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RESEARCH ARTICLE

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Growth performance and meat composition of rabbits fed diets supplemented with silkworm pupae meal

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Abstract

Aim of study: To determine the effect of different dietary levels of silkworm pupae meal (SWPM) on the growth performance of broiler rabbits and the chemical composition of their meat.

Area of study: Southern Poland, Europe.

Material and methods: Ninety Termond White rabbits were divided into three feeding groups. Control group rabbits were fed a diet containing 10% soybean meal (SBM). In the first experimental group, rabbits received a diet containing 5% SBM and 5% SWPM. The diet administered to the second experimental group was supplemented with 10% SWPM.

Main results: Both partial and complete replacement of SBM with SWPM in diets contributed to a decrease in the final body weights of rabbits (2416.50 and 2390.78 *vs*. 2616.78 g), average daily gains (30.23 and 30.52 *vs.* 33.12 g) and feed intake (5.61 and 5.15 *vs.* 6.51 kg), but it improved the feed conversion ratio (3.28 and 3.05 *vs.* 3.41 kg/kg). Rabbits fed diets supplemented with SWPM were characterized by lower values of selected carcass parameters such as carcass weight and dressing percentage. Experimental diets had no significant effect on the proximate chemical composition of meat, but they increased the levels of fatty acids $C_{18:3}$, $C_{22:5}$ and $C_{22:6}$.

Research highlights: The results of this study can be put into practice to replace conventional protein and fat sources in rabbit diets with insect meals (SWPM) in the production of rabbit meat for human consumption. Our findings can also contribute to the recycling of sericultural waste.

Additional keywords: insect meal; alternative animal diets; meat quality; health-promoting animal products.

Abbreviations used: ADF (acid detergent fiber); ADL (acid detergent lignin); BW (body weight); BWG (body weight gains); DBWG (daily body weight gains); DFA (hypocholesterolemic fatty acids); DP (dressing percentage); FCR (feed conversion ratio); FI (feed intake); MUFA (monounsaturated fatty acids); NDF (neutral detergent fiber); OFA (hypercholesterolemic fatty acids); PUFA (polyunsaturated fatty acids); SBM (soybean meal); SEM (standard error of the mean); SFA (saturated fatty acids); SWPM (silkworm pupae meal); UFA (unsaturated fatty acids).

Authors' contributions: All authors have contributed equally to this work (conception and design, statistical analysis and interpretation of data, drafting and critical revision of the manuscript). All authors have read and approved the final manuscript.

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Introduction

Silkworm pupae, the by-product of sericulture, are produced in large quantities mostly in Asia where their disposal is a serious environmental problem. However, silkworm pupae meal (SWPM) can be a rich source of dietary protein for human consumption and livestock feed (Datta, 2007; Patil *et al.* 2013). Silkworm pupae, which are dried and ground to produce meal, are considered to contain more than 50% protein with relatively high concentrations of nutritionally valuable amino acids such as lysine and methionine (Finke, 2002; Usub *et al.*, 2008). The actual protein content of silkworm pupae is lower, and exceeds 70% of the analytically determined value due to the presence of chitin (3-4%). Chitin contains nitrogen which apparently increases the levels of protein as well as total fiber and acid detergent fiber (ADF) in chemical analyses. The fat content of SWPM is also high, reaching up to 40% (Finke, 2002; Ioselevich *et al.*, 2004; Suresh *et al.*, 2012).

Nowadays soybean meal (SBM) is the main source of protein in diets for livestock, including rabbits (Heuzé *et al.*, 2017). Research has shown that in rabbit diets, SBM can be effectively replaced with by-products from the food-processing industry, such as rapeseed cake and dried distillers grains (Alagón *et al.*, 2014; Strychalski *et al.*, 2014) as well as legume seeds (Volek & Marounek, 2009; Gugołek *et al.*, 2015). Attempts have also been made to replace SBM with animal protein. Until recently, meat and bone meal was used in the formulation of animal rations, but then most countries agreed to ban the feeding of meat and bone meal to farm animals. Alternative dietary protein sources include insect meals such as SWPM whose efficacy has been investigated in various livestock species, mostly poultry (Mishra *et al.*, 2003; Jintasataporn, 2012; Makkar *et al.*, 2014; Ullah *et al.*, 2017).

