PAPER

FATTY ACID PROFILE AND SENSORY PROPERTIES OF ROE DEER MEAT AFTER MODIFIED ATMOSPHERE STORAGE

T. DASZKIEWICZ* and J. KONDRATOWICZ
Department of Commodity Science and Animal Raw Material Processing, University of Warmia and Mazury in Olsztyn, Oczapowskiego 5, 10-957 Olsztyn, Poland
*Corresponding author: tomasz.daszkiewicz@uwm.edu.pl

ABSTRACT

The aim of this study was to determine the effect of cold storage (2°C, 7 and 21 days) under vacuum and modified atmosphere (MA) conditions on the fatty acid (FA) profile and sensory properties of the *Longissimus thoracis et lumborum* from male roe deer. The total content of polyunsaturated FA tended to decrease during storage. Storage conditions had a limited ($P>0.05$) influence on the FA composition. Vacuum- and MA-packaged meat was characterized by high sensory quality during storage. However, samples packaged in MA composed of 40% CO_2+60% N_2 had a tendency to higher average scores for taste desirability after the third week of storage.

Keywords: game, cold storage, meat quality

1. INTRODUCTION

The consumption of game meat is relatively low despite its high nutritional and culinary value (SCHULP *et al.*, 2014). There are various reasons for the above, and one of them is a low variety of venison preservation techniques on the consumer market. In retail, game meat is available mostly in the form of vacuum-packaged and deep frozen products. Vacuum packaging inhibits the growth of aerobic microorganisms, limits lipid oxidation and prolongs the product's shelf life (STELLA *et al.*, 2018), but it also has several drawbacks, such as the dark color of meat and considerable drip loss, which compromises consumer acceptance (SAKOWSKA *et al.*, 2016).
The meat of wild animals is vacuum packaged on account of its unique quality attributes. Game meat is characterized by a high content of unsaturated phospholipids (VALENCAK *et al.*, 2015) and heme iron in myoglobin (WIKLUND *et al.*, 2006), and it is susceptible to auto-oxidation, which compromises its quality. To preserve the freshness of venison, oxygen is removed from the packaging during the vacuum packaging process. Freezing decreases water activity, slows down chemical and biochemical processes, inhibits microbial growth and extends the product's shelf life (ZHOU *et al.*, 2010). However, freezing, frozen storage and thawing lead to adverse changes in meat quality.
Modified atmosphere (MA) packaging preserves the attributes of fresh meat (DJENANE and RONCALÉS, 2018). The gas composition of MA is selected for a given type of meat to prevent undesirable changes in quality caused by microbial growth and oxidation or to preserve its attractive color (beef) (ZHANG *et al.*, 2015). Modified atmosphere packaging eliminates the drawbacks of vacuum packaging, such as considerable drip loss as well as packaging and product deformation, through the application of reduced pressure that increases consumer acceptance (ŠČETAR *et al.*, 2010). The effects of storage conditions (MA composition) and cold storage time on the quality of meat from farm animals, including poultry, and fish have been extensively researched (ZHANG *et al.*, 2015). However, their influence on the quality of venison, in particular meat from wild-living animals, remains insufficiently investigated. Therefore, the objective of this study was to determine the effect of vacuum packaging and MA packaging on the fatty acid profile and sensory properties of meat from male roe deer (*Capreolus capreolus* L.).

2. MATERIALS AND METHODS

2.1. Sampling, packaging and storage

The experimental materials comprised samples of the *Longissimus thoracis et lumborum* (LTL) muscle collected from the carcasses of 16 male roe deer aged 3 to 5 years, hunter-harvested in the forests of North-Eastern Poland (Sępopol Plain, Region of Warmia and Mazury) in June and July during one hunting season. During carcass dressing in a meat processing plant (within 48-54 h of harvest), right and left LTL muscles were cut out, placed in polyethylene bags on ice, and transported to the laboratory. Each muscle was divided into samples of similar weight, which were allocated to groups A, B, C and D. Samples A were immediately subjected to laboratory analyses, samples B were vacuum-packaged, samples C and D were packaged in MA containing 40% CO_2+60% N_2 and 60% CO_2+40% N_2, respectively. The samples were packaged in barrier bags made of ethylene-vinyl alcohol (EVOH) copolymer with the following gas permeability: O_2=1 ml/ m^2/24 h/bar/23°C, N_2<0.1 ml/m^2/24 h/bar/23°C, CO_2=1.6 ml/m^2/24 h/bar/23°C, H_2O=3

