Research Note: Effect of packaging atmosphere on the fatty acid profile of intramuscular, subcutaneous fat, and odor of goose meat

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ABSTRACT The aim of the study was to investigate changes of the fatty acid profile in the intramuscular and subcutaneous fat as well as odor sensory evaluation of goose packaged under different conditions of modified atmosphere (vacuum and high-oxygen modified atmosphere of 80% O_2 and 20% CO_2 composition) and stored under refrigeration (4°C) for 11 D. Packaging in a high-oxygen modified atmosphere had a negative impact on goose meat quality due to the reduction of polyunsaturated fatty acids (**PUFA**), PUFA/saturated fatty acids (**SFA**) and the increase of SFA, which means a substantial loss of its nutritional value. Goose meat can be stored for 11 D without changes in the fatty acid profile, provided that a vacuum is used that limits oxygen exposure. At the end of storage, a better sensory evaluation of the odor intensity in the vacuum-packed samples was also observed in comparison to high oxygen modified atmosphere. Vacuum packaging turned out to be a better method for preserving fatty acid profile and the odor of goose meat during 11 D of storage.

Key words: goose, modified atmosphere, vacuum, fatty acids, odor

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INTRODUCTION

Among the different meat species, goose supplies fat with one of the highest unsaturated/saturated fatty acids (**SFA**) ratios. However, the high percentage of unsaturated fatty acids (**UFA**) makes goose meat susceptible to oxidation, and off-odor may be formed during storage.

The production of goose meat in Poland is carried out mainly with the W-31 hybrids (♂♀), obtained as a result of cross-breeding a W-33 gander and a W-11 goose, i.e. based on the White Kołuda goose, which is characterised by good reproductive and meat ratios—e.g., high protein content and low lipid content, in which UFA constitute more than 70% of total content (Biesiada-Drzazga, 2014).

To increase the durability of food products, modified atmosphere packaging is used in the industry. Owing to the oxygen content in the modified atmosphere (**MA**), the packaging of high or low (including vacuum) oxygen content is distinguished. The high-oxygen MA (70% ÷ 80% O_2, 20% ÷ 30% CO_2) is commonly used in the food industry to preserve and even improve the red color of meat, especially for meat with high heme pigments content, including goose meat (Fernandes et al., 2014; Santos et al., 2015; Bonny et al., 2017). However, such atmospheric composition has limitations due to its oxidative activity. Poultry meat and particularly goose meat is susceptible to oxidation processes due to high content of UFA. In contrast, the maximum shelf life is achieved by an oxygen-free atmosphere, because in an anaerobic atmosphere increases meat oxidative stability (Alvarez et al., 2006; Seydim et al., 2006). Changes in fatty acid **(FA)** composition are essential indirect indicators of lipid oxidation in stored meat. Polyunsaturated fatty acids **(PUFA)** oxidation results in off-odor, off-flavors and reduction of food quality (Tao, 2015; Hęś, 2017). Particular importance for the nutritional value of edible fats lies in the composition of FA. Research shows that lauric acid (C12:0), myristic acid (C14:0), and palmitic acid (C16:0), which are SFA, raise blood cholesterol levels in low-density lipoproteins (**LDL**), increasing their coagulability, contributing to atherosclerosis and ischemic heart disease (WHO/FAO, 2008). Replacing products rich in SFA with foods containing PUFA lowers the concentration of cholesterol contained in LDL and the ratio of total cholesterol to cholesterol contained in the high-density lipoprotein (WHO/FAO, 2008), thereby reducing the risk of coronary heart disease (Williams and Salter, 2016).

The effect of modified atmosphere packaging on the FA profile from goose breast muscle lipids and subcutaneous fat has not been extensively studied. Therefore, the objective of the study was to evaluate changes in the FA profile of intramuscular and subcutaneous fat

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as well as odor sensory evaluation (**SE**) of goose packaged under different conditions of MA (vacuum and high-oxygen MA of 80% O_2, 20% CO_2 composition) during refrigerated (4°C) storage.

MATERIALS AND METHODS

Meat Preparation

Birds were kept in uniform conditions. Their rearing and fattening was organized in accordance with a prepared (Bieliński, 1983) and constantly improved rearing technology (Rosiński, 2000) to obtain a quality product termed as "the young Polish oats-fed goose".

The research material was the breast muscle of the White Kołuda female goose (average weight about 0.5 kg) from industrial slaughter. Cuts after cooling and qualitative and weight classification were divided into culinary elements. Breast muscles with skin were individually packed in a slaughterhouse, using type R-230 Multivac packaging machine (Multivac, Germany) in polyamide-polyethylene foil (permeability: O_2 = 25 $cm^3/m^2 \cdot 24h \cdot 0.1$ MPa; CO_2 = 85 $cm^3/m^2 \cdot 24h \cdot 0.1$ MPa; N_2 = 7 $cm^3/m^2 \cdot 24h \cdot 0.1$ MPa; water vapor < 3 $g/m^2 \cdot 24$ h) in a vacuum (99% vacuum is equal to 1.3 KPa) and a high-oxygen MA with a composition of 80% of O_2 and 20% of CO_2. Samples for experiments were chosen randomly.

