ANIMAL SCIENCE AND GENETICS *Published by the Polish Society of Animal Production*
vol. 19 (2023), no 1, 83-94
DOI: 10.5604/01.3001.0053.4180

Research Article **Open Access**

Carcass parameters of farmed sika deer

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SUMMARY

New methods for evaluating cervid carcasses without the need to divide them into primal cuts are constantly being sought. A possible solution could be the use of indirect methods based on correlations between carcass parameters and regression equations. Therefore, the aim of this study was to characterize the carcasses of farmed males of sika deer, and to determine the relationships between their parameters. The analyzed carcass parameters were found to be closely correlated. The regression equations derived in the study can be used to predict the weights of individual carcass cuts and, in the future, to facilitate carcass classification and grading.

KEY WORDS: **deer, *Cervus nippon*, deer farming, dressing percentage**

INTRODUCTION

According to the Act of 11 March 2004 on Animal Health Protection and Control of Infectious Animal Diseases (Journal of Laws 2004 No. 69, item 625), three cervid species are considered livestock: the red deer (*Cervus elaphus*), the sika deer (*Cervus nippon*), and the fallow deer (*Dama dama*). As a result, they can be farmed for meat. According to many authors, venison is characterized by high nutritional value and exceptional flavour (Dzierżyńska-Cybulko and Fruziński, 1997; Hutchison et al., 2010; Bureš et al., 2015; Milczarek et al., 2021; Hiemori-Kondo et al., 2022). Cervid meat has low fat content (Volpelli et al., 2003), which has been estimated at 0.9-3.3% in red deer. It also contains high concentrations of minerals and polyunsaturated fatty acids (Bureš et al., 2015; Daszkiewicz et al., 2018; Milczarek et al., 2021), and is rich in protein whose percentage ranges from 19% to 24% (Florek and Drozd, 2013).

The quality of livestock carcasses is evaluated based on slaughter traits (Keçici et al., 2020; Barcelos et al., 2021). In order to achieve high technological and market value, the carcass is dividedinto primal cuts and tissue components (Dzierżyńska-Cybulko and Fruziński, 1997;

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Received: 17.02.2023 Received in revised form: 21.03.2023
Accepted: 22.03.2023 Published online: 23.03.2023

Wilkiewicz-Wawro et al., 2003). However, carcass dissection may make it unmarketable. Therefore, new methods for evaluating livestock carcasses prior to dissection are constantly being sought. One of the solutions could be the use of indirect methods based on correlations between carcass weight and measurements vs. individual cuts (Czajkowska and Bogdaszewski, 2021). In the future, such methods may be used by game meat processing plants to classify the carcasses of wild-living and farmed deer.

In view of the above, the aim of this study was to characterize the carcasses of farmed male sika deer, and to determine the relationships between their parameters.

MATERIALS AND METHODS

The experimental materials comprised 14 carcasses of male sika deer, divided into two age groups: young (Y), aged two years (n=7) and old (O), aged three years and older (n=7). The animals were slaughtered in February 2022 in the Research Station in Kosewo Górne administered by the Institute of Parasitology of the Polish Academy of Sciences.

All animals were weighed within an accuracy of 0.5 kg. Each animal had an individual identification earring number and a transponder number. The deer were slaughtered in accordance with the current regulations (Journal of Laws No. 70, item 643; Council Regulation (EC) No. 1099/2009), as part of routine management practices on the farm, not for the needs of this experiment.

The animals were immobilized in a crush and stunned with a penetrating captive bolt gun. They were sacrificed by severing the carotid artery and bleeding. Within one hour post mortem, the carcasses were transported to the cold store where they were subjected to further processing.

Hanging carcasses were measured using a measuring tape, within an accuracy of 0.5 cm, to determine the following parameters:

- carcass length (from the tip of the nose to the base of the tail, along the centre of the head and the backbone);
- height at withers (from the highest point of the withers to the tip of the front hoof, with front legs perpendicular to the carcass);
- height at sacrum (from the highest point of the lumbar backbone to the tip of the hoof, along the hind leg);
- chest girth (behind the withers and shoulders).

