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Growth performance, mortality and body and carcass characteristics of rabbit fatteners related to crossbreeding of Mecklenburger Schecke sires with dam line of HYLA rabbits

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Abstract: The aim of the study was to evaluate the effect of crossing Mecklenburger Schecke (MS) males with the maternal commercial line of HYLA rabbits on the growth performance, mortality and body and carcass components of fattened rabbits under intensive farming conditions. The control (C) group consisted of albino crossbred rabbits of the HYLA combination AB sires × CD dams. The tested (T) group (MS sires × HYLA CD dams) consisted of rabbit crosses between the MS sires and the same dam line as in the C group. Rabbits of both groups were raised and fattened under identical nutritional and management conditions. The crossing of MS males with the maternal line of HYLA rabbits led to the acceptable growth performance of rabbits in the T group. The higher slaughter weight of rabbits in the T group as compared to rabbits in the C group ($P < 0.01$) was associated with the higher weight of hot carcass and higher proportions of fore and intermediate parts of carcass ($P < 0.01$). On the contrary, HYLA rabbits had a higher proportion of the hind part of carcass ($P < 0.001$); yields of hind leg meat and *musculus longissimus thoracis et lumborum* were not influenced by the genotype. However, since higher mortality was found in rabbits of the T group during fattening, it is not possible to recommend the MS breed as a common sire line used under conditions of intensive farming at this moment. Regarding the rabbit sex, slaughtered females showed a higher proportion of liver and a lower dressing percentage associated with the worse carcass compactness compared to males.

Keywords: crossbred rabbit; sire breed; commercial dam line; prolonged fattening; sex; meat production

Rabbit meat is a valuable and highly recommended foodstuff from many aspects. When compared to meat from other farmed animals, a relatively high proportion (34%) of the rabbit meat comes from non-commercial rabbit stocks with less intensive husbandry conditions (European Union 2017). Contemporary animal production can be specified as a result of the environment and nutrition that interact with the genetic background of an animal (Migdal et al. 2019).

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In general, the breeding scheme for commercial rabbit meat production involves a tree-way cross of specialized lines, when sire-line males that show high growth rate inseminate prolific crossbred females (Blasco et al. 2018). In case of rabbit intensive farming, fattening of specific high-performance albino crossbred lines still dominates on many large-scale farms. Due to the current increasing interest of consumers in the origin of animal foodstuff (Zapletal et al. 2020), an interesting preference regarding rabbit meat developed in a certain part of consumers. Specifically, some consumers started to perceive negatively rabbit meat originating from white-coloured albino crossbred lines that resemble laboratory lines of experimental rabbits. These consumers consider solidly or spotted coloured rabbits as more natural and they prefer the consumption of meat originating from these rabbits to that from albino crossbred lines.

Szendro et al. (2012) mentioned that coloured rabbit breeds involved in crossbreeding schemes can be used purposely in European organic farming and in alternative systems of meat production. Recently, the assessment of important production traits in some coloured rabbit breeds was performed to discover their potential for meat production (Dalle Zotte and Paci 2014; Tumova et al. 2014), while comprehensive studies about meat quality of crossbred rabbits are quite scarce, predominantly because of a small sample size and other methodologic complications (Blasco et al. 2018).

The Mecklenburger Schecke (MS) breed displays favourable growth intensity and when taking into consideration its other traits, it can be assumed that the MS breed would be used as a sire line in crossbreeding schemes to supply broiler rabbits. The medium-sized MS breed weighs about 4.5 kg to 5.5 kg and it is characterized by the well-muscled cylindrical body, with broad fore- and hindquarters. Regarding history of the MS breed, it belongs to the younger rabbit breed compared to the majority of medium-sized breeds, while the popularity of MS rabbits increases in Czech breeders nowadays, mainly because of their meatiness. The MS breed, like Checkered Giant and Rhinelander breeds, displays three specific colour genotypes – *kk*, *Kk* and *KK* called as "Self", "Standard marked" and "Chaplin", respectively. The colour genotype of the breed influences also its growth performance and health state, while rabbits having the solidly (*kk* genotype) or spotted (*Kk* genotype) coloured fur display higher growth intensity and live weight (LW) compared to rabbits that possess the prevailingly white coloured fur (*KK* genotype). Frequent subvitality of the *KK* genotype is caused by reduced *KIT* (v-kit Hardy-Zuckerman 4 feline sarcoma viral oncogene homolog) gene expression and leads to the abnormalities in enteric neurons and megacolon syndrome (Fontanesi et al. 2014).