Overall 250 goose breast muscles were tested—equal number of samples (100) were packed in vacuum and in a high-oxygen MAseparately. The control group comprised of 50 unpacked muscles, which were examined 24 h after the slaughter. Packed muscles were stored at 4°C in a refrigerator equipped with automatic temperature control and examined on the 4th, 7th, 9th, and 11th Dof storage (for each atmosphere 25 samples were used in the examination procedure). And as a result determinations were performed for each muscle.

Fatty Acids Analysis

Preliminary ground meat tissues (4.0 g) and subcutaneous fat (3.0 g) (removed from the breast muscle using knife) were homogenized with a model T 25 homogenizer (Ika Ultra-Turrax Corp.). Extraction of lipids was carried out according to the method described by Folch et al. (1956). The FA profiles were determined by the capillary gas chromatography technique. For the determination of FA composition the lipid samples were converted to their corresponding methyl esters by AOCS official method Ce 2–66 (AOCS, 1997). The FA methyl esters were analyzed using an Agilent Tech. 7890 A series gas chromatograph (Agil. Tech. Inc., St. Clara, USA) equipped with a flame-ionization detector (**FID**) and a silica capillary column HP 88 J&W Scientific series–100 m × 0.25 mm × 0.20 µm film thickness (Agil. Tech. Inc., St. Clara, USA).

Helium was used as the carrier gas at a head pressure of 2.0 mL/min constant flow. Air, hydrogen and helium make-up gas flow rates by FID detector were: 450, 40, and 30 mL/min, respectively. The injector and detector were maintained at 250°C and 280°C, respectively. The chromatographic conditions were as follows: the initial column temperature of 120°C was held for 1 min, increased to 180°C at 10°C/min and held for 10 min. Finally, the column temperature was elevated to 230°C at a rate of 5°C/min, and maintained for 5 min. The quantification of FA methyl esters of muscle lipids was carried out using non-adecanoic acid (C 19:0) as an internal standard. The peaks were identified by comparing the retention times with those of a mixture of external standard methyl esters (Supelco 37 F.A.M.E. Mix C 4–C 24 Component). The FA content was calculated as percentage of a sum of FA with the ChemStation Agilent Technologies program (Agil. Tech. Inc., St. Clara, USA).

The proportions of SFA, monounsaturated fatty acid **(MUFA)** and PUFA were obtained from the sum of all the identified SFA, MUFA and PUFA, respectively, expressed as percentage of the total FA.

Sensory Evaluation

The SE of odor intensity of goose breast muscles and subcutaneous fat was carried out at the sensory laboratory with all requirements according to the international standard (ISO, 1988). A trained, 7-member sensory panel participated in SE. A 6-point hedonic scale was used, 1 point meaning the lowest and 6 points the highest evaluation (criteria of a 6-point scale of the SE of odor intensity: 1–completely changed, putrid; 2–strongly changed; 3–slightly changed; 4–typical but less intense; 5–typical; and 6–ideal, typical. Surface odor intensity was assessed 30 min. after the pack was opened. A score < 3 was regarded as unacceptable. The intensity of the odor was expressed in conventional units (**CU**) (Stone et al., 1980).

Statistical Analysis

The data were performed with Statistica version 12.0 (StatSoft, Inc. 2012, Statistica software program). ANOVA was used to analyze differences between the type of packaging atmosphere and particular storage time within analyzed atmospheres. Post-hoc analysis was undertaken using Duncan's multiple range test at a 5% level of significance. Results were given as mean ± standard error of 5 independent determinations.

RESULTS AND DISCUSSION

The FA profile of intramuscular and subcutaneous goose fat is summarized respectively in Tables 1 and 2.

It has been determined that the type of atmosphere during storage influenced the FA profile of intramuscular and subcutaneous goose fat. But in the experiment described there was neither any change in the FA profile in samples packed in vacuum nor any difference

Table 1. Mean values (±standard error) of fatty acid profile (% of the total fatty acids) of goose meat packed in different atmospheres and stored at 4°C for up to 11 D.

