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COMPARISON OF THE TEXTURE, RHEOLOGICAL PROPERTIES AND MYOFIBRE CHARACTERISTICS OF SM (*SEMIMEMBRANOSUS*) MUSCLE OF SELECTED SPECIES OF GAME ANIMALS

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The texture, rheological properties and myofibre characteristics of *semimembranosus* muscles of four different species: wild boar (*Sus scrofa*), deer (*Cervus elaphus*), roe-deer (*Capreolus capreolus*), and fallow-deer (*Dama dama*) shot at 18 months during winter were compared. The muscle texture and rheological properties were determined with the TPA and relaxation tests, performed with an Instron 1140 apparatus. Myofibre characteristics (mean muscle fibre cross sectional area, percentage of type I, IIA and IIB fibres) were measured in muscle samples using a computer image analysis program.

The results demonstrate that the highest hardness, cohesiveness, chewiness, the highest mean fibre cross sectional area and percentage of type I fibre were typical of wild boar SM muscle. The lowest textural parameters and percentage of red fibres being recorded in roe deer meat, which at the same time showed the highest elasticity and viscosity.

INTRODUCTION

Increasing consumer concern is observed in the field of energetic and nutritional values of food, as well as in the role played by a correct diet in a healthy lifestyle. Recent statistical updates indicate the significantly enhanced consumer interest in the venison meat [Zin *et al.*, 2002], because of its high level of proteins, vitamins, mineral salts and lower, compared to meat of domestic slaughter animals, content of fat and cholesterol, as well as its lower level energetic value of about 90-110 kcal/100 g [Korzeniowski & Żmijewski, 2000]. The histochemical composition of wild animals meat differs somewhat from the composition of farm animals, and the difference stemming from different life conditions [Prost *et al.,* 1985; Rede *et al*., 1986; Korzeniowski *et al.,* 1991].

The unique properties of venison meat are caused by a different muscle fibre type content and reflect the physical, chemical, and morphological composition of the meat. In meat processing, red and white muscle fibres produce different palatabilities, as judged by tenderness, juiciness, texture, and flavor [Xiong, 1994].

Correlation between fibre diameter, connective tissue thickness, fibre type composition, and meat texture parameters values or rheological properties were observed in wild boar meat by Żochowska *et al.* [2005] and in deer and roe deer muscles by Żochowska-Kujawska *et al.* [2006a; 2007]. Some more studies suggest relationships between fiber type or size and texture or eating quality, especially tenderness in beef [Crouse *et al*., 1991; Maltin *et al*., 1998; Sobczak *et al.,* 2005]. Although the results are variable and sometimes contradictory. No correlation between muscle fiber traits and tenderness were found by Whipple *et al.* [1990] however Klont *et al.* [1998] suggest relationships exist between muscle fiber type and meat quality, particularly in pork. However, no data on comparison muscle fibre characteristic, structure, textural and rheological properties of several species of game animals could be found simultaneously in the available literature.

The objectives in this study were to compare fibre type, texture and rheological properties in SM (*semimembranosus*) muscles of game animals.

MATERIALS AND METHODS

A total of twenty carcasses from female of game animals (five carcasses in each group), of four different species: wild boar (*Sus scrofa*), deer (*Cervus elaphus*), roe-deer (*Capreolus capreolus*), and fallow-deer (*Dama dama*) shot at 18 months during winter in an enclosed area in the forest of the Western Pomeranian District were used. Shortly after being shot (30--45 min) 1 x 1 x 0.5 cm samples were taken from the mid-part of muscle *semimembranosus* (SM), frozen in liquid nitrogen and stored at -80°C for muscle fibre characteristics analysis. Half-carcasses of the experimental animals, kept at 4°C for 48 h from the moment of shooting were used to obtain the SM muscle.

About 4 cm thick slices were cut perpendicularly to the fibres from each muscle. The slices were placed in thermoresistant plastic bags, cooked in water at 85°C until the geometric

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centre reached 68°C, cooled and stored at 4°C for 12 h.

Myofibrils characteristics were made on liquid-nitrogen-frozen samples of muscle. In order to classify the muscle fibres into type I, IIA and IIB groups, cross sections (10 μm) were cut at -26°C with a cryostat HM 505 EV. The sections were placed on glass slides, stained using the myosin ATPase method [Guth & Samaha, 1970] with an alkaline preincubation solution (pH 10.4), and classified according to Brooke & Kaiser [1970] into three groups: type I (slow oxidative), type IIA (fast oxidative-glycolitic), and type IIB (fast glycolytic). Stained sections were examined with the image analysis system using a computer program (Multi Scan Base v.13). Percentage of different fibre types (%) (type I, type IIA, and type IIB) and mean fibre cross sectional area per muscle fibre bundle were computed (more than 10 bundles were examined for each muscle sample). A magnification of 100x was used.

