https://doi.org/10.17221/214/2020-VETMED

Thermography as a tool to monitor the velvet temperature and ossification stage of fallow deer (*Dama dama*) antlers under normal and modified photoperiodic conditions

Aleksandra Potrapeluk[1], *Pawel Janiszewski*[1]*, *Marek Bogdaszewski*[2]

[1]*Department of Fur-Bearing Animal Breeding and Game Management, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland*

[2]*Institute of Parasitology of the Polish Academy of Sciences, Research Station in Kosewo Gorne, Mrągowo, Poland*

**Corresponding author: janisz@uwm.edu.pl*

Citation: Potrapeluk A, Janiszewski P, Bogdaszewski M (2021): Thermography as a tool to monitor the velvet temperature and ossification stage of fallow deer (*Dama dama*) antlers under normal and modified photoperiodic conditions. Vet Med-Czech 66, 233–241.

Abstract: An increase in testosterone levels affects the shedding of velvet which, in turn, influences the behaviour of farm-raised fallow deer bucks. Consequently, the welfare of the farmed animals can be considerably improved by controlling the timing of the velvet shedding period. The aim of this study was to analyse changes in the velvet temperature and the timing of the velvet shedding in farm-raised fallow deer bucks exposed to a modified photoperiod. A total of 28 bucks were examined. The experimental group was subjected to an experimentally modified photoperiod before the direct observations and measurements of the antler temperatures with a thermal imaging camera. The acquired thermograms were useful for analysing the stages and the rate of the antler growth and for predicting the timing of the velvet shedding. The introduction of a long-day photoperiod in spring affected the growth and ossification of the antlers as well as the velvet shedding. The optimal time for antler cutting can be planned based on the identified changes in the velvet temperature in different parts of the antler.

Keywords: deer farming; stag; thermograph; velvet shedding; welfare

Fallow deer (*Dama dama*) and red deer (*Cervus elaphus*) are frequently farmed and kept in wildlife parks in Europe (Proskina and Pilvere 2010). These animals are farmed for venison with a high nutritional value (Hoffman and Wiklund 2006; Daszkiewicz et al. 2015), and they are regarded as a tourist attraction on account of their behaviour and appearance, which is often associated with the presence of antlers in males.

In adult fallow deer bucks, the annual antler growth cycle, which includes the bone growth, ossification, velvet shedding, hard antler stage and finally casting, is strongly correlated with the reproductive cycle (Gosch and Fisher 1989). The timing of the velvet shedding is considerably affected by the photoperiod and the resulting changes in hormonal levels (Bubenik 2006). Cervids begin to shed the velvet when the antlers are completely ossified (Schnare 1990). An increase in blood testosterone concentrations triggered by a photoperiodicity induces both the shedding of the velvet and the behavioural changes in farm-raised bucks. Their social organisation changes, males begin to show dominance and claim territory, and they compete for females during the rutting season (Chapman and Chapman 1975). The seasonal

https://doi.org/10.17221/214/2020-VETMED

changes in the behaviour of male cervids affect farm personnel and veterinarians because bucks can become more aggressive not only towards other males, but also towards humans. To minimise the relevant risks, fully developed and ossified antlers are often removed in fallow deer and red deer farms (Webster and Matthews 2006; Landete-Castillejos et al. 2012). This zootechnical procedure is performed after the complete ossification and velvet shedding of the antlers and is not connected to antler harvesting during the growth period, the so-called pant.

Natural physiological processes such as birth, offspring rearing (Pelabon et al. 1998; Cilulko-Dolega et al. 2018) and the growth of fawns in the winter period can be controlled on deer farms (Janiszewski et al. 2015). Performance traits such as the carcass meat content (Mulley and English 1985; Serrano et al. 2018), antler growth and quality (Gambin et al. 2017) and other traits or behavioural aspects can also be modified and controlled (Blanc and Therriez 1998; Goddard et al. 2001). Thermal imaging cameras are increasingly being applied in breeding practice on cervid farms (Cook and Schaefer 2002; Cook et al. 2005; Dunbar et al. 2009; Cilulko et al. 2013).

In captive-bred deer, antler ossification and the onset of velvet shedding can be monitored and controlled, which is an important consideration due to the above-mentioned changes in the behaviour of male fallow deer before and after shedding their velvet (Wilson and Stafford 2002).

The aim of this study was to analyse the changes in the velvet temperature using a thermo camera and the timing of the velvet shedding in farmed fallow deer bucks exposed to a modified photoperiod.