The use of silkworm meal as a substitute for SBM in rabbit diets was described by Carregal & Takahashi (1987). According to Aruga (1994), rabbits fed diets with SWPM were characterized by increased fat deposition and a significantly higher rate of fur growth. In a study by Liu *et al.* (1987), silkworm pupae were not analyzed as a feed additive (an experimental factor) but as a feed component, which points to their common use in China. However, this issue remains insufficiently investigated.

Since the global edible insect market is expected to expand, it appears that rabbit diets could be supplemented with SWPM, a rich source of protein and fat. Therefore, the aim of this study was to determine the effect of different dietary levels of SWPM on the growth performance of broiler rabbits and the chemical composition of their meat.

Material and methods

The animal protocol and the number of animals used in this study were consistent with the regulations of the Local Institutional Animal Care and Use Committee (Olsztyn, Poland), and the study was carried out in accordance with EU Directive 2010/63/EU for animal experiments (OJEU, 2010).

Animals and housing

The experimental animals were 90 Termond White rabbits (45 females and 45 males) reared on a farm located in southern Poland, Europe. The rabbits were randomly allocated to three groups. When the experiment began, the animals were 35 days old (weaning) and had average body weight (BW) of 722.87±24.33 g (mean±SEM). They were 91 days old when the experiment ended.

The experiment was performed in October and November, in a separate facility on a rabbit farm. All rabbits were kept in wire-mesh flat-deck cages measuring 0.5 × 0.6 × 0.4 m (two animals per cage). They had *ad libitum* access to feed served once a day via automatic feeders and water from nipple drinkers. The animals were housed under standard conditions with a temperature of 16-18°C, relative air humidity of 60-75%, forced room ventilation, and a controlled photoperiod (12 h light with intensity of 25 lx and 12 h dark).

Diets and experimental procedures

Control group rabbits were fed a diet containing 10% SBM. In the first experimental group (SBM/SWPM), rabbits received a diet containing 5% SBM and 5% SWPM. The diet administered to the second experimental group (SWPM) was supplemented with 10% SWPM. The ingredients of diets are presented in Table 1, whereas the chemical composition of diets and experimental factors are presented in Table 2. The fatty acid profiles of SBM and SWPM (expressed as % of total fatty acids identified) are presented in Table 3. All diets were isonitrogenous and their nutritional value corresponded to the requirements of growing meat-type rabbits (De Blas & Mateos, 2010).

During the experiment, the rabbits were weighed on an electronic scale within an accuracy of 1 g, and their BW was determined at the beginning and at the end of the feeding trial (35 and 91 days of age, respectively). Average daily body weight gains (DBWG) were also calculated. Total feed intake (FI) and feed conversion ratio (FCR) were determined.

At the end of the feeding trial, the animals were fasted for 24 h and sacrificed according to the standard guidelines for euthanizing experimental animals. The carcasses were skinned and eviscerated. The head was dissected along the occipital joint; the forepart was dissected between the 7th and 8th thoracic vertebrae, and the loin was dissected between the 6th and 7th lumbar vertebrae. The hind part with the perisacral area and hind legs was the remaining part of the carcass after dissection (Daszkiewicz *et al.*, 2012). The following slaughter performance data were collected: pre-slaughter weight, carcass weight with and without the head, dressing percentage I and II. Dressing percentages with and without the head (DP-I and DP-II, respectively) were calculated according to the following formula: DP-I = carcass weight with the head / slaughter weight × 100%, DP-II = carcass weight without the head/ slaughter weight × 100%. The proportion of the most valuable carcass cuts, *i.e.* the forepart, loin and the hind part, was also calculated and expressed in "g" and "%".

Table 1. Diet composition (% fresh matter).

