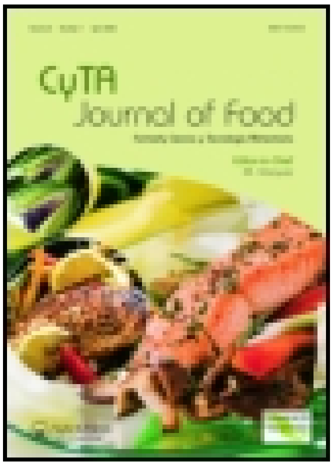

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Effect of packaging method and cold-storage time on chicken meat quality

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Effect of packaging method and cold-storage time on chicken meat quality

Efecto del método de envase y tiempo de almacenamiento por refrigeración en la calidad de la carne de pollo

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This study was performed to determine the effects of vacuum packaging (VP) and modified-atmosphere packaging (MAP) (CO_2/N_2 = 3:7) on the physicochemical properties and sensory attributes in chicken breast meat during storage at 2ºC±0.5ºC for 5, 10 and 15 days. Results showed that storage time influenced the physicochemical properties, except sensory attributes, shear force and shear energy of chicken meat. The extended storage time was causing an increase in the pH value, drip loss and in values of color parameters (L, a* b*) in chicken meat. Moreover, the packaging method affected values of drip loss, cooking loss and shear force. Fresh meat (0 days of storage) was characterized by the highest overall quality assessed with the semi-consumer scaling method. Storage time and packaging method were found to exert significant effects on the physicochemical parameters determined instrumentally and on sensory attributes of meat evaluated with the semi-consumer scaling method.

Keywords: chicken; meat quality; vacuum packaging; modified-atmosphere packaging

Este estudio se realizó para determinar los efectos del envase al vacío (VP) y el envase en atmosfera modificada (MAP) (CO_2/N_2 = 3:7) en las propiedades fisicoquímicas y los atributos sensoriales de la pechuga de pollo durante el almacenamiento a 2ºC ± 0,5ºC durante 5, 10 y 15 días. Los resultados mostraron que el tiempo de almacenamiento influenció en las propiedades fisicoquímicas, excepto en los atributos sensoriales, la fuerza cortante y el esfuerzo cortante de la carne de pollo. La extensión del tiempo de almacenamiento causó un aumento en el valor pH, la pérdida de goteo y los valores de los parámetros de color (L, a* b*) de la carne de pollo. Además, el método de envase afectó a los valores de pérdida de goteo, pérdida de cocción y fuerza cortante. La carne fresca (0 días de almacenamiento) se caracterizó por la mayor calidad total evaluada con el método de escala del semi-consumidor. Se observó que el tiempo de almacenamiento y el método de envase habían ejercido efectos significativos en los parámetros fisicoquímicos determinados de forma instrumental y en los atributos sensoriales de la carne evaluada con el método de escala del semi-consumidor.

Palabras clave: pollo; calidad de la carne; envase al vacío; envase en atmosfera modificada

Introduction

Meat quality is the key criterion of food product evaluation, whereas shelf life has a direct impact on quality changes. The shelf life of poultry meat is determined by: processing, distribution and storage conditions in both retail stores and households. Procedures applied throughout the production process, including packaging, should ensure the preservation of high quality and safety of food until the best-before date that should be indicated on each package (Regulation (EU) No 1169/2011). As emphasized by Dave and Ghaly (2011), a rapid quality deterioration is observed in improperly stored meat. This may result in sensory changes unacceptable to consumers and in meat spoilage. The short shelf life of cold-stored poultry meat is due to its composition (Poławska et al., 2011). Compared to the meat of other species, poultry meat is characterized by a higher content of unsaturated fatty acids (UFA) that are especially susceptible to oxidation processes, as well as by the presence of specific microorganisms which may freely proliferate under typical cold-storage conditions (+4°C) (Kozačinski et al., 2012). For this reason, a growing interest is observed among meat producers in methods the freshness of products of animal origin (Chiavaro, Zanardi, Bottari, & Ianieri, 2008). The main commonly applied methods include the use of packages extending the shelf life of meat, like MAP (packaging in modified atmosphere) and VP (vacuum packaging), as well as preservation through the addition of preserving agents, and freezing. Bearing in mind that contemporary consumers seek food products with the minimum of processing, the most attractive however seems to be the modern methods of packaging, including MAP and VP (Paramithiotis, Skandamis, & Nychas, 2009). The main advantages of prolonging the freshness of meat products by these methods include: reduced proliferation of aerobes and increased oxidative stability of meat as a result of oxygen elimination (Arvanitoyannis & Stratakos, 2012). In view of the above, this study was aimed at determining the effect of MAP and VP packaging methods on physicochemical properties and sensory attributes of cold-stored meat (+2°C).