g/m²/24 h/23ºC using the PP-5MG (015) vacuum packaging machine (TEPRO S.A., Koszalin, Poland). The samples were stored in a cooling chamber without forced air-flow at a temperature of 2ºC for 7 and 21 days. Meat quality was determined based on an analysis of the fatty acid profile of intramuscular fat (IMF), an evaluation of the sensory properties of meat, and shear force measurements.

2.2. Analytical procedures

The sensory properties of meat were evaluated after cooking in 0.6% NaCl solution at 96ºC (±2°C) until internal temperature reached 80ºC, as described by DASZKIEWICZ *et al.* (2012). Five panelists on a 5-point scale (5 points - most desirable, 1 point - least desirable) evaluated meat quality. Prior to the evaluation, the panelists had been trained in the sensory properties of cooked venison based on cooked beef loin as the reference standard. The panelists assessed encoded samples composed of 1 cm x 1 cm x 1 cm meat cubes, cut from the center of each cooked sample, cooled to room temperature. Redistilled water was made available to the panelists for mouth cleansing between samples. The sensory properties (aroma, taste, juiciness, tenderness) of up to 5 meat samples were assessed per session.
The maximum shear force required to cut meat samples (5 cylinder-shaped samples, 1.27 cm in diameter, 2 cm in height) across the grain was measured using a Warner-Bratzler head (500 N, speed 100 mm/min) attached to the Instron 5542 universal testing machine (Instron, Canton, Massachusetts, USA). The samples were prepared as described by HONIKEL (1998).
Intramuscular fat (IMF) was extracted by Soxhlet extraction (AOAC, 1990) with diethyl ether as the solvent in the Soxtec™ 2050 Auto Fat Extraction System (FOSS Analytical, Hilleroed, Denmark). The fatty acid profile of IMF was determined by gas chromatography using a UNICAM PU-4600 gas chromatograph with a flame ionization detector (FID) on a glass capillary column (length: 2.10 m, inner diameter: 4.0 mm); detector temperature - 250ºC, injector temperature - 225ºC, column temperature - 200ºC, carrier gas - argon, carrier gas flow rate - 50 ml/min. Fatty acid methyl esters were prepared by the modified Peisker method with chloroform: methanol: sulphuric acid (100:100:1 v/v) (ŻEGARSKA *et al.*, 1991).

2.3. Statistical analysis

The results were processed statistically by one-way ANOVA with the use of STATISTICA ver. 13.3 software (TIBCO Software Inc.). The statistical significance of differences between mean values in groups was determined using the Bonferroni correction at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1. Sensory properties of meat

A sensory evaluation confirmed high quality of meat from male roe deer irrespective of storage conditions (Table 1). Stored meat samples were characterized by lower aroma intensity than non-stored samples, and the differences were higher ($P \leq 0.05$) in MA-packaged meat. Stored samples received similar scores for aroma intensity, only vacuum-packaged samples stored for 21 days scored higher ($P \leq 0.05$) than samples packaged in MA

containing 60% CO_2 and 40% N_2. Storage time had no influence (P>0.05) on aroma desirability but after 21 days, MA-packaged meat received higher (P≤0.05) scores for this attribute than vacuum-packaged samples.

Table 1. Sensory properties (points) and shear force values (N) of meat from male roe deer stored in a modified atmosphere (arithmetic means±SD).