Components	Diet		
	SBM	SBM/SWPM	SWPM
Soybean meal	10.0	5.0	0.0
Dried silkworm pupae meal	0.0	5.0	10.0
Dried alfalfa	20.0	20.0	20.0
Wheat bran	42.0	42.0	42.0
Rapeseed meal	6.0	6.0	6.0
Corn DDGS	6.0	6.0	6.0
Arbocel	6.0	6.0	6.0
Dried beet pulp	5.0	5.0	5.0
Dried brewer's yeast	1.0	1.0	1.0
Whey powder	1.0	1.0	1.0
Sodium chloride (NaCl)	0.2	0.2	0.2
Chalk	1.3	1.3	1.3
Phosphate	0.5	0.5	0.5
Mineral-vitamin premix[1]	1.0	1.0	1.0
Total	100.0	100.0	100.0

SBM: soybean meal diet (control); SWPM: silkworm pupae meal; SBM/SWPM: diet with SBM and SWPM; DDGS: dried distillers grains with solubles; Arbocel: crude fiber concentrate. [1]Composition of mineral-vitamin premix (1 kg): vit. A, 3,500,000 IU; vit. D_3, 200,000 IU; vit. E, 28 g; vit. K_3, 200 mg; vit. B_1, 1.5 g; vit. B_2, 2.8 g; vit. B_6, 2.8 g; vit. B_{12}, 20 cg; folic acid, 200 mg; niacin, 10 g; biotin, 200 cg; calcium pantothenate, 7 g; choline, 30 g; Fe, 17 g; Zn, 2 g; Mn, 1 g; Cu (copper sulfate × $5H_2O$, 24,5%), 800 mg; Co, 1 g; I, 100 mg; Ca, 150 g; P, 100 g.

Analytical methods

Hind leg muscles were collected for analyses of the chemical composition and fatty acid profile of meat after 24 h of chilling at +4ºC. The content of dry matter, crude ash, total protein, ether extract, crude fiber, ADF and acid detergent lignin (ADL) was determined by standard methods (AOAC Int., 2006). Neutral detergent fiber (NDF), ADF and ADL were estimated in the FOSS TECATOR Fibertec 2010 System. NDF was determined according to the procedure proposed by Van Soest *et al.* (1991). The levels of amino acids in diets were determined using the Biochrom 20 plus amino acid analyzer and Biochrom amino acid analysis reagents (Biochrom Ltd., Cambridge, England). Gross energy content was determined using a bomb calorimeter (IKA® C2000 basic, Germany). To determine fatty acid composition, all fat samples were methylated by the modified Peisker method (Peisker, 1964) (1.5 cm^3 of a methanol:chloroform:concentrated sulfuric acid mixture, 100:100:1 v/v, was added to *ca.* 150 µL of fat, thermostat –80ºC, 3h), and fatty acid methyl esters were obtained. Fatty acids were separated and determined by gas chromatography: VARIAN CP–3800 gas chromatograph-Netherlands, flame-ionization detector (FID); capillary column (length = 50 m, ϕ = 0.25 mm, film d = 0.25 µm); split injector; split ratio 50:1; 1 µL sample; detector temperature, 250ºC; injector temperature, 225ºC; column temperature, 200ºC; carrier gas, helium;

Table 2. Chemical composition of diets and experimental factors (% fresh matter).

	Diet			Soybean meal	Silkworm pupae meal
	SBM	SBM/SWPM	SWPM		
Dry matter	88.70	88.84	89.14	88.68	93.19
Crude ash	7.41	7.31	7.20	6.02	3.93
Organic matter	81.29	81.53	81.94	82.66	89.26
Total protein	18.07	18.34	18.55	46.56	51.58
Ether extract	3.25	4.47	5.64	1.98	26.49
Crude fiber	13.39	13.33	13.29	4.44	3.73
N-free extracts	46.58	45.39	44.46	34.12	7.46
NDF	28.99	29.98	31.09	10.63	31.35
ADF	16.26	16.45	16.71	6.25	9.34
ADL	5.12	5.23	5.29	1.15	2.95
Lysine	0.92	0.92	0.92	2.99	2.85
Methionine+cystine	0.87	0.90	0.92	1.32	1.78
Threonine	0.81	0.82	0.83	1.72	1.96
Tryptophan	0.21	0.22	0.22	0.68	0.74
Gross energy [MJ/kg]	16.31	16.74	17.24	17.36	24.69

SBM: soybean meal diet (control); SWPM: silkworm pupae meal; SBM/SWPM: diet with SBM and SWPM; NDF: neutral detergent fiber; ADF: acid detergent fiber; ADL: acid detergent lignin.

