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Level of endoparasite infection in free-living wild boars in relation to carcass weight and sex

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Summary

Research into the determination of intestinal parasitic levels in free-living animals can provide knowledge enabling action to be taken to improve their health status. The aim of the study was to determine the relationship between the carcass weight of wild boars and the degree of endoparasite infection. The research was performed on 165 culled wild boars, from which a representative group (n = 50) was separated and divided according to sex (males n = 24, females n = 26) and age (2-3 years). Separate weight groups were defined for males (< 70 kg, n = 6; 70-80 kg, n = 9; > 80 kg, n = 9) and females (< 45 kg, n = 10; 45-60 kg, n = 10; > 60 kg, n = 6). Oesophagostomum spp., Ascaris suum, Trichuris suis, Eimeria spp. and Strongyloides ransomi were observed and defined in the study population. A statistically significant effect of the overall infection on carcass weight was obtained (F = 9.96; P ≤ 0.01). In the case of overall infection, a more than 7 kg lower carcass weight was observed in infected males. A carcass weight over 15 kg lower was noted for overall infection of females (F = 38.47; P ≤ 0.01), for which average EPG was 2946.67 ± 6485.31 with a median of 400 (50-25 300). Correlations were proven between sex and the average number of Eimeria spp. oocysts, and carcass weight for males (r = –0.84, P ≤ 0.05). In the case of females, correlations were noted between carcass weight and infection by nematodes (r = –0.63, P ≤ 0.05). Studies have shown that there is a need to monitor the environment in order to improve the condition of free-living animals.

Keywords: endoparasites, wild boar, carcass weight, sex

In recent years, there have been significantly increased numbers of wild boars (*Sus scrofa scrofa*) and therefore an increased population density (1). The wild boar, like the domestic pig, is an omnivorous animal especially vulnerable to various diseases, including diseases transmittable to humans. The level of low intensity helminth infection is still not monitored, because it is difficult to observe disease symptoms resulting from the infection.

The determination of the level of parasitic infestation has been presented in studies on domestically raised wild boars; however, in the case of free-living animals this subject has been treated only marginally (9, 17). Studies have focused on farmed animals not on wild animals. This is possibly because it is difficult to monitor/control infections in wild animals. Antiparasitic treatments are used in animals caught for breeding/production or for crossbreeding with domestic pigs (10, 22).

Given that it should be a priority to ensure maximum protection of human health, a program for the periodic assessment of infection among wild boars should be implemented, especially given the increasing population of this species, which increases the risk of the spread of internal parasites (5).

Research on methods of determining the degree of parasitic intestinal infection in free-living animals is an innovative element of wild life management, which can provide knowledge useful in improving the health and quality of individual game animals (e.g. through assessment of the condition of free-living wild boars). A pilot study of the intensity of intestinal parasites in wild boars confirmed a relationship between endoparasite infection and the development of the domestic pig, especially in terms of body weight and production levels (8, 11, 12).

The aim of the study was to determine the relationship between the carcass weight of wild boars and the degree of endoparasite infection.

Material and methods

Area characteristics. The study was conducted within the 7655 ha Forest District of Oleśnica in south western Poland in 2013-2016 at a latitude of: 50.4541, and longitude: 21.0649 50° 27′ 15″ north, 21° 3′ 54″ east, absolute height 171 m. The study area included 5299 ha of forest.

The climate of the research area is temperate. The area is one of the warmest areas of Poland. The average annual temperature is around 8.5°C, with the lowest temperatures being –15°C (January and February), the highest 25°C (July and August). The population of wild boars was about 1962.

Forest management was conducted in accordance with the management system for forests and game animal husbandry (16) – spring/summer and autumn cultivation of hunting plots, while during the winter the animals were fed. This activity is carried out in order to concentrate the animals in the areas where they will be hunted.

The research area consisted of 6.5 ha hunting plots, which in the study period were cultivated and sown with maize (15). During the study period, the animals were not treated with antiparasitic agents. During the experimental period there was no intervention in the natural environment of the animals. Forest management also did not deviate from the accepted and established rules of conduct.