The carcasses were eviscerated and skinned, and the lower parts of legs were removed at the carpal (forelegs) and tarsal (hind legs) joints.

The shoulders were separated from the carcass. The flank and the ribs were removed by cutting along the straight line stretching from the lumbar region of the saddle. Tenderloins were removed completely intact. The saddle was removed by making a cut perpendicular to the backbone in the cranial direction, from the 2nd to the 9th thoracic vertebrae. The neck was removed by cutting between the first cervical vertebra and the base of the skull in the cranial direction, and along the line separating the saddle in the caudal direction. The leg was removed by making a cut between the last but one and the last lumbar vertebrae.

The following terms are used in the subsequent sections of the article:

- dressing percentage 1 – the ratio between hot carcass weight after evisceration and body weight;
- dressing percentage 2 – the ratio between hot carcass weight after evisceration (without skin, head and the lower parts of legs) and body weight.

The results were processed statistically with the use of descriptive statistics. Arithmetic means ($\bar{x}$), standard deviations (s), standard error of the mean (SEM), and correlation coefficients were calculated. The results were analysed statistically by Student's t-test at significance levels of $P \leq 0{,}01$. Linear regression equations were derived for carcass weight and measurements to determine their relationships. All calculations were performed using Statistica version 13 PL (Software Inc. 2017).

RESULTS

The average body weight of all examined animals is presented in Table 1. It reached nearly 71 kg, and hot carcass weight after evisceration was determined at 50.82 kg. Dressing percentage 1 and dressing percentage 2 were 71% and around 55%, respectively. Four carcass measurements were performed, and the greatest difference between age groups was noted in carcass length. The average carcass length of all analyzed deer was 147 cm (Table 2).

Table 1.
Body weight, carcass weight and dressing percentage of sika deer

Parameter	Statistics	Total	Group		P
			Young	Old	
Body weight [kg]	$\bar{x}$	70.95	54.58	95.50	0.004
	s	25.83	4.76	25.00	
	SEM	8.17	1.94	12.50	
Hot carcass weight after evisceration [kg]	$\bar{x}$	50.82	39.02	68.53	0.001
	s	17.69	4.32	14.54	
	SEM	5.59	1.76	7.27	
Dressing percentage 1 [%]	$\bar{x}$	71.77	71.37	72.38	0.580
	s	2.60	2.22	3.36	
	SEM	0.82	0.91	1.68	
Carcass weight without skin, head and legs [kg]	$\bar{x}$	38.87	29.81	52.46	0.002
	s	14.02	3.52	12.59	
	SEM	4.43	1.44	6.29	
Dressing percentage 2 [%]	$\bar{x}$	54.79	54.50	55.21	0.671
	s	2.35	2.46	2.45	
	SEM	0.74	1.01	1.23	

Table 2.
Body and carcass measurements of sika deer

Parameter	Statistics	Total	Group		P
			Young	Old	
Carcass length [cm]	x̅	147.00	137.00	162.00	0.002
	s	15.31	3.90	13.34	
	SEM	4.84	1.59	6.67	
Chest girth [cm]	x̅	99.80	92.67	110.50	0.002
	s	10.80	5.82	6.24	
	SEM	3.41	2.38	3.12	
Height at withers [cm]	x̅	96.30	93.00	101.25	0.210
	s	9.82	6.29	13.00	
	SEM	3.11	2.57	6.50	
Height at sacrum [cm]	x̅	104.60	102.50	107.75	0.040
	s	4.14	3.15	3.59	
	SEM	1.31	1.28	1.80	

Among non-edible portions of the carcass, skin was characterized by the highest percentage content and weight (Table 3), whereas the lower parts of legs had the lowest proportion in the carcass and the lowest weight. A nearly two-fold difference in head weight was observed between age groups.

