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Selected freshness indices of skin and wings from organic chicken packaged in modified atmosphere

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Abstract

This study is part of a project aiming to optimize storage conditions for organic chicken meat. Selected indices of skin and wings from organic chicken were evaluated. A total of 24 samples were packaged in MAP-O_2 (80% O_2/20% CO_2), 24 samples in MAP-N_2 (70% N_2/30% CO_2) and 48 samples as a control. The samples were analysed on days 2, 7, 10 and 14 of storage during a 14-day storage period at 2 ± 2 °C. The surface colour of skin (L*a*b*), ammonia content, thiobarbituric acid reactive substances content (TBARS) and antioxidant capacity were assessed. The lightness values (L*) for chicken skin in MAP-O_2were increased on days 7 and 10 of the storage period, and were significantly ($P< 0.05$) higher than in the samples in MAP-N_2 and the control. Significant increases of TBARS were observed in the samples in MAP-O_2 from day7 and these values continued to increase until the end of the storage period. The antioxidant capacities of the samples in MAP-O_2 were mostly lower than those of the samples in MAP-N_2. Our results indicate that MAP-O_2only had a positive effect on skin colour, whereas MAP-N_2 maybe preferable for shelf-life prolongation.

Organic system, broiler chicken, shelf life, colour

The skin constitutes around 15% of the broiler carcass (Hayse and Marion 1973), while the yield of the wings is approximately 10% (Kokoszynski et al. 2013). The percentage of fat in the skin of broilers without adipose tissue is about 20–30%. The fat of poultry is characterized by a high proportion of unsaturated fatty acids and less cholesterol than fats from red meat, for which reason the market in edible chicken fat should thrive (Sheu and Chen 2002). The wings are usually consumed as muscle together with the skin. The proportion of skin in the wings is the highest of all culinary chicken meat portions, representing around 22%, i.e. twice the amount in the thighs (Tomaszewska-Gras and Konieczny 2010).

The effect of organic rearing systems on the colour indices and chemical composition of chicken skin and wings has been reported. The skin of organic chicken is more yellow and has a higher lipid content than the skin of conventional chicken (Abdullah and Buchtova 2017). The higher lipid content is reflected in the thickness and yellowish colour (higher b*) of skin from organic production systems (Sirri et al. 2010). The nutrition of organic poultry, consisting of high consumption of plant material rich in carotenoid pigments, is the main factor contributing to the yellowish colour of the skin (Fanatico et al. 2005). Our previous study (Abdullah and Buchtova 2016) indicated that the qualitative and quantitative properties of wings from organic broilers are different from those in conventional chickens. Although the shelf life of fresh chicken is limited primarily by bacterial growth (Hulanková et al. 2018), it has been indicated that organic chicken meat contains a larger amount of free radicals and has a shorter shel flife. Excessive carcass processing should, therefore, be avoided and a reduced storage period is recommended (Castellini et al. 2006).

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Modified atmosphere packaging (MAP) is one of the most commonly applied methods for extending the shelf life of meat (Paramithiotis et al. 2009). Although various compositions of oxygen (25–90%) and carbon dioxide (15–80%) can be used, the commonest combination is 80% O_2/20% CO_2(McMillin 2008). O_2 is not essential for chicken meat and could lead to differences in taste and smell, as in the case of turkey meat (Floros and Matsos 2005), though it inhibits the growth of anaerobic bacteria (D'Aoust 1991). Increased lipid oxidation is one of the disadvantages of a high-oxygen combination. Lipid oxidation determines meat quality and acceptability (Balamatsia et al. 2007). The mixture of gases in MAP has positive and negative effects on meat colour. Preservation of the bright red colour of meat is one of the advantages of a high-oxygen atmosphere (Lund et al. 2007). The main disadvantage of a high CO_2 concentration observed is a certain degree of darkening as a result of myoglobin formation (Luno et al. 1998).