Fatty acids	Packaging atmosphere	Storage time[1] (D)					Significance effects		
		0	4	7	9	11	PA	ST	PA × ST
SFA							***	***	***
	MA	29.66 ± 0.23^{a}	30.13 ± 0.07^{b,x}	31.14 ± 0.03^{c,x}	31.56 ± 0.08^{d,x}	33.11 ± 0.06^{e,x}			
	Vacuum	29.66 ± 0.23	29.59 ± 0.07^{y}	29.5 ± 0.04^{y}	29.68 ± 0.04^{y}	29.65 ± 0.08^{y}			
C 12:0							ns	ns	ns
	MA	0.24 ± 0.01	0.24 ± 0.004	0.24 ± 0.006	0.23 ± 0.009	0.25 ± 0.004			
	Vacuum	0.24 ± 0.01	0.23 ± 0.007	0.24 ± 0.004	0.22 ± 0.009	0.24 ± 0.002			
C 14:0							***	***	***
	MA	0.78 ± 0.004^{a}	0.87 ± 0.007^{b,x}	0.93 ± 0.01^{c,x}	0.95 ± 0.006^{c,d,x}	0.96 ± 0.01^{d,x}			
	Vacuum	0.78 ± 0.004	0.78 ± 0.007^{y}	0.79 ± 0.008^{y}	0.77 ± 0.009^{y}	0.79 ± 0.006^{y}			
C 15:0							***	***	***
	MA	0.23 ± 0.01^{a}	0.26 ± 0.01^{a}	0.34 ± 0.01^{b,x}	0.50 ± 0.01^{c,x}	0.67 ± 0.01^{d,x}			
	Vacuum	0.23 ± 0.01	0.24 ± 0.007	0.25 ± 0.006^{y}	0.25 ± 0.006^{y}	0.25 ± 0.006^{y}			
C 16:0							***	***	***
	MA	24.04 ± 0.21^{a}	24.11 ± 0.08^{a}	24.87 ± 0.01^{b,x}	24.95 ± 0.03^{b,x}	25.98 ± 0.02^{c,x}			
	Vacuum	24.04 ± 0.21	23.96 ± 0.05	23.94 ± 0.04^{y}	24.00 ± 0.07^{y}	23.96 ± 0.06^{y}			
C 17:0							ns	ns	ns
	MA	0.13 ± 0.006	0.13 ± 0.006	0.12 ± 0.009	0.12 ± 0.007	0.12 ± 0.006			
	Vacuum	0.13 ± 0.006	0.13 ± 0.005	0.13 ± 0.004	0.13 ± 0.004	0.13 ± 0.004			
C 18:0							***	***	***
	MA	4.24 ± 0.10^{a}	4.53 ± 0.03^{b,x}	4.63 ± 0.03^{b,x}	4.83 ± 0.08^{c,x}	5.14 ± 0.05^{d,x}			
	Vacuum	4.24 ± 0.10	4.25 ± 0.03^{y}	4.31 ± 0.03^{y}	4.31 ± 0.08^{y}	4.30 ± 0.003^{y}			
MUFA							***	***	***
	MA	42.89 ± 0.16^{a}	44.11 ± 0.07^{b,x}	44.37 ± 0.06^{b,x}	45.13 ± 0.07^{c,x}	45.55 ± 0.12^{c,x}			
	Vacuum	42.89 ± 0.16	42.91 ± 0.26^{y}	43.20 ± 0.28^{y}	42.98 ± 0.18^{y}	42.95 ± 0.09^{y}			
C 16:1							*	ns	ns
	MA	3.89 ± 0.25^{a}	3.95 ± 0.10^{a}	4.12 ± 0.05^{a,b}	4.31 ± 0.08^{a,b}	4.41 ± 0.09^{b,x}			
	Vacuum	3.89 ± 0.25	3.93 ± 0.07	4.03 ± 0.07	4.01 ± 0.07	3.88 ± 0.10^{y}			
C 17:1							***	***	***
	MA	0.06 ± 0.000^{a}	0.07 ± 0.004^{a,b}	0.08 ± 0.004^{b,c,x}	0.09 ± 0.004^{c,d,x}	0.10 ± 0.002^{d,x}			
	Vacuum	0.06 ± 0.000	0.07 ± 0.004	0.07 ± 0.005^{y}	0.06 ± 0.002^{y}	0.07 ± 0.004^{y}			
C 18:1							***	***	***
	MA	38.8 ± 0.14^{a}	39.92 ± 0.14^{b,x}	39,99 ± 0.07^{b,x}	40.54 ± 0.11^{c,x}	40.84 ± 0.07^{c,x}			
	Vacuum	38.8 ± 0.14	38.79 ± 0.25^{y}	38.94 ± 0.27^{y}	38.74 ± 0.15^{y}	38.86 ± 0.11^{y}			
C 20:1							***	***	***
	MA	0.16 ± 0.004^{a}	0.18 ± 0.004^{b,x}	0.19 ± 0.004^{b,c,x}	0.20 ± 0.008^{c,x}	0.20 ± 0.002^{c,x}			
