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CHANGES IN CHEMICAL COMPOSITION OF MEAT FROM ROE DEER (*CAPREOLUS CAPREOLUS* L.) BUCKS DURING COLD STORAGE UNDER VACUUM AND MODIFIED ATMOSPHERE

Tomasz Daszkiewicz[1], Paweł Janiszewski[2], Jacek Kondratowicz[1]

[1]Department of Commodity Science of Animal Raw Materials, [2]Department of Fur-bearing Animal Breeding and Game Management, University of Warmia and Mazury, Olsztyn

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Changes in the chemical composition, nitrogen content of water extracts, weight loss and shear force of meat from roe deer (*Capreolus capreolus* L.) bucks were analysed during 21-day cold storage (2°C) under modified atmosphere conditions (vacuum; 40% CO_2 + 60% N_2; 60% CO_2 + 40% N_2). A gradual increase in drip loss was observed over the storage period. The process of cold storage of roebuck meat in a modified atmosphere (MA) had no significant effect on the content of major chemical components. The dynamics of changes in the content of nitrogen compounds in water extracts of cold-stored meat was lower in MA-packaged samples, compared to the vacuum-packaged samples. The relatively low rate of protein degradation (proteolysis) in roebuck meat during ageing was reflected in the lack of considerable changes in the average values of shear force.

INTRODUCTION

The simplest method applied to extend the shelf-life of meat involves cold storage at a temperature above the freezing point of cell sap [Gill, 1996]. However, the time of cold storage of meat is limited, primarily due to microbial growth and lipid oxidation [Labadie, 1999]. Another important problem observed in cold-stored meat is drip loss [Gill, 1996]. Therefore, the shelf-life of such meat is often improved by modifying the composition of the internal atmosphere of a package.

Meat can be stored at controlled atmosphere (CA) or packed in modified atmosphere (MA) [Jeremiah, 2001]. Both methods are in use, because they successfully meet increasing consumer demand for natural, fresh (non-frozen) foods of extended shelf-life [Soriano *et al.*, 2006]. However, literature on changes taking place in cold-stored venison and on the possibility of game meat packing in a modified atmosphere is scant. Moreover, it should be stressed that most studies conducted to date focused on meat from farm-raised animals [Seman *et al.*, 1989; Vergara *et al.*, 2003].

The aim of this study was to determine the effect of cold storage (2°C, 21 days) under vacuum and modified atmosphere conditions (40% CO_2 + 60% N_2 and 60% CO_2 + 40% N_2) on changes in the chemical composition and nitrogen content of water extracts of meat from roe deer (*Capreolus capreolus* L.) bucks.

MATERIALS AND METHODS

The experimental materials consisted of carcasses of roe deer (*Capreolus capreolus* L.) bucks shot in forests of north-eastern Poland during the hunting season 2006/2007. Among the carcasses supplied to the Meat Processing Plant X, 16 carcasses of roebucks were selected for experiments, based on the following criteria: age of animals at harvest: 3 to 5 years; time that passed from harvest of animals to carcass cutting 48 to 54 h; no bullet damage to *musculus longissimus*; correct carcass evisceration procedure, no shot damage or contamination due to bullet; carcass temperature (measured at the geometric center of the thickest portion of the leg) – not higher than 7°C; acidity of *musculus longissimus* (at the last rib) pH_u 5.4 to 5.8 (to eliminate DFD meat).

Musculus longissimus was cut out of the left and the right side of each carcass, vacuum-packaged and transported to the laboratory in isothermal containers. The muscles from each carcass were divided into 6 parts which were allocated to three groups: A, B, C. Samples A were vacuum packaged, while samples B and C were packaged in a modified atmosphere (MA). Gas mixture composition was as follows: B – 40% CO_2 + 60% N_2, and C – 60% CO_2 + 40% N_2. Packaging was carried out with a packaging machine (Model PP-5MG (015), TEPRO S.A., Koszalin, Poland), using barrier bags made of AMILEN-UX 90 laminate (a high EVOH barrier between two PA plies with an EVA sealant layer) with gas permeability: O_2 = 1 cm^{-3} m^{-2} 24 h^{-1} bar^{-1} at 23°C; N_2 < 0.1 cm^{-3} m^{-2} 24 h^{-1} bar^{-1} at 23°C; CO_2 = 1.6 cm^{-3} m^{-2} 24 h^{-1} bar^{-1} at 23°C; and with water vapor transmission 3 g m^{-2} 24 h^{-1} at 23°C. The packaged samples were stored at 2°C for 7 and 21 days.

