Praca oryginalna *Original paper*

Effect of the upkeep method, in natural habitat or farm maintenance, on selected morphometrics of the digestive tract in fallow deer (*Dama dama*)

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Received 19.01.2024 *Accepted 08.04.2024*

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Summary

The research was performed on 116 fallow deer individuals, including 58 free-living and 58 farmed individuals. The age of the fallow deer ranged from 1.5 to 3 years. The research involved the use of free-living fallow deer carcasses acquired as a result of a cull during huntings in the Zamrzenica Forest Inspectorate, in the kujawsko-pomorskie province, whereas the farmed fallow deer carcasses were made available for research by the Bomafar Cervidae farm. Of all the individuals for each upkeep method, a group of does and a group of bucks were separated. The aim of the paper was to determine and to compare the values of the metrics of the alimentary tract in two different populations of fallow deer, namely living in a natural hunting ground and kept in the farm system. The morphometric measurements were performed on the carcasses without internal organs. The measurements were taken using the metal tape at the accuracy down to 1 millimetre. The measurements of the intestine length and the capacity of stomachs concerned the unpreserved material. The intestines not emptied from the contents were measured once they were spread on a wet non-adhesive surface. The results of the research demonstrated that the metrics of the digestive tract in fallow deer depend considerably on the method of the animal upkeep and on its sex and there were significant differences in the relative length of intestine and its respective sections.

Keywords: comparative anatomy, ruminants, intestines, *Cervidae*

Animal anatomy textbooks provide information on the absolute length of particular segments of the digestive system of farm animals as well as their length relative to the body length. The ratio of the body length to the total length of the intestines makes it possible to determine the nutrition method, that is, the type of animal diet, since there is a correlation between the food type and the intestinal length. Carnivorous species have the shortest alimentary canal, and therefore that their body length to intestinal length ratio is high 1 : 5 in dogs (1 : 4.7 in wolves). These proportions are quite different in ruminants, for example, 1 : 25 in sheep and 1 : 20 in cattle, 1 : 15 in pigs and 1 : 10 in horses. In other species the proportions are as follows: 1 : 1.3 in shrews, 1 : 1.9 in greater mouse-eared bats, 1 : 4 in martens, 1 : 8 in bears, 1 : 20.6 in European bison.

The results of the study of morphometrics and the anatomy of digestive organs in domestic and game animals, as well as other species living in natural habitats, are presented in various publications. The morphological features and intestinal length of cattle were studied by Zhang (20). The intestinal length of European bison was determined by Van (18), and the morphology of the stomach and intestines in interspecies hybrids of cattle and European bison were analysed by Heryani (4). The intestinal length in sheep was studied by Sultana (16). The organs of the digestive system in game animals of the family *Cervidae* were investigated by Mason (9), Pérez (11), Westerling (19), McGrosky (10) and Drescher-Kaden (2). The structure and function of the small intestine in ruminants were described by Ulyatt *et al*. The aim of this study was to compare the values of selected parameters of the digestive tract in two populations of roe deer; i.e., those living in natural environments and those kept in a farm system (17).

Material and methods

The study involved 116 individuals of fallow deer (*Dama dama*) dividing them into groups according to the upkeep method and sex. The study used animals 1.5 to 3 years of age, namely representing age class I. The animals at that age have also a fully developed alimentary canal. Both free-living and farmed roe deer originated from pure Hungarian lineage. Fallow deer have been broken down into 4 research groups:

Group I: male fallow deer (free-living bucks); research sample: 30 individuals,

Group II: male fallow deer (farmed bucks); research sample: 28 individuals,

Group III: female fallow deer (free-living does); research sample: 28 individuals,

Group IV: female fallow deer (farmed does); research sample: 30 individuals.