	Vacuum	0.16 ± 0.004	0.15 ± 0.004^{y}	0.16 ± 0.004^{y}	0.17 ± 0.006^{y}	0.15 ± 0.004^{y}			
PUFA							***	***	***
	MA	25.90 ± 0.13^{a}	24.64 ± 0.23^{b,x}	23.19 ± 0.10^{c,x}	21.39 ± 0.09^{d,x}	20.10 ± 0.22^{e,x}			
	Vacuum	25.90 ± 0.13	25.85 ± 0.15^{y}	25.77 ± 0.14^{y}	25.86 ± 0.08^{y}	26.00 ± 0.04^{y}			
C 18:2n-6							***	***	***
	MA	18.92 ± 0.02^{a}	18.01 ± 0.07^{b,x}	17.47 ± 0.07^{c,x}	16.19 ± 0.06^{d,x}	15.17 ± 0.14^{e,x}			
	Vacuum	18.92 ± 0.02	18.86 ± 0.05^{y}	18.73 ± 0.06^{y}	18.82 ± 0.04^{y}	18.88 ± 0.05^{y}			
C 18:3n-3							***	***	***
	MA	1.76 ± 0.04^{a}	1.58 ± 0.02^{b,x}	1.48 ± 0.02^{c,x}	1.44 ± 0.02^{c,x}	1.30 ± 0.04^{d,x}			
	Vacuum	1.76 ± 0.04	1.78 ± 0.01^{y}	1.78 ± 0.03^{y}	1.76 ± 0.02^{y}	1.79 ± 0.03^{y}			
C 20:2n-6							***	***	***
	MA	0.13 ± 0.002^{a}	0.10 ± 0.004^{b,x}	0.10 ± 0.005^{b,x}	0.08 ± 0.004^{c,x}	0.07 ± 0.004^{c,x}			
	Vacuum	0.13 ± 0.002	0.13 ± 0.007^{y}	0.13 ± 0.007^{y}	0.13 ± 0.006^{y}	0.12 ± 0.002^{y}			
C 20:3n-6							***	***	***
	MA	0.23 ± 0.006^{a}	0.22 ± 0.007^{a}	0.19 ± 0.004^{b,x}	0.19 ± 0.006^{b,x}	0.16 ± 0.002^{c,x}			
	Vacuum	0.23 ± 0.006	0.24 ± 0.004	0.22 ± 0.008^{y}	0.23 ± 0.004^{y}	0.22 ± 0.008^{y}			
C 20:4n-6							***	***	***
	MA	4.46 ± 0.12^{a}	4.39 ± 0.15^{a}	3.68 ± 0.03^{b,x}	3.29 ± 0.07^{c,x}	3.21 ± 0.03^{c,x}			
	Vacuum	4.46 ± 0.12	4.45 ± 0.09	4.49 ± 0.11^{y}	4.51 ± 0.07^{y}	4.58 ± 0.04^{y}			
C 20:5n-3							***	***	***
	MA	0.14 ± 0.01^{a}	0.10 ± 0.006^{b,x}	0.06 ± 0.008^{c,x}	0.05 ± 0.004^{c,x}	0.05 ± 0.004^{c,x}			
	Vacuum	0.14 ± 0.01	0.14 ± 0.01^{y}	0.14 ± 0.009^{y}	0.14 ± 0.01^{y}	0.14 ± 0.009^{y}			
C 22:6n-3							***	***	***
	MA	0.28 ± 0.01^{a}	0.25 ± 0.009^{a}	0.21 ± 0.008^{b,x}	0.16 ± 0.007^{c,x}	0.14 ± 0.008^{c,x}			
	Vacuum	0.28 ± 0.01	0.26 ± 0.01	0.28 ± 0.009^{y}	0.27 ± 0.01^{y}	0.25 ± 0.008^{y}			
Σ UFA							***	***	***
	MA	68.78 ± 0.27^{a}	68.75 ± 0.28^{a}	67.58 ± 0.10^{b,x}	66.50 ± 0.08^{c,x}	65.65 ± 0.27^{d,x}			
	Vacuum	68.78 ± 0.27	68.76 ± 0.36	68.57 ± 0.26^{y}	68.84 ± 0.17^{y}	68.93 ± 0.06^{y}			
PUFA/SFA							***	***	***
	MA	0.88 ± 0.01^{a}	0.82 ± 0.006^{b,x}	0.75 ± 0.004^{c,x}	0.68 ± 0.004^{d,x}	0.61 ± 0.007^{e,x}			
	Vacuum	0.88 ± 0.01	0.87 ± 0.005^{y}	0.87 ± 0.005^{y}	0.87 ± 0.003^{y}	0.88 ± 0.001^{y}			
n-6							***	***	***
	MA	23.73 ± 0.11^{a}	22.72 ± 0.22^{b,x}	21.45 ± 0.09^{c,x}	19.75 ± 0.08^{d,x}	18.61 ± 0.18^{e,x}			
	Vacuum	23.73 ± 0.11	23.67 ± 0.12^{y}	23.57 ± 0.12^{y}	23.69 ± 0.06^{y}	23.80 ± 0.02^{y}			