Table 3. Fatty acid profiles of soybean meal (SBM) and silkworm pupae meal (SWPM), expressed as % of total fatty acids identified.

Fatty acid	SBM	SWPM
$C_{12:0}$	0.00	0.05
$C_{14:0}$	0.29	0.18
$C_{15:0}$	0.06	0.00
$C_{16:0}$	14.23	24.41
$C_{16:1}$	0.16	0.92
$C_{17:0}$	0.21	0.15
$C_{17:1}$	0.09	0.09
$C_{18:0}$	4.35	6.91
$C_{18:1}$	17.94	35.59
$C_{18:2}$	52.83	4.81
$C_{18:3}$	8.73	26.39
$C_{20:0}$	0.36	0.35
$C_{20:1}$	0.16	0.00
$C_{20:2}$	0.06	0.00
$C_{20:4}$	0.00	0.15
$C_{22:0}$	0.53	0.00
SFA	20.03	32.05
MUFA	18.35	1.01
PUFA	61.62	66.94
UFA	79.97	67.95
DFA	84.32	74.86
OFA	15.68	25.14
UFA/SFA	3.99	2.12
DFA/OFA	5.38	2.98

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; UFA: unsaturated fatty acids; DFA: hypocholesterolemic fatty acids; OFA: hypercholesterolemic fatty acids.

flow rate, 1.2 cm^3/min. Fatty acids were identified by comparing the retention times of individual fatty acid methyl ester standards (Sigma-Aldrich) and the retention times of peaks in the analyzed samples. Fatty acids were expressed as a percentage of total fatty acids identified in the sample. The concentrations of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) as well as hypocholesterolemic fatty acids (DFA) and hypercholesterolemic fatty acids (OFA) were cal-culated. DFA = UFA+$C_{18:0}$, OFA=SFA-$C_{18:0}$. Unsaturated fatty acids (UFA) were the sum of MUFA and PUFA. The DFA/OFA and UFA/SFA ratios were also calculated.

Statistical analyses

Data are expressed as means ± standard error of the mean (SEM). The results were analyzed statistically by one-way analysis of variance (ANOVA), and the significance of differences among groups was determined by Duncan's multiple range test at a significance level of $p \leq 0.05$. All calculations were performed using Statistica 12.0 (StatSoft Inc., 2015).

Results

Mortality or diseases symptoms were not observed during the experiment. The initial BW of rabbits from the control group and experimental groups were similar (Table 4). At 91 days of age, control group rabbits were heavier than the animals from the group receiving 10% SWMP and those given 5% SBM and 5% SWMP (p=0.008). The average DBWG for the entire experimental period was approximately 3 g higher in the control group (p=0.041). Total FI throughout the experiment, BWG and FCR (p=0.016, p=0.036 and p=0.029, respectively) were lower in both experimental groups than in the control group.

Selected carcass quality parameters are shown in Table 5. Carcass weight with and without the head was lower in experimental groups than in the control group (p=0.043, p=0.002, respectively). No significant differences in DP-I and DP-II were found between the control group and the SBM/SWPM group. In the second experimental group, where SBM was completely replaced with SWPM, DP-I and DP-II were significantly lower than in the control group and the first experimental group (p=0.029, p=0.004, respectively). Similarly to carcass weight, the proportion of the forepart, Wloin and hind part in the carcass, expressed in g, decreased with increasing SWPM inclusion levels. The percentage content of the analyzed cuts in the carcass was comparable in all groups.

The chemical composition of hind leg muscles was similar in all groups (Table 6). The total protein content of meat ranged from 22.58 to 22.80%, and ether extract content ranged from 0.94 to 1.2%.