Study range and sample collection. The study focused exclusively on the intestinal nematode. The first stage of the study was conducted in 2013-2014 and random coproscopic samples n = 67 were picked from the ground immediately after defecation. Observations were conducted by a 6-person team from a pulpit located in the research area.

On the basis of preliminary results, that is species/genus richness, prevalence and especially the intensity of infection, the authors decided to attempt to identify relationships between carcass weight and the quantity of nematodes inhabiting the intestines of wild boars.

In the second stage of the research in 2015-2016, a representative group (n = 50) was separated off from a group of 165 hunted wild boars: sex (male n = 24, female n = 26) and age (2-3 years).

The wild boars were obtained from individual and collective hunting (24). Immediately after being shot, carcasses of wild boars were subjected to initial visual inspection, during which sex, age and carcass weight (kg) were determined.

Age was estimated based on tooth development, constituting a secondary sexual characteristic (18). On the basis of tooth development, tooth eruption patterns and physical appearance, the wild boars were categorized into two age groups (2-3 years) (14).

Carcass weight was determined with an electronic scale platform: 520 × 400 mm (lifting capacity 200 kg/100 g). Weight groups for defining the relationship between the overall infection and carcass weight were determined by a similar number of subgroups based on the normal distribution of the research population. Separate groups for males (< 70 kg, n = 6; 70-80 kg, n = 9; > 80 kg, n = 9) and females (< 45 kg, n = 10; 45-60 kg, n = 10; > 60 kg, n = 6) were defined.

Laboratory procedures. The parasitological analysis was carried out based on coproscopic methods. In the first stage of the study, 5 g of faeces was taken immediately after defecation from the ground and protected in plastic containers with a 4% formalin solution. In the second stage of the study, samples were taken immediately after animals had been shot. This process ran from 10-11.10.2015 to 16-17.01.2016. Samples were taken from the small intestine (56% identified parasites) and large intestine (24.5% identified parasites) (22). From the small intestine (section of the jejunum), sections of 20 cm were taken and stored in a plastic container with 4% formalin solution. Identification of the parasites was carried out using the Thienpont et al. (23) and Zajac and Conboy (25) methods. Due to the high level of similarity between the biometrics and morphology of nematode eggs belonging to the genus *Oesophagostomum*, specific identification is practically impossible. Therefore, in the following stage the eggs were identified only to the genus – *Oesophagostomum* spp.

Detection and isolation of eggs/oocysts from faeces were made using quantitative methods with McMaster chambers, with the preliminary purification of faeces (6). In order to detect the oocysts, cysts, and eggs, the flotation method was employed (6). This method was also used to eliminate potential low level infections. In order to estimate the level of infection for test animals, basic parasitology indicators were used: infection prevalence (%) – defined as the ratio of the number of positive samples to the total number of samples studied, the average number of eggs per gram of faeces (EPG), and the average number of the oocysts in a single sample.

Statistical analysis. The collected numerical material was analyzed statistically using Statistica 12.5. The following parameters were used to present the results: percentage, arithmetic average, standard deviation, median, minimal and maximal values to determine the range. The differences between nominal variables (prevalence and sex) were calculated by independent tests for two variables using Pearson's chi-square (χ^2). Arranged in 2 ×2 tables, the test took into account the correction for continuity (Yates correction). In the case of quantitative variables (EPG, carcass weight), each time before carrying out the relevant analyses a procedure was performed to check the conformity of distributions of individual variables to the normal distribution using the Shapiro-Wilk test. Normality testing was conducted for each subset defined by nominal variables. The significances of differences between mean EPG depending on sex were calculated using the non-parametric U Mann-Whitney test for two independent groups. The significance of differences between average carcass weight between the infected and uninfected animals and sex were determined by analysis of variance (ANOVA). Immediately before analysis, the assumption of variance homogeneity was tested using Levene's test. The levels of significant differences were P ≤ 0.05 and P ≤ 0.01. Relationships between average EPG and carcass weight, and the number of oocysts in a single sample and carcass weight were designated by r-Pearson's linear correlation coefficients. Coefficient r, P-value and illustrated dispersion of variables were determined.