Table 1 *Continued.*

Fatty acids	Packaging atmosphere	Storage time[1] (D) 0	4	7	9	11	Significance effects PA	ST	PA × ST
n-3							***	***	***
	MA	2.17 ± 0.03[a]	1.93 ± 0.02[b,x]	1.75 ± 0.03[c,x]	1.64 ± 0.03[d,x]	1.50 ± 0.04[e,x]			
	Vacuum	2.17 ± 0.03	2.18 ± 0.02[y]	2.20 ± 0.03[y]	2.17 ± 0.01[y]	2.17 ± 0.03[y]			
n-6/n-3							***	**	***
	MA	10.92 ± 0.12[a]	11.80 ± 0.09[b,x]	12.29 ± 0.25[b,c,x]	12.03 ± 0.22[b,c,x]	12.47 ± 0.30[c,x]			
	Vacuum	10.92 ± 0.12	10.86 ± 0.07[y]	10.74 ± 0.13[y]	10.91 ± 0.05[y]	10.96 ± 0.16[y]			

[1]The data are average values of 50 tests for storage time 0; 25 tests for storage time 4, 7, 9, 11 D.
[a–e]Means with different letters in the same row, differ at $P < 0.05$ in view of the time of storage.
[x,y]Means with different letters in the same column, differ at $P < 0.05$ in view of the packaging atmosphere.
Significance effects: $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; ns—not significant.
PA: packaging atmosphere, ST: storage time, MA: modified atmosphere (80% O_2 and 20% CO_2), SFA: saturated fatty acid, UFA: unsaturated fatty acid, MUFA: monounsaturated fatty acid, PUFA: polyunsaturated fatty acid.

in the proportion of SFA, MUFA, and PUFA in muscle lipids and subcutaneous fat throughout the whole storage time. In case of lipid samples packed in oxygen atmosphere, a decrease of PUFA and an increase of SFA and MUFA was noticed. Up to the 11th storage day the percent of SFA increased gradually in lipids samples packed in MA, mainly due to increased palmitic (C16:0) and stearic (C18:0) acids. The increase in SFA during storage in samples packed in MA could probably result from the degradation of PUFA, which generated low molecular weight compounds and possibly short chain FA.

Likewise the MUFA percentage rose gradually up to the 11th D due to increase in oleic (C18:1) and palmitoleic (C16:1) acids. Unfavorable in terms of nutrition was the lowering, in comparison to unpacked samples, the percentage of PUFA in both intramuscular and subcutaneous goose fat, due to the reduction of all types of PUFA individually. On the 11th D, the percentage of linoleic (C18:2), linolenic (C18:3), eicosadienoic (C20:2), eicosatrienoic (C20:3), arachidonic (C20:4), eicosapentaenoic (C20:5), and docosahexaenoic (C22:6) acid in intramuscular fat had fallen, in comparison to unpacked samples, respectively by: 19.82, 26.14, 46.15, 30.43, 28.03, 64.29, and 50.00% (Table 1); in case of subcutaneous fat the percentage of linoleic, linolenic, arachidonic, and eicosapentaenoic acid had lowered, in comparison to control samples, respectively by: 27.19, 48.72, 67.86 and 77.78% (Table 2).

The ratio of PUFA to saturated ones is an important indicator of fat quality, and its recommended dietary allowance should be higher than 0.40 (Simopoulos, 2003). It was demonstrated that the PUFA/SFA ratio did not change during sample storage in vacuum, but decreased in fat packaged in MA (Table 1; Table 2). Therefore, from the point of view of human nutritional, both the intramuscular fat and the subcutaneous fat of goose packaged in vacuum have a better PUFA/SFA ratio than those packaged in a high-oxygen modified atmosphere and stored in refrigerated conditions.

The n-6/n-3 ratio is a useful indicator of the food's nutritional value. Ideally, this should be less than 4 to 5:1 (Geldenhuys et al., 2013), but in practice it is usually more than 20:1 (Simopoulos, 2003, 2008; Farrell 2013; Materac et al., 2013) due to over-consumption of n-6 FA and foods containing SFA. In the human body this imbalance n-6/n-3 ratio can lead to, e.g., cancer or cardiovascular disease (Simopoulos, 2008). At the end of the storage period, higher *n-6/n-3* ratio was reported in samples packaged in MA, as compared to those packaged in vacuum (Tables 1 and 2). Although the *n-6/n-3* ratio in intramuscular and subcutaneous fat, regardless of the type of atmosphere, was higher than the recommended value, it was clearly lower than in the typical diet of most developed countries. It has been shown that the packaging of goose meat in vacuum is a better method to protect the FA profile of both intramuscular fat and subcutaneous fat.