Materials and methods

Animal material

The study material included medium-growing chickens of the experimental line (E) (Michalczuk, Damaziak, Łukasiewicz, &

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Table 1. Formulation and nutritional composition of chicken diets.

Tabla 1. Formulación y composición nutricional de dietas de pollo.

Item	0 to 14 days	15 to 35 days	36 to 49 days	50 to 56 days
Ingredient (%)				
Yellow maize	10.00	11.40	10.00	10.00
Wheat	53.00	55.00	59.60	60.80
Soybean meal	30.60	27.40	23.20	21.60
Limestone Ca	1.17	1.18	1.08	0.94
Sodium bicarbonate	0.20	0.14	0.14	0.16
Sodium chloride	0.24	0.28	0.28	0.26
Stimulator	0.01	0.01	0.01	0.01
Phosphatase 2-Ca	1.17	0.77	0.70	0.64
Soybean oil	2.10	2.40	3.60	4.40
Methionine	0.48	0.42	0.36	0.28
Lysine	0.36	0.34	0.36	0.28
Threonine	0.14	0.13	0.14	0.10
Vitamin-mineral premix[1]	0.53	0.53	0.53	0.53
Nutritional composition (% of weight)				
Gross energy (MJ/kg)	12.52	12.76	13.20	13.47
Crude fat	3.67	4.00	5.14	5.92
Crude protein	21.99	20.78	19.26	18.51
Methionine	0.70	0.63	0.57	0.50
Methionine + cysteine	1.08	1.01	0.92	0.84
Lysine	1.38	1.28	1.19	1.08
Crude ash	5.83	5.35	4.96	4.67

Note: [1]The vitamin-mineral premix supplied the following per kilogram of complete feed: Ca, 1005.165 mg; Mg, 11.55 mg; Na, 38.82375 mg; Se, 0.315 mg; Fe, 47.25 mg; Mn, 115.5 mg; Zn, 84.00, mg; Cu, 21.00 mg; J, 0.735 mg; vitamin A, 11,550 I.U.; vitamin D_3, 3150 I.U., vitamin E, 44 mg; vitamin K, 2.1 mg; vitamin B_1, 2.1 mg; vitamin B_2, 7.35 mg; vitamin B_6, 4.2 mg; vitamin B_{12}, 0.02625 mg; niacin, 73.5 mg; D-pantothenic acid, 16.8 mg; folic acid, 1.575 mg; choline chloride, 420 mg; biotin, 0.2625 mg; 1.4-β-D-xylanase, 262.5 FX; 6-phytase, 2100 FT; ethoxyquin, 0.1575 mg; citric acid (E330), 0.0945 mg; gallate, 0.0315 mg.

Nota: [1]La mezcla previa de vitaminas y minerales aportó los valores siguientes por kilogramo de alimento completo: Ca 1005,165 mg; Mg 11,55 mg; Na 38,82375 mg; Se 0,315 mg; Fe 47,25 mg; Mn 115,5 mg; Zn 84,00, mg; Cu 21,00 mg; J 0,735 mg; vitamina A 11,550 I.U.; vitamina D_3 3150 I.U., vitamina E 44 mg; vitamina K 2,1 mg; vitamina B_1 2,1 mg; vitamina B_2 7,35 mg; vitamina B_6 4,2 mg; vitamina B_{12} 0,02625 mg; niacina 73,5 mg; ácido D-pantoténico 16,8 mg; ácido fólico 1,575 mg; cloruro de colina 420 mg; biotina 0,2625 mg; 1,4-β-D-xilanasa 262,5 FX; 6-fitasa 2100 FT; etoxiquina 0,1575 mg; ácido cítrico (E330) 0,0945 mg; galato 0,0315 mg.