Texture and rheological measurements were made on thermally treated samples of muscles brought to about 18°C. After removal of the plastic sheets, 20±2 mm thick slices were cut out from each sample to determine their texture and rheological properties on an Instron 1140 apparatus interfaced with a computer. The texture was evaluated using the double penetration test. The test involved driving a 0.96 cm diameter shaft twice, parallel to the muscle fibre direction into a sample down to 80% of its height (16 mm), using a crosshead speed of 50 mm/min and a load cell of 50 N. The force-deformation curve obtained served to calculate meat hardness, cohesiveness and chewiness [Bourne, 1982]. The procedure was repeated 9–14 times on each sample.

Rheological properties were determined with the relaxation test run on the Instron 1140. A sample was compressed to 10% of its original height (2 mm) and left for 90 s. To calculate the elastic and viscous moduli, the general Maxwell's body model was used. The model involving a parallel coupling of a Hookes body and two Maxwell's bodies. The following relaxation equation was applied:

$$\sigma = \varepsilon \cdot \left[E_0 + E_1 \cdot \exp\left(\frac{-E_1 \cdot t}{\mu_1} \right) + E_2 \cdot \exp\left(\frac{-E_2 \cdot t}{\mu_2} \right) \right]$$

where: σ, stress; ε, strain; E_0, E_1, E_2, elasticity moduli of Hook's body and of the first and second Maxwell's bodies, respectively; μ_1, μ_2, viscosity moduli of the first and second Maxwell's bodies, respectively; t, time.

Calculated values of the three elastic moduli are summarized as their sum; similarly, the values of the two viscous moduli are presented as their sum. The relaxation test was run 3 times on each muscle. During textural and rheological measurements, the muscle fibres were aligned in the direction of force.

Statistical analyses of the data involved the calculation of the mean values and standard deviations (SD) for each muscle and each group of deer. The differences in textural and histochemical properties between the groups of animals for SM muscles were studied using the analysis of covariance. Treatment differences were tested for significance at the 1% level. All the calculations were performed with Statistica® v.5.0 PL software.

RESULTS AND DISCUSSION

As shown in Table 1, the highest percentage of type I fibres was found in the wild boar muscle, the lowest being typical of roe deer SM muscle. SM muscle from fallow deer, compared to the other animal muscles tested showed highest percentage of type IIB fibres and the lowest percentage of type IIA fibres. Lower percentage of white fibres was found in roe deer muscle and the lowest showed deer and wild boar meat. Our findings are in agreement with those found for game animals muscles by Żochowska-Kujawska *et al*. [2006a] who have shown that muscles of deer compared to roe deer contain a higher percentage of type I fibres. According to Pette & Staron [1997] muscle fibres undergo a continual alteration throughout life, and that "fibre type" merely reflects the constitution of a fibre at any particular time, and it is connected with different circumstances of animal life. Most accounts show that physical exercise increase oxidative metabolism and decrease glycolytic metabolism in muscles involved in the exercise [Essen-Gustavsson, 1993; Petersen *et al*., 1998], so the higher percentage of red fibres in wild boar meat could be connected maybe with the higher activity experienced by those animals. Also Pette & Staron [1997], Brameld *et al.* [1998] showed that many factors such as contractile activity, neurotrophic and growth factors, and nutrient can influence muscle growth and muscle fiber type composition in mammals.

When the muscles mean cross sectional area were compared (Table 1), wild boar meat was characterised by the highest fibre area and lower values of this element were found in SM muscles from roe deer and fallow deer. However, Żochowska-Kujawska *et al.* [2006a] showed that mean fibre cross section area of deer and roe deer SM muscles shot at 3 years was about the same in both group of animals tested. The total number of fibres and the proportion and spatial distribution of fibrer types of given muscle vary between species [Lefaucheur & Gerrard, 2000], however it is well-documented that body size is much more related to the total number of fibres than fiber cross sectional area [Plaghki, 1985].