Parameter	Storage (days)	Vacuum	Modified atmosphere	
			40% CO_2+60% N_2	60% CO_2+40% N_2
Aroma - intensity	0	4.13±0.85	4.13±0.85^{a}	4.13±0.85^{a}
	7	3.72±0.68	3.38±0.59^{b}	3.28±0.55^{b}
	21	3.75±0.86^{x}	3.34±0.54^{bxy}	3.22±0.45^{by}
Aroma - desirability	0	5.00±0.00	5.00±0.00	5.00±0.00
	7	4.88±0.22	4.94±0.17	4.97±0.13
	21	4.87±0.22^{x}	5.00±0.00^{y}	5.00±0.00^{y}
Taste - intensity	0	4.09±0.52	4.09±0.52^{a}	4.09±0.52^{a}
	7	3.91±0.55	3.78±0.45^{b}	3.75±0.37^{b}
	21	4.19±0.31^{x}	4.00±0.00^{aby}	4.06±0.17^{axy}
Taste - desirability	0	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}
	7	4.84±0.24^{a}	4.84±0.24^{ab}	4.88±0.22^{a}
	21	4.28±0.82^{bx}	4.78±0.36^{by}	4.38±0.62^{bxy}
Juiciness	0	3.59±0.38	3.59±0.38	3.59±0.38^{ab}
	7	3.44±0.54	3.66±0.44	3.69±0.40^{a}
	21	3.38±0.43	3.38±0.43	3.38±0.47^{b}
Tenderness	0	4.44±0.48^{a}	4.44±0.48^{a}	4.44±0.48
	7	4.56±0.57^{a}	4.63±0.50^{ab}	4.72±0.41
	21	4.97±0.12^{bx}	4.88±0.29^{bxy}	4.75±0.37^{y}
Shear force	0	21.27±4.42^{a}	21.27±4.42^{a}	21.27±4.42^{a}
	7	17.98±3.39^{b}	16.94±2.76^{b}	18.86±4.46^{ab}
	21	16.24±2.20^{b}	17.14±2.48^{b}	16.72±2.68^{b}

Values within a row with different superscript letters ($^{x-y}$) are significantly different ($P \leq 0.05$). Values within a column with different superscript letters ($^{a-b}$) are significantly different ($P \leq 0.05$).

During storage, taste intensity decreased in samples stored for 7 days compared with non-stored samples and samples stored for 21 days. This trend was more pronounced (P≤0.05) in MA-packaged meat than in vacuum-packaged meat. An analysis of the effect of storage conditions on taste intensity revealed that after 21 days, vacuum-packaged samples scored higher (P≤0.05) than samples packaged in MA composed of 40% CO_2 and 60% N_2.

Roe deer meat stored for 21 days was characterized by lower (P≤0.05) taste desirability than non-stored meat and meat stored for 7 days. Taste deteriorated at the slowest rate in meat packaged in MA composed of 40% CO_2 and 60% N_2, and at the fastest rate in vacuum-packaged meat and meat packaged in MA containing 60% CO_2 and 40% N_2.

Similar results were reported by SEMAN *et al.* (1989) who observed a decrease in the flavor desirability of meat from farm-raised male red deer. In their study, vacuum-packaged samples and samples packaged in MA consisting of 100% CO_2 were stored for 6,

12 and 18 weeks at -1°C. The undesirable changes in palatability most likely resulted from enzymatic and chemical reactions, and the accumulation of microbial metabolites. When analyzing the effects of chemical processes on the sensory properties of meat, attention should be paid to peroxidation of lipids, in particular polyunsaturated fatty acids (PUFAs) (PAPUC *et al.*, 2017).

Meat juiciness was comparable (P>0.05) in non-stored samples and MA-packaged samples stored for 7 days. The value of this attribute decreased after 21 days of storage. Storage conditions had no effect (P>0.05) on meat juiciness. However, MA-packaged samples stored for 7 days received somewhat higher average scores for juiciness than vacuum-packaged samples.

No differences (P>0.05) in juiciness were reported by HUR *et al.* (2013) in beef, PIASKOWSKA *et al.* (2016) in fallow deer meat and by SEMAN *et al.* (1989) in red deer meat packaged in MA consisting of CO_2 and N_2 or 100% CO_2 vs. vacuum-packaged samples. ORKUSZ (2018) and CLAUSEN *et al.* (2009) observed a decrease in the juiciness of samples (goose meat and beef, respectively) stored in MA containing 50-80% O_2.