Tokarska, 2013). The birds were reared in the intensive system on litter and fed in a three-stage system. Components and chemical composition (AOAC, 2005) of feed mixtures were presented in Table 1. In the 9th week, from a flock of 1000 chickens, 42 males with average BW were selected for slaughter. After slaughter and cooling of the carcasses (24 h/4ºC), breast muscles were dissected and subjected to further analyses.

Sample meat preparation

250 g samples were collected from the dissected muscles and divided into the following groups:

(1) Control group (C_{T0}), which included 6 breast muscles subjected to quality analysis of raw meat before packaging (24 h post slaughter).
(2) Group V which included breast muscles (n = 18) packed under vacuum using an EDESA VAC-DT+GV vacuum-packaging machine (2009).
(3) Group MA which included breast muscles (n = 18) packed under modified atmosphere: CO_2/N_2 = 3:7 (MA) using a SEALPAC M3 (2010) packaging machine with a WIT- GASETECHNIK KM 30–3 ME gas mixer (2009).

The packaged muscles were stored at a temperature of 2ºC ± 0.5 without of light. Three terms of analyses were applied in groups (2) and (3) depending on storage time: T_5 – after 5 days (d); T_{10} – after 10 d, and T_{15} – after 15 d. In this way, 7 groups with 6 replications were obtained, i.e. one control group (C_{T0}) and six experimental groups: $VP_{T5;}$ VP_{T10}; $VP_{T15;}$ $MAP_{T5;}$ MAP_{T10} and $MAP_{T15.}$ The above meat samples were subjected to quality analysis.

Meat quality

Raw meat

The pH value of the muscles was based on direct measurement by placing an ion-selective glass electrode halfway through the muscles in accordance with the Polish Standard (PN-ISO 2917:2001).

The instrumental measurement of the color parameters of raw meat was specified in the L*a*b* system using a Minolta chromameter (CR-400, Konica Minolta Inc., Tokyo, Japan). The measuring head with a diameter of 8 mm, a D65 illuminant (color temperature – 6500 K) and a standard 2° observer was used.

Drip loss was calculated as the percentage ratio of the weight of the meat after storage to the weight of the basic raw material before storage, according to the following formula:

$$DL = [(m_1\text{-}m_2): m_1] \times 100\%$$

in which:

DL – an indicator of drip loss in %
m_1 – the weight of raw material before storage in g,
m_2 – the weight of raw material after storage in g

Cooked meat

After determinations of pH value, color parameters and drip loss, the samples were cooked in a water bath (80ºC), so as to maintain a temperature of 75ºC in the geometric center of the muscle for 30 min; the temperature was measured by a thermocouple. Afterwards, the samples were cooled at a room temperature and chilled for another 12 h to a temperature of 4 ± 2°C.

Cooking loss was estimated as the percentage of the weight of the cooked samples compared to the weight of the raw samples, according to the following formula:

$$CL = [(m_1\text{-}m_2): m_1] \times 100\%$$

in which:

CL – an indicator of cooking loss in %
m_1 – the weight of raw material in g,
m_2 – the weight of cooked samples in g.

At each experimental time (0, 5, 10 and 15 d of storage), the shear force (WBSF) and Shear Energy (SE) were recorded on cooked meat. The analysis of selected texture constituents was carried out under the Warner-Bratzler method using the Instron device with the width and knife edge angle at 1.016 mm and 60°, respectively. The capacity of the measuring head of the machine amounted to 500 N, and the head movement speed was 200 mm.min^{-1} (const.).

The semi-consumer scaling method was carried out in accordance with ISO 4121:1998, ISO 6658:1998. The evaluation was conducted by the evaluators in standard conditions. A well-trained consumer panel of 30 people (aged 22–43) was engaged in the sensory assessment. Cooked poultry samples were evaluated using a scaling method according to the Polish Standards (PN-ISO 4121:1998) and PN-ISO 6658:1998. All the evaluations were performed at a sensory laboratory that conformed to all the requirements of the relevant standard (PN-ISO 8589). The sensory analysis was performed using a non-structured 10 cm intensity scale (0–10 arbitrary units (a.u.)) with defined border values: color (pink – brown), tenderness (tough – tender), juiciness (dry – moist), and overall quality (undesirable – desirable). Cooked poultry samples with dimensions 10 × 10 mm were presented to the panel in 100 ml covered white plastic cups. To purge the palate of sample residues, each panelist was provided with un-salted crackers and tea without sugar between tastings. The sensory evaluations were conducted in standard conditions, including room temperature, individual booths, and light of approximately 500 lx.