Very few studies have, to our knowledge, considered the impact of MAP on the skin and wings of chicken, particularly from organic rearing systems. The aim of this study was to observe the effect of high-oxygen MAP used by the producer (an organic farm) as compared to oxygen-free MAP (usually used for packaging chicken meat) on selected physical and chemical properties of the skin and wings of organic chicken.

Materials and Methods

Sample preparation and storage

This experimental analysis was carried out at the Department of Meat Hygiene and Technology (DMHT) at the Faculty of Veterinary Hygiene and Ecology, University of Veterinary and Pharmaceutical Sciences Brno (Czech Republic). Half-carcasses of fresh chicken (*Colour yield* hybrid), including the bone, muscle and skin, meeting the requirements laid down in regulation (EC) No. 889/2008,were obtained from an organic production farm (Biopark s.r.o., Lipova, Czech Republic) one day post slaughter. Chicken slaughter and processing were performed by the producer in compliance with Regulations (EC) Nos. 1099/2009 and 853/2004. The total number of analysed samples was 96 (half-carcasses of chicken). A total of 24 samples were packaged in MAP-O_2 (80% O_2/20% CO_2) using a Turbovac 320-ST-S (HFE Vacuum Systems, 's-Hertogenbosch, the Netherlands) and another 24 samples were packaged at the DMHT in MAP-N_2 (70% N_2/30% CO_2) using a Vac-Star S-223 GSL (Vac-Star CZ s.r.o., Pardubice, Czech Republic). Protective sheet [film Ergo.top-11mod/120 μm/flat-film, 5-layer coex film with the structure PA/Tie/EVOH/Tie/PE (Vepak, s.r.o., Brno, Czech Republic)] was used for packaging both MAPs. A total of 48 samples (24 for each MAP type) were aerobically packaged as a control using polyolefin film stretched over the tray. All the samples were stored at a temperature of 2 ± 2°C for 14 days. The sampling was conducted on day 2 of storage and repeated on days 7, 10, and 14 of storage. Six samples from MAP and six control samples were taken for analysis on each sampling day. The skin of the breasts and thighs was dissected from each carcass. The wings were separated from the carcasses at the shoulder joint and deboned (drumette and wing flat) after removal of the wing tip. Evaluation of selected freshness parameters – colour indicators (for the external surface of the skin), ammonia, thiobarbituric acid reactive substances content (TBARS) and antioxidant capacity –was performed on the skin (from the breast and thigh) and wings (muscles with skin). Samples were taken for the antioxidant capacity test from the same local area of the skin and the forearm muscle of the wing. Samples were put in 2-ml Eppendorf tubes and stored in a refrigeratorat acontrolled temperature (-70 °C) until analysis.

Measurement of gases

Measurement of gas concentrations in MAP-O_2 and MAP-N_2 was conducted by the insertion of a probe inside the packaging atmosphere using a Check Point II gas analyser (PBI Dansensor AS, Ringsted, Denmark). Two measurements were performed for each sample.

Colour indicators

Colour indicators (lightness, L*; redness, a*; yellowness, b*) of the raw external surface of the skin were measured according to the CIE L*a*b* system using a Minolta CM 2600d (Konica Minolta, Tokyo, Japan). Software (Spectra Magic 3.61) was used to calculate the variables, and the mean standard deviation ± (SD) of five measurements for each sample was reported.

Ammonia

The ammonia content was determined by the Conway method (microdiffusion followed by titration with sulphuric acid after displacement of ammonia into boric acid with potassium carbonate) (Helclová et al. 1990).

Thiobarbituric acid reactive substances content (TBARS)

A distillation method was used to determine TBARS; the oxidation products were quantified as malondialdehyde equivalents (Castellini et al.2002).