The analyzed meat was characterized by desirable tenderness, which further improved during storage, and differences (P≤0.05) were found for vacuum-packaged samples and samples packaged in MA consisting of 40% CO_2+60% N_2. After 21 days of storage, vacuum-packaged meat had the highest tenderness scores and meat packaged in MA composed of 60% CO_2+40% N_2 had the lowest tenderness scores (P≤0.05). The tenderness of samples packaged in MA consisting of 40% CO_2 and 60% N_2 was at an average level.

The results of tenderness evaluation were reflected in shear force values, which were lower (P≤0.05) in stored meat than in non-stored samples. No differences (P>0.05) were found between the average shear force values of meat stored for 7 and 21 days. Storage conditions had no effect (P>0.05) on shear force values.

The increase in tenderness of roe deer meat and the decrease in shear force values after cold storage, observed in our study, were related to the activity of endogenous and bacterial proteolytic enzymes. According to WIKLUND *et al.* (2014), meat from selected cervid species does not require aging due to its high tenderness, which probably would not show a further improvement during the process. PAULSEN *et al.* (2005) found no considerable differences in the average values of shear force between samples of roe deer meat stored in vacuum (3.5°C, 132 h) and samples collected from roe deer carcasses on day 5 *post mortem*. SEMAN *et al.* (1989) noted no differences (P>0.05) in the shear force values of meat from male red deer stored in vacuum and MA (100% CO_2) for 18 weeks.

3.2. Fatty acid composition of intramuscular fat

Storage time and conditions had no effect (P>0.05) on the content of saturated fatty acids (SFAs) in IMF (Table 2). Nevertheless, an increase in C 16:0 and C 18:0 content (in particular C 18:0) during storage contributed to an increase (P>0.05) in the total SFA pool.

Similarly to SFAs, storage time and conditions had a limited influence on the content of UFAs (Table 3). The differences between mean values in groups were small and statistically significant only for margoleic acid (C 17:1) and gadoleic acid (C 20:1). In vacuum-packaged meat, the content of C 20:1 was lower (P≤0.05) in non-stored samples and samples stored for 21 days compared with those stored for 7 days. After 7 days of storage, the content of C 17:1 and C 20:1 was higher (P≤0.05) in vacuum-packaged samples than in samples packaged in MA composed of 60% CO_2+40% N_2 and 40% CO_2+60% N_2, respectively.

Table 2. Percentage of saturated fatty acids in total fatty acids in the intramuscular fat of meat from male roe deer stored under vacuum and modified atmosphere conditions (arithmetic means ± SD).

Parameter	Storage (days)	Vacuum	Modified atmosphere	
			40% CO_2+60% N_2	60% CO_2+40% N_2
C 12:0	0	1.06±0.61	1.06±0.61	1.06±0.61
	7	1.02±0.49	1.09±0.71	0.92±0.35
	21	0.86±0.55	0.98±0.64	0.81±0.49
C 14:0	0	1.96±0.50	1.96±0.50	1.96±0.50
	7	1.90±0.27	2.05±0.66	1.81±0.34
	21	1.88±0.41	1.97±0.86	1.97±0.45
C 15:0	0	0.57±0.15	0.57±0.15	0.57±0.15
	7	0.56±0.18	0.59±0.19	0.53±0.11
	21	0.64±0.45	0.59±0.20	0.58±0.14
C 16:0	0	23.72±2.64	23.72±2.64	23.72±2.64
	7	23.59±1.47	23.86±1.84	23.58±2.16
	21	24.18±1.66	24.39±2.98	24.69±2.84
C 17:0	0	1.37±0.15	1.37±0.15	1.37±0.15
	7	1.37±0.15	1.40±0.23	1.35±0.19
	21	1.37±0.19	1.39±0.18	1.38±0.19
C 18:0	0	23.91±1.85	23.91±1.85	23.91±1.85
	7	24.22±3.14	24.56±2.18	24.03±1.85
	21	25.27±2.78	24.63±2.86	25.24±2.32
C 20:0	0	0.44±0.19	0.44±0.19	0.44±0.19
	7	0.45±0.17	0.49±0.30	0.39±0.10
	21	0.51±0.38	0.41±0.18	0.46±0.26
SFAs	0	53.04±4.13	53.04±4.13	53.04±4.13
	7	53.11±3.25	54.04±4.07	52.62±3.48
	21	54.72±4.09	54.35±3.78	55.13±3.70

SFAs - saturated fatty acids.