Table 3.
Weights and proportions of non-edible carcass components in sika deer

Parameter	Statistics	Total	Group		P
			Young	Old	
Skin [kg]	x̅	5.03	3.75	6.95	0.009
	s	1.89	0.60	1.37	
	SEM	0.60	0.24	0.68	
Skin [%]	x̅	7.09	6.87	7.28	0.297
	s	2.70	1.1	1.43	
	SEM	0.85	0.44	0.71	
Head [kg]	x̅	4.26	3.05	6.08	0.001
	s	1.75	0.18	1.34	
	SEM	0.55	0.07	0.67	
Head [%]	x̅	6.00	5.59	6.37	0.158
	s	2.50	0.33	1.40	
	SEM	0.80	1.28	0.70	
Legs [kg]	x̅	2.66	2.41	3.04	0.092
	s	0.58	0.58	0.35	
	SEM	0.18	0.24	0.18	
Legs [%]	x̅	3.75	4.42	3.18	0.068
	s	0.82	0.64	0.37	
	SEM	0.25	0.35	0.19	

The weights and proportions of edible carcass components in sika deer are presented in Table 4. The liver was the heaviest organ, and its weight reached 0.77 kg in younger animals and 1.38 kg in older animals. The weights of individual edible carcass components were lower in younger deer. Edible components accounted for approximately 3% of total carcass weight.

The legs and shoulders were the heaviest cuts, accounting for more than 36% and around 17% of total carcass weight, respectively (Table 5). The percentage of legs was lower in older animals, despite their highest weight.

Table 4.
Weights and proportions of edible carcass components in sika deer

Parameter	Statistics	Total	Group		P
			Young	Old	
Heart [kg]	$\bar{x}$	0.48	0.39	0.62	0.003
	s	0.14	0.07	0.10	
	SEM	0.04	0.03	0.05	
Heart [%]	$\bar{x}$	0.68	0.71	0.65	0.221
	s	0.20	0.13	0.10	
	SEM	0.05	0.05	0.05	
Liver [kg]	$\bar{x}$	1.01	0.77	1.38	0.011
	s	0.41	0.07	0.45	
	SEM	0.13	0.03	0.23	
Liver [%]	$\bar{x}$	1.42	1.41	1.45	0.996
	s	0.58	0.13	0.47	
	SEM	0.18	0.05	0.24	
Kidneys [kg]	$\bar{x}$	0.48	0.38	0.62	0.599
	s	0.65	0.60	0.79	
	SEM	0.20	0.24	0.39	
Kidneys [%]	$\bar{x}$	0.68	0.70	0.65	0.965
	s	0.92	1.10	0.83	
	SEM	0.28	0.44	0.41	

Table 5.
Weights and proportions of carcass cuts in sika deer

Parameter	Statistics	Total	Group		P
			Young	Old	
Leg [kg]	$\bar{x}$	13.83	11.04	18.01	0.003
	s	4.29	1.39	3.63	
	SEM	1.36	0.57	1.82	
Leg [%]	$\bar{x}$	36.05	37.07	34.53	0.061
	s	2.15	2.03	1.35	
	SEM	0.68	0.83	0.67	
Shoulder [kg]	$\bar{x}$	6.44	4.96	8.66	0.001
	s	2.19	0.74	1.61	

	SEM	0.69	0.30	0.81	
Shoulder [%]	$\bar{x}$	16.64	16.64	16.65	0.991
	s	1.13	1.28	1.04	
	SEM	0.36	0.52	0.52	
Neck [kg]	$\bar{x}$	3.23	1.80	5.38	0.048
	s	2.90	0.58	3.80	
	SEM	0.92	0.24	1.90	
Neck [%]	$\bar{x}$	7.52	6.13	9.60	0.126
	s	3.46	2.20	4.28	
	SEM	1.10	0.90	2.14	
Ribs and flank [kg]	$\bar{x}$	4.23	3.25	5.72	0.019
	s	1.78	0.54	2.03	
	SEM	0.56	0.22	1.01	
Ribs and flank [%]	$\bar{x}$	10.85	10.88	10.81	0.945
	s	1.49	1.11	2.14	
	SEM	0.47	0.45	1.07	
Saddle [kg]	$\bar{x}$	3.14	2.41	4.23	0.005
	s	1.16	0.39	1.07	
	SEM	0.37	0.16	0.53	
Saddle [%]	$\bar{x}$	8.08	8.10	8.05	0.924
	s	0.71	0.92	0.32	
	SEM	0.22	0.38	0.16	
Tenderloin [kg]	$\bar{x}$	0.61	0.50	0.77	0.013
	s	0.18	0.11	0.16	
	SEM	0.06	0.04	0.08	
Tenderloin [%]	$\bar{x}$	1.61	1.69	1.49	0.321
	s	0.30	0.30	0.27	
	SEM	0.09	0.12	0.14	