The aim of the study was to evaluate the effect of crossing MS males with the maternal commercial line of HYLA females on the growth performance, mortality and body and carcass components of fattened rabbits under intensive farming conditions.

MATERIAL AND METHODS

Animals, housing and diets

The study was carried out from June to September 2019 in the Genetic Centre of HYLA rabbits (Jaroměřice nad Rokytnou – Ratibořice, Czech Republic). On the farm, which mainly supplies semen doses from breeding sires and breeding dams of the HYLA crossbred rabbits to other commercial farms, neither synthetic allopathic veterinary drugs nor synthetic anticoccidial drugs have been used.

A total of 112 (56 males + 56 females) crossbred rabbits (control and tested groups) were used in the experiment. The control (C) group (28 males + 28 females) consisted of albino crossbred rabbits of the HYLA combination AB sires × CD dams. The tested (T) group (MS sires × HYLA CD dams; 28 males + 28 females) consisted of rabbit crosses between the MS sires and the same dam crossbred HYLA line CD as in the C group. Regarding MS sires included in the tested crossing, they originated from 3 small-scale hobby breeding stocks. All of the sires used (6 males) were the *kk* or *Kk* genotypes and showed outstanding body muscularity compared to the MS males of the same age. Dams of the HYLA line CD were inseminated with the heterospermic insemination dose, which contained spermatozoa of all involved MS sires. In both groups does gave birth at the same time. The proportion of does in relation to their parity number was similar in both assessed groups. Within a genotype group assessed, litters were equalised on the first day postpartum by cross-fostering. In a respective genotype group, all litters were accurately standardized to 8 and 9 kits per litter (kits of the same genotype) in the primipa-

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rous and older does, respectively. Within the entire experimental period, rabbits of both groups were raised and fattened under identical management conditions. At weaning (35 days of age), rabbits were housed in wire cages (2 rabbits per cage) with the floor density of 0.18 m^2 per rabbit. The cage size was 90 × 40 × 35 cm (length × width × height). The average live weight (LW) of weaned rabbits in the C and T group was 968 ± 163.9 g and 942 ± 171.6 g, respectively. The lighting period was 12 h light/12 h darkness, temperature ranged from 17 °C to 20 °C and relative humidity was 55% to 60%. Rabbits were fed *ad libitum* commercial compound pelleted feeds (De Heus a.s., Běstovice, Czech Republic), while the grower and finisher diet was used from the 35^{th} to the 64^{th} day of age and from the 65^{th} day of age to slaughter, respectively. The grower (K-Optimum) and finisher (K-Finisher) diets were composed of the following components: wheat bran, barley, sunflower expeller, sugar beet pulp, palm kernel expeller, grass meal, lucerne meal, malt sprouts, rapeseed meal, barley distillers dark grains, sunflower hulls, calcium carbonate, wheat, molasses, vinasse, salt, rye meal, vitamin and trace mineral premix.

In addition, the grower diet included also an anticoccidial agent Emanox (an extract of aromatic plants), while the finisher diet also included rapeseed expellers, oat and maize gluten.

The chemical composition of the diets used is shown in Table 1. The rabbits had free access to water provided by nipple drinkers.

Fattening performance and slaughter traits

Individual LW of rabbits was recorded at 35, 49, 63, 77, 91 and 108 days of age. At the same days, feed intake per genotype group was measured by weighing feed supplied and refused within the 4 experimental units (replicates; 7 cages per replicate). Thereafter, average daily weight gain and feed conversion ratio were calculated. Mortality was recorded daily.

