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Effect of housing system and breed on growth, slaughter traits and meat quality traits in rabbits

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The aim of the study was to determine the effect of housing conditions and breed on the growth, slaughter traits and meat quality traits of Blanc de Termonde (n=34; 15♂, 19♀) and Popielno White (n=28; 15♂, 13♀) rabbits. Until weaning at 35 days of age the young rabbits were kept with their mothers in wooden hutches. After weaning they were divided into two groups. Rabbits from group I (n=42; 21♂ and 21♀) were kept two per cage in a battery system. Each cage was 40 cm wide, 90 cm long and 35 cm high. Animals from group II (n=20; 8♂ and 12♀) were kept in boxes with dimensions of 100 x 100 x 100 cm, on deep litter. Four or five rabbits were kept in each box, with males and females separated. The rabbits were feed pellets *ad libitum*. They were weighed weekly from birth to 12 weeks of age. Slaughter and dissection were performed at 12 weeks of age. At 45 min after slaughter the pH in the longissimus lumborum and biceps femoris muscles was measured, as well as the colour (L*, a*, b*). In the case of growth and slaughter traits, significant differences between housing systems were observed, but the housing systems was not found to significantly influence the dressing percentage or meat quality traits. Breed did not significantly influence body weight (except for litter weight at birth), slaughter traits, or meat quality traits.

KEY WORDS: rabbit / housing system / slaughter traits / meat quality traits

The rabbit is a livestock species. Rabbits are used for multiple purposes; they provide fur, wool and meat, are used for experimental purposes, and are kept in homes as pets – especially miniature varieties. Currently, however, their main use is meat production. Rabbit meat is steadily gaining popularity, as it is lean, easily digestible and nutritious. It has high content of digestible complete protein (about 90%), high content of essential amino acids (EAA), and low cholesterol content [2], which gives rabbit meat a high position in a balanced diet.

Rabbit breeding is currently carried out by amateurs and hobbyists, who operate on a small scale, as well on large-scale farms specializing in the production of broiler rabbits.

Rabbits on amateur farms are usually kept on litter, in cages placed outdoors or indoors, and less often in boxes on deep litter. On large farms, rabbits are raised without litter, in one-, two- or three-storey cages, equipped with a water supply and feeders [1].

The choice of a breed of rabbits for meat production should take into account a number of factors, especially early sexual maturity, high fecundity and fertility, and a fast growth rate [10]. In addition to characteristics of live animals, attention should be paid to carcass traits such as low fat content and good musculature, dressing percentage, and the share of individual cuts in the carcass [4]. All these conditions are met by medium-sized rabbit breeds, of which New Zealand White, Californian, Blanc de Termonde and Popielno White are the most commonly raised in Poland [1].

In addition to selecting a breed, it is important to provide the animals appropriate environmental conditions. Rabbits require housing with suitable conditions for growth, development and reproduction. Because they are resistant to cold, able to withstand temperatures as low as −20°C, they can be kept outside all year round. However, they do not tolerate high temperatures well and avoid direct sunlight, so they should be protected against overheating, as well as against draughts and moisture. If the rabbits are kept in a system without litter, the female should be provided with a nesting box with litter she can use to build a nest [9]. Cages and boxes should be easy to clean and disinfect, and their design and manner of execution should facilitate observation and feeding of the animals. In addition, they should be constructed in such a way that removing the animals from them does not cause them pain or injury [2]. The size of boxes and cages should be adjusted to existing standards.

The aim of the research was to determine the effect of housing conditions in different rearing systems on the growth, slaughter performance and meat quality of Blanc de Termonde and Popielno White rabbits.

Material and methods

The study was conducted on rabbits of the breeds Blanc de Termonde – TB (n = 34; 15♂, 19♀) and Popielno White – PB (n = 28; 15♂, 13♀). Until weaning at 35 days of age, the young rabbits were housed with their mothers in wooden hutches in a building with a water supply (nipple drinkers), lighting (14L:10D), and forced ventilation.

The rabbits of both breeds were divided into two experimental groups. The rabbits in group I (n = 42, 22♂ and 20♀, 22 PB and 20 TB) were reared in a battery system with two rabbits per cage. The dimensions of a single cage were 40 cm x 90 cm x 35 cm (width x length x height). The group II animals (n = 20, 8♂ and 12♀, 6 PB and 14 TB) were reared in boxes with floor dimensions of 100 cm x 100 cm and a height of 100 cm, on deep litter, with 4–5 animals per box, divided according to sex. The animals in both groups were fed a commercial complete pelleted feed ad libitum. The pellets contained 10.2 MJ metabolic energy, 14% digestible fibre and 16.5% crude protein.

The pre-slaughter traits tested included the weight of the entire litter from birth to 24 h and at the age of one week; the weight was divided by the number of kits in the litter. The rabbits were weighed individually from week 2 to week 12, on the last working day of the week.