Results and discussion

The results from a pilot study and this project concerning the infection status of wild boars with endoparasites are shown in Table 1. Independently of endoparasite genus/species, 63 of the 67 tested wild boars were infected, with a prevalence level of 94% (pilot study). Total average EPG was 1245.09, with a median of 100 and minimal and maximal values in a range from 50 to 23 650.

Tab. 1. The frequency of wild boars infected with endoparasites from the pilot study and research population

Endoparasites	Prevalence		EPG	
	n	%	Mean ± SD	Me (x_{min}-x_{max})
Pilot studies (n = 67)				
Oesophagostomum spp.	21	31.3	71.43 ± 46.29	50 (50-200)
Ascaris suum	33	49.3	1825.76 ± 5424.29	100 (50-23 500)
Strongyloides ransomi	16	23.9	78.13 ± 51.54	50 (50-200)
Trichuris suis	4	5.9	55.56 ± 16.67	50 (50-100)
Eimeria spp.*	55	82.1	38.76 ± 97.65	7 (1-591)
Study population (n = 50)				
Oesophagostomum spp.	13	26.0	807.69 ± 1203.79	200 (50-3500)
Ascaris suum	16	32.0	2743.75 ± 6096.82	600 (50-25 000)
Strongyloides ransomi	6	12.0	175.00 ± 282.40	50 (50-750)
Trichuris suis	13	26.0	511.54 ± 1202.11	200 (50-4500)
Eimeria spp.*	24	48.0	76.83 ± 149.67	6 (1-591)

Explanation:* number of oocysts in a single sample

Prevalence within the research population was 60%, with an average EPG of 1242.00. The highest prevalence (82.1%) in the pilot study was observed for *Eimeria* spp., for which presence was confirmed in 55 samples. The average number of oocysts in a single sample was 38.76 ± 97.65. Similarly, in the research population the prevalence was 48%, but the average number of oocysts in a single sample was almost twice as high (76.83 ± 149.67). In terms of infection rate, the second most prevalent parasite was *Ascaris suum*, with a prevalence of 49.3% for the pilot study and 32% for the research population. This parasite was characterized by the highest average EPG, respectively 1825.76 ± 5424.29 (median 100) and 2743.75 ± 6096.82 (median 600). The prevalence and average EPG of *Oesophagostomum* spp. infection was 31.3% and 71.43 ± 46.29 in the pilot study; infection of *Strongyloides ransomi* was 23.9% and 78.13 ± 51.54.

However, in the research population the number of wild boars infected with *Oesophagostomum* spp. and *Trichuris suis* (prevalence 26%) was the same, with an average EPG for *Oesophagostomum* spp. of 807.69 ± 1203.79; and *Trichuris suis* 511.54 ± 1202.11. The lowest levels of infected animals were noted for *Strongyloides ransomi*, where the prevalence was 12%, and average EPG 175.00 ± 282.40.

Pronounced sexual dimorphism occurring in wild boar populations was also confirmed in the research population. The average carcass weight for males was 77.54 kg ± 7.06, while for females this was lower at 50.81 kg ± 9.64.

The relationships between parasitic infection and carcass weight of males were presented in the study (Fig. 1). All males located in the lightest weight class (carcass weight < 70 kg) were infected with endoparasites and average EPG was 1933.33 ± 1738.69. The prevalence in terms of species richness was 33.3%, 83.3%, 66.7% and 66.7%, respectively, for *Oesophagostomum* spp., *Ascaris suum*, *Trichuris suis* and *Eimeria* spp. None of the males in this group were infected with *Strongyloides ransomi*. In the weight group 70-80 kg, in less than half of the males (44.4%) was the presence of parasites reported, the average EPG being 2425.00 ± 3005.20. The types of infections were