Statistical analysis

Statistical analysis of the results was performed using Statistica 19.0 software (StatSoft Inc., Tulsa, USA). The significance of differences of the examined parameters among samples was checked using a two-way ANOVA method Tukey's test, at a significance level of $\alpha = 0.05$. Furthermore, the relation between sensorial and instrumental data was evaluated using Pearson's linear correlation at $P < 0.05$.

Results and discussion

The application of various types of packages and prolongation of storage time of meat may have significant effects upon its physicochemical properties (Table 2). Results achieved in the study demonstrated a significant ($P < 0.001$) effect of the storage time of meat on its pH value. Both in vacuum-packed meat (VP) and meat packaged in a modified atmosphere (MAP), the pH value was increasing along with extension of storage time. Wongwicharn, Phoolphund, Vongsawasdi, and Bomrungnok (2009) also observed pH increase in cold-stored (+4°C) meat packed in the MAP system. These authors suggest that this was due to rapid proliferation of specific microflora. Simultaneously, they emphasize that they did not expect those kinds of results and suggest that normally a drop in the pH value during storage seems to appear for MAP-packed meat, as these packages contain a significant volume of CO_2. Carbon dioxide degrades to HCO_3^- ions, thus causing slight acidification of meat (Fraqueza & Barreto, 2009). Abdalhai, Bashari, Lagnika, He, and Sun (2014) demonstrated a lower pH value after a longer storage period of meat in MAP type packages where gas composition was as follows: 60% CO_2 and 40% N_2, compared to vacuum-packed meat. Results achieved in our study for meat stored in MAP packages with gas composition of 30% CO_2 and 70% N_2, did not however confirm these findings. The lower concentration of CO_2 in $MAP_{T5\text{-}15}$ groups could have a significant effect upon pH changes in the analyzed meat. It may, therefore, be speculated that gas composition of MAP type packages is of key significance to pH changes in meat. This is most probably linked with possibilities created via modification of atmosphere for the rate of proliferation and type of microorganisms. Diversified composition and increased count of microorganisms in stored meat were reported to contribute to deterioration of the physicochemical properties of meat (Nowak & Krysiak, 2005).

Breast muscles stored in VP packages ($VP_{T5\text{-}15}$) were characterized by significantly ($P < 0.01$) higher drip loss compared to the MAP muscles ($MAP_{T5\text{-}15}$) (Table 2).The drip loss in vacuum-packed meat was higher compared to MAP packaging probably due to the strong underpressure. It was, additionally, demonstrated that storage time had a negative effect on meat and caused greater drip loss, which was also confirmed in other research (Abdalhai et al., 2014). As far as the use of the MAP system for poultry-meat packaging was concerned, the percentage drip loss noted on 15 d was similar to that determined on 5 d in meat stored in vacuum packages and reached ca. 1.5%. Poławska et al. (2014) also found the biggest drip loss when a vacuum-packaging system was used. Zakrys-Waliwander, O'Sullivan, O'Neill, and Kerry (2012) observed an opposite effect of the type of packages on drip loss from meat. When investigating the physicochemical properties of stored beef packed under vacuum (VP) and under modified atmosphere (MAP), they reported greater drip loss in meat packed under

Table 2. Selected quality characteristics of chicken breast muscles depending on the packaging method and storage time.

Tabla 2. Características de calidad seleccionadas en los músculos de pechuga de pollo dependiendo del método de envase y del tiempo de almacenamiento.