Antioxidant capacity

The antioxidant capacity was determined using the free radical scavenging ability of 2,2-diphenyl -1-picrylhydrazyl (DPPH) according to Heilerova et al. (2003). Preparation of the meat extract was performed according to Jung et al. (2010) with some modifications. Five ml of 5% trichloroacetic acid were added to 1 gram of meat sample and 3.33 ml of chloroform were added after homogenization (1130 × *g*/1 minute) in an ice bath. A fresh solution of radical stock solution was prepared daily. A solution of DPPH in methanol ($0.025 g \cdot l^{-1}$) at a volume of 3.8 ml was pipetted into a 1-cm cuvette and absorbance value A_0 measured against a blank at 515 nm using a GENESYSTM6 spectrophotometer (Thermo Electron Corporation, Beverly, USA). The meat extracts (200 µl) were added to the cuvette containing the DPPH solution (3.8 ml), and the absorbance was measured after 10 min (A_{10}). The measurements were performed in two replications.

The inhibition percentage of the DPPH radical by the samples was calculated according to the formula: % inhibition = $\{A_0 - A_{10} / A_0\} \times 100$

where A_0 is the absorbance of the control at t = 0 min;

A_{10} is the absorbance of the antioxidant at t = 10 min.

Statistical analyses

The analyses were conducted using Microsoft Office Excel 2003. Significance ($P < 0.05$) was estimated by *t*-test and ANOVA analysis of variance, with a *posthoc* Tukey test to find differences between independent variances using UNISTAT 6.0 (Unistat® Limited, London, England). All results in Figs 1–7 and Tables 1–4 of this study were used in the dissertation theses of the first author (Abdullah 2017).

Results

MAP gases

In MAP-O_2, the amount of O_2decreased significantly ($P < 0.05$) from day 7 of storage, whereas the amount of CO_2increased significantly ($P < 0.05$) from day 10 of storage. In MAP-N_2, the CO_2 percentage fell, while the percentage of N_2 was significantly increased on day 7 of storage ($P < 0.05$) (Table 1).

Table 1. Gas mixture composition (ratio in %, mean ± SD) in MAP-O_2 and MAP-N_2.

Gases in %		2nd day	7th day	10th day	14th day	Significance
MAP-O_2	O_2	81.53 ± 2.06^{c}	79.53 ± 3.25^{ab}	78.64 ± 3.13^{b}	75.28 ± 1.62^{a}	*
	CO_2	15.78 ± 1.07^{a}	17.18 ± 1.74^{ab}	18.41 ± 2.07^{b}	21.76 ± 1.23^{c}	*
	rest gas	2.69 ± 1.01	3.28 ± 1.25	2.94 ± 1.09	2.92 ± 0.75	NS
MAP-N_2	N_2	72.12 ± 0.47^{a}	79.43 ± 1.40^{b}	79.23 ± 1.40^{b}	78.56 ± 0.71^{b}	*
	CO_2	27.53 ± 0.60^{b}	20.06 ± 1.58^{a}	20.72 ± 1.49^{a}	21.42 ± 0.72^{a}	*
	O_2	0.33 ± 0.23^{b}	0.29 ± 0.26^{b}	0.05 ± 0.09^{a}	0.02 ± 0.03^{a}	*

MAP-O_2 modified atmosphere packaging (80% O_2/20% CO_2); MAP-N_2 modified atmosphere packaging (70% N_2/30% CO_2); values in the same row with different superscripts $^{a, b, c}$ are significantly different among 2nd, 7th, 10th, 14th days of storage; values in the same column with different superscripts $^{A, B, C}$ are significantly different among MAP-O_2, MAP-N_2 and control;* $P < 0.05$; NS - not significant.