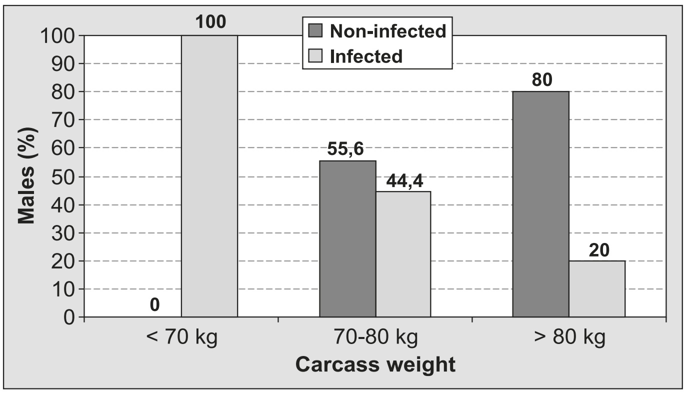

Fig. 1. Relationship between endoparasite infection and carcass weight of males

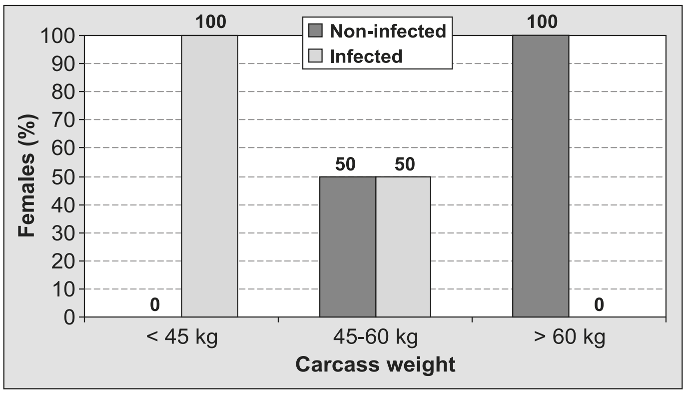

Fig. 2. Relationship between endoparasite infection and carcass weight of females

Ascaris suum (11.1%), *Strongyloides ransomi* (11.1%), *Trichuris suis* (22.2%) and *Eimeria* spp. (22.2%). The heaviest males were characterized by the lowest proportion of infected boars (20%), with an intensity at a level of 483.33 ± 448.14 EPG. *Oesophagostomum* spp. (11.1%), *Ascaris suum* (11.1%), *Trichuris suis* (33.3%) and *Eimeria* spp. (22.2%) were observed in this group.

Extremely interesting results for infection with endoparasites and carcass weight were observed for females (Fig. 2.). All females from the lowest weight group (< 45 kg) were infected (100%), with average EPG being 4180.00 ± 7758.43. Infection was observed with *Oesophagostomum* spp. (70.0%), *Ascaris suum* (70.0%), *Strongyloides ransomi* (20.0%), *Trichuris suis* (30.0%) and *Eimeria* spp. (100.0%). There were equal numbers of infected and non-infected females in the 60--70 kg weight group. The intensity of parasitic infection was 480.00 ± 604.77 EPG. Among parasites, *Oesophagostomum* spp. (30.0%), *Ascaris suum* (20.0%), *Strongyloides ransomi* (30.0%), *Trichuris suis* (10.0%) and *Eimeria* spp. (70.0%) were observed and identified. None of the females from the heaviest weight group (> 60 kg) were infected with the analyzed endoparasites.

Carcass weight of males in relation to infection is presented in Table 2. As a result of the analysis of variance in the plan for independent groups, a statistically significant effect on carcass weight was noted for overall infection (F = 9.96; P ≤ 0.01). A more than 7 kg decrease in carcass weight was noted for infected males. Average EPG was 1627.27 ± 1741.03, with median 500 (200-4550). Close disparity between carcass weights to 7.85 kg (F = 3.63; P ≤ 0.05) was shown for infection with *Oesophagostomum* spp. The number of males infected with *Oesophagostomum* spp. was, however, small (3 males, 12.5% prevalence, average EPG 1283.33 ± 1919.82, median 200 (150-3500)). The difference for the prevalence of this parasite was also proved: χ^2 (df = 1, n = 24) = 7.9; P ≤ 0.01. The highest differences in carcass weight for males – 11.45 kg (F = 29.12; P ≤ 0.01) – were noted for *Ascaris suum*, where the prevalence was 29.2%, with average EPG 1164.28 ± 1513.19 and median 500 (50-4000). Differences for infection with *Strongyloides ransomi* were statistically proven: χ^2 (df = 1, n = 24) = 10.6; P ≤ 0.01.

