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COLOR ANALYSIS AND SENSORY EVALUATION OF RED DEER (*CERVUS ELAPHUS*) MEAT FROM FARM AND HUNTING GROUNDS OF SLOVAKIA

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ABSTRACT

The objective of this study was to compare the meat colour and sensory attributes of red deer (*Cervus elaphus*) meat based on sex (male vs. female), age group (under 2 years vs. over 2 years), and origin (farmed vs. hunting grounds) in Slovakia. The focus was placed on the *musculus biceps femoris*, a representative muscle used in meat quality evaluation. Meat color was assessed using the CIE Lab* system, while sensory analysis was conducted by a trained panel following standardized tasting protocols. Significant differences were found in the L* value, representing meat lightness. Red deer from hunting grounds exhibited higher L* values, indicating lighter meat, compared to their farmed counterparts. This may be attributed to differences in physical activity levels, stress exposure, and feeding regimes between wild and farmed animals. No significant variations were detected in the a* (redness) and b* (yellowness) parameters. Sensory analysis, which evaluated attributes such as tenderness, juiciness, and flavour, did not show statistically significant differences between farmed and wild deer overall. However, minor tendencies were observed: younger animals and males tended to be rated slightly better in terms of tenderness and juiciness, though these differences did not reach statistical significance. These results add valuable insights to the understanding of game meat quality, emphasizing how environmental and biological variables distinctly affect meat characteristics. The results suggest that both farmed and wild red deer provide high-quality meat with minor differences that may be relevant for narrow marketing or culinary applications.

Keywords: *Cervus elaphus*, deer meat, colour, sensory evaluation

INTRODUCTION

For customers, deer meat is an excellent food product because of its many qualities and nutritional profile. A high percentage of lean meat, a high protein content, low intramuscular fat, low cholesterol, and high iron levels are some of its benefits. Accordingly, deer meat has a high proportion of unsaturated fatty acids compared to saturated fatty acids (SFA) and optimal levels of long-chain n-3 PUFA. Additionally, provide a healthy amount of vital minerals and amino acids **(Lorenzo *et al.*, 2018).** The consumption of red deer meat has grown during the past ten years (**Serrano *et al.*, 2020**). The two most significant deer species in Europe are fallow deer (*Dama dama*) and red deer (*Cervus elaphus*) **(Lorenzo *et al.*, 2018).**
Because red deer (*Cervus elaphus*) meat is so uncommon in the traditional meat market, it is considered an extra gourmet item **(Wiklund *et al.*, 2014)**. The red deer is economically important in European forestry, prized for hunting and as a source of venison. It plays a key role in the food industry and contributes to forest management practices in Europe **(Adenuga *et al.*, 2024)**. In Europe, the consumption of game meat is minimal, with only 2–4% of the population regularly eating this type of meat **(Andreotti, Borghesi, & Aradis, 2016)**. Several factors contribute to this low consumption rate, including the meat's high cost, limited availability, and a scarcity of recipes featuring game meat **(Morales *et al.*, 2018)**.
Among the two visually identifiable characteristics of deer meat (colour and marbling), colour is considered a physical parameter **(De Palo *et al.*, 2012)**. As such, meat colour is widely recognized as a crucial factor influencing consumer acceptance of a product. While dark meat might be perceived by consumers as indicative of a quality issue (such as dark, firm, and dry - DFD), in the case of deer meat, a deep red hue is associated with desirable quality attributes and is also regarded as a typical feature of this meat variety **(Maggiolino *et al.*, 2018)**.
Comparing the lives of red deer on the hunting grounds and on farms reveals differences in their behaviour, feeding habits, and interactions with the environment. While in hunting grounds their movement and diet are influenced by seasonal changes and the availability of natural resources, on farms cervids are provided with constant care and controlled conditions.
The main objective of this study was to evaluate and compare the meat color and sensory properties of red deer meat from farmed and hunted animals in Slovakia. The study also sought to determine whether gender (male vs. female) and age (over 2 years vs. under 2 years) affect these parameters of meat quality.