Based on the data in Table 6, it can be concluded that both the weight of the hot carcass after evisceration and carcass weight without skin, head and legs were significant ($p \leq 0.01$) in relationship to body weight. A positive correlation implies that the values of the above parameters increased with increasing body weight. The reverse was noted in dressing percentage 1 and dressing percentage 2, which were negatively correlated with body weight. Significant ($p \leq 0.01$) positive correlations were found between carcass length, chest girth, and height at sacrum vs. body weight. A similar relationship was found for the weight of skin, head, legs, heart, and liver ($p \leq 0.01$). High coefficients of correlation ($p \leq 0.01$; 0.98 to 0.99) were observed between the weights of shoulders, leg and saddle vs. body weight. An analysis of the proportions of the above cuts revealed a significant ($p \leq 0.01$) negative correlation between the percentage of leg and body weight.

Table 6.
Correlations between body weight and carcass parameters in sika deer

Parameter	**Body weight [kg]**
Hot carcass weight after evisceration [kg]	0.9935 *
Dressing percentage 1 [%]	-0.1685
Carcass weight without skin, head and legs [kg]	0.9939 *
Dressing percentage 2 [%]	-0.0019
Carcass length [cm]	0.9056 *
Chest girth [cm]	0.6902 *
Height at withers [cm]	0.5263
Height at sacrum [cm]	0.8077 *
Skin [kg]	0.9402 *
Skin [%]	-0.3908
Head [kg]	0.8546 *
Head [%]	-0.3509
Legs [kg]	0.6489 *
Legs [%]	-0.2707
Heart [kg]	0.9267 *
Heart [%]	0.4825
Liver [kg]	0.9327 *
Liver [%]	1.0007
Kidneys [kg]	-0.0641
Kidneys [%]	0.4825
Leg [kg]	0.9872 *
Leg [%]	-0.6578 *
Shoulder [kg]	0.9772 *
Shoulder [%]	-0.1692
Neck [kg]	0.8985 *
Neck [%]	0.7029 *
Ribs and flank [kg]	0.9047 *
Ribs and flank [%]	0.0369
Saddle [kg]	0.9774 *
Saddle [%]	0.0095
Tenderloin [kg]	0.9140 *
Tenderloin [%]	-0.4081

* $p \le 0.01$

Regression equations were also derived to estimate the values of carcass parameters that are difficult to measure based on the body weight of sika deer. The calculations for three primal cuts are presented in Table 7. Body weight was highly significantly correlated with leg weight. The correlation coefficient and the coefficient of determination were high ($r=0.987$ and $r^2=0.975$, respectively). The remaining equations, describing the effect of body weight on the weights of shoulders and saddle, also well fit the data. The calculated values were consistent with the actual values determined based on measurements of selected cuts, which confirms the goodness of fit of the linear regression model.

Table 7.
Regression equations for three primal cuts in sika deer carcasses

Cut	Regression equation	Correlation coefficient (r)	Coefficient of determination (r^2)	Value [kg]	
				Actual	Estimated
Leg	y = 2.1933 + 0.164x	0.987	0.975	13.83	13.83
Shoulder	y = 0.5533 + 0.083x	0.977	0.955	6.44	6.44
Saddle	y = 0.0269 + 0.0439x	0.977	0.955	3.14	3.14

DISCUSSION

A comparison of the results of this study with the findings of other authors may be difficult due to methodological differences in carcass dressing and the fact that the carcass parameters of sika deer have not been widely discussed in the literature.