Since the local market demanded production of heavy rabbits (slaughter weight of 3.0 kg and more), the experimental period lasted up to the 108^{th} day of rabbit age. At the end of the experiment, 30 (15 males + 15 females) rabbits per group were randomly selected, weighed and slaughtered without previous fasting in the abattoir. Slaughtered rabbits were mechanically stunned with a captive bolt gun and bled. Thereafter, the skin, genital organs, urinary bladder, full gastrointestinal tract and distal part of legs were removed according to Blasco and Ouhayoun (1993).

Carcass without lungs, heart, thymus, trachea, oesophagus, liver, kidneys, perirenal fat, but including head was weighed 30 min after slaughter to obtain the hot carcass (HC) weight. Dressing percentage was calculated by dividing the HC weight by the slaughter weight (SW). Dorsal length (DL), thigh length (TL) and lumbar circumference length (LCL) were measured as indicated by Blasco and Ouhayoun (1993) and the length to circumference ratio (LTCR) was calculated.

Then, the head was removed from the HC to acquire the hot reference carcass (HRC), which included the meat, bones and fat deposits. The HRC was thereafter dissected as indicated by Blasco and Ouhayoun (1993); cutting the anatomical joints, such as fore, intermediate and hind parts. Thereafter, both hind legs were deboned and both muscles *musculus longissimus thoracis et lumborum* (*MLTL*) were dissected from the fore and intermediate part of HRC. The yield of particular carcass components was calculated as their intrinsic weight to the HRC weight. The yield of skin, head, heart, liver, kidneys and perirenal fat was calculated as their intrinsic weight to the SW.

Table 1. Chemical composition of the diets (on dry matter basis)

Item	Units	Grower (day 35 to 64)	Finisher (after day 65)
Crude protein	g/kg	175.2	171.6
Crude fibre	g/kg	140.1	142.7
ADF	g/kg	200.3	208.3
NDF	g/kg	399.7	421.1
ADL	g/kg	41.3	41.5
Crude fat	g/kg	46.8	37.4
Crude starch	g/kg	169.0	167.4
Ash	g/kg	76.3	70.4
Calcium	g/kg	9.66	7.73
Inorganic phosphorus	g/kg	8.00	7.40
Sodium	g/kg	2.11	2.16
Potassium	g/kg	10.15	10.44
Gross energy	MJ/kg	18.5	18.1

ADF = acid detergent fibre; ADL = acid detergent lignin; NDF = neutral detergent fibre

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Statistical analysis

The data were statistically assessed using the Statistica CZ v10 software (StatSoft Inc., Tulsa, USA). The arithmetic mean and SEM were determined for LW, ADG, FCR and all of the monitored slaughter traits. To test the normal distribution of the data within the assessed groups, the Shapiro-Wilk test was used. Normality was found in all monitored variables.

One-way ANOVA was used for determination of the differences in the FCR between genotype groups of rabbits.

Two-way ANOVA was used to determine the differences between the assessed groups in the LW at 35 days of age and all of the monitored slaughter traits. The following mathematical model was used:

$$Y_{ijk} = \mu + G_i + S_j + (G \times S)_{ij} + e_{ijk} \quad (1)$$

where:

μ – overall mean;

G_i – fixed effect of genotype (i = HYLA and MS × HYLA);

S_j – fixed effect of sex (j = male and female);

$(G \times S)_{ij}$ – interaction between the genotype and sex;

e_{ijk} – random residual error.

When the analysis of variance showed significant differences between groups, Tukey's post-hoc test was used.

Since a significant effect of the genotype × sex interaction on the LW at 35 days of age was found, ANOVA was used to determine differences in LW from 49 to 108 days of age and ADG between genotypes and sexes.

The initial rabbit LW at the age of 35 days was used as a covariate. The differences for these traits were tested according to the following statistical model:

$$Y_{ijk} = \mu + G_i + S_j + (G \times S)_{ij} + B(x_{ij} - \bar{x}) + e_{ijk} \quad (2)$$

where:

μ – overall mean;

G_i – fixed effect of genotype;

S_j – fixed effect of sex;

$(G \times S)_{ij}$ – interaction between the genotype and sex

B – regression coefficient for covariate LW at 35 days of age;

e_{ijk} – random residual error.