The free-living animals were acquired as a result of a cull during individual and collective huntings in the area of the Zamrzenica Forest Inspectorate in the kujawsko-pomorskie province (50°30'N; 17°46'E). Afforestation in this area reaches 29.6%. In the Zamrzenica Forest District, the dominant habitat is fresh coniferous forest (40%) and fresh mixed coniferous forest (28%). There is also a significant proportion of fresh mixed deciduous forest (23%). The proportion of fresh deciduous forest is 5%. The remaining portion consists of other habitat types of forests, but their share is marginal. Farmed fallow deer were acquired from a breeding farm of red deer and fallow deer, Bomafar, at Dąbrówka (52°34'N; 15°49'E), the lubuskie province. The animals are kept in a housing system on green areas, where specialized agrotechnical procedures are carried out. There are natural tree stands and water reservoirs present. The animals were slaughtered in compliance with the applicable veterinary regulations.

The age of free-living fallow deer was determined based on teeth, namely age estimation from the wear of incisive teeth as well as lateral teeth, buccal, namely molar teeth and premolar teeth, applying the method developed by Przybylski (12). The method involves determining the degree of wear of registers on the surface of successive premolar teeth and on the masticatory surface of molar teeth. With age, teeth wear occurs due to food chewing and so in that part it is easiest to observe changes.

The carcass weight (in the skin without internal organs and blood) was determined after it was cooled down with electronic attested hook scales with the accuracy down to 0.1 kilogram.

Moreover, the data on the body weight of farmed fallow deer was also available, whereas in the group of does and bucks acquired from the hunting ground, the animal body weight was not determined due to the procedure while hunting in field conditions.

The morphometrics of internal organs of animals, due to its specificity, requires the use of specialist measurement devices and the selection of the adequate research methodology. This is very time-consuming and it is related to the need to overcome a number of technical and organizational barriers. The results of the measurements are a precious database for performing a number of profound analyses.

In the morphometrics study of alimentary canal in fallow deer, the esophagus was disregarded and the analysis covered its other segments in the abdominal cavity.

From viscera taken out from the abdominal cavity, the intestines were separated from stomach, after which the end of the duodenum was determined, following the position of the anterior fragment of duodenocolic fold. The beginning of ileum was identified by finding the posterior fragment of ileocecal fold. The intestine was separated into sections to take the measurements of the length and capacity, compliant with the methodology developed by Zimmerman (21).

The following measurements were taken: the total intestine length, the length of the small intestine, duodenum length, jejunum length, ileum length, large intestine length, cecum length, the length of colon with rectum, the capacity of rumen.

The results of the measurements of visceral organs were used for the calculation of the percentage share of respective parts of intestines in the intestine as a whole, the ratio of the length of the small intestine to large intestine, the ratio of the body length to the total length of intestines and the ratio of the body length to the length of colon with rectum.

All the measurement results, namely carcass measurement results and the measurement results of visceral organs, were exposed to the statistics analysis using Statistica 10 and Microsoft Office Standard 2013 OLP EDU. The two-factor analysis of variance was performed in the completely randomised design assuming the sex and the upkeep method as experiment factors. The significance of differences was verified with Tukey's post-hock test. The correlation of the traits was evaluated with the Pearson correlation coefficient (Pearson's r).

Results and discussion

The effect of sexual dimorphism and the animal upkeep method on the alimentary canal has been described based on the length of respective sections of alimentary canal and their proportions.

A review of the applicable literature shows that the research performed so far provided interesting and valuable information on stomachs in *Ruminantia* (1, 3, 6). However, the topic of intestine morphology in those animals was investigated by Westerling (19), Pytel (13)

Tab. 1. Length of respective sections of intestines and their share in the lengths of small intestine, large intestine and the total length, in fallow deer considering the upkeep method