Carcass weight data for females in relation to infection of females are presented in Table 3. A more than 15 kg lower carcass weight for females was observed and this was related with overall infection (F = 38.47;

Tab. 2. Carcass weight of males in relation to endoparasite infection

Endoparasites	Infection	Prevalence n	Prevalence %	EPG Mean ± SD	EPG Me (x_{min}-x_{max})	Carcass weight (kg) Mean ± SD
Total	0	11	45.8			$81.73^A \pm 4.05$
	1	13	54.2	1627.27 ± 1741.03	500 (200-4550)	$74.00^B \pm 7.19$
Oesophagostomum spp.	0	21	87.5^A			$78.52^a \pm 6.82$
	1	3	12.5^B	1283.33 ± 1919.82	200 (150-3500)	$70.67^b \pm 5.03$
Ascaris suum	0	17	70.8			$80.88^A \pm 4.73$
	1	7	29.2	1164.28 ± 1513.19	500 (50-4000)	$69.43^B \pm 4.72$
Strongyloides ransomi	0	23	95.8^A			$77.65^a \pm 7.18$
	1	1	4.2^B	50.00 ± 0.00	50 (50-50)	$75.00^a \pm 0.00$
Trichuris suis	0	15	62.5			$80.33^a \pm 5.55$
	1	9	37.5	650.00 ± 1445.68	200 (50-4500)	$72.89^a \pm 7.06$
Eimeria spp.*	0	17	70.8			$79.06^a \pm 5.63$
	1	7	29.2	62.57 ± 82.69	12 (1-200)	$73.86^a \pm 9.14$

Explanations: a, b – mean the different superscript letters differ significantly at p ≤ 0.05; A, B – p ≤ 0.01; 0 – non-infected, 1 – infected; * number of oocysts in a single sample

Tab. 3. Carcass weight of females in relation to endoparasite infection

Endoparasites	Infection	Prevalence n	Prevalence %	EPG Mean ± SD	EPG Me (x_{min}-x_{max})	Carcass weight (kg) Mean ± SD
Total	0	9	34.6			$61.00^A \pm 4.66$
	1	17	65.4	2946.67 ± 6485.31	400 (50-25 300)	$45.41^B \pm 6.69$
Oesophagostomum spp.	0	16	61.5			$55.69^A \pm 7.99$
	1	10	38.5	665.00 ± 1007.46	250 (50-3000)	$43.00^B \pm 6.43$
Ascaris suum	0	17	65.4			$55.41^A \pm 8.09$
	1	9	34.6	3972.22 ± 8006.14	1000 (50-25 000)	$42.11^B \pm 5.39$
Strongyloides ransomi	0	21	80.8^A			$52.00^a \pm 9.59$
	1	5	19.2^B	200.00 ± 308.22	50 (50-750)	$45.80^a \pm 9.07$
Trichuris suis	0	22	84.6^A			$52.09^a \pm 9.93$
	1	4	15.4^B	200.00 ± 141.42	150 (100-400)	$43.75^b \pm 2.36$
Eimeria spp.*	0	9	34.6			$61.00^A \pm 4.66$
	1	17	65.4	82.71 ± 171.79	5 (1-591)	$45.41^B \pm 6.69$