MATERIAL AND METHODS

The experiment was conducted at the Research Station of the Institute of Parasitology of the Polish Academy of Sciences in Kosewo Górne (Region of Warmia and Mazury, Poland N: 53°48'; E: 21°23'). The research station comprises a cervid farm with an estimated area of 200 ha where European fallow deer (approx. 300 animals) and red deer (approximately 100 animals) are kept.

No ethical approval was required, as there was no direct contact with the animals of the experimental and control groups during the entire experiment.

Changes in the velvet temperature and velvet shedding were monitored in fallow deer bucks. A total of twenty-eight bucks were investigated, and the animals were divided in two groups of experimental (E) and control (C) bucks of fourteen animals each. The housing and feeding conditions were identical in both groups.

The experimental group was subjected to an artificially (experimentally) modified photoperiod before the direct observations and temperature measurements with a thermal digital camera. Both groups of animals were kept in special experimental buildings, made of wood, during the photoperiodic variation. Artificial light was used to create a long day photoperiod from the beginning of January to mid-April in 2018. It is the final part of the period when fallow bucks carry hard antlers, which are usually cast in April and May (Kierdorf et al. 1993). The photoperiod in the experimental herd is presented in Table 1.

During the first two weeks of the experiment, the light period was 10 h, and it was automatically extended by one hour every two weeks until the achievement of a 16-hour light period. As a result, the natural day's length was extended by around 1.5 hours. The light intensity was 350 lx to 400 lx, and it was measured with an Abatronic AB-8809A light meter (Abatronic, Radom, Poland).

The experimental and control animals were divided into two age classes to determine the effect of age on the changes in the velvet temperature and the timing of the velvet shedding:

- Class 1 – young males aged 2–3 years (first and second antlers);
- Class 2 – mature males aged 4 years and older (third and successive antlers).

The above division was introduced to account for the fact that most fallow deer bucks begin to display

Table 1. Experimental photoperiod

Date	Day length
1–14 January	10 h
15–31 January	11 h
1–14 February	12 h
15–28 February	13 h
1–14 March	14 h
15–31 March	15 h
1–14 April	16 h

https://doi.org/10.17221/214/2020-VETMED

active mating behaviour at 4 years of age (Komers et al. 1997).

The changes in the velvet temperature and the timing of the velvet shedding were monitored between 21 June and 3 September 2018. The measurements were performed until the completion of the velvet shedding in all the individuals. The observations were conducted in five stages (periods) to support accurate analyses and comparisons of the changes in the velvet temperature between the age classes in both groups (Table 2).

The experimental and control bucks were kept in summer pastures during the direct observations and measurements of the antler temperatures. They had *ad libitum* access to meadow grass and fresh water. The observers used oats and freshly harvested twigs as bait to approach the animals and capture thermal images of a required quality allowing for all the thermal images to be taken from a similar distance of approximately 2 m, and with a similar body and antler position. A ThermoPro™ TP8 thermal digital camera (Wuhan Guide Infrared, Wuhan, China) was used to measure the surface temperature of the antlers and to determine the progression of the antler ossification. According to the manufacturer's specifications, the camera can be operated within a temperature range of –20 °C to 800 °C, and it has a thermal sensitivity of 0.08 °C at 30.0 °C. The measurements were performed before sunrise, between 3.30 a.m. and 5.00 a.m., to eliminate errors resulting from antler heating under exposure to solar radiation. At the same time, the air temperature was also automatically measured by the camera during the image capturing. The examined animals were also photographed with a Sony Alfa 200 digital camera (Sony, Tokyo, Japan) to generate additional data for the observations.

Every investigated buck was ear-tagged. The animal's identification number or name was displayed on the tag to facilitate the measurements of the antler temperatures in the individuals, group identification and analyses of the collected data. A Guide IR Analyser application was used to record the voice annotations during the thermal imaging and facilitate the correct identification of the animals in the thermograms.

Table 2. Research periods during the analysis of the changes in the velvet temperature in the fallow deer bucks

Period	Date	Observation days
I	21 June – 5 July	1–15
II	6 July – 20 July	16–30
III	21 July – 4 August	31–45
IV	5 August – 19 August	46–60
V	20 August – 3 September	61–75

A total of 1 227 thermal images were captured during the study, and 817 images of suitable quality were selected for further processing. The antler temperature was calculated based on the measurements conducted at three points:

- Measurement point 1 – at the base of the main beam (above the coronet);
- Measurement point 2 – at the mid-section of the main beam;
- Measurement point 3 – at the tip of the antlers (the tip of the palm in older bucks or the tip of beam in younger bucks without a developed palm).

