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COMPARISON OF MEAT QUALITY OF SELECTED EXOTIC ANIMALS SPECIES

PORÓWNANIE JAKOŚCI MIĘSA WYBRANYCH GATUNKÓW ZWIERZĄT EGZOTYCZNYCH

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Streszczenie. W pracy przedstawiono analizę jakości mięsa pochodzącego z najcenniejszych elementów tuszy dwóch gatunków zwierząt egzotycznych: kangura (udziec – *m. biceps femoris* i *m*. *semitendinosus*) oraz krokodyla (ogon – *m. longissimus*). Porównano wyniki badań histologicznych z wynikami instrumentalnej analizy tekstury i sensorycznej oceny jakości, a następnie z wynikami pomiarów wartości pH i wielkości ubytków cieplnych z mięsa. Stwierdzono istotny wpływ ($p \leq 0{,}01$) gatunku na średnie wartości elementów struktury (z wyjątkiem grubości *endomysium*) i spoistości (w ocenie instrumentalnej), a także średnie noty oceny sensorycznej (z wyjątkiem żuwalności) oraz ilości ubytków po obróbce cieplnej mięsa. Mięso krokodyla i kangura nie było natomiast istotnie zróżnicowane pod względem takich parametrów testu TPA jak: twardość, sprężystość, plastyczność, żuwalność i gumowatość. Mięśnie z udźca kangura zawierały mniejsze włókna mięśniowe, o mniej regularnym kształcie i grubsze *endomysium*. Jednocześnie cechowały się istotnie ($p \leq 0{,}01$) wyższymi wartościami pH i ubytków cieplnych, a w konsekwencji większą gumowatością, żuwalnością, spoistością, soczystością, wyczuwalnością tkanki łącznej i intensywnością zapachu, przy jednocześnie mniejszej twardości, kruchości, sprężystości i włóknistości niż mięsień ogona krokodyla. Z kolei mięsień ogona krokodyla był bardziej twardy, sprężysty, kruchy, włóknisty, o wyższej intensywności smaku niż mięśnie kangura, na skutek zaobserwowanych w tym surowcu większych włókien mięśniowych o bardziej regularnym kształcie, grubszego *perimysium* oraz większej zawartości tłuszczu śródmięśniowego.

Key words: crocodile, kangaroo, meat quality, muscle structure, sensory assessment, texture parameters.
Słowa kluczowe: jakość mięsa, kangur, krokodyl, ocena sensoryczna, parametry tekstury, struktura mięśnia.

INTRODUCTION

Among contemporary Poles a phenomenon to converge with western standards in many aspects of life is observed, including in the diversity of species consumed meat (Nowak 2008). However, the potential consumer wants to know the qualities of the meat of these species, which are an alternative to commonly eaten slaughter raw material (i.e. pork, poultry and beef). It therefore seems very important to know about the properties of these materials closer to consumers.

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Data from the Central Statistical Office showed that the average Pole in 2012 ate about 70 kg of meat, including 57% of pork, 38% of poultry (mainly chicken meat), 3% beef, and other species of about 2% (Kwasek 2013, Mieczkowski 2013). In recent years, with increasing awareness of nutrition consumers (Bertolini et al. 2005) an increase in interest in other (alternative) raw meat is observed (Kwasek 2013). The reason for this may be that the quality of the meat of wild animals, including exotic, described as comparable to or even better, in comparison with meat breeding species (Hoffman and Cawthorn 2012).

For example, kangaroo meat recommended for people who are on a low-fat diet, because of the preferred proportions of saturated fatty acids to monounsaturated and polyunsaturated (respectively 1.5:1:2) (Hoffman and Cawthorn 2012). As compared to bovine meat it has about 2.8 times higher fatty acids with n–3 (Kolanowski 2004), a similar protein content (20.3–22.5%), iron (1.8 mg/100 g) and zinc (4.6 mg/100 g), but still relatively low fat content (0.8–2%), and cholesterol (56 mg/100 g) (Wynn et al. 2004, Hoffman and Cawthorn 2012). The taste of kangaroo meat is more expressive than the traditionally consumed species and is similar to venison (Wynn et al. 2004, Hoffman and Cawthorn 2012). Probably due to the well-established in our culture propensity to consume meat of wild species, these kind of raw material is gaining recognition in Europe (Hercock 2004, Ampt and Owen 2008).