Explanations: as in Tab. 2

$P \leq 0.01$), average EPG 2946.67 ± 6485.31 with median 400 (50-25 300). Females infected with *Oesophagostomum* spp. (average EPG 665.00 ± 1007.46; median 250 (50-3000)) were lighter (43.00 kg compared to 55.69 kg; $F = 17.86$; $P \leq 0.01$). However, carcasses of females infected with *Ascaris suum* (average EPG 1164.28 ± 1513.19; median 500 (50-4000)) were over 13 kg lighter ($P \leq 0.01$). There were no statistically proven differences between carcass weights of females infected with *Strongyloides ransomi* ($P > 0.05$), but there was a statistically proven difference in infection: χ^2 (df = 1, n = 26) = 4.6; $P \leq 0.01$. Females infected with *Trichuris suis* (average EPG 650.00 ± 1445.68, median 200 (50-4500)) were lighter (43.75 kg) in comparison with non-infected animals (52.09 kg) ($F = 4.23$; $P \leq 0.05$). Additionally, statistically proven differences for infection with this parasite were reported: χ^2 (df = 1, n = 26) = 6.1; $P \leq 0.01$. The analysis of *Eimeria* spp. infection presented over 15.59 kg lighter carcasses for infected females ($F = 38.47$; $P \leq 0.01$), with an average number of oocysts in a single sample of 82.71 ± 171.79.

Statistical analysis of data demonstrated correlations between sex and endoparasite infection in the research population (Fig. 3 and 4). Strong negative correlations ($r = -0.84$, $P \leq 0.05$) were noted for males between carcass weight and logarithmized values for the average number of *Eimeria* spp. oocysts in a single sample. However, for females strong negative correlations ($r = -0.63$, $P \leq 0.05$) were observed between carcass weight and logarithmized values for total EPG for infection with nematodes. Information about endoparasites in free-living wild boars is still scant; therefore, the comparison of our own study results with those available in the literature is very difficult and requires special attention in the formulation of precise relationships.

The species richness of endoparasites for European wild boars was presented in the study conducted by Humbert and Henry (7) on the basis of results from the 1980s. The prevalence of these parasites ranged from 33 (in Germany) to 74 (in Poland), and as much as 98 (in Holland and France), so in combination with our own results (94% in the study population and 60% in the research population) these represent a large discrepancy. The overall prevalence was similar to results from the study by Popiołek et al. (17). However, these authors demonstrated a marginal prevalence of *Ascaris suum* and an almost two-times higher prevalence of *Trichuris suis* in comparsion to our own results. *Ascaris suum* was the second most common parasite in the research population. Thus, we cannot agree with the statement of de-la-Muela et al. (3) that the invasion of nematodes (*Ascaris suum*) has little importance in the case of parasitic infections in wild boars. Infection with *Trichuris suis* may in turn contribute to increased mortality in wild boars and low reproduction parameters (4). Popiołek et al. (17) highlighted, however, the fact that the simple life cycle and environmental resistance of this parasite determines its frequent diagnosis in coproscopic samples. Infections with *Oesophagostomum* spp. are specified on the level of the genus, because detailed morphological and biometric identification of *Oesophagostomum dentatum* and *Oesophagostomum quadrispinulatum* eggs occurring in Suidae in Poland seems to be impossible (12).

Carcass weight is an important element of observation for wild animals, especially wild boars (27, 28). This parameter, however, only occasionally appears in parasitic research and serves only for presenting an overall view of a research population (7, 13). Wild boars of the same sex, in the same ecosystem, of the same age and with the same abundance of food (identical feeding areas) should be of similar body/carcass weight. The occurrence of significant differences in carcass weights is the first warning sign concerning the health status of wild animals, and in particular the