Section of intestine	Unit / share [%]	Bucks			Does			Mean
		farmed	free-living	mean	farmed	free-living	mean	
Duodenum	cm	34.6	47.9	41.2	32.0	45.1	38.5	39.9
	% of small intestine length	3.21	3.95	3.60	3.19	3.95	3.59	3.57
	% of total intestine length	2.07	2.56	2.33	1.89	2.53	2.22	2.27
Jejunum	cm	1020	1141	1080	948	1071	1010	1045
	% of small intestine length	94.5	94.1	94.3	94.6	93.9	94.2	94.2
	% of total intestine length	61.1	68.3	64.7	56.8	64.1	60.5	62.6
Ileum	cm	24.8	23.9	24.35	22.5	25.0	23.8	24.1
	% of small intestine length	2.29	1.97	2.13	2.25	2.19	2.22	2.18
	% of total intestine length	1.48	1.28	1.38	1.33	1.40	1.37	1.37
Small intestine	cm	1079	1213	1146	1003	1141	1072	1109
	% of total intestine length	64.6	64.8	64.7	59.2	64.0	61.7	63.2
Cecum	cm	55.5	31.0	43.2	28.5	28.7	28.6	35.9
	% of large intestine length	9.40	4.71	7.05	4.12	4.47	4.30	5.68
	% of total intestine length	3.32	1.66	2.44	1.68	1.61	1.64	2.05
Colon with rectum	cm	535	628	581	662	613	638	609
	% of large intestine length	90.6	95.3	92.9	95.9	95.5	95.7	94.3
	% of total intestine length	32.0	33.5	32.8	39.1	34.4	36.7	34.7
Large intestine	cm	590	659	625	691	642	666	645
	% of total intestine length	35.4	35.2	35.3	40.8	36.0	38.3	36.8
Total length	cm	1670	1871	1770	1693	1783	1738	1754

Explanation: the correlation coefficient is statistically significant at p = 0.05.

and the intestines in red brocket, and in giraffes were studied by Sauer et al. (15).

The small intestine in mammals is divided into: duodenum (*duodenum*), jejunum (*jejunum*) and ileum (*ileum*). A variation in the length of the small intestine and its respective sections has been described many times in the representatives of the family *Suidae* (14) and carnivorans (8). The information on the length and the size of the small intestine based on the results of the research performed in 6 fallow deer individuals is reported by Westerling (19).

The length of duodenum was determined by the sex and the upkeep method; however, no interaction was reported between those factors. Duodenum in bucks was, on average, 3.1 cm longer, namely 7.5%, than in does (Tab. 1).

However, a definite effect was identified by the animal upkeep method, as well as the access to food and its diversity, on the length of the initial section of intestines. Free-living does and bucks showed the duodenum, on average, 13.2 cm, namely as much as 28.5% longer than the animals kept in pens. That regularity is visible and directionally compliant for both sexes. The length of duodenum in farmed fallow deer accounts for 3.9% of the total length of the small intestine, in free-living animals the percentage is slightly higher, i.e. by 0.7 percentage points (Tab. 1). For both sexes that dependence is identical. The share of the length of duodenum in the total length of intestines is slightly different in does and in bucks. However, the universal regularity of proportionally slightly longer duodenum to the total length of intestines in free-living animals is maintained.

The average length of the duodenum in fallow deer established by Westerling (19) was 0.58 m and it assumed a higher value than the average length of 39.92 cm calculated for own research data. The difference can be related to a different sample size, the age of the animals and their living conditions. In other *Cervidae* species, the mean length of duodenum is: in mule deer – 0.62 m, in reindeer – 0.64 m, and in elk – 1.15 m (19).

The longest section of the alimentary canal in fallow deer is the jejunum, its length similarly as that of the duodenum was determined by the sex and the upkeep method; however, the effect of the factors was independent. The length of the intestine section the discussed in bucks was 74 cm greater than in does, by 6.8% (Tab. 1).

Similarly as for the duodenum, free-living animals, as compared with the farmed animals, demonstrated as much as 123.7 cm longer jejunum; however, the relative difference in their length was definitely lower than for the duodenum and it accounted for 11.2%.