Crocodile meat was obtained primarily as a by-product of this reptile skin trade, and now is gaining consumer recognition preferred because of its nutritional value. For the most valuable and served in exclusive restaurants shall be considered meat from the tail due to the higher tenderness in comparison with other parts of the crocodile carcass (Hoffman et al. 2000, Cossu et al. 2007). Those kind of meat has a high protein content (about 21–22%) and low cholesterol (48 mg/100 g), sodium and fat (about 2%), which additionally has an equal proportion of fatty acid SFA:MUFA:PUFA (Hoffman et al. 2000, Hoffman and Cawthorn 2012).

The aim of the study was to compare the selected quality parameters of most valuable muscles of two exotic animals species (kangaroo and crocodile), as an alternative to meats traditionally consumed in our country.

MATERIAL AND METHODS

The study involved the most valuable elements of a kangaroo carcass (leg muscles – *m. biceps femoris* and *m. semitendinosus*) and crocodile (tail muscle – *m. longissimus*). Kangaroo leg muscles (5 pcs. of both muscles), and the tail of a crocodile (5 pcs.) came respectively from Australia and Zimbabwe. Deep-frozen muscles, maintaining the continuity of the chain freezing, were provided in place of the study. Each element was thawed for 24 hours and then the pH was measured using pH-meter CP-215 (ELMETRON, Poland). About 4 cm thick slices were cut perpendicularly to the fibres from each muscle – 4 slices were cut out from kangaroo muscles and 3 slices from the tail of a crocodile. One of the slices was used for histological studies, the remaining parts to examine the texture and sensory analysis.

Muscle structure were measured on raw samples, cut from the muscle of both groups of animals, two cuts being taken from each muscle. The samples about 0.7 x 0.7 x 1.5 cm were dehydrated in alcohol, fixed in Sannomiya solution, and embedded in paraffin blocks. The blocks were sectioned into 10 μm slices with a microtome. The sections were placed on glass slides, contrast-stained with hematoxylin and eosin, and sealed with Canada balsam (Burck 1975).

The Multi Scan Base v.13 computer image analysis software (Css Scan, Warszawa, Polska) was used to measure muscle fibre parameters (cross-sectional area, girth, H and V diameters), *endomysium* and *perimysium* thickness, and amount of intramuscular fat. More than 100 muscle fibre and *endomysium* and *perimysium* thickness and all intramuscular fat areas / samples were analyzed. The obtained results were calculated fibre shape (as a ratio of H and V diameters) and it is assumed that the ratio closer to the value of 1.000 a more regular (circular) muscle fiber shape.

Examination of texture and sensory evaluation was carried out on samples subjected to heat treatment. Muscle slices were weighed, packed in separate plastic bags and subjected to heat treatment in water at a temperature of 75–80ºC, until in the centre of the muscle reached a temperature of 70ºC. The temperature was controlled using a thermometer type MT-3 (ELTER, Poland). Subsequently, the samples (in plastic bags) were cooled down to about 12°C with cold water, weighed and stored at 3ºC for about 12 h until the analysis were made. Next, muscles were cut into slices 20 ±1 mm thick upright to the orientation of muscle fibres.

Muscle texture were assayed following the Texture Profile Analysis (TPA) procedures (Bourne 1982), with an Instron 1140. The test involved driving a 0.61 cm diameter shaft twice, in parallel to muscle fibre into a sample down to 80% of their original height (16 mm), using a crosshead speed of 50 mm min^{-1} and a load cell of 50 N. The force-deformation curve obtained during the TPA test served to calculate meat hardness, cohesiveness, springiness, plasticity, chewiness and gumminess (Bourne 1982). The TPA test was repeated 7–9 times on each sample of muscle.

Simultaneously with the instrumental texture analysis the sensory evaluation of meat was performed. The sensory evaluation of exotic meat was assessed by a trained expert panel of 5 members with a experience in texture analysis of meat and meat products (PN-ISO-6658:1998). The muscle tenderness, cohesiveness, springiness, juiciness, stringiness, connective tissue palatability, intensity of taste and flavor, were assessed using 7-point intensity scale of the features of Table 1.