All samples stored under vacuum and modified atmosphere conditions were analysed to determine their quality attributes, including weight loss during storage, chemical composition, nitrogen fractions content of water extracts of meat, and shear

Author's address for correspondence: dr hab. Tomasz Daszkiewicz, Department of Commodity Science of Animal Raw Materials, University of Warmia and Mazury in Olsztyn, ul. Oczapowskiego 5, 10-719 Olsztyn, Poland; tel.: (48 89) 523 43 84; fax: (48 89) 523 38 33; e-mail: tomasz.daszkiewicz@uwm.edu.pl

force. Weight loss of meat was estimated as described by Insausti *et al.* [2001]. The analysis of the chemical composition of meat included the determination of dry matter content, total protein content by the Kjeldahl method, fat content by the Soxhlet method and ash content [AOAC, 1990]. A water extract of meat was prepared as described by Herring *et al.* [1971]. Nitrogen fractions content of water extracts of meat (total nitrogen and non-protein nitrogen) were determined according to the Kjeldahl method. The content of protein nitrogen of water extracts of meat was calculated as the difference between total nitrogen and non-protein nitrogen. Shear force of meat was determined using a Warner-Bratzler head (500 N, speed 100 mm/min.) attached to an Instron universal testing machine (model 5542). The preparation of the meat samples and the measurement of shear force were performed as described by Honikel [1998].

All data were processed by one-way analysis of variance in order to determine the effect of MA type and storage time on each variable. Duncan's test was carried out to determine differences between groups. Statistical analyses were performed using STATISTICA (data analysis software system), ver. 7.1 [2005].

RESULTS AND DISCUSSION

In the present study weight loss increased as the time of cold storage was prolonged (Table 1). After the first 7 days of storage the highest weight loss (1.50%) was recorded in vacuum-packaged samples. Average weight loss in MA-packaged meat (at various ratios of CO_2 to N_2) was two- to three-fold lower. After 21 days of storage average weight loss was at a comparable level (2.17%) in vacuum-packaged meat and in meat packaged in a MA composed of 40% CO_2 + 60% N_2. In samples stored for 21 days in a MA composed of 60% CO_2 + 40% N_2 weight loss was higher by 0.61 percentage unit.

The considerable weight loss noted at the first stage of cold storage in vacuum-packaged roebuck meat, compared to MA-packaged samples, corresponds to the results obtained for other kinds of meat [Cayuela *et al.*, 2004; Doherty *et al.*, 1996; Sekar *et al.*, 2006]. This may be explained by the mechanical effect of reduced pressure on the texture of vacuum-packaged meat, which manifests itself in increased exudation of meat juice [Payne *et al.*, 1998]. A few studies only [Seman *et al.*, 1989; Sørheim *et al.*, 1996] point to lower weight loss in vacuum-packaged meat, in comparison with MA-packaged meat. Some authors [Doherty *et al.*, 1996; Seman *et al.*, 1989; Sørheim *et al.*, 1996] suggest that MA with an increased CO_2 content may intensify exudation of meat juice. In the current experiment, meat packaged in a MA with 60% of CO_2 was characterised by greater weight loss than meat packaged in a MA with 40% of CO_2, but those differences were found to be statistically non-significant.