Packaging method had a significant effect on the SE of odor intensity in the goose meat and subcutaneous fat (Table 3). The odor of the unpacked breast muscles and subcutaneous fat was found to be ideal, characteristic for chilled goose meat and fat (Table 3). It was observed that the SE of odor intensity did not change for subcutaneous fat stored in vacuum, whereas in fat packed under MA, deterioration of the odor was noticed during storage. On the 11th D, the odor intensity of the subcutaneous fat in MA was still typical but less intense in comparison to control samples (4.28; Table 3). The odor intensity decreased with storage up to 11th D in breast muscles packed both in MA and vacuum. From 4th to 11th D goose meat stored under MA had lower SE intensity of odor than meat under vacuum (Table 3). At the end of storage, goose meat stored in vacuum was characterized by the typical odor but less intense in comparison to unpacked samples (4.12 CU; Table 3), whereas the odor intensity of MA packed samples was slightly changed (3.48; Table 3). It is hard to explain why the SE of odor intensity of muscles stored in vacuum was decreased while the FA profile did not change. Perhaps the growth of microorganisms was associated with a decrease of SE of odor intensity.

The obtained data indicate negative effect of high oxygen MA storage on the FA profile and the nutritional value of goose meat and subcutaneous fat. The lower extent of oxidation in samples stored in vacuum

Table 2. Mean values (±standard error) of fatty acid profile (% of the total fatty acids) of subcutaneous goose fat packed in different atmospheres and stored at 4°C for up to 11 D.

