The effect of soluble collagen on the texture of fallow deer meat

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Abstract

The aim of this study was to evaluate the effect of soluble collagen on the texture of farmed fallow deer (*Dama dama*) meat. We evaluated two parts of the body (leg – *Musculus gluteus medius*, and shoulder – *Musculus triceps brachii*). The total content of collagen and soluble collagen and the texture parameters of selected samples of farmed fallow deer meat were determined in the work. Noticeable differences can be seen in these results in the content of total collagen and soluble collagen and texture parameters (TPA). A statistically significant difference was detected only in the content of total collagen ($P < 0.05$). The dependence was proven here, showing that the more soluble collagen there is, the more tender (softer) the meat is, and the maximum TPA is therefore lower. The shoulder had a higher content of soluble collagen in $mg.g^{-1}$ (1.98 $mg.g^{-1}$), and a lower TPA (36.82 N) was used in measuring texture. The result was a more tender (softer) shoulder.

Farmed fallow deer, meat collagen, texture

Introduction

Deer farming has become extremely popular in recent years. Farming fallow deer is becoming widespread largely due to the high quality of its meat and the fact that it is undemanding and adapts well to various conditions (Krása and Hlaváček 1993). Fallow deer meat is delicately fibrous and has a low content of connective tissue compared to usual farm animals (Mojto et al. 1999, Winkelmayer et al. 2005).

The content and composition of collagen in the meat is one of the principal attributes influencing meat texture. Meat containing a higher proportion of soluble collagen is more likely to be tender after cooking (Purslow 2005).

Collagen is the most widespread and abundant protein in connective tissue. It is slightly stretchy, strong, and resistant to proteases in its native state. It differs significantly from other proteins in its amino acid composition. It is peculiar for its high content of hydroxy acids, and hydroxyproline (which is not found in any other protein) in particular. Collagen in intramuscular connective tissue is arranged in three hierarchical domains; endomysium ensheaths individual skeletal muscle fibres, perimysium ensheaths groups of muscle fibres, and epimysium ensheaths entire muscles. The arrangement of the perimysial network, and the size of the collagen fibres, has a direct influence on the toughness of the meat (Lepetit 2008). The toughness of the meat is attributed in connective tissue to the level of cross-linking of collagen fibres during heating. This cross-linking increases over time, for which reason the meat of older animals is tougher. The difference between cross-linked collagen and collagen that is not cross-linked is based on their solubility. Collagen that is not cross-linked is more soluble, for which reason it is known as soluble collagen (Jeremiah et al. 2003). When meat is cooked, its toughness increases between 40 and 50 °C due to the inception of denaturation of myofibrillar proteins. Another increase occurs between 60 and 70 °C due to the denaturation of collagen at 65 °C. A third increase occurs between 70 and 90 °C when actomyosin precipitates and dehydrates (Palka 1999).

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Methods for assessing meat texture are divided into three categories. Sensory analysis is generally used for the assessment of tenderness. Today, however, it is often replaced by instrumental methods and indirect methods.

The most widely used instrumental physical methods for the assessment of meat texture include TPA (texture profile analysis) and the W-B test (shear method according to Warner and Bratzler). The chemical method largely used for assessment of meat texture is assessment of connective tissue, during which the solubility of collagen, the nature of its cross links and its extractability are determined (Kamdem and Hardy 1995).

The aim of this work was to evaluate the dependence of texture parameters on the parameters of collagen, its content and solubility in farmed fallow deer meat.

Materials and Methods

The samples of meat came from male fallow deer (*Dama dama*) farmed in the Hodonín district – a total of 12 animals. The deer had similar properties (age 1.5 years, average weight 28.5 kg). These samples were divided into two groups according to anatomical origin (leg – *Musculus gluteus medius*, shoulder – *Musculus triceps brachii*).

Samples for chemical analyses were homogenised and subsequently wrapped in aluminium foil and stored at a temperature of 0–4 ºC. Whole samples following cooking (60 min/70 °C at the centre of the sample) were used for the measurement of texture parameters.

The content of total collagen was determined as the content of hydroxyproline. The sample was hydrolysed with sulphuric acid (105 °C for a period of 14 hours). Subsequent spectrophotometric determination was performed with the agent p-dimethylaminobenzaldehyde at a wavelength of 550 nm.