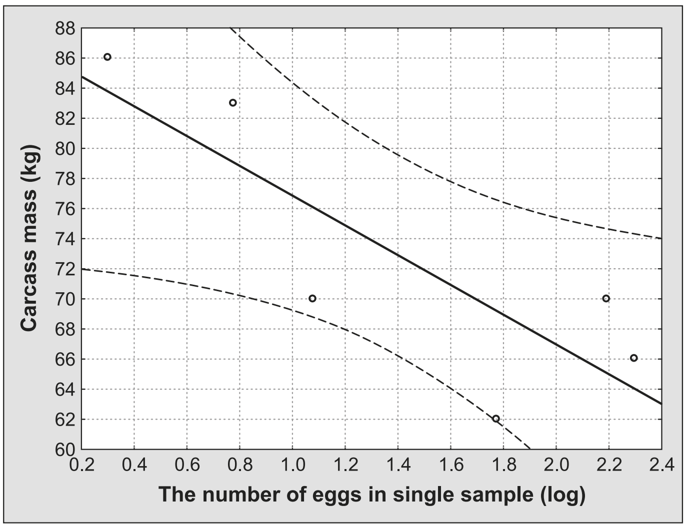

Fig. 3. Dispersion of carcass weight (kg) depending on the number of oocysts in a single sample (log) for males

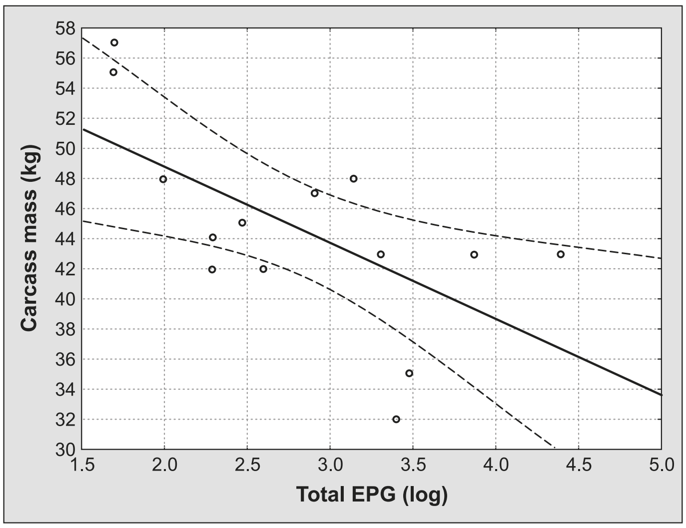

Fig. 4. Dispersion of carcass weight (kg) depending on total EPG (log) for females

physiology of the digestive system. However, animals infected with parasites occasionally demonstrate good health and no changes to their internal organs (3).

Differences in the carcass weight of finishers result first from health status, then hierarchy in the herd, and finally from genetic determinants between individuals (21). Carcass weight of finishers is an important indicator of quality and economic value during production (2). The raw material obtained from longer and heavier carcasses is more attractive and easy to exploit for commercial development (26). Results for the carcasses of finishers infected with endoparasites indicate a strong relationship between these characteristics (12, 21).

The precise correlation of age and sex in our study allows accurate referencing of differences, resulting mainly from infection with observed parasites. Discussion and comparison of parasitic parameters with other studies is difficult, because the only research on carcass weight and parasites in wild pigs was conducted by Järvis et al. (9). These authors noted a negative correlation ($P = 0.04$, $r = –0.22$) between the level of infection and carcass weight. However, there is no precise information on the carcass weight diversification of hunted boars in terms of any sex-infection relation.

Sex analysis in the case of infection only showed a higher proportion of *Oesophagostomum* spp. infection for females, and this had also been observed in another study (19). However, in line with earlier research results (3, 9), our study also showed no other effect of sex on the degree of infection. The largest loss of weight in the case of infected (1) and non-infected (0) males was demonstrated during *Ascaris suum* infection, while for females during *Eimeria* spp. infection.

Oesophagostomum spp., *Ascaris suum*, *Trichuris suis*, *Eimeria* spp. and *Strongyloides ransomi* were observed and defined in the study population. A statistically significant effect of the overall infection on carcass weight was achieved ($F = 9.96$; $P \leq 0.01$). In the case of overall infection, a more than 7 kg lower carcass weight was observed in infected males. A carcass weight over 15 kg lower was noted for overall infection of females ($F = 38.47$; $P \leq 0.01$), for which average EPG was 2946.67 ± 6485.31 with a median of 400 (50-25 300). Diagnostic studies on genus/species richness in free-living wild boars with increasing populations, and thus increasing infection areas, are appropriate and should be continued.

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