Packing (P) and storage time (S, days)	Control	MAP			VP			*P* – values		Interactions
	0	5	10	15	5	10	15	P	S	P × S
pH	5.75^{ab} ± 0.01	5.74^{a} ± 0.02	5.74a ± 0.02	5.79 b ± 0.04	5.73a ± 0.02	5.78ab ± 0.03	5.98 c ± 0.02	ns	***	***
Drip loss (%)	–	0.97^{a} ± 0.07	1.20 b ± 0.06	1.52 c ± 0.02	1.48 c ± 0.06	1.75d ± 0.16	2.01e ± 0.02	***	***	***
L*	56.70^{a} ± 0.43	57.58^{a} ± 0.75	59.68 b ± 0.64	85.53d ± 0.38	57.51a ± 0.74	56.35a ± 0.99	83.31 c ± 0.23	ns	***	***
a*	2.74^{bc} ± 0.23	2.00^{bc} ± 0.31	3.69 cd ± 0.77	3.71d ± 0.53	0.95a ± 0.25	1.44ab ± 0.29	3.26 cd ± 0.26	*	***	***
b*	2.91^{ab} ± 0.13	3.10^{ab} ± 1.19	4.29 b ± 1.33	9.84 c ± 0.15	2.63a ± 0.22	2.41a ± 0.35	9.45 c ± 0.17	ns	***	***
Cooking loss (%)	18.85^{c} ± 0.86	15.14^{ab} ± 1.06	13.30a ± 0.77	15.00ab ± 1.08	14.88ab ± 1.95	13.84a ± 0.63	16.67bc ± 1.13	***	***	***
WBSF (N)	9.30^{ab} ± 0.44	10.55^{b} ± 1.53	9.34ab ± 0.62	9.26ab ± 0.51	8.30a ± 0.90	8.55a ± 0.29	7.75a ± 0.25	***	ns	**
SE (J)	0.03 ± 0.01	0.03 ± 0.01	0.02 ± 0.00	0.03 ± 0.00	0.02 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	ns	ns	ns

Note: L* – lightness; a* – redness; b* – yellowness; WBSF – shear force; SE – shear energy; $^{a, b, c, d}$ – means in the same row with different letter are significantly different; *** – $P < 0.001$; ** – $P < 0.01$; * – $P < 0.05$; ns – not significant; MAP – modified atmosphere packaging; VP – vacuum packaging.

Nota: L* – ligereza; a* – color rojizo; b* – color amarillento; WBSF – fuerza cortante; SE – esfuerzo cortante; $^{a, b, c, d}$ – los promedios en la misma fila con diferente letra son significativamente distintos; *** – $P < 0{,}001$; ** – $P < 0{,}01$; * – $P < 0{,}05$; ns – no es significativo; MAP – envase en atmosfera modificada; VP – envase al vacío.

the MAP system. However, these differences ought to be explained by various compositions of gases, compared to our study, as the above authors applied oxygen and carbon dioxide at 80% and 20%, respectively. Such a high content of oxygen in the package could be of key significance to the enhancement of the oxidation processes of both lipids and proteins. Oxidation of proteins may result in damage of their structure, which may have a direct impact on changes in the physicochemical properties of meat, including increased juice loss (Traore et al., 2012).

The highest cooking loss was observed in fresh meat 24 h post slaughter (Table 2). In contrast, during storage of meat, it was observed that cooking loss decreased till 10 d in both the VP and MAP groups. In this period, no differences were noted in this parameter depending on the applied packaging system. On 15 d, analyses showed a significant increase of cooking loss in muscles stored in both types of packages, however a significantly greater ($P < 0.001$) cooking loss was noted in the VP group, compared to the MAP group. The initial decrease of cooking loss along with extending meat-storage time is natural and results from the increased content of exogenous enzymes (Jama et al., 2008). The increase of cooking loss on 15 d of storage may indicate highly advanced transformations in the muscle tissue, the intensity of which may result in changes of muscle protein structure (Iwanowska et al., 2010).