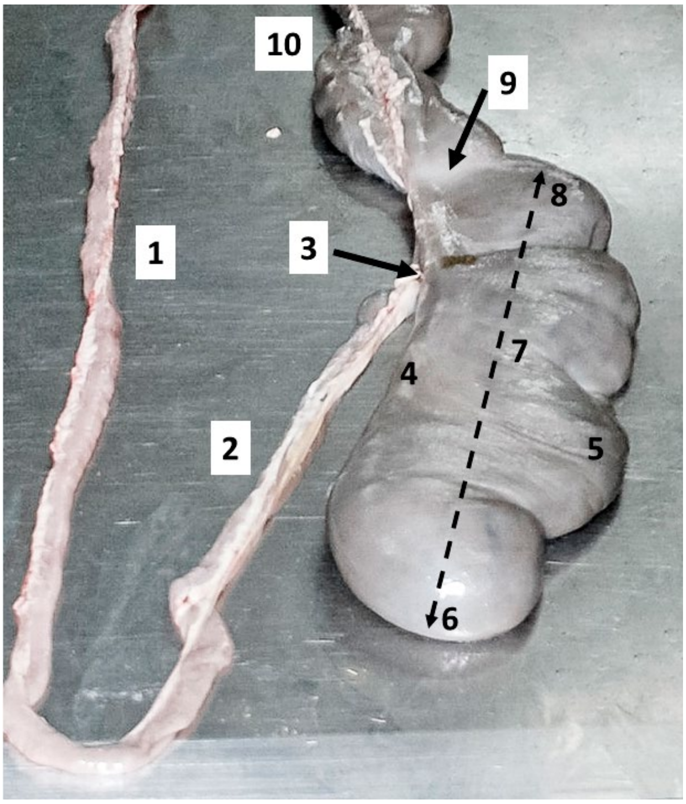

Fig. 1. Cecum with accompanying structures. Note the considerable length (dashed arrow) of the cecum in free-living males, while in most ruminants this part of the large intestine does not reach large sizes
Legend: 1 – final part of jejunum; 2 – ileum; 3 – ileal orifice; 4 – lesser curvature of cecum; 5 – greater curvature of cecum; 6 – apex of cecum; 7 – body of cecum; 8 – base of cecum; 9 – cecocolic orifice; 10 – ascending colo

The length of the jejunum accounts for 93.9-94.6% of the total length of the small intestine; the indicator is quite stable since only inconsiderably is it determined by the sex and the animal upkeep method (Tab. 1). The jejunum in fallow deer accounted for an average of 62.6% of the total length of intestines; however, in free-living does it accounted for 64.1% and in farmed females – 56.8%; and the difference in the length is 7.4 percentage points. For bucks the corresponding difference was very similar and it accounted for 7.2 percentage points. The average length of jejunum in fallow deer was 10.92 m (19), which was similar to the average value, 10.45 m, determined based on own research results. In other *Cervidae* species, the average length of the jejunum was in mule deer – 10.88 m, in reindeer – 15.64 m and in elk – 28.74 m (19).

The shortest part of intestines in fallow deer is the ileum, the length of which determines the interactive effect of the upkeep method and the sex. As for bucks, free-living animals demonstrate a 3.3% lower length of ileum than farmed animals. As for does, it is just the opposite; free-living does show a 10.0% greater length of that section of intestines, as compared with farmed does (Tab. 1). The ileum accounts for an average of 2.2% of the total length of small intestine and for an average of 1.4% of the total length of intestines. Relative differences in the share of the length of ileum in the total length of intestines depending on the factors considered are inconsiderable since that segment of the intestine also inconsiderably participates in forming the intestinal tract. The average length of ileum in fallow deer identified by Westerling (19) was 0.41 m, which, as compared with the results of own research, 0.24 m, shows an essential difference which can be due to the differences in the group size, the animal age, the conditions of living and the animal gene pool. The average length of ileum in other Cervidae species accounted for in mule deer – 0.38 m, in reindeer – 0.61 m and in elk – 0.55 m (19).