The fatty acid profile of hind leg muscles is presented in Table 7. The level of $C_{12:0}$ was highest in group SWPM whereas the levels of $C_{18:3}$, $C_{22:5}$ and $C_{22:6}$ were higher in both experimental groups. The concentrations of $C_{17:0}$ and $C_{20:1}$ in rabbit muscles were highest in the control group. No significant differences were found between major fatty acid groups (SFA, MUFA, PUFA).

Discussion

The lower final BW of experimental group rabbits presented in Table 4 (p=0.008) probably resulted from lower FI (p=0.016) or the presence of chitin which

Table 4. Growth performance of rabbits (mean±SEM).

Specification	Group			*p* value
	SBM	SBM/SWPM	SWPM	
Body weight, 35 days (g)	721.98±20.11	724.04±25.64	722.59±27.25	0.911
Body weight, 91 days (g)	2616.78±48.50[a]	2416.50±51.75[b]	2390.78±47.62[b]	0.008
Daily body weight gains 35-91 (g)	33.12±1.18[a]	30.23±0.97[b]	30.52±0.95[b]	0.041
Feed intake (kg)	6.51±1.83[a]	5.61±1.32[b]	5.15±1.25[b]	0.016
Body weight gain (kg)	1.91±0.26[a]	1.71±0.24[b]	1.69±0.21[b]	0.036
Feed conversion ratio (kg/kg)	3.41±0.07[a]	3.28±0.07[a]	3.05±0.05[b]	0.029

SBM: soybean meal diet (control); SWPM: silkworm pupae meal; SBM/SWPM: diet with SBM and SWPM; SEM: standard error of the mean. [a,b]Within rows, values with different letters are significantly different ($p<0.05$).

Table 5. Carcass characteristics of rabbits (mean±SEM).

	Group			*p* value
	SBM	SBM/SWPM	SWPM	
Body weight (g)	2616.78±48.50[a]	2416.50±51.75[b]	2390.78±47.62[b]	0.008
Carcass weight (g)				
with head	1378.12±28.85[a]	1271.14±32.09[b]	1221.13±24.13[b]	0.043
without head	1241.14±22.40[a]	1185.13±23.81[a]	1088.00±19.05[b]	0.002
Dressing percentage (%)				
I with head	52.66±0.81[a]	52.60±0.73[a]	51.08±0.86[b]	0.029
II without head	47.43±0.76[a]	49.04±0.79[a]	45.51±0.71[b]	0.004
Forepart				
(g)	480.56±11.33[a]	465.38±15.82[a]	424.46±12.28[b]	0.040
(%)	38.72±0.26	39.27±0.29	39.01±0.032	0.819
Loin				
(g)	318.02±7.26[a]	304.50±14.19[a]	282.76±16.09[b]	0.022
(%)	25.62±0.19	25.69±0.17	25.99±0.21	0.925
Hind part				
(g)	442.56±9.14[a]	415.25±11.02[a]	380.78±8.59[b]	0.017
(%)	35.66±0.20	35.04±0.22	35.00±0.27	0.360

SBM: soybean meal diet (control); SWPM: silkworm pupae meal; SBM/SWPM: diet with SBM and SWPM; SEM: standard error of the mean. [a,b]Within rows, values with different letters are significantly different ($p<0.05$).

Table 6. Proximate chemical composition of hind leg muscles in rabbits (%; mean±SEM).

	Group			*p* value
	SBM	SBM/SWPM	SWPM	
Dry matter	24.91±0.23	24.75±0.32	24.71±0.24	0.845
Crude ash	1.22±0.01	1.21±0.01	1.20±0.01	0.655
Total protein	22.58±1.13	22.80±0.27	22.66±0.15	0.702
Ether extract	0.94±0.14	1.13±0.18	1.20±0.10	0.466

SBM: soybean meal diet (control); SWPM: silkworm pupae meal; SBM/SWPM: diet with SBM and SWPM; SEM: standard error of the mean.

