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Comparison of selected metric traits of the digestive system in farmed and wild fox populations*

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Long-term breeding work on farms and the use of properly balanced diets has led to differences between farmed and wild fox populations in metric traits of the gastrointestinal system, the determination of which was the aim of this study. Wild foxes were harvested in north-eastern Poland. Forty foxes (20 animals per group in an equal sex ratio) were examined for rate of digesta passage and length of digestive tract segments. Compared to farmed foxes, the wild population had a highly significantly greater intestine to body length ratio (3.23 to 3.71) and duodenum to body length ratio (0.58 to 1.01), which was due to the type of food consumed. Stomach contents of wild foxes were dominated by vertebrates (75.6%) and invertebrates (14.6%), with plant foods accounting for the smallest proportion (9.8%). Chemical analysis of digesta showed that compared to farmed foxes, wild foxes had lower proportions of crude protein (13.2% and 16.3%, respectively) (P≤0.01) and crude fat (6.2% and 8.1%, respectively) (P≤0.01), and a higher proportion of crude fibre (6.9% and 5.2%, respectively) (P≤0.05). Deficiency of essential food nutrients contributed to the low body weight of the wild foxes.

KEY WORDS: farmed fox / wild fox / digestive system

The wild fox is the largest member of the genus *Vulpes* and at the same time the most widely distributed member of the carnivore family (Carnivora). It has spread with human expansion, reaching as far as Australia. About 35 species of fox are known worldwide, but only two, the arctic fox (*Vulpes lagopus* L.) and the common fox (*Vulpes vulpes* L.), are raised in cages. Breeding of foxes is thought to have begun in the 18th century, when they were bred under semi-feral conditions with some human intervention. However, it was not until 1894 that the first fox farm was established on Prince Edward Island (Canada). After early efforts by the owners (Dalton and Oulton) to breed foxes had failed, they introduced rigorous selection and improved feeding and rearing methods. As a result, at a 1904 fur auction in London

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a pelt from a farmed fox was sold at four times the price of a pelt from a caught fox [5]. This success increased interest in cage breeding and new farms began to be established.

After many years of intensive breeding work on fox farms, the productive (domestication) traits of farmed foxes came to differ considerably from the traits of wild animals. Clear differences are observed in productive traits subject to improvement, notably hair coat quality, coat colour, body weight, measurable traits of elements of the skeletal and digestive systems, and even animal temperament [4, 6].

The aim of this study was to determine differences in the structure of the digestive tract and analyse stomach digesta in farmed foxes compared to the wild population.

Material and methods

The experiment used farmed silver foxes from a farm belonging to the Experimental Station of the National Research Institute of Animal Production in Chorzelów, as well as wild foxes harvested in north-eastern Poland in late autumn (20 animals per group in an equal sex ratio). The foxes were kept in standard cages designed for this species. After the harvest, both farmed and wild animals received the same feed and had constant access to water. The feed mixture was formulated to meet the nutrient requirements for this group of animals and contained typical components available on the Polish feed market: crude protein 12.01%, crude fat 8.64% and crude fibre 0.69% (gross energy 7.313 MJ/kg).

In addition, gastric contents from wild foxes were examined in 10 animals that were shot by hunting clubs in northern Poland.

Live animals were examined for final live body weight and rate of digesta passage.

The rate of digesta passage was analysed for 3 days using feed marked alternately with iron oxide and beet extract. Gastrointestinal transit time was measured 30 minutes after feeding until the first defecation.

Foxes were subjected to production slaughter in late November according to the procedure used for this species of animals.

Postmortem examination included measurement of different digestive tract segments, analysis of stomach contents and nutrient analysis (in wild animals that were shot).

After skinning, the length of the trunk together with the neck was measured from the occipital squama to the tail head, the body cavity was opened, and the internal organs were dissected. After the intestine was removed from the body cavity it was separated from the stomach. Measurements were made of the length of the oesophagus, stomach, duodenum, jejunum, ileum, caecum, colon and rectum. All digestive tract segments were spread on a wet, impervious surface and their length was measured with a tape measure. Oesophageal length was measured from the larynx to the stomach. Different intestinal segments were measured after removal of the mesentery. Duodenal length was measured from the duodeno-pyloric junction to the duodenojejunal flexure, adjacent to the duodenocolic fold of peritoneum. Jejunal length was measured from the duodenojejunal flexure to the beginning of the ileocecal fold, and ileal length from the ileocaecal fold to the ileal orifice. The caecum was straightened out by the removal of connective tissue fragments and then measured from the apex to the ileal orifice. The colon and rectum were measured from the ileal orifice to the anus. These measurements were used to determine total intestinal

length and total small and large intestine length. For comparison, the ratio of the length of the digestive tract, intestine and duodenum to the length of the body was calculated. The percentage of individual segments in the total intestine was determined as well.