A chi-square test was used to compare differences in the mortality of fattened rabbits in relation to the genotype and sex.

The differences between assessed groups were considered significant at $P < 0.05$.

RESULTS

Within the entire monitored period of fattening, the higher LW of rabbits in the C group at the age of 49 and 63 days ($P < 0.001$) as compared to rabbits in the T group also resulted in the higher ADG values of rabbits in the C group in the period of 35 to 77 days ($P < 0.01$; Table 2). Thereafter, in the period of 64 to 77 days and of 92 to 108 days, a significant increase in the growth rate was shown by the T group compared to the C group ($P < 0.001$ and $P < 0.01$; respectively), which led to the higher LW of rabbits in the T group compared to those in the C group at the end of fattening ($P < 0.05$).

Concerning the effect of sex, the males within both genotypes showed a higher LW at the age of 49 and 63 days ($P < 0.05$) compared to the females. In addition, a significant effect of genotype × sex interaction on the initial LW was found ($P < 0.01$), determining the lowest LW of 35-day-old females of the T group.

Concerning FCR of both fattened rabbit genotypes (Table 3), its lower value was observed in rabbits of the C group as compared to rabbits of the T group in the post-weaning period ($P < 0.05$), while on the contrary, the T group showed the lower FCR in the period of 64 to 77 days than the C group ($P < 0.05$). However, the FCR value for the entire monitored fattening period did not vary between both genotypes ($P > 0.05$).

Higher mortality of fattened rabbits of the T group as compared to those of the C group was found in the periods of 50 to 63 and of 92 to 108 days of age ($P < 0.05$; Table 4). Regarding the entire monitored period, insignificantly higher mortality was observed in the T group than in the C group (19 vs 8 rabbits, respectively; $P = 0.057$).

A significantly higher SW of rabbits in the T group ($P < 0.01$) as compared to rabbits in the C group was associated with the higher weight of HC ($P < 0.01$) and HRC ($P < 0.05$; Table 5). The dressing percentage at 108 days was not influenced by the genotype assessed ($P > 0.05$), while its higher value was found in males compared to females (60.8% vs 59.5%, respectively;

https://doi.org/10.17221/192/2020-CJAS

Table 2. Live weight and average daily gain of rabbits depending on the genotype and sex in particular periods of fattening (means ± SEM)

Item (g)	Genotype				*P*-values		
	HYLA		MS × HYLA		genotype	sex	genotype × sex
	M	F	M	F			
Rabbits housed	56	56	56	56			
Live weight							
At 35 day	929 ± 27.7[a,b]	1 007 ± 32.7[a]	986 ± 24.2[a,b]	897 ± 37.5[b]	0.400	0.861	0.008
At 49 day	1 317 ± 22.8	1 327 ± 23.8	1 275 ± 33.4	1 133 ± 38.9	< 0.001	0.027	0.213
At 63 day	1 756 ± 39.1	1 672 ± 45.7	1 599 ± 43.7	1 474 ± 40.7	< 0.001	0.018	0.847
At 77 day	2 246 ± 38.5	2 256 ± 43.9	2 376 ± 40.3	2 209 ± 57.9	0.343	0.090	0.087
At 91 day	2 632 ± 63.2	2 679 ± 65.6	2 741 ± 46.1	2 689 ± 58.0	0.316	0.981	0.494
At 108 day	2 937 ± 54.9	2 984 ± 54.2	3 056 ± 52.7	3 101 ± 62.9	0.037	0.437	0.672
ADG							
35 to 49 day	29.8 ± 2.67	24.5 ± 2.51	21.6 ± 2.34	18.8 ± 2.31	< 0.001	0.029	0.201
50 to 63 day	33.9 ± 2.69	27.2 ± 2.72	23.5 ± 2.14	22.7 ± 2.46	0.003	0.130	0.580
64 to 77 day	38.0 ± 3.31	43.9 ± 2.99	59.1 ± 3.22	56.3 ± 3.82	< 0.001	0.642	0.226
78 to 91 day	30.1 ± 3.19	32.7 ± 3.03	28.1 ± 1.42	36.4 ± 3.80	0.789	0.066	0.400
92 to 108 day	19.2 ± 1.21	19.1 ± 1.65	21.7 ± 1.24	25.5 ± 1.19	0.002	0.195	0.362