Each colour thermogram featured a thermal palette for analysing the distribution and variations in the temperature at different measurement points. Measurements were performed based on the methodology described by Bowers et al. (2010) for examining red deer antlers, with certain modifications to account for the anatomical differences in the fallow deer.

The following data were recorded during measurements:

- Antler surface temperature in each experimental and control buck, with an indication of the animal's age, measured at three points to the nearest 0.01 °C;
- The animal's age;
- The date of the measurement;
- The date of the velvet shedding;
- The temperature of the ambient air on the day of measurement.

The statistical analysis involved the determination of arithmetic means ($\bar{x}$) and standard deviations (SD). The data were analysed by a two-way analysis of variance/multivariate analysis of variance (ANOVA/MANOVA) (group × period) and a one-way ANOVA (group or period). The significance of the differences in the mean values between the period and groups was determined by Duncan's test. Pearson's correlation coefficient was calculated to determine the strength of the relationships between the following variables: the animal's age and the date of the velvet shedding, the animal's

https://doi.org/10.17221/214/2020-VETMED

age and the temperature of the ambient air on the day of the velvet shedding, the date of the velvet shedding and the temperature of the ambient air on that day. All the calculations were performed using Statistica 2012 software (v11.0). The significance was set at $P \leq 0.05$.

RESULTS

Timing of the velvet shedding

The collected data revealed that the control group bucks aged 2–3 years shed the velvet between 18 August and 9 September (research period IV–V). In the older bucks from the control group, the velvet shedding occurred between 28 August and 3 September (research period V). It should be noted that in the vast majority of class 2 (mature) males, the velvet shedding took place between 28 and 31 August.

The above indicates that the shedding period in the older males was considerably shorter than in the younger bucks. In the younger males from the experimental group, which had been exposed to a modified photoperiod before the measurements, the velvet shedding occurred between 19 July and 2 August (research periods II–III). Successive stages of velvet shedding were observed 1 month earlier relative to the younger bucks from the control group. In the experimental males aged 4 years and older, the shedding took place between 24 July and 3 August (research period III). In this group, the velvet shedding also occurred 1 month earlier than in the corresponding age class in the control group. In the mature experimental bucks, the velvet shedding occurred in period IV in all the individuals. In the mature bucks from the control group, the velvet shedding period could not be precisely identified. The younger males from the experimental group shed the velvet in period III, whereas the younger bucks from the control group shed the velvet in period V.

Changes in the surface temperature of the velvet antlers

Table 3 presents the resulting changes in the antler temperatures measured in three measurement

Table 3. Changes of the mean ($\bar{x}$ ± SD) antler temperatures (°C) in three measurement points and specific study periods in the young and mature bucks

Point	Group	Research periods					ANOVA		
		I	II	III	IV	V	group	period	interaction
I age class									
1	C	29.82^{ab} ± 1.55	*31.88^{a} ± 0.68	*32.52^{a} ± 0.56	*28.97^{b} ± 1.22	19.73^{c} ± 2.96	0.000 1	0.000 1	0.000 5
	E	29.78^{a} ± 2.81	30.65^{a} ± 0.40	26.31^{b} ± 5.06	21.28^{c} ± 1.52	18.26^{d} ± 1.70			
2	C	31.90^{a} ± 1.00	*33.14^{a} ± 0.76	*34.47^{a} ± 0.46	*30.72^{ab} ± 0.59	17.80^{c} ± 3.97	0.000 1	0.000 1	0.000 5
	E	30.41^{a} ± 1.59	31.85^{a} ± 1.30	26.70^{b} ± 6.06	19.64^{c} ± 1.58	16.09^{d} ± 2.21			
3	C	34.04^{a} ± 0.57	34.65^{a} ± 0.65	*35.32^{a} ± 0.97	*32.43^{ab} ± 0.63	17.78^{c} ± 5.17	0.000 1	0.000 1	0.000 1
	E	33.80^{a} ± 1.83	33.67^{a} ± 0.76	27.87^{b} ± 7.06	18.03^{c} ± 0.90	14.66^{d} ± 2.70			
II age class									
1	C	*31.43^{ab} ± 1.51	*32.24^{a} ± 2.02	*32.77^{a} ± 1.73	*29.15^{b} ± 1.62	*26.23^{c} ± 2.85	0.0001	0.0001	0.0001
	E	29.58^{a} ± 1.79	30.11^{a} ± 1.16	30.51^{a} ± 1.78	23.41^{b} ± 3.42	13.46^{c} ± 3.46			
2	C	32.43^{ab} ± 1.73	32.72^{ab} ± 1.09	*34.09^{a} ± 1.20	*30.71^{b} ± 1.73	*26.77^{c} ± 3.92	0.000 1	0.000 1	0.000 1
	E	31.33^{a} ± 1.10	31.74^{a} ± 0.80	31.67^{a} ± 1.57	20.16^{b} ± 5.16	10.70^{c} ± 3.47			
3	C	33.72^{ab} ± 1.11	34.29^{a} ± 1.13	*34.97^{a} ± 1.17	*32.64^{b} ± 1.30	*28.14^{c} ± 3.53	0.000 1	0.000 1	0.000 1
	E	32.75^{a} ± 1.04	33.08^{a} ± 0.96	33.10^{a} ± 0.90	20.32^{b} ± 5.93	10.31^{c} ± 3.36			