In the wild foxes collected by shooting, the stomach contents were rinsed and the material obtained was treated with non-enzymatic detergent and passed through a fine-meshed sieve (0.7 mm) to separate plant material from animal material. Food ingredients were weighed on an analytical balance.

The stomach contents of the wild and farmed foxes were analysed for dry matter (SOP M.011:2006; crude protein (SOP M.007:2006), crude fat (SOP M.013:2006), crude fibre (SOP M.012:2006) and ash (SOP M.014:2007) (SOP – Standard Operation Procedure, M – number of procedure at the Central Laboratory of the NRIAP).

The results of the single-factor experiment were analysed statistically using analysis of variance (ANOVA). Significant differences between means in groups were estimated with Duncan's multiple range test. The calculations were made in Statistica 7.1 PL using the following linear model:

$$y_{ij} = \mu + a_i + e_{ij}$$

where:

y_{ij} – observed value of a trait
μ – mean value of a trait in the population
a_i – effect of experimental group (1, 2)
e_{ij} – random error.

Results and discussion

In recent years, fur farming has been characterized by intensification of production and increased genetic progress in populations. Diets have been modified to meet the highest quality standards because breeding success can no longer be obtained through proper formulation of rations and basic nutrients alone; it is also necessary to account for feed additives and to monitor physiological processes.

The mean body weight of the farmed foxes was highly significantly higher than that of the wild foxes, with a non-significant difference in carcass length (Table 1). Highly significant differences between the animals were found for all measurable traits of the digestive tract except for the colon and rectum, where the means differed significantly, and of all the measured segments only the jejunum was shorter in foxes living in the wild. Wild foxes had a significantly greater ratio of the length of the digestive tract and duodenum to the length of the body, while the ratio of intestine to body length differed significantly.

The proportion of individual segments in the total intestine showed higher percentages ($P \leq 0.01$) for duodenal and ileal lengths in wild foxes, and for jejunal length in farmed foxes, while the differences between the other segments were not significant (Table 2).

Like other studies [4], our study also showed that the mean pre-slaughter weight of animals (in November) was significantly higher in the farmed foxes. The considerably greater body weight of the farmed foxes is due to long-term breeding work and properly balanced diets used throughout the rearing period [6].

Table 1 – Tabela 1

Measurements of different segments of the digestive tract (cm)

Średnie wyniki pomiaru poszczególnych odcinków przewodu pokarmowego (cm)

Item Wyszczególnienie	Foxes – Lisy		SEM
	farmed hodowlane	wild dzikie	
Body weight (kg) Masa ciała (kg)	6.74^{A}	5.42^{B}	1.27
Body length Długość tuszki	64.15	63.0	7.54
Total length of the digestive tract Całkowita długość przewodu pokarmowego	243.4^{A}	275.7^{B}	12.5
Oesophagus length Długość przełyku	25.17^{A}	28.77^{B}	0.49
Stomach length Długość żołądka	10.55^{A}	13.15^{B}	0.31
Total intestine length Całkowita długość jelit	207.7^{A}	233.8^{B}	21.1
Small intestine, including: Jelito cienkie, w tym:	168.7^{A}	190.9^{B}	3.40
Duodenum Dwunastnica	37.15^{A}	64.05^{B}	2.55
Jejunum Jelito czcze	123.5^{A}	106.0^{B}	2.41
Ileum Jelito biodrowe	8.00^{A}	20.85^{B}	1.14
Large intestine, including: Jelito grube, w tym:	39.02^{A}	42.87^{B}	0.63
Caecum Jelito ślepe	4.42^{A}	5.47^{B}	0.17
Colon and rectum Okrężnica i jelito proste	34.65^{a}	37.40^{b}	0.55
Digestive tract to body length ratio Stosunek długości przewodu pokarmowego do tułowia	3.79^{A}	4.37^{B}	0.06
Intestine to body length ratio Stosunek długości jelit do tułowia	3.23^{a}	3.71^{b}	0.41
Duodenum to body length ratio Stosunek długości dwunastnicy do tułowia	0.58^{A}	1.01^{B}	0.35