A very significant parameter of meat evaluation by consumers is its color, which is perceived as an indicator of product freshness and quality (Lynch, Kastner, & Kropf, 1986). One of the main assumptions of the modern packaging methods is to preserve the desirable color for possibly the longest period of time (Gazalli et al., 2013). The type of packages applied in our study affected only the value of a* color parameter (Table 2). In general, a* values decreased with increasing storage time in packaging without oxygen. However, in the case of storage at 2ºC in vacuum and MAP storage (30%CO_2, 70%N_2), this parameter decreased on day 5 and then increased on day 10 and remained constant throughout day 15. Redness change was most likely caused by the presence of oxygen. Even short exposure to oxygen, when meat is removed from packages can immediately change redness and the bright red color can be recovered (Mancini & Hunt, 2005). In turn, storage time had a significant effect on changes of all color parameters (L*a*b*). Fresh meat and meat stored for 10 d in both MAP and VP packages was characterized by appropriate lightness value (L*). On d 15 of cold storage, significant ($P < 0.001$) lightening of meat was observed and an increase in L* parameter above the value specified for non-defective meat (Owens, Matthews, & Sams, 2000). Likewise, significant increase was noted in the value of b* parameter on 15 d of storage. A successive increase in the value of this parameter was observed in the MAP-packed meat over the entire storage period, whereas in VP meat the value of this parameter (b*) was similar till 10 d, and then increased nearly 4 times on 15 d. According to Jouki and Khazaei (2012), the increase in b* parameter value could be explained by changes in meat pigmentation during storage. During long-term cold-storage, metmyoglobin is synthesized which is, generally, responsible for changes in meat color. Saucier, Gendron, and Gariepy (2000) also observed a significant increase in b* parameter value in stored poultry meat. They explain these changes with progressing processes of meat spoilage and especially emphasize the oxidative processes which – as demonstrated by Fraqueza and Barreto (2009) – proceed in poultry meat despite the use of oxygen-free MAP packages.

Results of this study demonstrated that $MAP_{T5\text{-}15}$ meat was characterized by a significantly ($P < 0.01$) higher shear force compared to $VP_{T5\text{-}T15}$ meat (Table 2). Similar results were reported by Chen et al. (2007) on day 6 and 14 who analyzed the shear force in red claw crayfish (*Cherax quadricarinatus*) meat depending on the applied packaging system. Our study showed no effect of storage time on shear force. No differences were either shown on the value of shear energy depending on the applied packaging system and storage time. Tenderness, expressed instrumentally as the shear force, is the result of many ongoing processes in meat *post mortem*. According to Koohmaraie et al. (2002), meat tenderness is determined by the proteolysis of key myofibrillar proteins, the function of which is to preserve the structural integrity in muscle fibers. *Post mortem* proteolytic degradation causes the weakening of muscle fibers and thus contributes to meat tenderization. Based on results achieved in the study, it may be concluded that the above processes do occur in chicken meat over a short period of time, which is indicated by the lack of the effect of storage time on values of both shear force and shear energy needed to cut the meat.

The sensory assessment demonstrated the highest tenderness for meat of chickens on 10 d of storage (Table 3). It was significantly better evaluated than in the other analytical terms (0, 5 and 15 d). Simultaneously, it is noteworthy hat on 10 d of storage analyses the stinginess of the meat was significantly lower ($P < 0.01$), which could be the reason why the tenderness of the meat was given such a high score. A high negative correlation of both attributes may confirm the above assumptions (Table 4). The packing system was found not to affect the

Table 3. The semi-consumer scaling method of sensory evaluation of cooked breast meat depending on the packaging method and storage time.

Tabla 3. Método de escala del semi-consumidor según la evaluación sensorial de la carne de pechuga de pollo cocinada dependiendo del método de envase y tiempo de almacenamiento.

Packing (P) and storage time (S, days)	Control	MAP			VP			*P* – values		Interactions
	0	5	10	15	5	10	15	P	S	P × S
Tenderness	6.62ab ± 0.45	6.71^{ab} ± 0.43	7.35 b ± 0.54	6.22ab ± 0.62	5.51a ± 0.71	7.16 b ± 1.11	6.15ab ± 0.44	ns	**	**
Stringy	5.80ab ± 0.59	4.52^{ab} ± 0.57	4.41a ± 1.29	6.35ab ± 0.66	5.04^{ab} ± 0.54	4.39a ± 1.00	6.41 b ± 1.02	ns	***	**
Juiciness	5.81ab ± 0.88	7.95^{b} ± 0.32	6.49ab ± 1.57	6.63^{ab} ± 0.56	7.34^{ab} ± 1.65	5.64ab ± 0.40	5.35^{a} ± 0.92	ns	*	*
Color	7.81bc ± 0.46	8.17^{c} ± 0.46	7.31 b ± 0.92	7.07 b ± 0.31	6.07^{ab} ± 0.27	5.78a ± 0.46	5.53a ± 0.65	***	ns	***
Overall quality	8.25d ± 0.57	7.56^{cd} ± 0.16	7.36 c ± 0.32	6.62 b ± 0.13	5.16a ± 0.26	5.67a ± 0.31	5.62a ± 0.13	***	***	***

Note: $^{a, b, c, d}$ – means in the same row with the different letter are significantly different; *** – $P < 0.001$; ** – $P < 0.01$; * – $P < 0.05$; ns – not significant.