The analysis of the total length of the small intestine shows that it is determined by the sex and the upkeep method irrespectively; no interactive effects of the factors considered were proven. Fallow deer males reveal a longer small intestine than females; by an average of 77.7 cm, namely 6.8%. However, a greater effect on the parameter is found for the animal upkeep method. Fallow deer living in the natural environment show 137.8 cm, namely a 11.7% longer small intestine than the fallow deer farmed in enclosure. It is noteworthy that the share of the length of small intestine in the total length of intestines in fallow deer bucks is not in the same way affected by the upkeep conditions as in does. For the farmed and free-living bucks, the share accounts for 64.6% and 64.8%, respectively (Tab. 1).

As for does, the proportions are more varied. Farmed does have a proportionally shorter small intestine than the large intestine than the does feeding in natural conditions in which the share of the length of small intestine in the total length of intestines accounted for 64% and it was 4.8 percentage points greater, as compared with the farmed does.

In the present study the total length of the small intestine expressed as average value was 11.46 m which was similar to the value of 11.87 m demonstrated by Westerling (19). The total mean length of the small intestine determined by Westerling (19) was in mule deer – 11.88 m, in reindeer – 16.89 m and in elk – 30.44 m.

The length of cecum in fallow deer depended on the sex and the upkeep method; a significance of the interaction of those factors was also noted. Bucks showed, on average, a much longer cecum than does: the difference was 14.4 cm, which accounts for as much as 33.6% of the relative difference. A considerable difference was also noted depending on the upkeep method. Farmed animals had, on average. 11.6 cm, namely 28.0%, longer cecum than the free-living ones. The interactions, however, show that the length of large intestine in does for both upkeep methods and in free-living bucks were similar; however, farmed bucks definitely showed a greater length of that section of large intestine (Tab. 1).

As a result, the length of the cecum in farmed bucks participated more considerably (9.4%) in the length of the large intestine and in the total length of intestines (3.3%) than in the other three animal groups compared for which the corresponding values ranged from 4.1-4.7% and 16-17%, respectively (Tab. 1).

Westerling (19) and Pytel (13) showed that the mean length of cecum in fallow deer was 0.27 m and 0.23 m, respectively, and it differed essentially, as compared with the value of 0.43 m recorded in the present research. The average length of the cecum in other Cervidae species was in mule deer – 0.26 m, in reindeer – 0.40, in elk – 0.44 m (19) in red deer – 0.35 m in bucks and 0.31 m in does, in roe deer – from 0.18 m to 0.21 m, in cattle; calves on the 41st day of life – 30.8 cm, on the 81st day of life – 31.6 cm, in zebu – 0.51 m, in European bison – in adult 0.87 cm and at the age of 1.5 years of age – 63.3 m, in 7-8 month-old – 51.3 cm, in sheep – 30.2 cm (13), in giraffes – 0.79 m (15). Hofmann (5) reports on the capacity of cecum in roe deer being 393 ml, and its ratio to the capacity of rumen and reticulum (ruminoreticular) – 1 : 8-10.

The percentage share of the length of cecum in the total length of large intestine in the fallow deer individuals accounted for 5.68%, and in 6-month-old does – slightly less (4.68%) (13).

The length of the colon with rectum was determined both by the sex and the animal upkeep method as well as by their interaction. Provided all the metrics of intestines segments in fallow deer described so far were greater in size in males, the mean length of colon with rectum in does was 56.3 cm, namely 8.8%, longer than in bucks. Free-living animals showed that part of intestines being, on average, 19.9 cm (3.2%) longer than in fallow deer farmed in enclosure. However, in free-living animals the length of colon with rectum in both sexes did not differ significantly, and as for farmed animals the difference was considerable: 127.2 cm, which accounts for as much as 19.2% in favour of does. As a result, the length of that section of the alimentary canal in farmed does accounted for a greater percentage of the total length of intestines (39.1%) than in the other animal groups compared (Tab. 1).