A gradual increase in weight loss observed in cold-stored roebuck meat could possibly affect its chemical composition. However, an analysis of the proximate composition of meat (Table 1) showed no significant differences in dry matter content between samples cold-stored for 21 days in a MA of various composition. The lack of increase in the dry matter content of meat despite increasing weight loss due to the exudation of meat juice was probably related to the loss of nutrients contained in this juice, primarily soluble proteins and non-protein nitrogen compounds, whose content of the aqueous phase of meat increases as a result of autolytic changes. Savage *et al.* [1990] demonstrated that 1 mL of pork exudate obtained during cold storage may contain approximately 112 mg of proteins, mostly water-soluble sarcoplasmatic proteins. This was confirmed by analysis of total protein content, which was found to decrease slightly in all samples cold-stored for 21 days, except for the vacuum-packaged ones.

An analysis of the chemical composition of meat indicated that the average ash content increased as the time of cold storage was prolonged. However, the differences among groups were small and could be connected with an analytical error. The composition of modified atmosphere had no significant ($p>0.05$) impact on the content of ash in meat.

Changes in the chemical composition of cold-stored roebuck meat, observed in this study, generally correspond to the results of experiments involving pork and beef [Meller *et al.*, 1998; Sobina & Meller, 1999]. However, an increase in the content of particular components (in particular dry matter) was usually more distinct in beef and pork than in roebuck meat, which was a direct effect of higher water loss in the former. On the other hand, some authors [Ahnstroöm *et al.*, 2006; Daszkiewicz *et al.*, 2003; Ruiz de Huidobro *et al.*, 2003] reported no significant changes in the water content of cold-stored meat.

Storage conditions had no significant effect on the average values of the ratio between total nitrogen contained in water extracts and the total nitrogen content of roebuck meat (Table 2). However, attention should be paid to a tendency towards a decrease in this nitrogen fraction in meat stored in a MA composed of 40% CO_2 + 60% N_2, and its increase in vacuum-packaged samples. Meat packaged under vacuum conditions contained also considerably more non-protein nitrogen, compared to the MA-packaged meat.

An analysis of quantitative changes in particular nitrogen fractions in water extracts of cold-stored meat showed no

TABLE 1. Weight loss (%) and chemical composition of meat (g/kg) after storage under vacuum and modified atmosphere (means±S.E.).

Traits	Storage time (days)	Modified atmosphere*		
		Type A	Type B	Type C
Weight loss	7	$1.50^{axy}\pm0.13$	$0.53^{ax}\pm0.11$	$0.67^{ay}\pm0.08$
	21	$2.17^{a}\pm0.17$	$2.17^{a}\pm0.54$	$2.78^{a}\pm0.69$
Dry matter	7	254.1±1.6	255.7±1.9	253.9±1.6
	21	251.4±1.2	254.4±1.2	252.9±1.3
Crude protein	7	$227.3^{a}\pm1.2$	227.6±1.3	226.8±1.3
	21	$222.6^{a}\pm0.7$	225.6±1.4	224.3±1.6
Fat	7	4.0±0.6	4.8±1.0	5.0±0.8
	21	5.1±0.6	5.0±0.8	5.7±0.8
Ash	7	10.8±0.4	$10.2^{a}\pm0.3$	$10.7^{a}\pm0.4$
	21	11.8±0.5	$12.0^{a}\pm0.4$	$11.8^{a}\pm0.3$

SE – standard error. Modified atmosphere*: Type A – vacuum, Type B – 40% CO_2 + 60% N_2, Type C – 60% CO_2 + 40% N_2. Values in the same row with the same letters are significantly different, xy – $p\leq0.05$. Values in the same column with the same letters are significantly different, aa – $p\leq0.05$.

TABLE 2. The ratio between fractions of nitrogen compounds in meat and shear force of meat after storage under vacuum and modified atmosphere (means±S.E.).