DG = average daily gain; F = female; M = male; MS = Mecklenburger Schecke
[a,b]Means within a row with different superscript letters differ at $P < 0.05$

Table 3. Feed conversion ratio of rabbits depending on the genotype in particular periods of fattening (means ± SEM)

FCR (g/g)	Genotype		*P*-value
	HYLA	MS × HYLA	
Rabbits housed	56	56	
Experimental period			
35 to 49 day	3.31 ± 0.197	4.24 ± 0.285	0.037
50 to 63 day	4.36 ± 0.257	4.02 ± 0.255	0.384
64 to 77 day	4.13 ± 0.234	3.14 ± 0.206	0.019
78 to 91 day	5.74 ± 0.253	5.77 ± 0.267	0.938
92 to 108 day	9.33 ± 0.290	9.52 ± 0.314	0.672
35 to 108 day	5.44 ± 0.218	5.52 ± 0.297	0.641

FCR = feed conversion ratio; MS = Mecklenburger Schecke

Table 4. Mortality of rabbits depending on the genotype and sex in particular periods of fattening

Item (*n*)	Genotype		Sex		*P*-values	
	HYLA	MS × HYLA	M	F	genotype	sex
Rabbits housed	56	56	56	56		
Experimental period						
35 to 49 day	1	3	2	2	0.326	1.000
50 to 63 day	1	7	2	6	0.036	0.172
64 to 77 day	5	4	4	5	0.929	0.664
78 to 91 day	1	1	1	1	0.914	0.939
92 to 108 day	0	4	2	2	0.035	0.912
35 to 108 day	8	19	11	16	0.057	0.387

F = female; M = male; MS = Mecklenburger Schecke

$P < 0.05$). Concerning yields of the respective body components from the SW, rabbits of the T group showed higher proportions of skin and perirenal fat and lower proportions of head and liver compared to rabbits of the C group ($P < 0.001$). Besides that, the females within both genotypes showed lower proportions of skin ($P < 0.05$) and head ($P < 0.001$) and higher proportion of liver ($P < 0.001$) compared to the males. Also, a significant effect of genotype × sex interaction on the proportion of head was found ($P < 0.001$). Regarding yields of the respective carcass components from the weight of HRC, rabbits of the C group showed higher proportions of hind part ($P < 0.001$) and lower proportions of fore part ($P < 0.01$) and intermediate part ($P < 0.01$) compared to rabbits of the T group. Yields of hind leg meat and MLTL from the weight of HRC were not influenced by either genotype or sex ($P > 0.05$); however, a significant effect of genotype × sex interaction on the proportion of MLTL was found out ($P < 0.01$).

https://doi.org/10.17221/192/2020-CJAS

Table 5. Body and carcass characteristics of 108-day-old rabbits depending on the genotype and sex (means ± SEM)