Colour indicators

The lightness values (L*) for the skin of the breast in MAP-O_2 increased on days7 and 10 of the storage period, and were significantly higher ($P < 0.05$) than inthe samples in MAP-N_2 and the control (Fig. 2). Generally, the redness (a*) values of chicken skin decreased during the storage period, with at least significant differences in the skin of the breast under MAP-O_2, the skin of the thigh under MAP-N_2 and under the control atmosphere (Figs 4 and 5). On the last storage day, the control samples were significantly

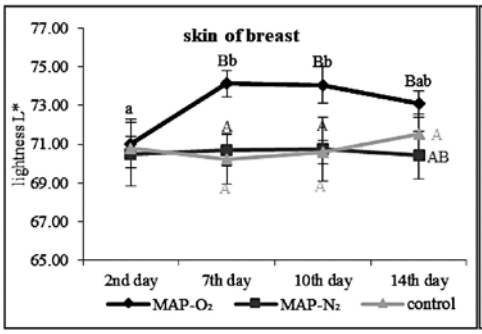

Fig. 2. Skin of breast

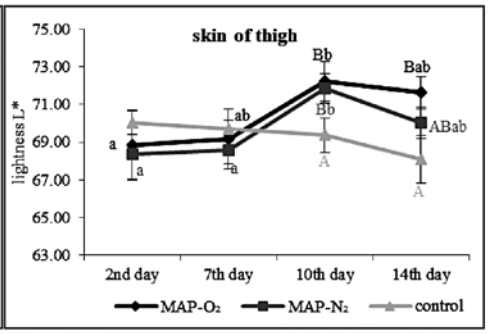

Fig. 3. Skin of thigh

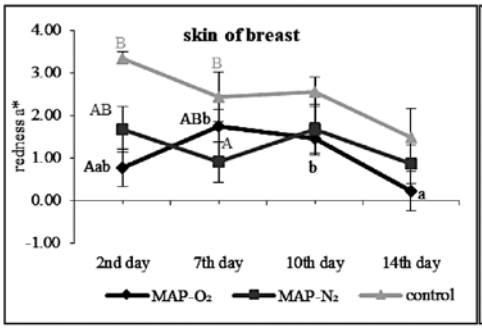

Fig. 4. Skin of breast

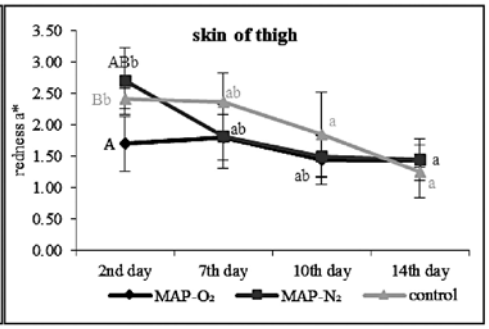

Fig. 4. Skin of breast

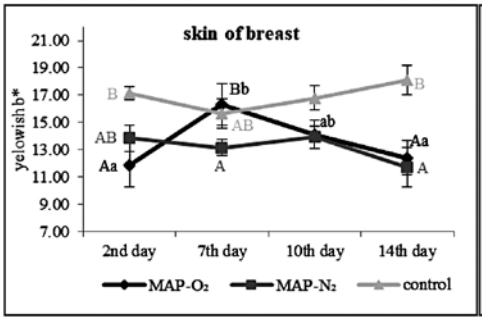

Fig. 6. Skin of breast

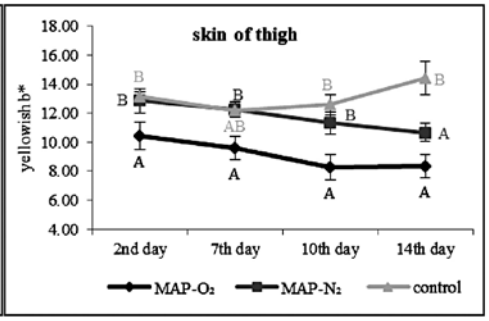

Fig. 7. Skin of thigh

Figs 2–7: MAP-O_2 modified atmosphere packaging (80% O_2/20% CO_2), MAP-N_2 modified atmosphere packaging (70% N_2/30% CO_2), values of the colour indices (lightness L*, redness a*, yellowish b*) of breast and thigh skin with different superscripts $^{a, b, c}$ are significantly different ($P < 0.05$) among 2nd, 7th, 10th, 14th days of storage, values with different superscripts $^{A, B, C}$ are significantly different ($P < 0.05$) among MAP-O_2, MAP-N_2 and control.

