.2	0.9bA ±0.2	1.5cA ±0.3
Skin color / Barwa skóry								
L*	72.2aA ±1.9	71.6aA ±1.7	69.9aA ±2.0	69.5aA ±1.1	70.3aA ±3.9	69.6aA ±2.6	67.4aA ±2.4	68.2aA ±2.1
a*	3.8aA ±0.9	3.5aA ±1.1	3.4aA ±1.0	3.2aA ±1.8	3.2aA ±1.0	3.3aA ±1.0	3.4aA ±1.3	3.0aA ±1.9
b*	5.1aA ±1.4	4.9aA ±2.5	4.0aA ±2.0	4.5aA ±1.9	4.3aA ±2.0	4.0aA ±2.3	6.9aA ±1.8	5.0aA ±2.1
Muscle tissue color / Barwa tkanki mięśniowej								
L*	55.6aA ±1.7	54.1aA ±1.2	53.5abA ±2.0	50.1bA ±1.8	53.2aA ±1.9	52.3aA ±1.5	51.4abA ±2.3	49.7bA ±2.9
a*	10.5aA ±1.1	10.7aA ±2.8	9.0aA ±1.5	8.9aA ±2.3	9.5aA ±1.4	9.7aA ±1.8	9.2aA ±1.2	10.5aA ±3.1
b*	6.9aA ±1.5	7.1aA ±0.9	6.7aA ±1.3	5.3aA ±1.8	4.9aA ±1.2	5.2aA ±0.9	4.9aA ±1.6	4.3aA ±1.4
MAP packages / Opakowania MAP								
pH	6.1aA ±0.1	6.1aA ±0.2	6.2aA ±0.1	6.2aA ±0.1	6.1aA ±0.2	6.2aA ±0.2	6.1aA ±0.1	6.2aA ±0.1
Drip loss [%] Ilość wycieku do opakowania [%]	0.9aB ±0.2	1.2aB ±0.5	1.7abB* ±0.3	2.9bB ±0.6	1.1aB ±0.1	2.0bB ±0.4	3.0bB* ±0.3	2.8cB ±0.5
Skin color / Barwa skóry								
L*	73.8aA ±1.1	72.2abA ±3.1	70.6abA ±2.2	69.7bA ±1.9	70.8aA ±1.7	69.0abA ±3.0	67.9abA ±3.2	65.8bA ±2.9
a*	4.6aA ±0.8	4.4aA ±1.2	4.9aA ±2.0	3.9aA ±2.5	3.6aA ±0.9	3.5aA ±1.5	3.9aA ±1.2	2.9aA ±2.2
b*	5.6aA ±1.8	6.0aA ±1.6	5.8aA ±2.4	5.3aA ±1.2	4.7aA ±2.0	5.0aA ±1.9	4.7aA ±2.2	4.6aA ±1.8
Muscle tissue color / Barwa tkanki mięśniowej								
L*	58.2aA ±2.5	55.6abA ±1.3	55.3abA ±2.3	53.7bA ±1.5	53.4aA ±2.1	51.3abA ±3.3	51.1abA ±1.3	48.7bA ±1.8
a*	11.5aA ±1.7	11.7aA ±2.2	12.1aA ±3.3	11.4aA ±1.0	10.2aA ±1.4	10.3aA ±1.9	11.1aA ±3.2	10.4aA ±1.4
b*	6.8aA ±1.2	7.5aA ±1.8	6.9aA ±1.7	6.5aA ±1.4	5.6aA ±1.5	6.4aA ±1.9	5.9aA ±1.2	5.7aA ±1.1

[a, b, c] – mean values in the row marked with different letters are significantly different at $p \leq 0.05$. The letters refer to the effect of storage time on the changes in chicken thighs quality, separately for raw material packed in PVC overwrap and MAP, for particular storage conditions. [A, B] – mean values in the column, for particular characteristics, marked with different letters are significantly different at $p \leq 0.05$. The letters refer to the effect of packaging system on the changes in chicken thighs quality, separately for raw material stored in cooling room or display case, for particular days of storage. [*] – mean values in the row, for particular days of storage, marked with * are significantly different at $p \leq 0.05$. The letters refer to the effect of storage conditions on the changes in chicken thighs quality, separately for raw material packed in PVC overwrap and MAP.