Means in rows with different letters differ significantly (a, b – P≤0.05; A, B – P≤0.01)

Średnie w wierszach oznaczone różnymi literami różnią się istotnie (a, b – P≤0,05; A, B – P≤0,01

Adapted to digesting feeds of animal origin, which are high in protein and fat, the digestive tract of foxes is relatively simple, has a limited capacity, and is much shorter than that of omnivores and herbivores, because nutrient-dense meat is not as complex to digest as mixed or plant foods. The type of natural diet is closely related to intestinal length and digesta transit time [3, 11]. The intestine to body length ratio suggests that the intestine is shorter in carnivores than in omnivores or herbivores. This ratio is 3-5:1 in foxes, dogs, mink, wolves and cats, 6:1 in chickens, 15:1 in pigs, and 25:1 in sheep [1, 8].

Measurable traits of the organs of the digestive system in many groups of farmed and wild animals show considerable differences, which are largely linked to the type, pattern

Table 2 – Tabela 2

Udział poszczególnych odcinków jelit w jelicie jako całości (%)

Proportion of intestinal segments in total intestine (%)

Foxes Lisy	Total intestine length Całkowita długość jelit	Duodenum length Długość dwunastnicy	Jejunum length Długość jelita czczego	Ileum length Długość jelita biodrowego	Caecum length Długość jelita ślepego	Colon and rectum length Długość okrężnicy i jelita prostego
Farmed Hodowlane	100	17.89^{A}	59.46^{A}	3.851^{A}	2.128	16.68
Wild Dzikie	100	27.40^{B}	45.34^{B}	8.917^{B}	2.339	15.99

Means in columns with different letters differ significantly (A, B – P≤0.01)

Średnie w kolumnach oznaczone różnymi literami różnią się wysoko istotnie (A, B – P≤0,01)

and amount of food consumed, seasonal changes, intestinal bacteria, or intestinal parasites. The animal's digestive tract consists of several parts, in which the food is ingested, masticated, enzymatically digested, moved, and absorbed, and in which faeces are formed. These segments are specialized for the type of food ingested [3].

Compared to the stomach of other species of monogastric animals, the simple, single--compartment stomach of carnivorous animals is a large organ relative to body size. The differences observed in stomach length between wild and farmed foxes may be associated with the quantity and quality of food consumed. Farmed animals receive balanced food that differs in composition and consistency (after grinding) from that consumed by wild animals. The amount, pH, digestive power and rate of secretion of gastric juice vary according to the type of food. Poorly masticated food stays in the stomach longer than thoroughly masticated food [1, 7]. Stomach size can be related not only to the food ingested, but also to the cyclic pattern of its consumption. In the wild, animals consume their food occasionally and completely fill their stomachs.

In the present study, we found highly significant differences in the length of all intestinal segments in wild foxes except for the jejunum, which was longer in farmed foxes. According to Szymeczko and Skrede [9, 10], small intestinal length ranges from 177 to 207 cm in arctic foxes, and according to Kulawik et al. [4] from 173 to 264 cm in wild red foxes and from 145 to 207 cm in farmed foxes, depending on body weight and sex. These findings correspond with our results. The duodenum is the initial segment of the small intestine, where the transition from gastric to intestinal digestion occurs. Duodenal absorption is very small (about 8% of digested food), but the duodenum is where digestion takes place with pancreatic juice, bile and intestinal juice. Depending on the type of food, the pH of duodenal contents may vary between 4.0 and 8.5. In wild animals, the digestive process in the duodenum takes much longer because the food is varied and often poorly masticated; for this reason this segment is noticeably longer. Similarly, plant food, which is eaten in greater amounts by wild foxes, takes longer to break down than meat. In the study by Kulawik et al. [4], duodenal length in the total intestine was 9.38% in female farmed foxes and 9.35% in males (16.5-29 cm), with total intestinal length of 207.5-264.5 cm. In wild foxes, duodenal length in the total intestine was 11.89% and 11.67%, respectively (26.5-41 cm), with total intestinal length of 219.0-330.0 cm. In our study, we obtained a much higher

percentage of duodenum in the total intestine and a lower total intestinal length of less than 250 cm. Brudnicki et al. [2] reported intestinal length in arctic foxes ranging from 271 to 323 cm, with a body weight of 6.0-9.40 kg.