Fatty acids	Packaging atmosphere	Storage time[1] (d)					Significance effects		
		0	4	7	9	11	PA	ST	PA ×ST
SFA									
	MA	28.80 ± 0.31^{a}	29.34 ± 0.05^{a}	30.53 ± 0.10^{b,x}	31.16 ± 0.02^{c,x}	31.56 ± 0.10^{c,x}	***	***	***
	Vacuum	28.80 ± 0.31	28.86 ± 0.13	28.86 ± 0.08^{y}	28.85 ± 0.08^{y}	28.85 ± 0.12^{y}			
C 12:0							***	***	***
	MA	0.21 ± 0.005^{a}	0.24 ± 0.002^{a}	0.27 ± 0.004^{b,x}	0.31 ± 0.006^{c,x}	0.37 ± 0.008^{d,x}			
	Vacuum	0.21 ± 0.005	0.22 ± 0.007	0.21 ± 0.005^{y}	0.23 ± 0.006^{y}	0.22 ± 0.008^{y}			
C 14:0							***	***	***
	MA	0.67 ± 0.005^{a}	0.81 ± 0.007^{b,x}	0.89 ± 0.009^{c,x}	1.06 ± 0.009^{d,x}	1.16 ± 0.01^{e,x}			
	Vacuum	0.67 ± 0.005	0.69 ± 0.004^{y}	0.71 ± 0.008^{y}	0.70 ± 0.008^{y}	0.70 ± 0.009^{y}			
C 15:0							***	***	***
	MA	0.32 ± 0.006^{a}	0.35 ± 0.006^{a}	0.45 ± 0.009^{b,x}	0.48 ± 0.007^{c,x}	0.55 ± 0.01^{d,x}			
	Vacuum	0.32 ± 0.006	0.33 ± 0.009	0.33 ± 0.009^{y}	0.32 ± 0.009^{y}	0.31 ± 0.008^{y}			
C 16:0							***	***	***
	MA	22.20 ± 0.11^{a}	22.43 ± 0.01^{a}	23.20 ± 0.09^{b,x}	23.50 ± 0.03^{b,c,x}	23.62 ± 0.08^{c,x}			
	Vacuum	22.20 ± 0.11	22.24 ± 0.09	22.21 ± 0.07^{y}	22.23 ± 0.09^{y}	22.20 ± 0.09^{y}			
C 17:0							ns	ns	ns
	MA	0.11 ± 0.004	0.12 ± 0.006	0.11 ± 0.000	0.11 ± 0.000	0.11 ± 0.003			
	Vacuum	0.11 ± 0.004	0.10 ± 0.004	0.12 ± 0.008	0.10 ± 0.007	0.11 ± 0.009			
C 18:0							***	***	***
	MA	5.29 ± 0.01^{a}	5.41 ± 0.01^{b,x}	5.62 ± 0.009^{b,x}	5.71 ± 0.01^{b,x}	5.76 ± 0.01^{d,x}			
	Vacuum	5.29 ± 0.01	5.27 ± 0.01^{y}	5.29 ± 0.01^{y}	5.28 ± 0.01^{y}	5.31 ± 0.01^{y}			
MUFA							***	***	***
	MA	50.41 ± 0.29^{a}	51.33 ± 0.24^{a,b,x}	51.95 ± 0.07^{b,x}	53.00 ± 0.03^{c,x}	53.99 ± 0.06^{d,x}			
	Vacuum	50.41 ± 0.29	50.62 ± 0.08^{y}	50.50 ± 0.19^{y}	50.93 ± 0.15^{y}	50.75 ± 0.13^{y}			
C 16:1							***	***	***
	MA	3.39 ± 0.11^{a}	3.78 ± 0.06^{b,x}	4.14 ± 0.08^{c,x}	4.39 ± 0.07^{c,d,x}	4.60 ± 0.05^{d,x}			
	Vacuum	3.39 ± 0.11	3.41 ± 0.11^{y}	3.45 ± 0.06^{y}	3.47 ± 0.07^{y}	3.39 ± 0.07^{y}			
C 17:1							***	***	***
	MA	0.05 ± 0.000^{a}	0.06 ± 0.000^{b,x}	0.07 ± 0.000^{b,x}	0.08 ± 0.000^{c,x}	0.09 ± 0.000^{d,x}			
	Vacuum	0.05 ± 0.000	0.05 ± 0.000^{y}	0.05 ± 0.000^{y}	0.05 ± 0.000^{y}	0.05 ± 0.000^{y}			
C 18:1							***	***	***
	MA	46.8 ± 0.18^{a}	47.32 ± 0.19^{a,b}	47.52 ± 0.02^{b,x}	48.62 ± 0.08^{c,x}	49.04 ± 0.02^{d,x}			
	Vacuum	46.8 ± 0.18	46.99 ± 0.08	46.83 ± 0.13^{y}	47.23 ± 0.13^{y}	47.14 ± 0.16^{y}			
C 20:1							***	***	***
	MA	0.17 ± 0.000^{a}	0.19 ± 0.000^{b,x}	0.22 ± 0.000^{c,x}	0.25 ± 0.001^{d,x}	0.25 ± 0.001^{d,x}			
	Vacuum	0.17 ± 0.000	0.17 ± 0.000	0.17 ± 0.000	0.17 ± 0.000^{y}	0.17 ± 0.000^{y}			
PUFA							***	***	***
	MA	19.34 ± 0.42^{a}	18.20 ± 0.20^{b,x}	17.03 ± 0.19^{c,x}	15.50 ± 0.18^{d,x}	13.72 ± 0.31^{e,x}			
	Vacuum	19.34 ± 0.42	19.28 ± 0.23^{y}	19.60 ± 0.21^{y}	19.15 ± 0.22^{y}	19.28 ± 0.21^{y}			
C 18:2n-6							***	***	***
	MA	17.32 ± 0.19^{a}	16.45 ± 0.17^{b,x}	15.53 ± 0.17^{c,x}	14.22 ± 0.14^{d,x}	12.61 ± 0.20^{e,x}			
	Vacuum	17.32 ± 0.19	17.40 ± 0.11^{y}	17.40 ± 0.09^{y}	17.48 ± 0.20^{y}	17.29 ± 0.18^{y}			
C 18:3n-3							***	***	***
	MA	1.56 ± 0.02^{a}	1.41 ± 0.03^{b,x}	1.23 ± 0.02^{c,x}	0.83 ± 0.03^{d,x}	0.80 ± 0.03^{e,x}			
	Vacuum	1.56 ± 0.02	1.53 ± 0.02^{y}	1.54 ± 0.02^{y}	1.49 ± 0.02^{y}	1.53 ± 0.02^{y}			
C 20:4n-6							***	***	***
	MA	0.28 ± 0.000^{a}	0.21 ± 0.000^{b,x}	0.17 ± 0.000^{c,x}	0.16 ± 0.000^{d,x}	0.09 ± 0.000^{e,x}			
	Vacuum	0.28 ± 0.000	0.30 ± 0.000^{y}	0.30 ± 0.000^{y}	0.29 ± 0.000^{y}	0.30 ± 0.000^{y}			
C 20:5n-3							***	***	***
	MA	0.18 ± 0.000^{a}	0.13 ± 0.000^{b,x}	0.11 ± 0.000^{c,x}	0.07 ± 0.000^{d,x}	0.04 ± 0.000^{e,x}			
	Vacuum	0.18 ± 0.000	0.18 ± 0.000^{y}	0.19 ± 0.000^{y}	0.18 ± 0.000^{y}	0.18 ± 0.000^{y}			
Σ UFA							***	ns	**
	MA	69.75 ± 0.26^{a}	69.53 ± 0.44^{a,b}	68.99 ± 0.25^{a,b}	68.50 ± 0.14^{b,c,x}	67.72 ± 0.40^{c,x}			
	Vacuum	69.75 ± 0.26	69.90 ± 0.30	70.10 ± 0.40	70.08 ± 0.35^{y}	70.03 ± 0.39^{y}			
PUFA/SFA							***	***	***
	MA	0.67 ± 0.01^{a}	0.62 ± 0.007^{b,x}	0.56 ± 0.007^{c,x}	0.50 ± 0.005^{d,x}	0.43 ± 0.01^{e,x}			
	Vacuum	0.67 ± 0.01	0.67 ± 0.007^{y}	0.68 ± 0.007^{y}	0.66 ± 0.006^{y}	0.67 ± 0.01^{y}			
n-6							***	***	***
	MA	17.6 ± 0.35^{a}	16.66 ± 0.17^{b,x}	15.70 ± 0.17^{c,x}	14.38 ± 0.14^{d,x}	12.69 ± 0.20^{e,x}			
	Vacuum	17.6 ± 0.35	17.62 ± 0.21^{y}	17.83 ± 0.19^{y}	17.50 ± 0.21^{y}	17.52 ± 0.18^{y}			
n-3							***	***	***
	MA	1.74 ± 0.08^{a}	1.55 ± 0.03^{b}	1.34 ± 0.02^{c,x}	1.12 ± 0.03^{d,x}	0.83 ± 0.04^{e,x}			
	Vacuum	1.74 ± 0.08	1.66 ± 0.02	1.76 ± 0.02^{y}	1.66 ± 0.02^{y}	1.76 ± 0.02^{y}			
n-6/n-3							***	***	***
	MA	10.11 ± 0.28^{a}	10.79 ± 0.14^{a}	11.75 ± 0.19^{b,x}	12.92 ± 0.28^{c,x}	15.36 ± 0.50^{d,x}			
	Vacuum	10.11 ± 0.28	10.62 ± 0.12	10.11 ± 0.07^{y}	10.54 ± 0.13^{y}	9.95 ± 0.07^{y}			