C = control group; E = experimental group

*Significant differences between the means from groups C and E in a given research period ($P < 0.05$); $^{a–d}$Means (in rows) marked with different letters differ significantly ($P < 0.05$); 1, 2, 3 – measurement points

https://doi.org/10.17221/214/2020-VETMED

points and the specific study periods in the young and mature bucks.

A significant influence of a modified daylight length (P < 0.000 1*)* as well as the study period (P < 0.000 1) on the antler temperatures was noted in all three measurement points and both buck groups, which can indicate noticeable differences in the process of antler ossification.

In the younger bucks subjected to extended daylight conditions (E), the decrease in the antler temperatures was noted already after the research period II, i.e., after ca. 4 weeks since the start of the temperature recording – a temperature decrease from 29.78 °C to 26.31 °C (P < 0.05) at the base of the antler, as well as in the remaining two measurement points, i.e., the mid-sections (from 30.41 °C to 26.70 °C; P < 0.05) and the top of the antler (from 33.80 °C to 27.87 °C; P < 0.05). In the subsequent study periods, there was a further significant decrease in the antler temperatures, i.e., a decrease down to 18.26 °C, 16.09 °C and 14.66 °C (P < 0.05) at the base, mid-section and top of the antlers, respectively. On the other hand, any significant antler temperature decrease in the bucks from the control group (C) was manifested noticeably later, not sooner than the research period V – ca. 30–45 days later than the experimental group. Between the research period IV and V, the temperatures decreased from 28.98 °C to 19.78 °C (P < 0.05) at the base of the antlers, from 30.72 °C down to 17.80 °C (P < 0.05) in the mid-section and from 32.43 °C down to 17.78 °C (P < 0.05) at the top of the antlers.

The young bucks in both the control and experimental groups did not manifest any temperature decrease at any measurement point in research period I and V (group × research period interaction, P < 0.000 1).

The older bucks subjected to extended daylight conditions (E) showed an antler temperature decrease at the base of the antler after research period III, i.e., after ca. 6 weeks since the start of the temperature recording (a decrease from 29.58 °C to 23.41 °C; P < 0.05), and down to 13.46 °C (P < 0.05) in research period V. A similar trend was noted as well in the remaining two points, i.e., a temperature decrease in the mid-section of the antlers from 31.33 °C in the first period to 20.16 °C in period IV (P < 0.05) and further down to 10.70 °C; the decrease at the top of the antlers was from 32.75 °C in period I to 23.32 °C (P < 0.05) in period IV and further down to 10.31 °C (P < 0.05) in period V. In the older bucks from the control group, no noticeable antler temperature decrease was noted after research period V, similar to the young bucks control group. In the time interval from research period I to the IV, the antler temperatures were relatively constant, after which a temperature decrease was noted between research period IV and V – 29.15 °C to 26.23 °C (P < 0.05) at the base, 30.71 °C to 26.77 °C, (P < 0.05) at the mid-section, and 32.64 °C to 28.14 °C (P < 0.05) at the top of the antlers.

In the mature bucks control group (C), the temperatures at the base of the antlers were higher during all the research periods compared to the experimental group (E), whereas in the two initial research periods at the mid-section and top of the antlers, the temperatures were similar (group × research period interaction, P < 0.000 1).