($P < 0.05$) more yellow (higher b*) than the samples under both MAPs (Figs 6 and 7) and this fact was also noted by the naked eye (Plate XVI, Fig. 1).

Ammonia content

The amount of ammonia in the samples under MAP-N_2 was more constant; it remained constant until day 10 in the skin and up to the end of the storage period in the wings. The ammonia content in the control samples increased significantly ($P < 0.05$) from day 7 of

storage and was consistently significantly higher than in the samples under both MAP (Table 2).

Content of TBARS

In general, the TBARS values in the samples in MAP-N_2 were the lowest, except for day 2 (the skin of the thigh and wing), when the lowest values were found in the control samples. The samples of wings under MAP-N_2 were protected from secondary lipid oxidation, with no significant elevation in the TBARS level during the storage period. Significant increases inTBARS were observed in the MAP-O_2 samples from day 7and the values continued to increase up to the end of the storage period (Table 3).

Antioxidant capacity

The DPPH percentage inhibition values in theskin and wing samples in MAP-O_2 were mostly lower than in the samples in MAP-N_2. The antioxidant capacity showed an increasing trend from day 2 to day 10 of storage and then fell, particularly in the samples under MAP-N_2 (Table 4).

Discussion

MAP gases

A decrease in O_2 in MAP-O_2 was also observed by Tománková et al. (2012). According to Balamatsia et al. (2007), there are many factors related to the exhaustion of O_2 and conversion to CO_2, including the rapid growth and metabolism of bacteria, the enzymatic activity of muscle and the decarboxylation of biogenic amines. It can be assumed that the decreasing oxygen content in MAP-O_2 from day 7 of storage may be related to the demonstrated massive development of microorganisms on the skin of the breasts and thighs (Hulankova et al. 2018). Atmospheric changes in MAP-N_2 are due to the natural interaction of the gases present with the packaged chicken portion.The reaction of carbon dioxide with the water in meat juice produces carbonic acid, for which reason its volume in MAP-N_2decreases slightly. The observed changes in the composition of the gas mixture in MAP are common and are not relevant to the shelf life of the packaged meat, as a sufficient excess of the gas mixture is applied to the MAP.

Colour indicators

Colour is an important quality characteristic of fresh meat which has a major influence on retail purchase decisions. The mixture of gases in MAP has positive and negative effects on the colour parameters of meat (Lund et al. 2007). Lower (L*) values for breast skin in MAP-N_2 (Figs 1 and 2) could be due to the negative effect (colour deterioration) of CO_2 as a result of metmyoglobin formation (Hur et al. 2013). The reduction of redness resulted from the formation of reactive oxygen species and free radicals developmental myoglobin oxidation (during lipid peroxidation), leading to a rancid odour and surface discoloration (Filgueras et al. 2010). However, a similar decrease of redness values in chicken skin under MAP was found by Tománková et al. (2012). An increase in the b* value during cold storage could be due to changes in meat pigmentation resulting from metmyoglobin synthesis (Jouki and Khazaei 2012). Saucier et al. (2000) indicated that an increase to the yellowish (b*) parameter of stored poultry meat is due to progressing processes of meat spoilage and, in particular, oxidative processes that occur in chicken meat in spite of the use of oxygen-free MAP packaging. Our results show a clearer influence of both MAPs on the yellowish (b*) parameter than their effect on redness (a*),which could be attributed to the chemical composition of chicken skin which is characterized by a high lipid and low myoglobin content. However, the changes of skin colour demonstrated instrumentally and observed optically (Fig. 1) may be related more to the development of contaminating

Table 2. Ammonia values (mg/100g, mean ± SD) of skin and wings of chicken in MAP-O_2, MAP-N_2 and control.