The content of soluble collagen was determined by the modification of methodologies according to Palka 1999, Liu et al. 1994, Hill 1966, and Bergman and Loxley 1963. The sample (5 g) was homogenised with 12 ml of 33% Ringer’s solution and heated at a temperature of 77 °C for a period of 70 minutes. The sample was then centrifuged in a centrifuge (15 minutes at 2.000 rpm). Spectrophotometric determination was performed with the agent p-dimethylaminobenzaldehyde at a wavelength of 550 nm. This process determined the content of insoluble collagen. The content of soluble collagen was calculated from the difference between total collagen and insoluble collagen. The measurement of the texture parameters of meat (maximum force and cohesiveness, cooked meat) – TPA (Texture Profile Analysis) was performed on an Instron 5544 tensile tester, cylindrical samples were measured (height 10 mm and diameter 12 mm), with the instrument’s piston simulating chewing. The results were subjected to statistical evaluation using the programme Statistica CZ 7 from the company Statsoft Inc. (Czech Republic). A Student’s t-test ($P < 0.05$) was used to determine the differences between the individual anatomical parts.

Results and Discussion

Table 1 shows the results of the given tests for the leg (*Musculus gluteus medius*) and shoulder (*Musculus triceps brachii*) of farmed fallow deer. Clear differences can be seen between the given anatomical parts. The visible differences between total collagen content and TPA values are particularly noteworthy, and enable a comparison of the given parts in dependence on soluble collagen (converted from % to $mg \cdot g^{-1}$). A statistically significant difference was found only for total collagen content ($P < 0.05$). Such differences were not found for other parameters. Fig. 1 expresses the dependence between maximum TPA force and content of soluble collagen in $mg \cdot g^{-1}$. Our results proved the dependence such that the

Table 1. Values of parameters for leg and shoulder of farm-reared fallow deer

	Leg	Shoulder	*P* <
Total collagen content [$mg \cdot g^{-1}$]	5.70 ± 1.48	10.13 ± 5.33	0.05
of which soluble collagen [%]	27.93 ± 10.45	24.42 ± 16.49	N.S.
Content of soluble collagen [$mg \cdot g^{-1}$]	1.64 ± 0.82	1.98 ± 1.48	N.S.
Max. force [N]	41.87 ± 17.27	36.82 ± 10.50	N.S.
Cohesiveness [-]	1.25 ± 0.03	1.25 ± 0.02	N.S.

N.S. – no statistically significant difference

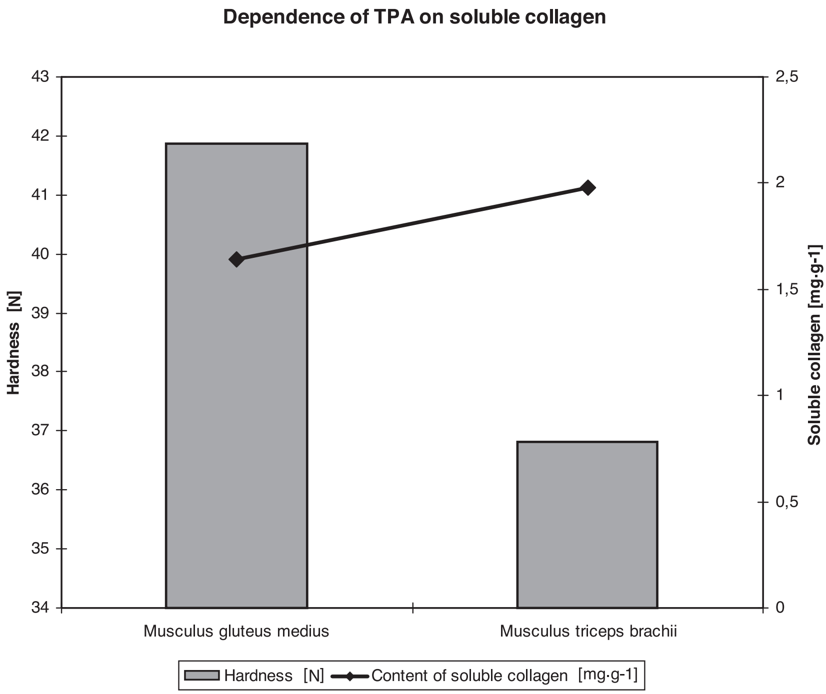

Fig. 1: Dependence of TPA (max. force) on soluble collagen

meat should be more tender (softer) the more soluble collagen there is, and the maximum TPA force should, therefore, be lower. This result is also due to the fact that the shoulder contained almost twice as much total collagen.