It is worth mentioning that the antler temperatures in the mature buck control group (C) in the last observation period (V) was higher compared to the bucks in the experimental group (E) – the temperature difference was 12.77 °C (P < 0.05) at the base, 16.07 °C (P < 0.05) at the mid-section and 17.38 °C (P < 0.05) at the top of the antlers, which can indicate an ongoing ossification process in this specific buck group, a process that had already ended in the experimental group members. This process had a different run in the young buck groups (Table 3).

Correlations

The correlation coefficients were calculated to determine the strength of the relationships between the animals' age and the velvet shedding date, between the animals' age and the ambient temperature on the velvet shedding date, and between the velvet shedding date and the ambient temperature on that day. The results are presented in Table 4.

Table 4. Correlation coefficients between the selected variables

	Air temperature	Shedding date
Air temperature	–	–
Shedding date	–0.793**	–
Age	–0.131**	0.170**

**P < 0.01

https://doi.org/10.17221/214/2020-VETMED

The correlation between the velvet shedding date and the animals' age was positive and highly significant (r = 0.170, P < 0.01), which suggests that the velvet shedding tends to occur later in older bucks. A highly significant negative correlation (r = −0.793, P < 0.01) was noted between the velvet shedding date and the ambient temperature on the day of the measurement, which could suggest that lower air temperatures tend to delay the velvet shedding. The animal's age and ambient temperature on the velvet shedding day were bound by a highly significant negative correlation (r = −0.131, P < 0.01), which could imply that the older bucks tend to shed the velvet on colder days.

DISCUSSION

The applicability of infrared thermography for monitoring the growth of cervid antlers has rarely been investigated in the literature. The present study examined changes in the antler temperatures in European fallow deer in the final stages of the antler growth, i.e., ossification. The acquired thermograms were useful for the analysis of the stages and the rate of the antler growth and to predict the timing of the velvet shedding.

Bowers et al. (2010) relied on thermal imaging to analyse the growth of antlers in red deer, and reported results that are similar to our findings. The cited authors divided red deer stags into two age groups (younger than 2 years and older than 2 years) and conducted observations for 112 days. The researchers identified three antler growth stages. In the first stage (observation days 0 to 28), the average temperatures reached 39 °C at the base of the main beam in all the stags, and it was only around 0.5 °C higher at the mid-section of the beam. The reported differences in the antler temperatures between the measurement points do not coincide with our findings. In the work of Bowers et al. (2010), the average temperatures were around 0.03 °C higher at the mid-section of the beam than at the tip of the antlers, whereas, in our study of fallow deer, the corresponding differences were 1.5 °C on average. In the study, the temperature measured at the tip of the antlers in the second stage of antler growth (observation days 28 to 70) reached 38.4 °C and was identical to that determined at the mid-section of the beam, whereas the temperature at the base was 37.9 °C. In the last stage of antler growth (observation days 70 to 112), the average temperatures were determined at 36.8 °C at the base and 35.7 °C at the tip. Bowers et al. (2010) performed the temperature measurements when the antlers were covered with velvet, and they did not investigate the velvet shedding from both beams. Our study analysed the velvet shedding period, which is an important stage in the antler growth cycle. The results of our study indicate that velvet shedding is directly preceded by a sudden and relatively rapid decrease in the antler temperatures, where the temperature at the base exceeds that measured at the tip of the antlers. This stage probably marks the complete ossification of the antlers, and it is followed by the velvet shedding. The temperature changes in growing and then mineralising the antlers are directly related to their blood supply. One of the haemostatic functions of the blood in the cardiovascular system is heat transport. The growing antlers are covered by velvet, which is richly vascularised, and innervated by sensory nerve fibres that grow out along the route of the major blood vessels in the velvet (Wislocki 1942; Waldo et al. 1949). Branches of the superficial temporal artery ascend each antler through the pedicle providing a rich supply of blood to the velvet and supplying nutrients to the developing bone. Some arterial tributaries profusely integrate in the apices of the antler where rapid growth occurs. Veins accompany the arteries and empty into the superficial veins. Arterial transport between the pedicle and the antlers diminishes rapidly as the bone density increases. The narrowing of the vascular channels restricts the circulation until finally it ceases (Waldo et al. 1949). After completion of the antler growth and mineralisation, the velvet is shed from the antlers that thereafter consist solely of bare bone and are referred to as hard antlers (Bubenik 2006).