MATERIAL AND METHODS

For this experiment, 80 individuals of *Cervus elaphus* from the hunting ground and from farm breeding were used. The number of animals from the farm was 40 individuals, of which 10 females and 10 males over 2 years old and 10 females and 10 males under 2 years old. Red deer from the hunting grounds had the same representation (n = 40 individuals; 10 females and 10 males over 2 years old and 10 females and 10 males under 2 years old). Red deer from farm breeding came from three districts of Slovakia, and in terms of hunting grounds, deer came from all over Slovakia (districts: Malacky, Zlaté Moravce, Rimavská Sobota, Brezno, Rožňava, Levice, Detva). The animals were acquired through de-sedation and transported in cooling boxes at 4 °C to the Institute of Food Science (SPU Nitra). The red deer carcasses were then dissected in their entirety.

Color analysis

The Konica Minolta CM-2600d spectrophotometer was used to measure color. The study was conducted using the D65 light source, a 10° observer with an 8 mm port diameter, and the SCI (Specular Component Included) configuration. The CIE color space L*, a*, and b* were used to represent the measured coordinates. Muscle tissue from the *musculus biceps femoris* was used for color analysis.

Sensory evaluation

Sensory evaluation was carried out in accordance with the requirements for the evaluation of quality indicators. Before the analysis itself, the meat samples were baked at a temperature of 210 °C for about 30 minutes. The monitored parameters were taste, aroma, juiciness, tenderness. A 5-point scale was used for the evaluation, where 5 points was the highest score and 1 point was the lowest score. 10 evaluators (women and men) aged 25 to 50 years participated in the sensory evaluation. Before the evaluation began, all participants were informed and trained in sensory evaluation.

Statistical analysis

ANOVA with Duncan's test was used to compare the final results of the groups under analysis. A significance level (α) of 0.05 was applied for all statistical tests.

The analysis was conducted using XLSTAT software (XLSTAT Addinsoft, statistical and data analysis solution, 2021, New York, NY, USA).

RESULTS AND DISCUSSION

Color analysis

Table 1 shows that the parameter L* (lightness) is significantly higher in wild deer (37.21 ± 2.69) compared to those from farmed deer (34.23 ± 2.59; $p = 0.004$). This result suggests that the muscles of wild animals are lighter, which may be a consequence of differences in nutrition, physical activity or stress level before slaughter. On the other hand, the parameters a* and b* (indicating the shade of red and yellow) do not differ statistically significantly between the two groups ($p = 0.406$ and $p = 0.096$), indicating that the basic colour shade remains relatively consistent regardless of the rearing conditions.

Table 1 Comparison of colour changes of the *musculus biceps femoris* of red deer on a farm and in the hunting ground

	Farm breeding	Hunting ground	*p*-value
L*	34.23 ± 2.59^{b}	37.21 ± 2.69^{a}	0.004
a*	12.27 ± 1.18^{a}	11.84 ± 1.44^{a}	0.406
b*	8.72 ± 0.76^{a}	9.48 ± 1.28^{a}	0.096

Legend: Upper index a, b represents a statistically significant difference between the groups in the column after ANOVA statistical analysis (t-test) (α=0.05).

Table 2 divides the animals into two age categories. In deer older than 2 years, the parameter L* is lower in farmed animals (33.29 ± 1.03) compared to wild animals (36.54 ± 2.60; $p = 0.011$). In addition, the parameter b* (yellowness) is also lower in older farmed animals (8.34 ± 0.38) than in wild animals (9.39 ± 1.28; $p = 0.044$), while the parameter a* remains unchanged. In younger deer (under 2 years), the differences in the parameters L*, a*, or b* are not statistically significant, although a similar trend is visible for L* (farmed lower than wild; $p = 0.079$). These results suggest that the environment in which the animals are kept has a more pronounced effect on muscle colour
in older animals, which may be due to cumulative differences in living conditions.

Table 2 Comparison of color changes of the *musculus biceps femoris* of red deer between farm breeding and hunting ground by age

	FB over 2y	HG over 2y	*p*-value	FB under 2y	HG under 2y	*p*-value
L*	33.29 ± 1.03^{b}	36.54 ± 2.60^{a}	0.011	35.42 ± 3.62^{b}	38.32 ± 2.54^{a}	0.079
a*	12.34 ± 0.97^{a}	12.29 ± 1.27^{a}	0.940	12.20 ± 1.56^{a}	11.09 ± 1.44^{a}	0.195
b*	8.34 ± 0.38^{b}	9.39 ± 1.28^{a}	0.044	9.43 ± 0.32^{a}	9.62 ± 1.31^{a}	0.777

Legend: FB – farm breeding; HG – hunting ground. Upper index a, b represents a statistically significant difference between the groups in the column after ANOVA statistical analysis (t-test) (α=0.05).