Table 1. Seven-point scale of selected quality traits intensity
Tabela 1. Siedmiopunktowa skala natężenia wybranych cech jakościowych

Qualitative trait Cecha jakościowa	The terms for border scoring systems Określenia dla granicznych skal punktowych	
Tenderness Kruchość	1 point – hard 1 pkt – twarda	7 points – very tender 7 pkt – bardzo krucha
Cohesiveness Spoistość	1 point – do not cohesive 1 pkt – niespoista	7 points – very cohesive 7 pkt – bardzo spoista
Springiness Sprężystość	1 point – do not springy 1 pkt - niesprężysta	7 points – very springy 7 pkt – bardzo sprężysta
Chewiness Żuwalność	1 point – low chewiness 1 pkt – niska żuwalność	7 points – high chewiness 7 pkt – wysoka żuwalność
Juiciness Soczystość	1 point – dry 1 pkt – sucha	7 points – very juicy 7 pkt – bardzo soczysta
Stringiness Włóknistość	1 point – imperceptible fibers 1 pkt – niewyczuwalne włókna	7 points – highly perceptible fibers 7 pkt – silnie wyczuwalne włókna
Perceptible of connective tissue Wyczuwalność tkanki łącznej	1 point – imperceptible connective tissue 1 pkt – niewyczuwalna tkanka łączna	7 points – abundant connective tissue 7 pkt – obfita tkanka łączna
Flavor intensity Intensywność smaku	1 point – low 1 pkt – niska	7 points – high 7 pkt – wysoka
Odor intensity Intensywność zapachu	1 point – unperceptible 1 pkt – niewyczuwalna	7 points – very intensive 7 pkt – bardzo intensywna

Cooking drip loss (%) was calculated from the difference in muscle weight before and after thermal treatment.

Obtained samples were statistically analyzed (STATISTICA software, version 10 – StatSoft, Polska). The 1-way analysis of variance (ANOVA) was used to determine the effects of the animal species on selected quality parameters of these meat. To determine the significance of differences between mean values of examined parameters Tukey's HSD test was used (for samples with uneven numbers) at the level of $p \leq 0.01$ (StatSoft 2006).

RESULTS AND DISCUSSION

The data in Table 2 shows that the muscles of exotic species significantly ($p \leq 0.01$) differ in terms of the size of the examined structure elements. The crocodile tail muscle contained a significantly ($p \leq 0.01$) greater muscle fibers of more regular shape and thicker *perimysium* as well as a higher amount of intramuscular fat in comparison to the kangaroo leg muscles. The fiber cross-section area in the crocodile tail muscle was about 5-fold higher, girth and diameter about 2-fold higher, the thickness of the *perimysium* 1.5 times, and the amount of intramuscular fat up to 7.4 times higher than the same parameters describing the kangaroo meat. Muscles of the kangaroo leg was characterized by thicker *endomysium*, although the differences in the size of the element between the two species were not significant ($p > 0.01$).

Table 2. Mean values of structure elements of kangaroo and crocodile muscles
Tabela 2. Średnie wartości elementów struktury mięśni kangura i krokodyla

Parameter Parametr	Species – Gatunek		Effect of species Wpływ gatunku
	kangaroo kangur	crocodile krokodyl	
Muscle fiber – Włókno mięśniowe			
Cross-section area [μm^2] Pole powierzchni przekroju poprzecznego	640.11^a ±5.40	3166.72^b ±509.19	**
Girth [μm] Obwód	116.80^a ±3.21	244.63^b ±17.50	**
Diameter H [μm] Średnica H	30.49^a ±1.34	63.33^b ±5.66	**
Diameter V [μm] Średnica V	31.84^a ±0.16	63.66^b ±7.24	**
Shape factor [-] Współczynnik kształtu	0.958^a	0.995^b	**
Connective tissue – Tkanka łączna			
Perimysium thickness [μm] Grubość *perimysium*	7.55^a ±0.23	11.21^b ±1.34	**
Endomysium thickness [μm] Grubość *endomysium*	1.52^a ±0.04	1.31^a ±0.07	n.s.
Intramuscular fat content [μm^2] Zawartość tłuszczu śródmięśniowego	6 669^a ±128	49 575^b ±4 145	**

Explanatory notes – Objaśnienia:
mean value ± standard deviations – wartość średnia ± odchylenie standardowe;
$^{a, b}$ – values marked with identical letters in rows are not significantly different between animal species at the 0.01 level of probability – wartości oznaczone w wierszach tymi samymi literami nie różnią się istotnie pomiędzy gatunkami zwierząt przy α = 0,01;
Effect of species – Wpływ gatunku:
n.s. – non significant – nieistotny;
** – significant ($p \leq 0.01$) – istotny ($p \leq 0,01$).

An analysis of texture parameters (Table 3) shows that the species of animals did not significantly affect the diversity of the mechanical properties of the kangaroo and crocodile muscles. The leg kangaroo muscles were less tough and springy, and more gummy, chewy and with higher plasticity than the muscle of the crocodile tail. At the same time the kangaroo muscles was characterized by significantly ($p \leq 0.01$) higher cohesiveness than the crocodile, and the difference in the value of this parameter between the two species was about 39%.