In the present study, the photoperiod modification in the spring stimulated the antler growth, ossification and velvet shedding in European fallow deer. It should be emphasised that the start date of the antler growth in the experimental group was also earlier compared to the group not subjected to artificial daylight, which was the topic of other studies (Bogdaszewski 2019; unpublished results). Light is the key stimulus that determines the reproduction and physiological processes in many animal species, including cervids. In the pioneering research conducted by Jaczewski (1954), red deer shed and regrew antlers twice during a single

https://doi.org/10.17221/214/2020-VETMED

year in response to a modified photoperiod. In the above study, the light period was shortened between April and June. Jaczewski (1954) observed that the shortening of a day's length to 8 h promoted more rapid antler growth, antler shedding and regrowth in the same season. In our study, the experimental fallow deer bucks were exposed to an artificially prolonged daily light period. As a result, the antler growth began and was completed earlier in the experimental group than in the control group (without artificial illumination in the spring). The antler ossification was completed at an earlier date in both the young and mature experimental bucks. It should also be noted that photoperiod modification synchronised the antler ossification in the young and old males. This observation could have practical implications by facilitating the organisation of farming operations and planning veterinary procedures in fallow deer farms.

Research has demonstrated that hormonal treatments (oestradiol and stilboestrol) can also stimulate antler growth (Bubenik 2006). In fallow deer, velvet shedding and antler casting occurs at around 80% and 25% of the maximum testis volume, respectively (Gosch and Fisher 1989). These correlations were also observed in fallow deer bucks exposed to a shorter annual photoperiod (Gosch and Fisher 1986). The relationship between the testis volume and the timing of the velvet shedding was not investigated in our study, but the presence of such a correlation can be hypothetically postulated.

The results of this study indicate that the velvet shedding is also influenced by the animals' age. The young bucks from both the experimental and the control group shed the velvet earlier than the mature males. The young bucks shed velvet between 19 July and 2 August in the experimental group and after 18 August in the control group. The mature bucks from the experimental group, exposed to a prolonged photoperiod, shed the velvet between 2 and 9 August. The velvet shedding period could not be accurately determined in the mature control bucks, which could imply that antler growth proceeded more naturally in these animals. Age was an important determinant in the velvet shedding in both groups. Such a correlation was also observed in a study of farmed fallow deer in New Zealand, where younger bucks also shed the velvet earlier than mature males (Riney 1954). It should be noted that the cited research (Riney 1954) was conducted at a different latitude, and the examined animals shed the velvet in the second half of February, i.e., approximately six months earlier than in our study.

Goss (1969) conducted pioneering research into the effects of the age and the photoperiod on the annual antler growth cycle in sika deer. In the cited study, the age did not exert a significant influence on the velvet shedding in the sika deer exposed to a modified photoperiod. The above findings could be attributed to the fact that Goss (1969) examined only two stags – a two-year-old male and a mature stag. However, it should be noted that the mature stag responded more rapidly to the changes in the photoperiod than the young male. Jaczewski (1954) did not report a correlation between the animals' age and the timing of the velvet shedding in males exposed to a modified photoperiod, whereas such a correlation was clearly noted in our study of farmed fallow deer.

Antler growth and velvet shedding can also be affected by other factors. According to many authors, dominance hierarchy plays an important role in cervids, and a higher social rank promotes antler growth and, consequently, earlier velvet shedding in red deer and fallow deer (Bartos and Losos 1997). However, in a study by Bartos et al. (2004), the onset of velvet shedding was negatively correlated with the social status of male white-tailed deer.

Prichard et al. (1999) demonstrated that the age differentiated the size of the antlers in a reindeer herd. However, the authors were unable to determine the correlation between the antler size and the velvet shedding because the antlers are routinely removed in farmed cervids (Prichard et al. 1999).

The study by Rolf and Enderle (1999) provides interesting insight into antler growth in fallow deer. The authors demonstrated that despite the presence of an ossified antler bone at the beginning of the velvet shedding, the antler remained a living bone until casting. A histological examination revealed the presence of a well-developed vascular system within the antler core that kept the antlers moist and contributed to their elasticity. High impact resistance is a critical feature between the velvet shedding and antler casting when deer fights are most frequent. The claim that the antler structure was still a living bone during the velvet shedding, as shown by Rolf and Enderle (1999), could not be confirmed when comparing the results of this study. On the contrary, the data from

https://doi.org/10.17221/214/2020-VETMED

the thermal images indicate that, right after the velvet shedding (research period V), the temperature recorded at the tips of the deer stag antlers was close to the ambient air temperature, indicating a completely osseous (and thereby non-living) tissue (unpublished own data). The thermal imaging, however, only shows the superficial temperature of the measured object and further investigation is required into the topic of the internal temperature in the antlers.