[a, b, c] – średnie wartości w wierszu oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$. Litery odnoszą się do wpływu czasu przechowywania na zmiany w jakości ud kurcząt, osobno dla surowca pakowanego na tacce i w MAP, dla poszczególnych warunków przechowywania. [A, B] – średnie wartości w kolumnie, dla poszczególnych wyróżników, oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$. Litery odnoszą się do wpływu sposobu pakowania na zmiany w jakości ud kurcząt, osobno dla surowca przechowywanego w chłodni i regale chłodniczym, dla poszczególnych dni przechowywania. [*] – średnie wartości w wierszu, dla poszczególnych dni przechowywania, oznaczone * różnią się istotnie przy $p \leq 0,05$. Litery odnoszą się do wpływu warunków przechowywania na zmiany w jakości ud kurcząt, osobno dla surowca pakowanego na tacce i w MAP.

end of storage time, both in cooling room or display case, the amount of drip loss in MAP packages was established at the level of approximately 3%. According to Abdalhai et al. [2014], the extension of the storage time has a negative impact on the quality of meat, causing increased drip loss. A large and increasing amount of leakage, especially when it exceeds the capacity of the hygroscopic (absorption) insert, worsens the appearance of packaged meat and limits its stability.

The amount of drip loss in MAP packages for all days of storage was significantly higher ($p \leq 0.05$) in comparison to the PVC overwrap. Similar tendencies were observed by Chmiel and Słowiński [2018] during storage of chicken breast meat packed in PVC overwrap and under high-oxygen MAP. An increased amount of drip loss could be caused by high (~ 75%) O_2 content in the MAP packages. One of the possible causes of drip loss may be changes in proteins, including enzymes that reduce their capacity to retain the water, and changes in the structure of capillaries of myofibrils during storage of the meat [Al-Nehlawi et al. 2013].

There were no significant ($p > 0.05$) differences between amount of drip loss in PVC overwrap packages stored in cooling room or display case. For MAP packages a significant difference was observed only on day 7 (Table 2). According to Chmiel et al. [2018] the amount of drip loss in the PVC overwrap packages was higher in case of the chicken breast meat stored in the display case as compared to that stored in the cooling room.

There were no clear changes in the L*, a* and b* color components of skin of the chicken thighs packed in PVC overwrap. However, in the case of skin color of the raw material packed in MAP it was observed a significant ($p \leq 0.05$) reduction of the L* color component (lightness) on the last day of storage, irrespective of storage conditions (Table 2). In case of muscle tissue color it was only observed that L* color component decreased as storage time increased, for thighs in PVC overwrap or MAP packages stored in cooling room or display case, reaching significantly ($p \leq 0.05$) lower value in comparison to day 1 at the end of the experiment (Table 2). However, no significant differences ($p > 0.05$) in a* and b* color components of skin and muscle tissue of chicken thighs between the two packaging methods, storage conditions and storage time were found (Table 2). No changes in the values of a* and b* color components of chicken breast meat during storage in PVC overwrap or high-oxygen MAP were also observed by Chmiel and Słowiński [2018].

CONCLUSIONS

The gas composition in the MAP packages has changed during the storage. Along with the extension of the storage time, a progressive decrease in the O_2 content and an increase in the CO_2 content in the packages were observed. These changes, especially at the end of the storage time, could be caused by the development and activity of microorganisms using O_2 for their life processes and producing CO_2.

Among the selected quality characteristics, the storage time and packing method had a significant effect only on the amount of drip loss into the packages with the chicken thighs. As the storage time of chickens' thighs was extended, the amount of drip loss increased (regardless of the storage conditions and packaging method) and it was higher

with the use of MAP packaging compared to the PVC overwrap. There was no clear effect of the above-mentioned factors on the pH of the muscle tissue. Packing in MAP with a high oxygen content also does not seem necessary to improve the color of the skin or muscle tissue of chicken thighs, due to the lack of unequivocal changes in the L*, a* and b* color components.

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WPŁYW SPOSOBU PAKOWANIA, CZASU I WARUNKÓW PRZECHOWYWANIA NA JAKOŚĆ UD KURCZĄT

Streszczenie. Celem pracy było określenie wpływu sposobu pakowania (na tacce oraz w atmosferze modyfikowanej z wysoką zawartością tlenu – MAP), czasu oraz warunków przechowywania (chłodnia lub regał chłodniczy) na jakość ud kurcząt. W opakowaniach MAP dokonano pomiaru stężenia gazów. We wszystkich próbkach oznaczono ilość wycieku do opakowania, dokonano pomiaru pH tkanki mięśniowej oraz składowych barwy L*, a* i b* zarówno skóry, jak i tkanki mięśniowej. Stwierdzono, że wraz z wydłużeniem czasu przechowywania obserwowano tendencję do obniżania się zawartości O_2 i wzrostu zawartości CO_2 w opakowaniach MAP. Ilość wycieku do opakowania MAP dla wszystkich dni przechowywania była istotnie wyższa ($p \leq 0{,}05$) w porównaniu z ilością wycieku do opakowania typu tacka. Wraz z wydłużaniem czasu przechowywania systematycznie wzrastała również ilość wycieku do opakowania, niezależnie od sposobu pakowania i warunków przechowywania surowca.

Słowa kluczowe: uda z kurcząt, pakowanie MAP, pakowanie na tacce, jakość