In a study by Masuko and Souma (2009), the average body weight of Japanese sika deer was 66.4 ± 8.3 kg at 24 months of age, and 83.4 ± 12.8 kg at 36 months of age, which is consistent with the present findings (Table 1). Hanzal et al. (2018) reported that the average body weight of sika deer in Czechia ranged from 56.67 kg to 60.92 kg in animals aged 2-3 years, and from 59.42 kg to 88.25 kg in those aged 4-5 years. Janiszewski et al. (2007) found that the carcass weight of wild-living sika deer varied depending on the month/season of harvest. In the cited study, the average carcass weight (without head) of stags ranged from 41.80 kg to 51.07 kg between October and January. Changes in the carcass weight of sika deer were also observed across years (Janiszewski et al., 2007). The heaviest animals were harvested in the hunting season of 1996/1997, and their carcass weight reached 57.87 kg, compared with only 52.84 kg in 1993/1994; the average carcass weight of male sika deer has decreased considerably since 2001.

Carcass fat content is higher in wild-living cervids than in their farmed counterparts (Daszkiewicz et al., 2015). It is difficult to improve the quality of meat from wild deer. However, the results of long-term research show that in effectively managed deer farms, carcass parameters and meat quality can be modified by various factors such as the diet, place of slaughter, herd management and housing during the winter, and castration (Janiszewski et al., 2014; Kudrnáčová et al., 2018; Kim et al., 2019; Pérez-Serrano et al., 2019; Pérez-Serrano et al., 2020). In the work of Dzierżyńska-Cybulko and Fruziński (1997), the lean content of deer carcasses exceeded 73%. In a study by Czajkowska and Bogdaszewski (2021), the dressing percentage of farmed fallow deer, calculated as the ratio of cold carcass weight to body weight, was lower (50.09%) than that determined in the present experiment. Hanzal et al. (2018) found that carcass weight after evisceration approximated 44.6 kg in sika deer aged 2-3 years, and it ranged from 44.5 kg to 71 kg in animals aged 4-5 years. Lower values were noted for chilled carcasses (Hanzal et al., 2018). In the current study, dressing percentage 1 in the group of younger sika deer (Table 1) considerably exceeded the value determined for farmed 2.5-year-old fallow deer (63.82%) (Švrčula et al., 2019). Farm-raised and wild-living cervids can be compared based on dressing percentage 1 (Table 1). Dressing percentage, expressed as the ratio of carcass weight before evisceration in the hunting ground to carcass weight after evisceration, is affected by the animal's body weight, age, sex, digestive tract contents, and nutritional status. In cervids, dressing percentage is as follows: red deer - 52 – 60%, moose - 65 – 70%, fallow deer - 48 – 56%, roe deer - 59% (Dzierżyńska-Cebulko and Fruziński, 1997). The dressing percentage of the animals analyzed in this study exceeded the above values.

Due to differences between sika deer subspecies, body and carcass measurements may differ across countries. According to Putman (2000), the body length of stags living in Switzerland is 128−150 cm, compared with 142 cm in England. Janiszewski et al. (2007) examined male sika deer in Poland and found that average carcass length (without head) was 108 cm, carcass weight was 47 kg, height at withers was 81 cm, height at sacrum was 87 cm, and chest girth was around 92 cm. Similar results were obtained in the younger group of farmed male sika deer in the present study (Table 2). According to Putman (2000), the height at withers of stags is 74−84 cm in Switzerland and 79−84 cm in England, which is consistent with the values noted in this experiment (Table 2).

Kwiatkowska et al. (2009) reported that skin had the highest percentage (9.21%) and legs had the lowest percentage (3.80%) among non-edible components in red deer carcasses, and similar observations were made in the current study (Table 3). Hanzal et al. (2018) found that sika deer aged 2-3 years were characterized by leg weight of 1.24 – 1.28 kg, and head weight of 1.62 – 2.72 kg, whereas in animals aged 4-5 years, the respective values were 1.25-1.66 kg and 3.42-5.16 kg. An analysis of farm-raised fallow deer aged 2.5 years revealed that the average weight of non-edible components was 8.8 kg (Švrčula et al., 2019). In the current study, non-edible components accounted for nearly 17% (Table 3), and in the work of Żmijewski et al. (2020) – for 12.48%.