Table 3 analyses the influence of environment on muscle colour by sex. In females, the parameter L* is lower in farmed animals (34.01 ± 2.28) compared to wild animals (37.05 ± 2.84; $p = 0.041$). A similar trend is also observed in males, although the difference appears to be slight. The parameters a* and b* do not differ between farmed and wild animals in either females or males ($p > 0.05$). These results indicate that muscle colour, particularly in terms of brightness (L*), is influenced by the environment, with wild deer having lighter muscle, which is evident in both sexes.

Table 3 Comparison of color changes of the *musculus biceps femoris* of red deer between farm breeding and hunting ground by gender

	FB female	HG female	*p*-value	FB male	HG male	*p*-value
L*	34.01 ± 2.28^{b}	37.05 ± 2.84^{a}	0.041	34.41 ± 3.29^{b}	37.39 ± 2.58^{a}	0.057
a*	12.69 ± 0.81^{a}	11.68 ± 1.46^{a}	0.151	11.76 ± 1.48^{a}	12.02 ± 1.45^{a}	0.746
b*	8.80 ± 0.63^{a}	9.39 ± 1.39^{a}	0.370	8.61 ± 0.98^{a}	9.57 ± 1.18^{a}	0.147

Legend: FB – farm breeding; HG – hunting ground. Upper index a, b represents a statistically significant difference between the groups in the column after ANOVA statistical analysis (t-test) (α=0.05).

Bureš *et al.* (2014) compared qualitative attributes in several species of game. In farm-raised deer, the same values of the colour components L*, a*, b* were observed as we obtained in our research. **Purchas *et al.* (2010)** studied meat quality traits of red deer of both sexes at around 20 months of age. In the parameter L*, our results reached lower values in both females and males. In parameter a*, similar results were observed and in the parameter b*, our results reached twice higher values compared to the study. Our results are also consistent with those published by **Bokor *et al.* (2023).** In our study, L* values are significantly higher in wild animals compared to farmed animals. The published L* value of 36.2 ± 2.7 falls within this interval and supports the trend that wild animals have lighter muscle. Our measurements show a* values approximately between 11.09 and 12.69, which corresponds to the published value of 11.5 ± 1.2. This indicates a consistent shade of red between the studies. The b* values are almost identical, indicating that the yellowness parameter is also very similar in both cases. Comparable results were also obtained by **Serrano *et al.* (2020).**

Sensory evaluation

Variations in texture, flavour, and appearance are crucial characteristics that impact both domestic and game meat sectors **(Resurreccion, 2003)**. The results of the sensory evaluation indicate that there were no significant differences in sensory properties such as taste, aroma, juiciness, tenderness between the farmed (FB) and wild (HG) deer samples. The *p*-values for all parameters in table 4 are significantly higher than 0.05, indicating that the differences between these groups are not statistically significant.

Table 4 Comparison of sensory evaluation between farm and rangeland red deer

	Farm breeding	Hunting ground	*p*-value
Taste	3.72 ± 0.66^{a}	3.70 ± 0.77^{a}	0.843
Aroma	3.99 ± 0.84^{a}	3.95 ± 0.84^{a}	0.779
Juiciness	3.21 ± 0.97^{a}	3.28 ± 0.87^{a}	0.628
Tenderness	3.71 ± 0.82^{a}	3.44 ± 0.85^{a}	0.052

Legend: Upper index a, b represents a statistically significant difference between the groups in the column after ANOVA statistical analysis (t-test) (α=0.05).

In Table 5, where the samples were divided by age (over 2 years and under 2 years), most parameters were again not shown to be significantly different between the groups. The exception is the tenderness of the meat in younger individuals (FB < 2y and HG < 2y), where a statistically significant difference was shown ($p = 0.004$). This suggests that the meat of younger farmed deer may be softer, and more tender compared to wild deer.