Table 7. Fatty acid profile of hind leg muscles in rabbits (expressed as % of total fatty acids identified; mean±SEM).

Fatty acid	Group			*p* value
	SBM	SBM/SWPM	SWPM	
$C_{12:0}$	0.13±0.01[b]	0.12±0.01[b]	0.19±0.04[a]	0.026
$C_{14:0}$	2.58±0.18	2.26±0.14	2.18±0.14	0.161
$C_{14:1}$	0.13±0.01	0.11±0.02	0.11±0.02	0.559
$C_{15:0}$	0.60±0.03	0.50±0.02	0.53±0.04	0.110
$C_{16:0}$	30.95±1.28	28.62±0.79	28.92±1.16	0.281
$C_{16:1}$	2.09±0.19	2.08±0.34	2.13±0.25	0.989
$C_{17:0}$	0.95±0.06[a]	0.72±0.02[b]	0.79±0.06[b]	0.019
$C_{17:1}$	0.36±0.03	0.31±0.03	0.34±0.04	0.549
$C_{18:0}$	12.80±0.71	11.22±0.67	11.75±0.59	0.243
$C_{18:1}$	21.24±0.81	22.44±0.75	23.20±0.82	0.228
$C_{18:2}$	21.91±1.54	22.45±0.60	20.76±1.03	0.602
$C_{18:3}$	2.82±0.30[b]	5.12±0.21[a]	5.02±0.66[a]	0.001
$C_{20:0}$	0.23±0.01	0.22±0.01	0.25±0.02	0.416
$C_{20:1}$	0.41±0.03[a]	0.31±0.01[b]	0.30±0.03[b]	0.005
$C_{20:2}$	0.38±0.04	0.31±0.01	0.30±0.02	0.071
$C_{20:4}$	1.78±0.24	2.27±0.12	2.23±0.24	0.201
$C_{20:5}$	0.04±0.03	0.02±0.004	0.03±0.02	0.683
$C_{22:0}$	0.22±0.03	0.26±0.02	0.25±0.03	0.556
$C_{22:5}$	0.31±0.06[b]	0.56±0.04[a]	0.60±0.09[a]	0.010
$C_{22:6}$	0.07±0.01[b]	0.10±0.01[a]	0.12±0.01[a]	0.016
SFA	48.46±2.01	43.92±1.48	44.86±1.76	0.180
MUFA	24.23±0.94	25.25±1.09	26.08±1.03	0.443
PUFA	27.31±2.11	30.83±0.84	29.06±1.80	0.361
UFA	51.54±2.01	56.08±1.48	55.14±1.76	0.180
DFA	64.34±2.71	67.30±2.08	66.89±2.36	0.340
OFA	35.66±1.45	32.70±0.89	33.11±1.35	0.216
UFA/SFA	1.06±0.12	1.28±0.08	1.23±0.10	0.184
DFA/OFA	1.80±0.23	2.06±0.15	2.02±0.20	0.229

SBM: soybean meal diet (control); SWPM: silkworm pupae meal; SBM/SWPM: diet with SBM and SWPM; SEM: standard error of the mean; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; UFA: unsaturated fatty acids; DFA: hypocholesterolemic fatty acids; OFA: hypercholesterolemic fatty acids; [a,b]within rows, values with different letters are significantly different ($p<0.05$).

(as mentioned in the Introduction section) apparently increases the protein content of the ration (Usub *et al.*, 2008). Thus, the actual protein content of experimental diets could be lower than that shown in Table 3. Moreover, the genomes of selected herbivorous animal species such as rabbits and guinea pigs do not contain functional acidic chitinase (Chia) genes, and therefore they are unable to digest chitin (Tabata *et al.*, 2018).

Edible insects are a rich source of highly available fat (Finke, 2002). As expected, the DBWG of rabbits calculated for the entire experiment was higher in the control group than in the experimental groups. The values of FCR were lower in rabbits fed experimental diets containing SWPM than in control group animals. FI was lower in the experimental groups, most likely due to the higher energy value of experimental diets resulting from a higher concentration of fat from SWMP. The higher energy value of feed has long been associated with lower FI and higher utilization efficiency, and such a correlation has been reported by *e.g.* Fernandez & Fraga (1996).