Hanzal et al. (2018) observed that liver weight was 1.12-1.36 kg in sika deer aged 2-3 years, and around 2.35 kg in older stags. Different results were obtained in this experiment (Table 4). In the cited study, average kidney weight was 0.37 kg in younger animals, which is consistent with the present findings (Table 4). In older stags examined by Hanzal et al. (2018), kidney weight ranged from 0.18 kg to 0.24 kg, and the value noted in this study was considerably higher. Švrčula et al. (2019) demonstrated that the proportion of edible components in the carcasses of male fallow deer was 5.25% (3 kg).

The most valuable cuts, i.e. the leg and shoulders, have the highest proportion in the carcasses of game animals (Zin et al., 2002), which was also observed in the current experiment (Table 5). Pérez-Serrano et al. (2019) found that in the carcasses of Iberian wild red deer aged 56±7.29 months (with average weight of 36.7 kg), the leg and shoulders accounted for 39.4% and 20.2%, respectively. In the carcasses of red deer, the leg was heaviest (22.5 kg), followed by the shoulders (10.7 kg), and these cuts accounted for approximately 40% and 19% of total carcass weight, respectively, whereas the proportion of the neck was 10.14% (Kwiatkowska et al., 2009). In Iberian red deer harvested in winter, the neck accounted for 6.87% of total carcass weight (Pérez-Serrano et al., 2019). Švrčula et al. (2019) analyzed farmed fallow deer aged 29 months and determined the average weights of the saddle (loin), shoulders and leg at 6.94 kg (19.12%), 5.76 kg (15.85%) and 12.91 kg (35.58%), respectively. Similar values were obtained in the present study (Table 5), excluding the saddle.

The relationships between carcass parameters, investigated in this study, have been rarely researched in cervids, which makes it difficult to compare the present findings with the results of previous studies. Potential methodological differences could pose yet another problem. In the research performed by Czajkowska et al. (2021), the weights of the heart, kidneys and liver in 20-

month-old farmed fallow deer bucks were 0.34 kg, 0.26 kg and 0.62 kg, respectively, and a significant ($p \leq 0.01$) correlation was noted only between liver weight and body weight. Yokoyama et al. (2001) examined northern sika deer in Hokkaido Island in Japan and found that kidney weight was correlated with body weight ($r=0.9$), unlike in the present study. A relatively low correlation between total body weight and kidney weight ($r=0.4$ at $p<0.05$) was also observed by Hanzal et al. (2018) in sika deer in Czechia.

A significant correlation between body weight and shoulder weight ($r=0.98$) was noted by Łabecka and Gardzielewska (1975) in red deer, and similar relationships were observed in this study. Highly significant correlations between the weights of carcass cuts and total carcass weight in red deer were found by Janiszewski (2009), and correlation coefficients for the leg and shoulders reached $r=0.82$ and $r=0.84$, respectively. According to Trziszka (1991), leg weight is closely correlated with carcass weight in cervids. The above data confirm that the carcasses of different cervid species can be evaluated before they are divided into sections, based on the correlations between carcass cuts.

CONCLUSIONS

The following conclusions can be drawn from the present study:

1. The average body weight of farmed male sika deer was 70.95 kg.
2. The dressing percentage of a hot carcass was 71.77%, and the dressing percentage of a chilled carcass without skin, head and the lower parts of legs was 54.79%. These values are satisfactory and could encourage meat producers and processing plants to introduce sika deer carcasses into the market.
3. The legs had the highest proportion of total carcass weight (over 36%), followed by the shoulders (approx. 17%).
4. The analyzed carcass parameters were found to be closely correlated. The regression equations derived in the study can be used to predict the weights and percentages of individual cuts without the need to divide the carcass into portions.
5. In the future, indirect methods for assessing the carcasses of farmed deer may facilitate their classification and grading.

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