Storage time had no effect (P>0.05) on total content of UFAs, but the total content of PUFAs was lower in stored samples, particularly (P≤0.05) those vacuum-packaged and packaged in MA containing 40% CO_2 and 60% N_2, than in non-stored samples (Table 3). As a result, the PUFAs/SFAs ratio was slightly lower in stored meat (Table 4). The total content of monounsaturated fatty acids (MUFAs) increased (P>0.05) in meat stored for 7 days and decreased (P>0.05) in meat stored for 21 days (Table 3).

Increased PUFA content is desirable in view of the nutritional value and health-promoting properties of meat but they can also lead to undesirable changes in the product's quality during storage. Auto-oxidation of PUFAs contributes to undesirable changes in the aroma and taste of meat as well as to the formation of compounds that decrease the nutritional value of meat, and toxic compounds (PAPUC *et al.*, 2017).

Therefore, meat packaging must protect the product against the adverse effects of oxygen. This applies also to the meat of wild animals, which is rich in both PUFAs and heme iron that catalyzes auto-oxidation. In practice, vacuum and MA packaging are used to prevent

oxygen from entering the package - oxygen is replaced with appropriately selected gas mixtures.

Table 3. Percentage of unsaturated fatty acids in total fatty acids in the intramuscular fat of meat from male roe deer stored under vacuum and modified atmosphere conditions (arithmetic means ± SD).

Parameter	Storage (days)	Vacuum	Modified atmosphere	
			40% CO_2+60% N_2	60% CO_2+40% N_2
C 14:1	0	0.15±0.08	0.15±0.08	0.15±0.08
	7	0.17±0.07	1.12±0.06	0.15±0.07
	21	0.41±0.72	0.27±0.42	0.13±0.07
C 16:1	0	2.22±0.20	2.22±0.20	2.22±0.20
	7	2.38±0.43	2.50±0.45	2.36±0.38
	21	2.28±0.66	2.34±0.38	2.43±0.47
C 17:1	0	0.24±0.04	0.24±0.04	0.24±0.04
	7	0.29±0.04^{x}	0.26±0.05^{xy}	0.23±0.02^{y}
	21	0.29±0.12	0.27±0.05	0.27±0.10
C 18:1	0	26.28±4.46	26.28±4.46	26.28±4.46
	7	27.53±4.38	27.12±4.42	26.54±4.75
	21	26.79±3.92	26.02±4.89	25.88±2.99
C 18:2	0	12.07±2.41	12.07±2.41	12.07±2.41
	7	11.07±1.95	10.78±1.92	11.94±3.60
	21	10.75±2.46	11.39±2.81	11.22±3.25
C 18:3	0	2.19±0.47	2.19±0.47	2.19±0.47
	7	1.85±0.53	1.93±0.57	1.98±0.62
	21	1.80±0.60	1.92±0.71	1.75±0.59
C 20:1	0	0.39±0.13^{a}	0.39±0.13	0.39±0.13
	7	0.55±0.09^{bx}	0.44±0.10^{y}	0.48±0.10^{xy}
	21	0.40±0.05^{a}	0.41±0.12	0.42±0.15
C 20:4	0	4,80±4.73	4.80±4.73	4.80±4.73
	7	3.06±0.65	2.81±0.77	3.69±1.81
	21	2.57±1.25	3.03±1.00	2.77±1.07
MUFAs	0	29.28±4.31	29.28±4.31	29.28±4.31
	7	30.92±4.36	30.44±4.23	29.77±4.83
	21	30.16±3.46	29.31±4.98	29.13±2.97
PUFAs	0	19.07±4.89^{a}	19.07±4.89^{a}	19.07±4.89
	7	15.97±2.74^{b}	15.53±2.83^{b}	17.61±5.80
	21	15.12±3.62^{b}	16.35±4.14^{ab}	15.74±4.66
UFAs	0	46.96±4.13	46.96±4.13	46.96±4.13
	7	46.89±3.25	45.96±4.07	47.38±3.48
	21	45.28±4.09	45.65±3.78	44.87±3.70

MUFAs - monounsaturated fatty acids; PUFAs - polyunsaturated fatty acids; UFAs - unsaturated fatty acids (MUFAs + PUFAs).