In the current study, the ossification of the antlers was assessed by measuring the temperature at different parts of the beam. Thermal imaging is, thus, a useful technique for monitoring the process. This knowledge concerning the ossification is frequently useful on zoo gardens or cervid farms to guarantee the safety of personnel and to prevent lethal accidents during deer fights (Mattiello 2009). Antler cutting dates should be carefully planned to improve the animal welfare, minimise stress and eliminate pain without the need for pharmacological sedation (Cook and Schaefer 2002; Cook et al. 2005; Webster and Matthews 2006).

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

Bartos L, Losos S. Response of antler growth to changing rank of fallow deer buck during the velvet period. Can J Zool. 1997 Nov;75(11):1934-9.

Bartos L, Miller KV, Osborn D. Relationship between dominance and antler cycle in white-tailed deer Odocoileus virginianus. Acta Theriol. 2004 Dec;49(4):517-25.

Blanc F, Therriez M. Effects of stocking density on the behavior and growth of farmed red deer hinds. Appl Anim Behav Sci. 1998 Mar;56(2-4):297-307.

Bowers S, Gandy S, Dickerson T, Brown C, Strauch T, Neuendorff D, Randel R, Willard S. Evaluating velvet antler growth in red deer stags (Cervus elaphus) using hand-held and digital infrared thermography. Can J Anim Sci. 2010 Mar;90(1):13-21.

Bubenik GA. Seasonal regulation of deer reproduction as related to the antler cycle – A review. Vet Arhiv Suppl. 2006;76:275-85.

Chapman D, Chapman N. Fallow deer. Lavenham Suffolk, UK: Terence Dalton Limited; 1975. 271 p.

Cilulko J, Janiszewski P, Bogdaszewski M, Szczygielska E. Infrared thermal imaging in studies of wild animals. Europ J Wildl Res. 2013 Feb;59(1):17-23.

Cilulko-Dolega J, Janiszewski P, Bogdaszewski M. The applicability of thermography during the breeding season and early nursing in farmed fallow deer. Int J Appl Res Vet Med. 2018;16(2):186-96.

Cook NJ, Schaefer AL. Stress responses of wapiti (Cervus elaphus canadensis) to removal of velvet antler. Can J Anim Sci. 2002 Mar;82(1):11-7.

Cook NJ, Chuch JS, Schaefer AL, Webster JR, Matthews LR, Suttie JM. Stress and pain assessment of velvet antler removal from Elk (Cervus elaphus canadensis) and Reindeer (Rangifer tarandus). Online J Vet Res. 2005; 9(1):13-25.

Daszkiewicz T, Hnatyk N, Dabrowski D, Janiszewski P, Gugolek A, Kubiak D, Smiecinska K, Winiarski R, Koba-Kowalczyk M. A comparison of the quality of the Longissimus lumborum muscle from wild and farm-raised fallow deer (Dama dama L.). Small Rumin Res. 2015 Aug; 129:77-83.

Dunbar MR, Johnson SR, Rhyan JC, McCollum M. Use of infrared thermography to detect thermographic changes in mule deer (Odocoileus hemionus) experimentally infected with foot-and-mouth disease. J Zoo Wildl Med. 2009 Jun;40(2):296-301.

Gambin P, Serrano MP, Gallego L, Garcia A, Cappelli J, Ceacero F, Landete-Castillejos T. Does Cu supplementation affect the mechanical and structural properties and mineral content of red deer antler bone tissue? Animal. 2017 Aug;11(8):1312-20.

Goddard PJ, Summers RW, Macdonald AJ, Murray C, Fewcett AR. Behavioral responses of red deer to fences of five different designs. Appl Anim Behav Sci. 2001 Aug 27; 73(4):289-98.

Goss RJ. Photoperiodic control of antler cycles in deer. I. Phase shift and frequency changes. J Experim Zool. 1969 Mar;170(3):311-24.

Gosch B, Fisher K. Saisonal bedingte Anderungen der Gonadenfunktion adulter Damhirsche (Dama dama L.) bei normaler und kunstlich beschleunigter Photoperiode [Seasonal changes in the gonadal function of adult fallow deer (Dama dama L.) with normal and artificially accelerated photoperiod]. In: Dieterlen F, editor. Kurzfassungen der Vortrage und Posterdemonstrationen [Abstracts of lectures and poster demonstrations]. Hamburg: P. Parey; 1986. p. 22-3.German.