In carnivores, as in other species of monogastric animals, the jejunum, where most digestion takes place, is the longest segment of the small intestine. Kulawik et al. [4] reported jejunal length ranging from 142 to 216 cm in wild foxes and from 125 to 180 cm in farmed red foxes. According to Brudnicki et al. [2], jejunal length in farmed arctic foxes ranges from 198-235 cm. The values obtained in our study were lower, which may be due to the lower body weight of the animals studied as compared to those studied in the studies cited.

The large intestine, which consists of the caecum, colon and rectum, is short in fur-bearing carnivores compared to the extensive large intestine of herbivores. In our study, we obtained lower values for the length of caecum, colon and rectum than those reported by Kulawik et al. [4] for both wild and farmed red foxes. It should be remembered, however, that the digestive tract, in particular the parameters of its length, depend on the type of food consumed [3, 7], and a plant-based diet contributes to a longer large intestine.

The digesta passage rate was significantly greater in farmed foxes (Table 3).

The analysis of gastric contents revealed that vertebrates and invertebrates accounted for the highest percentage (75.6% and 14.6%, respectively), and plant foods the lowest (9.8%).

Chemical analysis of stomach digesta showed that the digesta of wild foxes, compared to farmed foxes, was characterized by lower crude protein and crude fat (P≤0.01), and higher crude fibre (P≤0.05) (Table 4).

Table 3 – Tabela 3

Digesta passage rate in the foxes (peristalsis)

Szybkość przechodzenia treści pokarmowej przez układ pokarmowy lisów (perystaltyka)

Foxes Lisy	Digesta passage rate (in minutes) Czas przechodzenia karmy przez przewód pokarmowy (w minutach)	SEM
Farmed Hodowlane	369.0^{a}	11.28
Wild Dzikie	334.5^{b}	13.20

Means in columns with different letters differ significantly (a, b – P≤0.05)
Średnie w kolumnach oznaczone różnymi literami różnią się istotnie (a, b – P≤0,05)

Table 4 – Tabela 4

Results of chemical analysis of the stomach contents of food in wild and farmed foxes (%)

Wyniki analizy chemicznej treści pokarmowej żołądka lisów dzikich i hodowlanych (%)

Foxes Lisy	Dry matter Sucha masa	Crude ash Popiół	Crude protein Białko ogólne	Crude fat Tłuszcz surowy	Crude fibre Włókno surowe
Farmed Hodowlane	32.8	3.2	16.3^{A}	8.1^{A}	5.2^{a}
Wild Dzikie	30.5	4.2	13.2^{B}	6.2^{B}	6.9^{b}

Means in columns with different letters differ significantly (a, b – P≤0.05; A, B – P≤0.01)
Średnie w kolumnach oznaczone różnymi literami różnią się istotnie (a, b – P≤0,05; A, B – P≤0,01)

From the present study we cannot precisely determine the year-round diet of the wild foxes, but the higher amounts of crude fibre in their gastric contents may suggest that they ingest greater amounts of plant foods. The gastric contents of the wild foxes were also found to contain fragments of the filled digestive tract of their herbivorous prey, which increased the content of crude fibre.

In conclusion, long-term breeding work and the use of proper diets on farms have led to differences between populations of farmed and wild foxes in many metric traits of the gastrointestinal system.

Compared to the population of farmed foxes, the wild foxes were characterized by a highly significantly greater intestine to body length ratio, which was due to the type of food consumed.