Values within a row with different superscript letters ($^{x-y}$) are significantly different ($P \leq 0.05$). Values within a column with different superscript letters ($^{a-b}$) are significantly different ($P \leq 0.05$).

Table 4. The ratio of unsaturated fatty acids to saturated fatty acids in the intramuscular fat of meat from male roe deer stored under vacuum and modified atmosphere conditions (arithmetic means ± SD).

Parameter	Storage (days)	Vacuum	Modified atmosphere	
			40% CO_2+60% N_2	60% CO_2+40% N_2
UFAs/SFAs	0	0.90±0.14	0.90±0.14	0.90±0.14
	7	0.89±0.11	0.86±0.13	0.91±0.12
	21	0.84±0.13	0.85±0.13	0.82±0.12
MUFAs/SFAs	0	0.56±0.11	0.56±0.11	0.56±0.11
	7	0.59±0.11	0.57±0.11	0.57±0.11
	21	0.56±0.09	0.55±0.12	0.53±0.07
PUFAs/SFAs	0	0.36±0.11^{a}	0.36±0.11^{a}	0.36±0.11
	7	0.30±0.05^{ab}	0.29±0.06^{b}	0.34±0.12
	21	0.28±0.08^{b}	0.30±0.08^{ab}	0.29±0.10

MUFAs - monounsaturated fatty acids; PUFAs - polyunsaturated fatty acids; UFAs - unsaturated fatty acids (MUFAs + PUFAs).
Values within a column with different superscript letters ($^{a-b}$) are significantly different ($P \leq 0.05$).

The beneficial effect of oxygen-free packaging that limits lipid peroxidation in game meat was reported by FAROUK and FREKE (2008). They noted a lower content of malondialdehyde (an indicator of auto-oxidative changes) in samples of the *Semimembranosus* muscle of red deer, which were vacuum-packaged and stored for 9 months, in comparison with samples that were placed in bags that permitted free exchange of air between the inside and outside of the packaging.
Unfortunately, vacuum and MA packaging with oxygen-free gas mixtures cannot completely inhibit undesirable changes in the quality of cold-stored meat products. Under industrial conditions, O_2 cannot be entirely removed from the vacuum or MA packaging. According to BERRUGA *et al.* (2005), the presence of "residual oxygen", less than 2% is sufficient to promote lipid peroxidation. In the present study, this could be the reason for a decrease in PUFAs content in the IMF of roe deer after storage.

4. CONCLUSIONS

Due to the absence of significant changes in sensory properties and fatty acid profile between vacuum-packaged and MA-packaged samples of roe deer meat during storage, the suitability of those packaging methods and the composition of gas mixtures should be analyzed in view of the values of other attributes that are important from the consumer's perspective (color, drip loss, microbial counts).

REFERENCES

AOAC. 1990. "Official Methods of Analysis" 15th ed. Association of Official Analytical Chemists, Washington, DC.

Baryłko-Pikielna N., Kossakowska T. and Baldwin Z. 1964. The selection of optimal method to prepare beef and pork for the sensoric evaluation. Roczniki Instytutu Przemysłu Mięsnego 1:111-132.

Berruga M.I., Vergara H. and Galleo L. 2005. Influence of packaging conditions on microbial and lipid oxidation in lamb meat. Small Ruminant Res. 57:257-264.

Clausen I., Jakobsen M., Ertbjerg P. and Madsen N.T. 2009. Modified Atmosphere Packaging Affects Lipid Oxidation, Myofibrillar Fragmentation Index and Eating Quality of Beef. Packag. Technol. Sci. 22:85-96.

Daszkiewicz T., Kubiak D., Winarski R. and Koba-Kowalczyk M. 2012. The effect of gender on the quality of roe deer (*Capreolus capreolus* L.) meat. Small Ruminant Res. 103:169-175.
Farouk M.M. and Freke C. 2008. Packaging and storage effects on the functional properties of frozen venison. J. Muscle Foods 19:275-287.