Table 3. Mean values of texture parameters of kangaroo and crocodile muscles
Tabela 3. Średnie wartości parametrów tekstury mięśni kangura i krokodyla

Parameter Parametr	Species – Gatunek		Effect of species Wpływ gatunku
	kangaroo kangur	crocodile krokodyl	
Hardness [N] Twardość	48.63^{a} ±7.36	55.05^{a} ±10.08	n.s.
Cohesiveness [–] Spoistość	0.450^{a} ±0.067	0.323^{b} ±0.051	**
Springiness [cm] Sprężystość	1.07^{a} ±0.10	1.17^{a} ±0.18	n.s.
Plasticity [cm] Plastyczność	0.53^{a} ±0.10	0.43^{a} ±0.18	n.s.
Chewiness [N · cm] Żuwalność	23.54^{a} ±6.64	20.95^{a} ±6.55	n.s.
Gumminess [N] Gumowatość	21.84^{a} ±4.46	17.89^{a} ±4.67	n.s.

Explanatory notes as in Table 2 – Objaśnienia jak w tabeli 2.

Based on the results of sensory analysis (Table 4) it was noted that besides the chewiness, the sensory quality parameters of the tested muscles was significantly ($p \leq 0.01$) depends on the animal species. The crocodile tail muscle compared to a kangaroo leg muscles was rated as significantly ($p \leq 0.01$) more tender (about 2.50 pts.), springy (about 1.00 pts.), stringy (about 4.75 pts.), with clearly distinguishable taste (about 2.00 pts.). Significantly ($p \leq 0.01$) greater cohesiveness (about 1.25 pts.), juiciness (1.00 pts.), connective tissue palpability (4.00 pts.) and smell (about 2.75 pts.) were found in the kangaroo leg muscles than in the crocodile tail muscle.

Table 4. Average scores from sensory evaluation of kangaroo and crocodile muscles
Tabela 4. Średnie noty oceny sensorycznej mięśni kangura i krokodyla

Parameter Parametr [points – punkty]	Species – Gatunek		Effect of species Wpływ gatunku
	kangaroo kangur	crocodile krokodyl	
Tenderness – Kruchość	4.50^{a} ±0.01	7.00^{b} ±0.25	**
Cohesiveness – Spoistość	4.00^{a} ±0.50	2.75^{b} ±0.25	**
Springiness – Sprężystość	5.00^{a} ±0.25	6.00^{b} ±0.01	**
Chewiness – Żuwalność	6.00^{a} ±0.50	6.00^{a} ±0.25	n.s.
Juiciness – Soczystość	6.00^{a} ±0.01	5.00^{b} ±0.25	**
Stringiness – Włóknistość	2.25^{a} ±0.25	7.00^{b} ±0.25	**
Perceptible of connective tissue Wyczuwalność tkanki łącznej	5.00^{a} ±0.25	1.00^{b} ±0.25	**
Flavor intensity Intensywność smaku	4.25^{a} ±0.25	6.25^{b} ±0.01	**
Odor intensity [points] Intensywność zapachu	4.25^{a} ±0.25	1.50^{b} ±0.25	**

Explanatory notes as in Table 2 – Objaśnienia jak w tabeli 2.

When comparing pH and the amount of cooking loss of examined muscles (Table 5) demonstrated that the species significantly ($p \leq 0.01$) affected the values of the analyzed parameters. The kangaroo leg muscles characterized by a significantly ($p \leq 0.01$) higher values of pH and cooking loss in comparison to the crocodile tail muscle, and the differences between species amounted to respectively 1.4 and 46%.

Table 5. pH value and cooking loss of kangaroo and crocodile muscles
Tabela 5. Wartość pH i wielkość wycieku cieplnego mięśni kangura i krokodyla

Parameter Parametr	Species – Gatunek		Effect of species Wpływ gatunku
	kangaroo kangur	crocodile krokodyl	
pH value – Wartość pH [–]	5.63^{a} ±0.04	5.55^{b} ±0.03	**
Cooking loss – Wyciek cieplny [%]	27.64^{a} ±2.14	18.94^{b} ±0.35	**

Explanatory notes as in Table 2 – Objaśnienia jak w tabeli 2.

Based on the study, showed a significant ($p \leq 0.01$) differences in histology, pH values, amount of cooking loss and sensory quality between kangaroo and crocodile muscles. However animal species had no significant effect on the TPA test parameters (with the exception of cohesiveness). The kangaroo leg muscles had significantly higher cohesiveness (in both the instrumental and sensory assessments), resulting probably from a thicker *endomysium* surrounding muscle fibers and a lower amount of intramuscular fat between the fiber bundles, which increased the degree of integration of structural elements of muscle at this level.