Nota: $^{a, b, c, d}$ – los promedios en la misma fila con la letra diferente son significativamente distintos; *** – $P < 0{,}001$; ** – $P < 0{,}01$; * – $P < 0{,}05$; ns – no es significativo.

Table 4. Correlation coefficients between indicators of breast meat.

Tabla 4. Coeficientes de correlación entre los indicadores de la carne de pechuga.

	Drip loss (%)	L*	a*	b*	Cooking loss (%)	WBSF (N)	SE (J)	Tenderness	Stringy	Juiciness	Color	Overall quality
pH	0.03	−0.29	0.69	−0.65	0.90	−0.11	−0.34	−0.22	0.67	−0.14	0.88	0.83
Drip loss (%)		0.55	0.55	−0.04	−0.38	0.31	−0.08	−0.77	0.45	−0.99	−0.39	−0.21
L*			−0.28	−0.42	−0.35	−0.52	−0.67	0.11	−0.42	−0.41	−0.68	0.03
a*				−0.09	0.32	0.55	0.19	−0.85	0.99	−0.68	0.51	0.20
b*					−0.71	0.78	0.94	−0.30	0.01	0.03	−0.36	−0.92
Cooking loss (%)						−0.40	−0.44	0.22	0.32	0.29	0.91	0.92
WBSF (N)							0.90	−0.79	0.62	−0.41	0.01	−0.65
SE (J)								−0.45	0.30	0.00	−0.03	−0.75
Tenderness									−0.84	0.86	−0.04	0.31
Stringy										−0.59	0.57	0.15
Juiciness											0.24	0.17
Color												0.68

Note: L* – lightness; a* – redness; b* – yellowness; WBSF – shear force; SE – shear energy.

Nota: L* – ligereza; a* – color rojizo; b* – color amarillento; WBSF – fuerza cortante; SE – esfuerzo cortante.

discussed traits. In contrast, the study demonstrated a significant ($P < 0.05$) effect of storage time on meat juiciness, with the highest scores given to MAP_{T5} and VP_{T5} meat. Lower juiciness in the C_{T0} group in consumer evaluation may result from significantly higher cooking loss. The high cooking loss may cause the sensation of meat dryness. The evaluated parameter was also affected by juice drip from meat. The noted significant increase ($P < 0.001$) of drip, depending on meat-storage time, was very strongly correlated with the evaluated juiciness (Table 4). The packaging method had a significant ($P < 0.01$) effect on color and overall quality of meat. Higher scores were given to the MAP-packed meat. Similar results were obtained by Abdalhai et al. (2014), however their study demonstrated a significant effect of storage time mainly on sensory attributes. The authors still observed changes in the overall quality scores after 14 d of meat storage in both MAP and VP systems. Lower scores in color parameters and texture appeared as early as on 6 d of storage. However, in Abdalhai et al's. (2014)study, the meat was stored at a higher temperature (+4°C) than in our study. According to results of a study by Cegielska-Radziejewska, Tycner, Kijowski, Zabielski, and Szablewski (2008), it should be concluded that temperature is of key significance to the preservation of desirable meat traits even during the application of modern packaging systems. The authors emphasize that in order to maintain the appropriate parameters of meat quality, the storage temperature should be as low as possible, because temperature increase causes proliferation of microorganisms that are responsible for meat quality deterioration. In addition, when using MAP type packages containing CO_2, the low temperature facilitates increased solubility of gas and thereby ensures better protection of the product (Farber, 1991).

Conclusion

Based on the results achieved, it should be concluded that the type of poultry-meat packaging may affect its physicochemical parameters like drip loss, cooking loss and shear force, as well as its sensory attributes. In addition, it needs to be emphasized that values of most of the analyzed parameters were influenced, to the greatest extent, by storage time. Meat packed under both systems (MAP and VP) was characterized by proper quality even on 10 d of storage, whereas on 15 d its quality was subject to significant deterioration, which was indicated by disorders in color parameters (L* and b*), a significant increase in cooking loss and poorer results of the semi-consumer evaluation.

Disclosure statement

No potential conflict of interest was reported by the authors.

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