Trait	Genotype				*P*-values		
	HYLA		MS × HYLA		genotype	sex	genotype × sex
	M	F	M	F			
Rabbits slaughtered	15	15	15	15			
Slaughter weight (SW) (g)	2 877 ± 71.3	3 010 ± 66.6	3 131 ± 56.6	3 102 ± 62.9	0.009	0.427	0.215
Hot carcass (HC) (g)	1 742 ± 50.7	1 771 ± 55.2	1 913 ± 37.3	1 865 ± 37.5	0.006	0.838	0.403
Hot reference carcass (HRC) (g)	1 587 ± 47.0	1 600 ± 51.5	1 725 ± 35.4	1 683 ± 31.7	0.011	0.729	0.514
Dressing-out (% of SW)	60.5 ± 0.74	58.8 ± 0.67	61.1 ± 0.47	60.1 ± 0.21	0.077	0.016	0.446
Skin (% of SW)	10.2 ± 0.25	9.9 ± 0.21	12.9 ± 0.19	12.0 ± 0.32	< 0.001	0.016	0.186
Head (% of SW)	4.4 ± 0.06^{A}	4.0 ± 0.05^{B}	4.0 ± 0.06^{B}	4.0 ± 0.05^{B}	< 0.001	< 0.001	< 0.001
Heart (% of SW)	0.3 ± 0.01	0.2 ± 0.01	0.2 ± 0.01	0.2 ± 0.01	0.119	0.128	0.152
Liver (% of SW)	2.5 ± 0.07	2.9 ± 0.11	2.2 ± 0.05	2.5 ± 0.06	< 0.001	< 0.001	0.627
Kidneys (% of SW)	0.6 ± 0.02	0.5 ± 0.02	0.6 ± 0.01	0.6 ± 0.02	0.260	0.702	0.228
Perirenal fat (% of SW)	0.5 ± 0.09	0.5 ± 0.09	1.3 ± 0.10	1.1 ± 0.09	< 0.001	0.319	0.306
Fore part (% of HRC)	35.9 ± 0.33	35.2 ± 0.17	36.4 ± 0.29	36.3 ± 0.28	0.005	0.127	0.204
Intermediate part (% of HRC)	21.9 ± 0.37	23.1 ± 0.26	23.8 ± 0.27	23.7 ± 0.52	0.001	0.138	0.075
Hind part (% of HRC)	33.8 ± 0.21	33.9 ± 0.18	32.7 ± 0.18	32.9 ± 0.20	< 0.001	0.406	0.686
Hind legs meat (% of HRC)	23.9 ± 0.17	24.1 ± 0.13	23.7 ± 0.17	24.0 ± 0.20	0.476	0.189	0.727
MLTL (% of HRC)	13.3 ± 0.19^{b}	13.8 ± 0.29^{a,b}	14.0 ± 0.22^{a}	13.4 ± 0.13^{a,b}	0.478	0.859	0.005
DL (cm)	30.7 ± 0.29	31.2 ± 0.30	28.8 ± 0.18	29.7 ± 0.30	< 0.001	0.012	0.505
TL (cm)	10.7 ± 0.13	10.8 ± 0.14	10.3 ± 0.10	10.2 ± 0.12	< 0.001	0.954	0.464
LCL (cm)	18.2 ± 0.33	17.9 ± 0.35	17.8 ± 0.26	17.3 ± 0.14	0.083	0.163	0.632
LTCR	2.28 ± 0.033	2.35 ± 0.031	2.20 ± 0.028	2.31 ± 0.017	0.019	0.003	0.471

DL = dorsal length; F = female; LCL = lumbar circumference length; LTCR = length to circumference ratio; M = male; MLTL = *m. longissimus thoracis et lumborum*; MS = Mecklenburger Schecke; TL = thigh length
^{a,b}Means within a row with different superscript letters differ at $P < 0.05$; ^{A,B}Means within a row with different superscript letters differ at $P < 0.01$

As for linear measurements of a rabbit carcass (Table 5), rabbits in the C group showed the longer DL and TL compared to rabbits in the C group ($P < 0.001$) and this resulted in a higher value for LTCR in HYLA rabbits ($P < 0.05$). In addition, slaughtered rabbit females had the longer DL ($P < 0.05$) and higher value for LTCR ($P < 0.01$) as compared to males.

DISCUSSION

Growth performance

Because the weaning LW of rabbits was considerably influenced by the genotype × sex interaction, this initial LW was used as a covariate in a statistical model to evaluate both assessed effects on the following LW and ADG. When compared to HYLA rabbits of the C group, MS sired rabbits of the T group had lower LW at 49 and 63 days of age. However, MS sired rabbits achieved a higher final LW than HYLA rabbits at the end of fattening. The weaning LW of HYLA rabbits in the present study was slightly lower than that reported by Martins et al. (2018) in the same HYLA rabbits weaned at the same age (1 027 g to 1 067 g). The achieved LWs of both rabbit genotypes at the age of 91 days in the present study met the current market requirements in the Czech Republic more than those observed at 77 days. Rabbits in the present study received diets that contained neither synthetic allopathic veterinary drugs nor synthetic anticoccidial drugs, and this could lead to rather a lower growth rate of rabbits in the course of the entire fattening period. In addition, females of the present study showed lower LW as compared to males at 49 and 63 days of age. Growth rate of rabbits in the present study