Indices		2nd day	7th day	10th day	14th day	Significance
Skin of breast	MAP-O_2	12.41 ± 1.96^{ABa}	14.21 ± 2.36^{Aab}	15.30 ± 3.86^{Aab}	17.79 ± 0.63^{Ab}	*
	MAP-N_2	14.56 ± 4.19^{Ba}	13.20 ± 3.51^{Aa}	12.52 ± 1.64^{Aa}	17.85 ± 5.57^{Ab}	*
	control	11.40 ± 2.33^{Aa}	20.91 ± 4.31^{Bb}	30.97 ± 6.26^{Bc}	42.74 ± 6.55^{Bd}	*
Significance		*	*	*	*	-
Skin of thigh	MAP-O_2	12.07 ± 2.51^{ABa}	12.92 ± 0.48^{Aab}	$15.64 \pm 2.52Ab$	21.70 ± 1.62^{Bc}	*
	MAP-N_2	12.71 ± 3.44^{Ba}	13.62 ± 1.45^{Aab}	12.64 ± 1.95^{Aa}	15.90 ± 3.94^{Ab}	*
	control	10.57 ± 2.38^{Aa}	20.58 ± 4.66^{Bb}	33.43 ± 10.75^{Bc}	54.70 ± 5.79^{Cd}	*
Significance		*	*	*	*	-
Wing	MAP-O_2	15.65 ± 2.18^{a}	19.27 ± 3.56^{Aab}	23.38 ± 5.70^{Ab}	24.14 ± 1.93^{Ab}	*
	MAP-N_2	14.94 ± 2.29	17.91 ± 7.90^{A}	16.38 ± 2.46^{A}	18.47 ± 4.09^{A}	NS
	control	15.05 ± 2.13^{a}	30.16 ± 8.12^{Bb}	46.50 ± 13.02^{Bc}	58.06 ± 7.88^{Bd}	*
Significance		NS	*	*	*	-

MAP-O_2 modified atmosphere packaging (80% O_2/20% CO_2); MAP-N_2 modified atmosphere packaging (70% N_2/30% CO_2); values in the same row with different superscripts $^{a, b, c}$ are significantly different among 2nd, 7th, 10th, 14th days of storage; values in the same column with different superscripts $^{A, B, C}$ are significantly different among MAP-O_2, MAP-N_2 and control;* $P < 0.05$; NS - not significant.

Table 3. Thiobarbituric acid reactive substances (mg MDA·kg^{-1}, mean ± SD) of skin and wings of chicken in MAP-O^2, MAP-N^2 and control

Indices		2nd day	7th day	10th day	14th day	Significance
Skin of breast	MAP-O_2	9.48 ± 2.59^{Ba}	22.13 ± 2.26^{Bb}	30.00 ± 6.76^{Bc}	32.50 ± 6.84^{Cc}	*
	MAP-N_2	3.79 ± 0.42^{Aa}	8.64 ± 2.95^{Ac}	5.75 ± 0.90^{Ab}	5.91 ± 1.04^{Ab}	*
	control	4.46 ± 1.32^{Aa}	9.78 ± 6.06^{Aab}	9.62 ± 4.09^{Aab}	14.72 ± 8.79^{Bb}	*
Significance		*	*	*	*	-
Skin of thigh	MAP-O_2	6.30 ± 3.34^{Ba}	15.05 ± 2.33^{Bb}	25.13 ± 4.98^{Cc}	25.74 ± 6.84^{Bc}	*
	MAP-N_2	3.49 ± 0.88^{Aab}	4.31 ± 0.79^{Ab}	3.23 ± 0.26^{Aa}	8.05 ± 1.29^{Ac}	*
	control	2.90 ± 1.43^{Aa}	5.69 ± 2.89^{Aab}	5.87 ± 1.69^{Bab}	8.11 ± 5.37^{Ab}	*
Significance		*	*	*	*	-
Wing	MAP-O_2	4.81 ± 2.92^{Ba}	8.47 ± 2.99^{Bab}	12.46 ± 4.30^{Bbc}	15.33 ± 5.45^{Bc}	*
	MAP-N_2	1.91 ± 0.44^{A}	2.83 ± 0.90^{A}	2.57 ± 1.78^{A}	2.44 ± 0.32^{A}	NS
	control	1.70 ± 0.57^{Aa}	4.81 ± 2.50^{Ab}	3.65 ± 2.50^{Ab}	4.46 ± 1.91^{Ab}	*
Significance		*	*	*	*	-