The differences in carcass quality characteristics between groups (Table 5) were related to differences in the BW and average DBWG of rabbits (Table 4). The performance parameters of rabbits from all groups, presented in Tables 4 and 5, remained within normal limits for broiler rabbits of medium-sized breeds raised in Central Europe (Chełmińska & Kowalska, 2013; Bălăceanu *et al.*, 2014; Strychalski *et al.*, 2014).

The chemical composition of hind leg muscles (Table 6) could be considered typical of broiler rabbits aged 90 days (Marounek *et al.*, 2007; Volek & Marounek, 2009; Daszkiewicz *et al.*, 2012; Strychalski *et al.*, 2014). An increase in the fat content of hind leg muscles, noted in rabbits fed diets supplemented with SWPM, could result from a higher content (Bălăceanu *et al.*, 2014) and origin (Gasco *et al.*, 2017) of dietary fat. Our results corroborate the findings of other authors. A correlation between an increase in the vegetal oil content of diets and higher fat concentrations in rabbit meat was observed by Bălăceanu *et al.* (2014). In a study by Gasco *et al.* (2017), the substitution of soybean oil by *Tenebrio molitor* or *Hermetia illucens* fat in rabbit diets increased perineal fat deposition in the carcass, which could point to the high availability and metabolism of insect-derived fats in higher animals (*Eutheria*).

There is considerable evidence to indicate that the fatty acid composition of animal diets influences the fatty acid profile of meat. Lin *et al.* (1993) demonstrated that the fatty acids of dietary fats may greatly affect adipose fatty acid composition in rabbits. According to Trebušak *et al.* (2011), dietary supplementation with vegetable oils may exert a beneficial effect on the fatty acid profile of rabbit meat. In the cited study, linseed oil added to diets decreased SFA concentrations in meat. The present findings differ from the results of studies investigating higher animals, mammals and birds. Andrade *et al.* (2018), who analyzed the efficacy of different vegetable and animal fats in rabbits, found that neither animal performance nor meat composition were affected by dietary lipid sources. Beef tallow and poultry fat contributed to a lower proportion of MUFA and PUFA in meat compared with vegetable oils. The above authors concluded that the dietary inclusion of soybean oil was advantageous because it increased the PUFA content of rabbit meat. Interestingly, the effect of fish oil was different and similar to that exerted by insect-derived lipids. Kowalska & Bielański (2009) reported that dietary supplementation with fish oil led to a hig-hly significant increase in the levels of n-3 PUFA, especially eicosapentaenoic acid and docosahexaenoic acid, in the lipid fraction of rabbit leg muscles.

To date, only a few studies have investigated the effect of insects incorporated into rabbit diets on the fatty acid profile of meat. Dalle-Zotte *et al.* (2018), who analyzed whether Black Soldier Fly fat and extruded linseed oil affected the fatty acid index of hind leg meat in rabbits, found that diets with Black Soldier Fly fat reduced the concentrations of intramuscular fatty acids but increased the content of $C_{12:0}$ and $C_{14:0}$ in meat, compared with linseed. In the cited study, the lipid profiles of meat from Black Soldier Fly-fed rabbits were less healthy, but meat from linseed-fed rabbits was more susceptible to oxidation. The findings of the current study do not support the above results, but it should be stressed that the fatty acid profiles of Black Soldier Fly fat (Dalle-Zotte *et al.,* 2018) and silkworm pupae fat (Table 3) are considerably different.

In conclusion, both partial and complete replacement of SBM with SWPM in diets contributed to a decrease in the final BW of rabbits, average DBWG and FI, but improved FCR. Rabbits fed diets supplemented with SWPM were characterized by lower values of selected carcass quality parameters. Experimental diets had no significant effect on the proximate chemical composition of meat, but they considerably increased the levels of fatty acids $C_{18:3}$, $C_{22:5}$ and $C_{22:6}$.

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