Table 5 Comparison of sensory evaluation between farm and rangeland red deer by age

	FB over 2y	HG over 2y	*p*-value	FB under 2y	HG under 2y	*p*-value
Taste	3.56 ± 0.60^{a}	3.62 ± 0.78^{a}	0.727	3.93 ± 0.93^{a}	3.82 ± 0.75^{a}	0.574
Aroma	4.00 ± 0.76^{a}	3.94 ± 0.85^{a}	0.699	3.98 ± 1.07^{a}	3.97 ± 0.83^{a}	0.994
Juiciness	3.00 ± 0.96^{a}	3.29 ± 0.82^{a}	0.122	3.48 ± 1.00^{a}	3.27 ± 0.96^{a}	0.405
Tenderness	3.34 ± 0.75^{a}	3.35 ± 0.87^{a}	0.966	4.18 ± 0.93^{a}	3.59 ± 0.82^{b}	0.004

Legend: FB – farm breeding; HG – hunting ground. Upper index a, b represents a statistically significant difference between the groups in the column after ANOVA statistical analysis (t-test) (α=0.05).

Table 6 compares the sensory evaluation between males and females. Again, the differences are mostly insignificant, except for juiciness in males ($p = 0.037$), where the meat of farmed males appears to be less juicy compared to wild males. This difference may be influenced by diet, exercise level or physiological factors.

Table 6 Comparison of sensory evaluation between farm and rangeland red deer by gender

	FB female	HG female	*p*-value	FB male	HG male	*p*-value
Taste	3.70 ± 0.62 [a]	3.80 ± 0.74 [a]	0.530	3.75 ± 0.73 [a]	3.58 ± 0.80 [a]	0.396
Aroma	3.82 ± 0.86 [a]	3.97 ±0.81 [a]	0.409	4.20 ± 0.79 [a]	3.93 ± 0.87 [a]	0.196
Juiciness	3.56 ± 0.87 [a]	3.33 ± 0.88 [a]	0.238	2.78 ± 0.98 [b]	3.23 ± 0.87 [a]	0.037
Tenderness	3.72 ± 0.84 [a]	3.59 ± 0.75 [a]	0.431	3.70 ± 0.82 [a]	3.27 ± 0.94 [a]	0.061

Legend: FB – farm breeding; HG – hunting ground. Upper index a, b represents a statistically significant difference between the groups in the column after ANOVA statistical analysis (t-test) (α=0.05).

Daszkiewicz *et al.* (2009) compared the sensory analysis of red deer meat of both sexes from hunting grounds. They monitored 4 parameters: aroma, taste, juiciness and tenderness on a 5-point scale. The results of this study show higher scores in each parameter compared to our results. Higher sensory evaluation of red deer was also observed in the work of **Hutchison *et al.* (2010)**. Similar conclusions were reached by **Piaskowska *et al.* (2015)** as by the previous authors. In each monitored parameter, a higher sensory evaluation was achieved compared to our results, which we recorded.

CONCLUSION

This study demonstrates that the rearing environment has a significant effect on the L* (lightness) parameter of red deer (*Cervus elaphus*) meat, with wild deer exhibiting lighter muscle tissue compared to farmed individuals. These differences are likely influenced by factors such as physical activity, natural diet, and stress levels in the wild. In contrast, the a* (redness) and b* (yellowness) values remained relatively stable across both environments, suggesting that the core colour characteristics of deer meat are not highly sensitive to rearing conditions. Additionally, observed variations in meat colour by age and gender - particularly in older animals and females - suggest that environmental influences may be cumulative over time and biologically mediated. These findings are important for understanding how intrinsic and extrinsic factors contribute to visual meat quality, which plays a critical role in consumer perception and market value. Sensory evaluation revealed no statistically significant differences between farmed and wild deer meat in terms of tenderness, juiciness, flavour, and aroma. However, minor trends observed in younger and male deer indicate potential subtle effects worth further investigation, especially considering the importance of these traits for consumer satisfaction. Overall, the study highlights the importance of considering both environmental and biological factors in venison production and quality assessment. The combination of objective colour analysis and sensory evaluation provides a comprehensive framework for evaluating game meat. These insights may support targeted breeding, rearing, and marketing strategies, particularly for premium game meat products in niche markets.

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