MAP-O_2 modified atmosphere packaging (80% O_2/20% CO_2); MAP-N_2 modified atmosphere packaging (70% N_2/30% CO_2); values in the same row with different superscripts $^{a, b, c}$ are significantly different among 2nd, 7th, 10th, 14th days of storage; values in the same column with different superscripts $^{A, B, C}$ are significantly different among MAP-O_2, MAP-N_2 and control;* $P < 0.05$; NS - not significant.

psychrotrophic microorganism sand a more intense occurrence of proteolytic, lipolytic and oxidative processes in the skin. Contrary to expectations, the skin colour of chicken in the high-oxygen atmosphere (MAP-O_2) was significantly lower than in the control samples (21% O_2= oxygen in air), for which reason attribution of the differences in the yellowish colour of chicken skin to the oxygen percentage alone must be rejected.

Ammonia content

The spoilage of samples in the air atmosphere through protein breakdown caused free

Table 4. Antioxidant capacity (DPPH % inhibition, mean ± SD) of skin and wings of chicken in MAP-O_2, MAP-N_2 and control.

Indices		2nd day	7th day	10th day	14th day	Significance
Skin of breast	MAP-O_2	28.54 ± 1.27^{b}	26.05 ± 1.51^{Aa}	26.61 ± 1.71^{a}	26.67 ± 2.10^{a}	*
	MAP-N_2	29.11 ± 2.60^{ab}	30.57 ± 4.69^{Bb}	25.88 ± 1.54^{a}	26.77 ± 2.86^{a}	*
	control	29.19 ± 2.10^{b}	28.08 ± 2.52^{ABab}	27.11 ± 1.74^{a}	26.15 ± 2.19^{a}	*
Significance		NS	*	NS	NS	-
Skin of thigh	MAP-O_2	28.95 ± 1.83	27.69 ± 2.56^{A}	27.69 ± 1.34^{A}	28.67 ± 1.80	NS
	MAP-N_2	30.97 ± 2.99^{bc}	32.72 ± 2.97^{Cc}	27.93 ± 2.23^{ABa}	28.93 ± 2.15^{ab}	*
	control	29.77 ± 2.48^{ab}	30.03 ± 2.57^{Bb}	29.23 ± 1.53^{Bab}	28.14 ± 2.13^{a}	*
Significance		NS	*	*	NS	-
Wing	MAP-O_2	28.08 ± 3.16^{AB}	26.28 ± 1.15^{A}	27.22 ± 1.81	26.83 ± 1.57^{A}	NS
	MAP-N_2	30.28 ± 5.54^{Bab}	34.21 ± 5.68^{Cb}	29.28 ± 1.88^{a}	31.06 ± 2.71^{Bab}	*
	control	27.11 ± 1.79^{Aa}	30.28 ± 3.45^{Bb}	29.07 ± 2.46^{ab}	29.39 ± 3.51^{Bb}	*
Significance		*	*	NS	*	-