Gosch B, Fisher K. Seasonal changes of testis volume and sperm quality in adult fallow deer (Dama dama) and their relationship to the antler cycle. J Reprod Fertil. 1989 Jan; 85(1):7-17.

https://doi.org/10.17221/214/2020-VETMED

Hoffman LC, Wiklund E. Game and venison – Meat for the modern consumer. Meat Sci. 2006 Sep;74(1):197-208.

Jaczewski Z. Wplyw oswietlenia dziennego na poroze jelenia (Cervus elaphus L.) [The effect of photoperiod on antler of Red deer (Cervus elaphus L.)]. Fol Biol. 1954;2:133-43. Polish.

Janiszewski P, Daszkiewicz T, Cilulko J. The effect of wintering conditions on the body weight and carcass quality of farm-raised fallow deer (Dama dama). Bulg J Agric Sci. 2015;21(3):674-9.

Kierdorf U, Schultz M, Fischer K. Effects of an antiandogen treatment on the antler cycle of male fallow deer (Dama dama L.). J Exp Zool. 1993 Jul;266(1):195-205.

Komers PE, Pelabon C, Stenstrom D. Age at first reproduction in male fallow deer: Age-specific versus dominance specific behaviors. Behav Ecol. 1997 Jul;8(4):456-62.

Landete-Castillejos T, Estevez JA, Ceacero F, Garcia AJ, Gallego L. A review of factors affecting antler composition and mechanics. Front Biosci E. 2012 Jun;(4)7:2328-39.

Mattiello S. Welfare issues of modern deer farming. Ital J Anim Sci. 2009 Mar;8(Suppl. 1):205-17.

Mulley RC, English AW. The effect of castration on Fallow deer (Dama dama) on body growth and venison production. Anim Prod. 1985 Dec;41(3):359-91.

Pelabon C, Yoccoz NG, Ropert-Coudert Y, Caron M, Peirera V. Suckling and allosuckling in captive Fallow deer (Dama dama, Cervidae). Ethol. 1998 Jan;104(1):75-86.

Prichard A, Finstad G, Shain D. Lactation in yearling Alaskan reindeer: Implications for growth, reproduction, and survival. Rangifer. 1999 Apr;19(2):77-84.

Proskina L, Pilvere I. Development tendencies of deer breeding sector in Latvia. Econ Sci Rur Develop. 2010; 21:74-81.

Riney T. Antler growth and shedding in a captive group of fallow deer (Dama dama) in New Zealand. Trans Roy Soc N Zeal. 1954 Sep;82(2):569-78.

Rolf HJ, Enderle A. Hard fallow deer antler: A living bone till antler casting? Anat Rec. 1999 May 1;255(1):69-77.

Schnare H. Sekundare Geschlechtsmerkmale des Damhirsches (Dama dama L.). Vorstellung und Diskussion anhand photoperiodischer Manipulationen und physiologischer Grundlagen: Schadel, Stirnzapfen und Rosen [Secondary sex characteristics among fallow deer (Dama dama L.). Presentation and discussion by means of photoperiodic manipulation and physiological foundations: Skull, antler buds, roses]. Z Jagdwis. 1990 Dec; 36(4):209-18. German.

Serrano MP, Maggiolino A, Lorenzo JM, De Palo P, Landete-Castillejos T, Gambin P, Cappelli J, Dominguez R, Perez-Barberia FJ, Gallego L. Meat quality of farmed red deer fed a balanced diet: Effects of supplementation with copper bolus on different muscles. Animal. 2018 Apr; 13(4):888-96.

Waldo CM, Wislocki GB, Fawcett DW. Observations on the blood supply of growing antlers. Am J Anat. 1949 Jan; 84(1):27-61.

Wilson PR, Stafford KJ. Welfare of farmed deer in New Zealand. 2. Velvet antler removal. N Zeal Vet J. 2002 Dec; 50(6):221-7.

Wislocki GB. Studies on the growth of deer antlers. I. On the structure and histogenesis of the antlers of the Virginia deer (Odocoileus virginianus borealis). Am J Anat. 1942 Nov;71(3):371-415.

Webster JR, Matthews LR. Behaviour of red deer following antler removal with two methods of analgesia. Livestock Sci. 2006 Apr;100(2-3):150-8.

Received: November 6, 2020
Accepted: February 22, 2021