Traits	Storage time (days)	Modified atmosphere*		
		Type A	Type B	Type C
Ratio between total N of water-soluble compounds and total N in meat (%)	7	28.72±0.39	28.05±0.45	28.97±0.35
	21	29.63±0.39	28.26±0.64	28.70±0.50
Ratio between N of water-soluble protein compounds and total N in meat (%)	7	13.20±0.33	13.13±0.33	13.61±0.32
	21	12.84±0.53	12.24±0.77	13.20±0.72
Ratio between N of water-soluble non-protein compounds and total N in meat (%)	7	15.52[ax]±0.21	14.92[ax]±0.20	15.37±0.12
	21	16.79[ax]±0.36	16.02[a]±0.23	15.50[x]±0.31
Ratio between N of water-soluble protein compounds and total N of water-soluble compounds (%)	7	45.88±0.71	46.73±0.58	46.87±0.62
	21	43.16±1.49	42.59±2.35	45.56±1.87
Shear force (N)	7	17.98±0.85	16.94±0.69	18.86±1.12
	21	16.24±0.55	17.14±0.62	16.72±0.67

SE – standard error. Modified atmosphere*: Type A – vacuum, Type B – 40% CO_2 + 60% N_2, Type C – 60% CO_2 + 40% N_2. Values in the same row with the same letters are significantly different, xx – $p \leq 0.05$. Values in the same column with the same letters are significantly different, aa – $p \leq 0.05$.

statistically significant differences between vacuum- and MA--packaged samples with regard to the ratio of water-soluble nitrogen to total nitrogen. However, a tendency towards an increase in total water-soluble nitrogen was observed in vacuum-packaged meat stored for an extended period of time.

A substantial increase was noted in the amount of non-protein nitrogen in water extracts of cold-stored meat packaged under vacuum and MA (40% CO_2 + 60% N_2) conditions. The proportion of this nitrogen fraction in total nitrogen was significantly ($p \leq 0.05$) higher in meat samples stored for 21 days than in those stored for 7 days. No significant increase in non-protein nitrogen was recorded over this period of time in meat stored in a MA composed of 60% CO_2 + 40% N_2.

Available literature provides no data on proteolytic changes in game meat that could be confronted with the present results. A gradual increase in the amino nitrogen content of aged meat from red deer and roe deer was reported by Smolińska & Szmańko [1975]. It should be stressed, however, that those authors analysed meat stored below freezing point for 4 months.

It may be concluded that changes in the content of particular nitrogen fractions in cold-stored roebuck meat were comparable to those observed in pork and beef [Daszkiewicz & Wajda 2003; Feidt *et al.*, 1998; Meller *et al.*, 1998; Sobina, 1998]. The only difference between meat from roebucks and slaughter animals concerned the rate of autolytic changes, which was found to be slower in meat from roebucks, thus permitting to retain its unique flavor for a longer time. The rate of autolytic changes was also slower in MA-packaged samples, compared to those packaged under vacuum conditions.

Proteolytic changes lead to, among others, an improvement in meat tenderness, reflected in a decrease in shear force value. In this study the average values of shear force of meat packaged in a MA of various composition (Table 2) were at a comparable level (no statistically significant differences) at successive stages of cold storage. A slight decrease in shear force was recorded in vacuum-packaged and in MA (60% CO_2 + 40% N_2) samples stored for 21 days.

The lack of significant differences in the average values of shear force of cold-stored roebuck meat can be explained by the relatively low rate of proteolytic changes. The lack of significant differences in the average values of shear force of vacuum-stored roe deer meat (3.5°C; 132 h) was also confirmed by Paulsen *et al.* [2005]. Seman *et al.* [1989] observed no significant changes in shear force of meat from red deer stags, stored for 18 weeks under vacuum and MA conditions (100% CO_2). Vergara *et al.* [2003] noted a decrease in shear force of meat from red deer hinds, stored for 23 days in a MA composed of CO_2, O_2 and N_2 at various concentrations.

CONCLUSIONS

1. Vacuum-packaged meat had higher initial weight losses (after 7 days of storage) than meat stored in a modified atmosphere (40% CO_2 + 60% N_2 and 60% CO_2 + 40% N_2).

2. The process of cold storage in a modified atmosphere (MA) and vacuum had no significant effect on the content of major chemical components in roebuck meat.

3. Changes in the content of nitrogen compounds in water extracts of cold-stored meat were smaller in MA-packaged samples, compared to the vacuum-packaged ones.

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