This could to contribute to the observed in this study increase in chewiness, gumminess and connective tissue palatability, and at the same time to reduce the tenderness of this material.

No significant differences in the other instrumental texture parameters could be a result of various effects of individual structure elements on meat texture. An effect of muscle fiber size (Fiedler et al. 1986, Lachowicz et al. 2004), the connective tissue thickness (Sadowska and Kołodziejska 1994, Lachowicz et al. 2004, Żochowska et al. 2005) and marbling (Nam et al. 2009) on the meat texture of farmed and wild species of animals is widely known. The our study shows that crocodile muscle hardness could be a consequence of larger muscle fibers and thicker connective tissue at the level of fiber bundles (*perimysium*), while kangaroo muscle hardness may be connected with a thicker connective tissue surrounding the fiber (*endomysium*), lower content of intramuscular fat and higher amount of cooking loss.

Reported in a sensory evaluation significantly greater springiness, tenderness, stringiness and relatively good juiciness of the crocodile tail muscle could be associated with larger fiber of a more regular shape and thicker *perimysium* as well as higher content of intramuscular fat (marbling), which was also reported by Hoffman and Cawthorn (2012).

These data showed that a large marbling of crocodile tail muscle was combined with a more intense flavor of these raw material, but not with the intensity of the smell. In contrast, more intense odor was observed in kangaroo muscle.

Different marbling effect on meat flavor components (taste and smell) of both animal species may result from differences in composition (especially in the phospholipids content) and the amount of fatty acids contained in the intramuscular fat, being carrier of flavor and aroma (Kołczak 2007, 2008).

The examined muscles of two animal species in life are highly active. It is in these parts of the body are a plurality of trailers muscle to bone, which is associated with a higher content of the connective tissue (Żochowska et al. 2005), as observed in the work thicker *perimysium* in crocodile tail muscle and *endomysium* in kangaroo leg muscles.

Thus, the structure and properties of connective tissue may have an effect on losses after a heat treatment of raw material and juiciness (Avery et al. 1996, Litwińczuk et al. 2004, Młynek 2007), or meat tenderness (Sadowska and Kołodziejska 1994, Pospiech et al. 2003, Lachowicz et al. 2004, Żochowska et al. 2005). Higher tenderness of crocodile tail muscle could result in addition of considerably lower pH, as lower pH values after resolution of rigor mortis, leads to the activation of proteolytic endogenous enzymes which contributed to gradually tissue-degrading of meat texture during maturation (Alagón et al. 2015), and thus improving meat tenderness (Nam et al. 2009).

CONCLUSIONS

1. Meat of both exotic species were characterized by good quality. The kangaroo leg muscles were characterized by delicate structure, intense flavor and smell, well palpable connective tissue and good tenderness, cohesiveness, springiness and juiciness. The crocodile tail muscle were very tender and stringy, with very intense flavor.
2. Due to the characteristics of the histological structure and texture of the kangaroo and crocodile muscles, and recorded in many publications their nutritional value, both examined exotic species may be an alternative to the traditionally consumed pork, poultry or beef.

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Abstract. The paper presents a quality analysis of meat from most valuable elements of carcass of two exotic animals species: kangaroo (silverside – *m. biceps femoris* and *m. semitendinosus*) and crocodile (tail – *m. longissimus*). It compared results of histological assays with results of instrumental analysis of texture and sensory evaluation and then with results of measurements of pH value and cooking losses of meat. It was found a significant ($p \leq 0.01$) effect of animal species on average values of structural elements (with exception of thickness of *endomysium*) and cohesiveness (in instrumental assessment) of meat, as well as average scores of sensory evaluation (with exception of chewiness) and cooking losses of meat. Crocodile and kangaroo meat was not significantly different in terms of TPA test parameters such as hardness, springiness, plasticity, chewiness and gumminess. Muscles from leg of kangaroo were contained smaller muscle fibers with less regular shape and thicker

endomysium. At the same time these muscles were achieved significantly ($p \le 0.01$) higher pH, and higher cooking losses and consequently higher gumminess, chewiness, cohesiveness, juiciness, perceptibility of connective tissue and intensity of odor, while the lower hardness, tenderness, springiness and stringiness than muscle from tail of crocodile. Muscle from tail of crocodile was more tough, springy, tender, stringy, and with a higher intensity of flavor than kangaroo muscles as a consequence of observed in raw material muscle fibers with higher cross-section area, of more regular shape, thicker *perimysium*, and higher content of intramuscular fat.