The length of the colon with rectum, the mean value in fallow deer determined in own research was 609 cm which exceeded the value of that measurement by 47 cm established by Pytel (13). In roe deer, the length of that segment of large intestine ranges from 394.2 cm to 454.5 cm; in cattle, calves from 299.8 cm to 335.2 cm; in European bison aged 7-8 months 566.7 cm in the animal aged 16 years – 1206 cm, in black buck – 570 cm, in Barbary sheep – 470 cm, in mouflon – 540 cm, in sheep – 559 cm and it was 2.3% longer in females (13).

In the present research in fallow deer does, a greater than in bucks length of colon with rectum was found, and as a result its greater share in the total length of intestines, which was also demonstrated in sheep females (13).

In roe deer, Pytel (13) determined the ratio of the relative length of colon with rectum to the body length as being in fawns: 4.15 : 1 females, 4.32 : 1 males, in roe deer aged 1 year to 3.5 years in males – 4.12 : 1, in females – 4.20 : 1, in the animals above 3.5 years of age in females – 4.28, in males – 4.37. The percentage share of the length of large intestine in the total length of intestines was in fawns 30.29% and 30.56%, in animals in the age range from 1 to 1.5 years – 30.74% and 30.40%, in roe deer above 3.5 years of age – 30.78% and 30.96%, respectively.

In the present research the share of the length of colon with rectum to the body length in farmed fallow deer was 4.3 : 1, while in free-living fallow deer 4.5 : 1. The length of the large intestine depended on the sex and its interaction with the animal upkeep method. Does demonstrated a 41 cm (6.3%) longer large intestine than bucks. Free-living animals showed, on average, 8.3 cm (1.3%) longer large intestines than those farmed in enclosure; however, the difference was not significant. It was noted, however, that the length of the large intestine in fallow deer of both sexes is affected, to a varied degree, by the animal upkeep method. Farmed bucks showed a 10.4% shorter large intestine than free-living bucks, while the large intestine in farmed does was 7.1% longer than in the free-living ones. The share of the large intestine in the total length of intestines was, on average, 36.8%; however, in does farmed in enclosure the percentage was clearly greater than in the other animal groups compared and it accounted for 40.8% (Tab. 1).

The present research results demonstrated that the average length of the large intestine in fallow deer is 6.45 m and it accounts for 36.8% of the total intestine length. The percentage share of that intestine in the total intestines length was as follows: farmed bucks – 35.3%, farmed does – 40.8%, free-living bucks – 39.5% and free-living does – 36%. Westerling (19) reports on the length of the large intestine in fallow deer being 6.76 m, which accounts for 57% of the total length of intestines. Pytel (13) identified that the length of large intestine in 6 month-old doe in fallow deer was 4.91 m. In comparison, the length of the large intestine in mule deer is 6.55 m and it accounts for 55.0% of the total length of intestines in reindeer: 8.74 m and 51.7% as well as in elk – 17.03 m and 56.0%, respectively (19). In red deer, the total length of the large intestine in bucks reaches 975 cm, in does – 774 cm, in roe deer – from 412.6 to 475.4 cm, in cattle: calves, 41-day-old – 330.6 cm, 81-day-old – 366.8 cm; in European bison depending on the age: 7-8 month-old – 618 cm, 1.5 year-old – 770.7 cm, 16-year-old – 1206 cm; in sheep – 569 cm in females and 606.6 cm in males (13). Lönnberg (7) found that the length of the large intestine accounts for 25-26% of the length of the small intestine

Tab. 2. Matrix of correlation coefficients of selected intestinal features of bulls and doe deer in farm and free-living systems