[1]The data are average values of 50 tests for storage time 0; 25 tests for storage time 4, 7, 9, 11 D.

$^{a–e}$Means with different letters in the same row, differ at $P < 0.05$ in view of the time of storage.

^{x,y}Means with different letters in the same column, differ at $P < 0.05$ in view of the packaging atmosphere.

Significance effects: $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; ns—not significant.

PA: packaging atmosphere, ST: storage time, MA: modified atmosphere, 80% O_2 and 20% CO_2; SFA: saturated fatty acid, UFA: unsaturated fatty acid, MUFA: monounsaturated fatty acid, PUFA: polyunsaturated fatty acid.

Table 3. Mean values (±standard error) of odor sensory evaluation (SE) of the goose breast muscles and subcutaneous fat packed in different atmospheres and stored at +4°C for up to 11 D.

SE[2] [CU]	Packaging atmosphere	Storage time[1] (d) 0	4	7	9	11	Significance effects PA	ST	PA × ST
Breast muscles							***	***	***
	MA	6.00 ± 0.00[a]	5.32 ± 0.09[b,x]	4.92 ± 0.05[c,x]	4.12 ± 0.06[d,x]	3.48 ± 0.10[e,x]			
	Vacuum	6.00 ± 0.00[a]	5.84 ± 0.07[a,y]	5.24 ± 0.09[b,y]	4.48 ± 0.10[c,y]	4.12 ± 0.10[d,y]			
Subcutaneous fat							***	***	***
	MA	5.64 ± 0.09[a]	5.24 ± 0.08[b]	4.64 ± 0.09[c,x]	4.40 ± 0.09[c,d,x]	4.28 ± 0.09[d,x]			
	Vacuum	5.64 ± 0.09	5.48 ± 0.10	5.44 ± 0.10[y]	5.40 ± 0.09[y]	5.40 ± 0.10[y]			

[1]The data are average values of 50 tests for storage time 0; 25 tests for storage time 4, 7, 9,11 D.
[2]Scale of scores: 6 = typical; 1 = completely changed; CU—conventional units.
[a–e]Means with different letters in the same row, differ at $P < 0.05$ in view of the time of storage.
[x,y]Means with different letters in the same column, differ at $P < 0.05$ in view of the packaging atmosphere.
Significance effects: $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; ns—not significant.
PA: packaging atmosphere, ST: storage time, MA: modified atmosphere, 80% O_2 and 20% CO_2.

resulted from to the fact that meat was not exposed to oxygen.

It can be concluded that packaging in a high-oxygen atmosphere facilitated the lipid oxidation of both intramuscular and subcutaneous goose fat during cold storage, resulting in changes in the FA profile, lowering the percentage of PUFA and increasing the SFA and MUFA content, and changing the odor intensity of breast muscles and the subcutaneous fat. Vacuum storage protects the intramuscular and subcutaneous fat from oxidation, so that the FA profile and the odor intensity of the subcutaneous fat during storage remain unchanged. The results of our research confirm that the lack of oxygen or its low concentration limits the oxidation processes in meat.

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