Djenane D., Roncalés P. 2018. Carbon Monoxide in Meat and Fish Packaging: Advantages and Limits. Foods 7, 12.

Honikel K.O. 1998. Reference methods for the assessment of physical characteristics of meat. Meat Sci. 49:447-457.

Hur S.J, Jin S.K., Park J.H., Jung S.W. and Lyu H.J. 2013. Effect of Modified Atmosphere Packaging and Vacuum Packaging on Quality Characteristics of Low Grade Beef during Cold Storage. Asian-Australas. J. Anim. Sci. 26:1781-1789.

Orkusz A. 2018. Effects of packaging conditions on some functional and sensory attributes of goose meat. Poultry Sci. 97:2988-2993.

Papuc C., Goran G.V., Predescu C.N. and Nicorescu V. 2017. Mechanisms of Oxidative Processes in Meat and Toxicity Induced by Postprandial Degradation Products. Compr. Rev. Food Sci. F. 16:96-123.

Paulsen P., Bajer F., Winkelmayer R., Smulders F.J.M. and Hofbauer P. 2005. Zu Qualitätsparametern von vakuumverpacktem Rehfleisch. Gewonnen durch Zerlegung von Rehen 12 bzw. 24 h nach dem Erlegen. Fleischwirtschaft 11:14-17.

Piaskowska N., Daszkiewicz T., Kubiak D. and Zapotoczny P. 2016. Quality of meat (*Longissimus dorsi*) from male fallow deer (*Dama dama* L.) packaged and stored under vacuum and modified atmosphere conditions. Asian Austral. J. Anim. 29: 1782-1789.

Sakowska A., Guzek D. and Wierzbicka A. 2016. Effects of carbon monoxide treatment before vacuum packaging on the physical parameters and consumer evaluations of raw beef. Food Sci. Technol. (Campinas) 36:485-492.

Ščetar M., Kurek M. and Galič K. 2010. Trends in meat and meat products packaging - a review. Croat. J. Food Sci. Technol. 2:32-48.

Schulp C.J.E., Thuiller W. and Verburg P.H. 2014. Wild food in Europe: A synthesis of knowledge and data of terrestrial wild food as an ecosystem service. Ecol. Econ.105:292-305.

Seman D.L., Drew K.R. and Littlejjohn R.P. 1989. Packaging venison for extended chilled storage: comparison of vacuum and modified atmosphere packaging containing 100% carbon dioxide. J. Food Protec. 52:886-893.

Stella S., Bernardi C., Tirloni E. 2018. Influence of Skin Packaging on Raw Beef Quality: A Review. J. Food Qual. Volume 2018, Article ID 7464578.

Valencak T.G., Gamsjäger L., Ohrnberger S., Culbert N.J. and Ruf T. 2015. Healthy n-6/n-3 fatty acid composition from five European game meat species remains after cooking. BMC Res. Notes 8:273-278.

Wiklund E., Sampels S., Manley T.R., Pickova J. and Littlejohn R.P. 2006. Effects of feeding regimen and chilled storage on water-holding capacity, colour stability, pigment content and oxidation in red deer (*Cervus elaphus*) meat. J. Sci. Food Agric. 86:98-106.

Wiklund E., Farouk M. and Finstad G. 2014. Venison: Meat from red deer (*Cervus elaphus*) and reindeer (*Rangifer tarandus tarandus*). Animal Front. 4:55-61.

Żegarska Z., Jaworski J. and Borejszo Z. 1991. Evaluation of the Peisker Modified Method for Extracting Methyl Esters from Fatty Acids. Acta Acad. Agricult. Tech. Olst. Technol. Aliment. 24:25-33.

Zhang M., Meng X., Bhandari B., Fang Z. and Chen H. 2015. Recent Application of Modified Atmosphere Packaging (MAP) in Fresh and Fresh-Cut Foods. Food Rev. Int. 31:172-193.

Paper Received May 28, 2019 Accepted April 21, 2020