https://doi.org/10.17221/192/2020-CJAS

was influenced by both the genotype and the sex. The tested MS sired offspring showed lower growth intensity from weaning to 63 days of age, whereas, thereafter they achieved its considerably higher level from 64 to 77 days and from 92 to 108 days of age as compared to HYLA rabbits. Modern lines of meat-type rabbits have been bred for earliness in growth, which results in a younger slaughter age caused by the high growth intensity mainly in the post-weaning period; it was confirmed also in the present study. The highest growth intensity in both rabbit genotypes of the present study was reached in the period of 64 to 77 days of age, while its considerably higher level was observed in MS sired offspring, which resulted in the equalization of LW values in both rabbit genotypes at 77 days of age.

In the present study, the performed crossing led to the higher FCR value of the tested MS sired rabbits compared to HYLA broiler rabbits in the C group from weaning to 49 days of age, whereas, on the contrary, the favourably lower FCR value was found in the MS sired rabbits in the period of 64 to 77 days of age. The lower FCR values and the higher ADG values were confirmed in the above-mentioned periods. For the entire monitored period, there was no difference in FCR values between both rabbit genotypes assessed; these values are higher than those found by Stastnik et al. (2019) in the HYLA rabbits fattened for 103 days (4.30 g/g). It can be concluded that in terms of prolonged fattening in the present study, the tested MS sired rabbits showed the promising results of growth performance.

Mortality

The performed crossing of a commercial dam line of HYLA rabbits with MS males in the present study resulted in an unfavourable higher mortality rate of MS sired offspring compared with commercial HYLA broiler rabbits for the entire monitored period ($P = 0.057$); the tested MS sired rabbits showed significantly higher mortality in the period of 50 to 63 days and of 92 to 108 days of age. The highest mortality in the present study occurred from 50 to 77 days of age, while these findings are similar to those reported by Szendro et al. (2008; 2010), who found the mortality peak in fattened rabbits at the age of 42 to 56 days and of 64 to 77 days, respectively. The mortality rate of fattened rabbits on commercial farms may sometimes be rather high, ranging from 3.5% to 25% (Szendro et al. 2008; 2010); sometimes, the mortality of fattened rabbits even exceeds this range (Martins et al. 2018). It follows from the present study that the use of MS males that originated from a few small-scale hobby stocks where breeders did not select breeding rabbits intentionally for disease resistance led to the higher mortality of their offspring in the environment of an intensive commercial farm respecting some rules for organic production (e.g. strict restriction of medications). So, in this respect, the performed crossing cannot be recommended to supply rabbit offspring that would be fattened intentionally on commercial farms under intensive production conditions, mainly if high pathogen loads are expected in the environment. For this purpose, deliberate selection of the MS breed for higher disease resistance would be necessary at first. Concerning the production of commercial broiler rabbits, the targeted breeding for higher disease resistance has recently begun in the sire and dam lines of the selection nucleus. Selecting rabbits for general disease resistance based on the simple visual assessment of the presence of infectious diseases seems to be very promising, while this breeding approach may enhance the immune response of rabbits; Gunia et al. (2015) proved that simple health records, measured once on growing rabbits of the selection nucleus, can be used to improve disease resistance. However, disease resistance mechanisms are often pathogen-specific, while tolerance mechanisms that prevent or repair damage can be rather host- than pathogen-specific, and therefore they can offer general protection for a range of pathogens. Gunia et al. (2018) proved the improvement in both tolerance and resistance to diseases caused by selecting rabbits with a more efficient innate immune response. Lowering of the disease prevalence through selection for the host resistance can be expected at the level of 4% to 6% per generation. As for non-specific disease resistance of rabbits, the biological mechanisms underlying this resistance are not yet fully understood, whereas the commensal microflora in the rabbit caecum and appendix seems to be a key regulator in developing and maintaining the common immune function (Gunia et al. 2018; Zhao et al. 2020) by a direct interaction with the lymphocyte function (Kooij et al. 2016). Besides that, respiratory syndromes were revealed as the most frequent cause of rabbit mortality in the present study. According

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to Gunia et al. (2018) these syndromes in rabbits are caused mainly by *Pasteurella multocida*.