REFERENCES

1. BRUDNICKI W., SKOCZYLAS B., NOWICKI W., WACH J., 2008 – Cechy metryczne jelita lisa pospolitego (*Vulpes vulpes* L.). ***Prace Komisji Nauk Rolniczych i Biologicznych*** BTN B 64, 21-26.
2. BRUDNICKI W., NOWICKI W., BRUDNICKI A., WACH J., KIRKIŁŁO-STACEWICZ K., SKOCZYLAS B., JABŁOŃSKI R., GRZYWACZ K., 2011 – Metrical features of the ventral part of the alimentary canal in arctic fox (*Alopex lagopus* L.). ***Journal of Central European Agriculture*** 12 (2), 276-282.
3. DOROŻYŃSKA N., CYMBOROWSKI B., RADZIKOWSKA M., 1971 – Wpływ pokarmu na strukturę i funkcję przewodu pokarmowego u przedstawicieli różnych grup zwierzęcych. ***Przegląd Zoologiczny*** XV (1), 40-45.
4. KULAWIK M., NOWICKI S., PRZYSIECKI P., FRĄCKOWIAK H., 2013 – Porównawcze badania metryczne lisa pospolitego (*Vulpes vulpes*) hodowlanego i dziko żyjącego. ***Nauka Przyroda Technologie*** 7 (4), 42-13.
5. PIÓRKOWSKA M., 2010 – Lis – perspektywy hodowli. ***Wiadomości Zootechniczne,*** R. XLVIII, 4, 85-97.
6. PRZYSIECKI P., NOWICKI S., FILISTOWICZ A., NAWROCKI Z., FUCHS B., FILISTOWICZ A., 2006 – The effect of selected animal husbandry procedures on the production performance of silver foxes. ***Acta Fytotechnica et Zootechnica*** 1, 198-200.
7. RADZIKOWSKA M., 1981 – Wpływ różnej diety na budowę i czynności przewodu pokarmowego szczura (*Rattus rattus* L.). ***Przegląd Zoologiczny*** 25 (1), 83-92.
8. SZYMECZKO R., 2001 – Ileal and total digestibility of amino acids in feeds used in mink and polar fox nutrition. ***Journal of Animal and Feed Sciences*** 10, Suppl. 1, 211-222.
9. SZYMECZKO R., SKREDE A., 1990 – Protein digestion in mink. ***Acta Agriculture Scandinavica*** 40, 189-200.
10. SZYMECZKO R., SKREDE A., 1991 – Protein digestion in fistulated polar foxes. ***Scientifur*** 3, 227-232.
11. VHILE S.G., SKREDE A., AHLSTRŘM Ř., SZYMECZKO R., HOVE K.**,** 2005 – Ileal and total tract nutrient digestibility in blue foxes (*Alopex lagopus*) fed extruded diets containing different protein sources. ***Archives of Animal Nutrition*** 59, 61-72.

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Porównanie niektórych cech metrycznych układu pokarmowego populacji lisów pospolitych hodowlanych i dziko żyjących

Streszczenie

Wieloletnia, intensywnie prowadzona praca hodowlana na fermach oraz stosowanie zbilansowanego żywienia doprowadziło do zróżnicowania cech metrycznych przewodu pokarmowego populacji pospolitych lisów hodowlanych i dziko żyjących, a określenie ich było celem badań. Osobniki dzikie odłowione zostały w północno-wschodnim rejonie kraju. Badaniami objęto 40 zwierząt (po 20 sztuk w grupie przy równym udziale płci), określając szybkość przechodzenia treści pokarmowej przez przewód pokarmowy i długość poszczególnych odcinków przewodu pokarmowego. W porównaniu do lisów hodowlanych, populacja dzika odznaczała się wyższym wysoko istotnym stosunkiem długości jelit do tułowia (3,23 do 3,71) i długości dwunastnicy do tułowia (0,58 do 1,01), co było spowodowane rodzajem spożywanej karmy. W treści żołądka dzikich lisów procentowo najwięcej było kręgowców (75,6%) i bezkręgowców (14,6%), najniższy procent stanowiły pokarmy roślinne (9,8%). Wyniki analizy chemicznej treści pokarmowej wykazały u lisów dzikich, w stosunku do hodowlanych, mniejszy procent białka ogólnego (odpowiednio 13,2% i 16,3%; $P \leq 0,01$) i tłuszczu surowego (odpowiednio 6,2% i 8,1%; $P \leq 0,01$), natomiast wyższy włókna surowego (odpowiednio 6,9% i 5,2%; $P \leq 0,05$). Niedobory podstawowych składników pokarmowych w karmie wpłynęły na niską masę ciała lisów dzikich.

SŁOWA KLUCZOWE: lis pospolity hodowlany / lis dziki / przewód pokarmowy