Differences in muscle structure or different contents of red and white fibres in the muscles tested were connected with the differences in the textural and rheological parameters observed in this study. Of all the animal tested, the highest values of hardness, cohesiveness and chewiness were recorded in the SM muscle of wild boar, the lowest values of this pa-

TABLE 1. Mean percentage and cross sectional area of fibre type of game animals SM muscle.

Fibre type	Species			
	Wild boar	Deer	Roe deer	Fallow deer
Percentage:				
– I (%)	35.13[c]	27.72[ab]	21.96[a]	30.00[bc]
– IIA (%)	27.87[c]	30.92[c]	22.12[b]	9.44[a]
– IIB (%)	37.00[a]	42.36[a]	55.92[b]	60.56[b]
Mean fibre cross sectional area (μm^2)	2296[c]	1689[b]	1527[a]	1564[ab]

[a], numbers in columns, marked with identical superscripts are not significantly different within an animal group (p≥ 0.05).

TABLE 2. Texture parameters and rheological properties of game animals SM muscle.

Parameter	Species			
	Wild boar	Deer	Roe deer	Fallow deer
Hardness (N)	46.98[c]	39.27[b]	27.71[a]	42.33[bc]
Cohesiveness (-)	0.516[c]	0.429[b]	0.339[a]	0.449[b]
Chewiness (N × cm)	28.12[c]	17.18[b]	10.81[a]	17.10[b]
Sum of elastic moduli (kPa)	134,9[b]	115.5[a]	141.7[b]	99.87[a]
Sum of viscous moduli (kPa *x* s)	5210[c]	4282[b]	6896[c]	1209[a]

[a], numbers in columns, marked with identical superscripts are not significantly different within an animal group (p≥ 0.05).

rameters and the highest viscous and elastic moduli typically being in the roe deer muscle. The lowest values of rheological properties were observed in fallow deer muscle. No significant differences in the textural parameters and rheological properties were found between deer and fallow deer SM muscles (Table 2).

No information about simultaneously comparison of muscle texture and rheological properties in those species of animals was found in the present literature. However, numerous authors comparing muscles of wild boars and pigs [Lachowicz *et al.,* 2004] or deer and roe deer [Żochowska-Kujawska *et al.,* 2006a; 2007] have reported a similar order of hardness for SM muscles and showed wild boar meat to be tougher that either roe deer, fallow deer and deer. Whereas higher values of viscosity moduli of wild boar SM muscle compared with the pig were reported also by Żochowska-Kujawska *et al*. [2006b].

Therefore, the differences in texture and rheological properties between animals species demonstrated in this study, according to numerous authors may have resulted from differences in structural elements, and a higher hardness being related to a higher mean fibre cross sectional area [Żochowska *et al.*, 2005]. The differences may have resulted also from different composition and properties of muscles proteins and lipids in particular muscle fibre types [Xiong, 1994], or according to Dransfield [1994] and Koohmaraie [1996] higher content of calpastatin in red fibres being the most important factors. As shown by Karlsson *et al.* [1999], type I fibres contained neutral lipids, whereas only about 26% of type IIA, and 1% of type IIB fibres contained neutral lipids and the same time had a higher content triglyceride which may be one factor of importance for meat quality, especially for meat tenderness. However according to Kłosowska [1975], red fibres are characterised by thicker endomysium, so the higher hardness of wild boar muscles with a high percentage of type I fibres found in this study could be connected with a thicker connective tissue. Also Karlsson *et al.* [1999] and Kłosowska & Fiedler [2003] reported that a higher percentage of white muscle fibres in muscles was inversely proportional to the shear forces. A positive correlation between the percentage or percentage area of white fibres and tenderness has also been found in bovines [Seideman *et al.,* 1986]. Relationships between histological characteristics and eating quality are highly controversial, because this was not confirmed by Solomon & Lynch [1988] who found increasing the percentage of red fibres at the expense of white fibres through dietary manipulation improved tenderness and juiciness. Similarly, a positive relationship between proportion of type I fibres and juiciness and flavor in lamb has been reported by Valin *et al.* [1982].

CONCLUSIONS

To sum up, it can be concluded that the highest hardness, cohesiveness, chewiness, the highest mean fibre cross sectional area and percentage of type I fibre were typical of wild boar SM muscle. The lowest textural parameters and percentage of red fibres being recorded in roe deer meat, which at the same time showed the highest elasticity and viscosity. The lowest values of rheological properties and at the same time the highest percentage of type IIB fibres were found in fallow deer meat.

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