Specific parameter		Length							
		duodenum	jejunum	cecum	colon with the rectum	iliac intestine	small intestine	large intestine	total intestinal
		free-living							
Lenght – farmed: duodenum	♀	x	−0.81	0.00	−0.42	−0.25	−0.81	−0.42	−0.84
	♂	x	0.64	0.33	0.12	0.04	0.67	0.13	0.55
jejunum	♀	−0.04	x	−0.04	0.23	0.22	1.00	0.23	0.96
	♂	0.08	x	0.49	0.34	−0.27	1.00	0.36	0.89
cecum	♀	−0.35	0.63	x	0.30	0.53	−0.03	0.33	0.06
	♂	0.60	0.52	x	0.42	−0.04	0.49	0.46	0.57
colon with the rectum	♀	0.53	0.30	−0.34	x	0.28	0.23	1.00	0.49
	♂	0.31	0.00	0.37	x	0.28	0.35	1.00	0.72
iliac intestine	♀	−0.06	0.28	0.19	0.08	x	0.24	0.30	0.29
	♂	−0.34	−0.16	−0.23	−0.62	x	−0.21	0.27	−0.03
small intestine	♀	−0.01	1.00	0.62	0.32	0.31	x	0.23	0.96
	♂	0.10	1.00	0.53	0.00	−0.14	x	0.37	0.90
large intestine	♀	0.48	0.46	−0.14	0.98	0.13	0.48	x	0.48
	♂	0.38	0.08	0.49	0.99	−0.62	0.08	x	0.74
total intestinal	♀	0.06	0.99	0.55	0.44	0.31	0.99	0.59	x
	♂	0.20	0.96	0.64	0.28	−0.31	0.96	0.36	x

$r_{xy} = 0$	$0.1 \le r_{xy} < 0.3$	$0.3 \le r_{xy} < 0.5$	$0.5 \le r_{xy} < 0.7$	$0.7 \le r_{xy} < 0.9$	$0.9 \le r_{xy} < 1$
non correlated	poor	average	high	very high	almost full

Explanation: red font – the correlation coefficient is statistically significant at p = 0.05.

in species representing the subfamily Bovidae, and it reaches 33-38% in the other species representing the family Bovidae. In the present research, it was found that the share is, respectively, in farmed fallow deer – 61.53%, and in free-living fallow deer – 55.26%. The ratio of the body length to the total length of intestines in the fallow deer studied was: free-living bucks – 1 : 14, free-living does – 1 : 12.5, farmed bucks – 1 : 11, farmed does – 1 : 13.6, respectively.

The total length of intestines depended on the animal upkeep method. The interaction of factors in the analysis of variance was insignificant, although the result is borderline p = 0.0508. Such significance, however, is seen from Tukey's HSD test. The average length of intestines in the animals studied was 1754 cm. Animals feeding in natural conditions showed, on average, 146.1 cm, namely 8.0%, longer intestines than farmed animals. The interactions demonstrate that, as for does, the difference in the length of intestines in favour of the animals kept under natural conditions is 89.6 cm (5.0%), while the corresponding difference for bucks is definitely greater and it is 201.9 cm (10.8%).

Based on the obtained metric measurements of the digestive tract in free-living and farmed roe deer, the level of correlation between individual segments of the intestines was assessed, taking into account intersex dependencies (Tab. 2). Out of a total of 28 pairs compiled in the correlation coefficient matrix, 42.86% were statistically significant in free-living animals, 35.71% in farmed does, and 39.28% in bull deer.

Particular attention should be paid to the differences in the correlation level between intestinal features such as: total length of the intestine and length of the duodenum; length of the small intestine and duodenum; and length of the small intestine and length of the cecum between both examined populations. Noticeable differences were also observed in the correlation between the length of the colon and duodenum between males and females in both groups.

In conclusion, the level of correlation between the two groups ranged from high to complete in 32.14% of pairs in farmed does and 35.71% in free-living animals. The research results showed that the metrics of carcass and alimentary canal in fallow deer kept under farm conditions differ from those traits in the animals acquired from the hunting ground. Irrespective of the fallow deer sex, the values of metrics of digestive system organs in animals kept on farms were lower.

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