MAP-O_2 modified atmosphere packaging (80% O_2/20% CO_2); MAP-N_2 modified atmosphere packaging (70% N_2/30% CO_2); values in the same row with different superscripts $^{a, b, c}$ are significantly different among 2nd, 7th, 10th, 14th days of storage; values in the same column with different superscripts $^{A, B, C}$ are significantly different among MAP-O_2, MAP-N_2 and control;* $P < 0.05$; NS - not significant.

amino acid production, and sequentially more NH_3 and amine formation (Karabagias et al. 2011). Production of ammonia increased due to the deamination of amino acids during the spoilage process (Singhal et al. 1997). According to Kozačinski et al. (2012), the ammonia content increases proportionally with the duration of meat storage and a positive correlation has been found between the ammonia content in chicken fillet and the total bacteria count. The more constant ammonia content in the samples under MAP-N_2 in this study could be due to the advantageous role of such anoxygen-free modified atmosphere in respect of the proliferation of microorganisms and their biochemical and, in particular, proteolytic activity.

TBARS content

A high TBARS content is a negative aspect of organic chicken meat attributed to the high level of PUFAs and the peroxidability index, as well as the high kinetic activity of birds under an organic system (Dal Bosco et al. 2016). The role of a high-oxygen MAP in elevating the TBARS values of chicken meat during chilled storage was also reported by Jongberg et al. (2014) and Tománková et al. (2012). Secondary lipid oxidation occurs in skin samples even in MAP-N_2. Modified atmospheres are appropriate technology for meat product protection, but an oxygen-free MAP is not always guaranteed and oxygen permeation through packaging barriers may occur (Kerry et al. 2006). Saucier et al. (2000) confirmed that ongoing processes of meat spoilage and, in particular, oxidative processes appeared in chicken meat in spite of the use of oxygen-free MAP packaging. However, Jongberg et al. (2014) indicated that lipid oxidation and the formation of rancid off-flavours is dependent more on the storage time than on the packaging atmosphere. The results of this study indicated that an oxygen-free atmosphere (MAP-N2) prevented secondary oxidation only in samples of wings, with TBARS values increasing significantly in skin samples during the storage period. The greater susceptibility of skin samples to secondary oxidation could be due to their larger lipid content (Abdullah and Buchtova 2016).

Antioxidant capacity

The antioxidant content is relatively high in plant materials, herbs and berries (Descalzo and Sancho 2008). Natural grass ingestion by organic chickens increases the amount of carotenoids, tocopherols and flavonoids and, thereby, the antioxidant capacity in their meat. Antioxidants obtained by poultry from pasture play an important role in the oxidative stability of meat (Dal Bosco et al. 2016). The lower antioxidant capacity of the samples in MAP-O_2 could be attributed to endogenous antioxidant destruction by an oxidation process (Clausen et al. 2009). Exposure of "hidden" antioxidant amino acids resulting from protein denaturation may be the reason for variation in antioxidant capacity during the storage period, particularly in the samples under MAP-N_2. Protein denaturation occurs due to CO_2 absolution by the tissues of samples in MAP-N_2 leading to both production of carbonic acid and lactic acid formation through the metabolism of lactic acid bacteria. The destruction of the cell membrane can lead to the release of some antioxidant compounds, thereby increasing their reactivity against radical probes (Serpen et al. 2012). Xiao et al. (2011) reported that intrinsic antioxidants diminished as the storage time increased.

The mixture of gases in both MAP had positive and negative effectson the skin and wings of organic broilers. Anadvantageous effect of a high-oxygen MAP on the colour indicators of chicken skin,which could influence consumer purchasing decisions,was observed. The positive impact of MAP-N_2 was more pronounced on selected chemical properties (ammonia content, TBARS values and antioxidant capacity) of skin and wings. Based on these results, and despite high levels of oxygen,we can conclude that MAP protected and improved the colour of chicken skin until the end of the storage period, for which reason an oxygen-free modified atmosphere (MAP-N_2) is preferable for packaging the skin and wings of organic chicken.

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