Dutson (1974) indicated that total collagen content was not closely related to the changes in tenderness associated with advancing age or post-mortem aging, but was related to tenderness differences among muscles, while percentage soluble collagen content was related to tenderness changes associated with advancing age and post-mortem aging. According to Hill (1966) and Fang et al. (1999) the solubility of intramuscular collagen falls with the age of the animal.

Meat collagen characteristics have usually been analysed to obtain information on beef tenderness. Gross et al. (1984) and Raes et al. (2003) found that the collagen content of bovine *M. longissimus dorsi* (LD) is around 5.0–7.0 mg·g^{-1}. Nold et al. (1999) reported that the collagen content of porcine LD is 3.4–4.1 mg·g^{-1}, while according to Coro et al. (2000) the collagen content of broiler *M. pectoralis* is 4.4–5.7 mg·g^{-1}. Collagen solubility in these muscles, after the samples have been heated in Ringer's solution at 77 °C for 60–70 minutes, is 14.4–17.0% for bovine LD (Cross et al. 1984), 8.1–11.1% for porcine LD (Seideman et al. 1989) and 26% for broiler *M. pectoralis* (Coro et al. 2000). Bovine *M. semitendinosus* contains 7.9–9.6 mg·g^{-1} of collagen (Liboriussen et al. 1977), porcine *M. semitendinosus* up to 8 mg·g^{-1} (Nold et al. 1999), while the collagen solubility in these muscles is around 11% (Liboriussen et al. 1977) and 25% (Fang et al. 1999), respectively.

The amount of soluble collagen was similar in the raw samples and samples cooked to 50 °C, but were slightly higher at 60 °C. At 70 °C, the percentage of soluble collagen almost doubled as compared to the raw material. There was a dramatic decrease in the soluble collagen content of the samples in the range 80 ± 121 °C. These changes were probably the effect of collagen shrinkage at around 60 °C and its gelatinisation and loss from the cooked meat above 70 °C. There is also the possible transformation of soluble collagen into an insoluble form during cooling of the meat (Palka 1999).

Volpelli et al. (2003) indicated a collagen content of *M. longissimus thoracis et lumborum* of 2.72 $mg \cdot g^{-1}$ and of *M. semimembranosus* of 3.08 $mg \cdot g^{-1}$ in 18-month-old fallow deer males. There was no effect of diet on muscle collagen, and this agrees with the lack of effect on muscle rheological properties. Collagen solubility decreased in the *M. longissimus thoracis et lumborum* of older deer (34.61 % in 18-month-olds as opposed to 22.58% in 30-month-olds), and this agrees with the higher W-B shear force values found in their muscles. The *M. semimembranosus* total collagen (2.61 and 2.93 $mg \cdot g^{-1}$) and its soluble fraction was similar for the 18-month and 30-month-old deer (26.39 and 28.46%), in agreement with the lack of difference between the compression values of SM in the two tested age groups.

The total collagen content was similar as for beef, though, as Volpelli et al. (2003) and Goodson et al. (2001) state, the collagen content in deer is more thermolabile, similarly as for collagen in lamb meat.

Conclusions

Meat texture is dependent on many factors – not merely external factors (breed, age, sex, etc.), but also on internal factors (degree of maturity of meat, chemical composition, etc.). In terms of chemical composition, the factors most affecting meat texture are water content, content of intramuscular fat, protein content and the content and quality (solubility) of collagen. Our aim was to assess the dependence between meat texture and content of soluble collagen. It is clear from our results that this dependence exists and it is substantiated by our measurements, with leg meat having a lower content of soluble collagen in $mg \cdot g^{-1}$ and a larger TPA force being used in the measurement of texture.

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