Slaughter traits

As for the body and carcass composition of rabbits in the present study, 108-day-old MS sired rabbits compared with commercial HYLA rabbits showed the higher SW and HRC, and higher proportions of skin, perirenal fat and carcass fore and intermediate parts. On the contrary, HYLA rabbits had the higher proportions of head, liver and carcass hind part. Values of SW and carcass weight of MS sired rabbits in the present study are considerably higher than those reported by Dalle Zotte and Paci (2014) in the 112-day-old Vienna Blue and Burgundy Fawn sired rabbit crossbreds fattened under an organic production system. Moreover, Szendro et al. (2010) found a sire effect on the liver proportion within 5 rabbit genotypes fattened for 77 days, which is in agreement with the finding of the present study. The performed crossing in the present study led to a twofold increase in the perirenal fat content of the tested MS sired rabbits, who exhibited a considerably higher ability to deposit adipose tissue in the body of MS sired rabbits compared to HYLA rabbits. This finding is not in agreement with the results of studies conducted by Szendro et al. (2010), Chodova et al. (2014) and Dalle Zotte and Paci (2014), in which the rabbit genotype did not influence the amounts of perirenal fat. In addition, the females of the present study had lower proportions of skin and head and a higher proportion of liver compared to the males.

Concerning yields of assessed carcass components, findings indicate that 108-day-old MS sired rabbits of the present study showed the less developed carcass hind part in comparison with the other parts of the carcass compared with HYLA rabbits that have been selected intentionally for higher meatiness over generations. However, there was no difference in the yield of hind leg meat between the assessed genotypes, which proves acceptable meatiness of hind legs in the tested MS sired rabbits at this age. The dressing percentage (HCW/SW) was affected only by the rabbit sex, while males displayed its favourable level compared to females, which is not in agreement with the finding of Dalle Zotte and Paci (2014). In addition, values for the dressing percentage in the present study are similar to those found by Volek et al. (2014) in the Czech White rabbit breed at the age of 89 days and also by Uhlirova et al. (2018) in Hyplus broiler rabbits at 73 days of age. However, the dressing percentage of HYLA rabbits in the present study was slightly lower than that reported by Stastnik et al. (2019).

Regarding linear measurements of the rabbit carcass in the present study, the tested MS sired rabbits had a shorter carcass length, which resulted in a lower value of the LTCR compared to HYLA rabbits, and thus the MS sired rabbits had better carcass conformation. Pla et al. (1996) proved that the carcass compactness that influences its market acceptance is substantially affected by the rabbit genotype, which is in agreement with the finding of the present study. The LTCR values in the present study were slightly lower than those reported by Molina et al. (2018) in 87-day-old New Zealand White rabbits. In addition, Molina et al. (2018) stated that if rabbits are fed balanced diets, the compactness of their carcasses is affected only by the genotype, rearing system and management. However, in the present study, the sex of rabbits had a substantial effect on the LTCR values, while females showed its less favourable value compared with males (2.33 vs 2.24, respectively), mainly due to the longer dorsal length.

CONCLUSION

The crossing of MS males with the maternal line of HYLA females led to acceptable growth performance and favourable meat production in the MS sired rabbits slaughtered at 108 days of age. In this regard, MS males appear to be potential seedstock sires for rabbit crossbreeding, while MS sires also pass the spotted or dark coloured fur to their offspring. However, since considerably higher mortality was found in the tested MS sired rabbits during fattening, it is not possible to recommend the MS breed as a common sire line used under conditions of intensive rabbit farming at this moment. For this purpose, it is necessary to select the MS breed deliberately for higher disease resistance at first.

Regarding the sex of rabbits, females showed lower LW at 49 and 63 days of age compared to males. When compared to males, slaughtered females had a higher proportion of liver and a lower dressing percentage associated with the worse carcass compactness.

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Conflict of interest

The authors declare no conflict of interest.

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