The rabbits were slaughtered between the ages of 83 and 90 days, following 24 h fasting with uninterrupted access to water. The animals were stunned, bled and skinned, and then the carcasses were eviscerated and cooled for 24 h at 4°C. Next, the carcasses were divided into three cuts – the anterior part, loin and rear part, which were subjected to detailed dissection. The slaughter traits evaluated were body weight before slaughter, cold and hot carcass weight, weight of the loin and the anterior and rear parts, and the weight of meat, bone and fat in individual carcass cuts. In addition, the hot and cold dressing percentages were calculated using equations proposed by Bieniek [5] and Blasco [6]:

$$\text{DP 1} = \frac{\textit{carcass weight after slaughter without head and organs}}{\textit{pre-slaughter weight of animal}} * 100\%$$

$$\text{DP 2} = \frac{\textit{cold carcass weight}}{\textit{pre-slaughter weight of animal}} * 100\%$$

The pH of the longissimus lumborum and biceps femoris muscles was measured at 45 minutes and at 24 hours after slaughter. The measurements were made with a Consort C561 pH meter, accurate to within 0.01. At the same time, the colour (L* – lightness, a** – red component, and b** – yellow component) was measured with a Minolta CR-410 colorimeter (Minolta Co. Ltd., Osaka, Japan).

Statistical analysis was performed with the SAS statistical package [12], using PROC MIXED. The model included fixed effects, i.e. housing system, breed, and the interaction between housing system and breed. The significance of differences between means was determined using the Tukey-Kramer test. The analysis was performed at a significance level of $p \leq 0.05$.

Results and discussion

There was no significant interaction ($p \leq 0.05$) between the housing system and the rabbit breed. There were no significant differences between males and females for any of the traits analysed, so the results of the experiment are presented in the tables without reference to sex.

There were significant differences ($p \leq 0.05$) in the body weight of rabbits at birth and in the first week of rearing, but they were due to the number of kits in the litter, not their body weight. The housing system significantly affected body weight from 6 to 12 weeks of rearing. No significant differences were observed in the period during which the animals

stayed with their mothers (weeks 2–5 of rearing). Rabbits housed in the battery system attained higher weight gains than those raised in boxes. The animals kept in the battery system reached a final weight 445 g higher than that of animals reared in boxes. The breed influenced only the weight of the rabbits at birth and in the first week of rearing. These differences were also the result of the number of young born in the litter, not their body weight (Table 1).

Table 1
Effect of housing system and breed on body weight of rabbits ($\bar{x}$ ±SD)

Body weight (g)	Housing system		Breed	
	battery n=42	box n=20	PB n=28	TB n=34
At birth	71^{a} ±8	61^{b} ±4	64^{a} ±4	72^{b} ±9
Age (in weeks)				
1	168^{a} ±18	127^{b} ±27	156 ±26	155 ±30
2	265 ±30	247 ±36	248 ±24	268 ±36
3	367 ±53	349 ±77	338 ±51	381 ±63
4	630 ±91	516 ±125	575 ±68	609 ±141
5	913 ±94	792 ±154	866 ±81	883 ±157
6	1201^{a} ±109	998^{b} ±161	1135 ±109	1140 ±190
7	1468^{a} ±135	1263^{b} ±169	1406 ±149	1403 ±194
8	1723^{a} ±146	1512^{b} ±179	1658 ±166	1657 ±200
9	2013^{a} ±191	1701^{b} ±210	1968 ±233	1875 ±247
10	2276^{a} ±176	1974^{b} ±226	2216 ±169	2156 ±280
11	2576^{a} ±235	2231^{b} ±220	2574 ±255	2385 ±273
12	2798^{a} ±253	2353^{b} ±260	2752 ±299	2586 ±335

PB – Popielno White
TB – Blanc de Termonde
a, b – mean values in the same row with different letters differ significantly at $p \leq 0.05$

Bielański and Pankowski [3], in a study on the effect of the housing system on the body weight of Popielno White rabbits, showed that rabbits housed in single-storey cages weighed 511.2 g in the 5th week of rearing, 1348.7 g in week 8, 1878.5 g in week 10, 2608.9 g in week 11, and 2992.4 g in week 12. Similar results were obtained by Pinheiro et al. [11] in a study on the effect of the housing system on the growth parameters and carcass quality of crossbred New Zealand White x Californian rabbits. The authors reported that on day 87, the body weight of rabbits kept in open-air pens was on average 2705 g, as compared to 3062 g in a standard cage system.

The rearing system had a significant effect on the final weight of the animals at slaughter and on the hot and cold carcass weights (Table 2). The body weight at slaughter of rabbits kept in the battery system was about 551 g greater than that of animals reared in boxes. The hot carcass weight of animals kept in the battery system was on average 1538.95 g, while that of animals reared in boxes was 1221.37 g. The cold carcass weight of rabbits from the two housing systems was 1484.52 g and 1183.63 g, respectively. The breed was not found to significantly ($p \leq 0.05$) affect body weight at slaughter or the hot or cold carcass weight.

Dalle Zotte et al. [8] showed that the body weight at slaughter (2590 g), hot carcass weight (1564 g) and cold carcass weight (1510 g) of white Pannonian rabbits kept in cages were significantly higher ($p \leq 0.05$) than in the case of rabbits kept in a box system, for which the corresponding values were 2531 g, 1531 g, and 1483 g. Similarly, Pinheiro et al. [11] found that the slaughter weight of rabbits kept in open-air pens was lower than that of caged rabbits, with values of 2717 g and 3091 g, respectively, and the corresponding cold carcass weights were 1333 g and 1490 g.

The statistical analysis showed significant differences in the weight of individual carcass cuts of rabbits from the two rearing systems, which is linked to the higher body slaughter weight attained by the rabbits from the battery system, described above. The values for individual features are as follows: weight of anterior part of carcass – 639.60 g (battery system) and 486.74 g (box); weight of loin – 304.81 g (battery system) and 240.47 g (box); weight of rear part – 540.12 g (battery system) and 456.42 g (box). The breed did not significantly ($p \leq 0.05$) affect these cuts. The mean weights of the front part, loin and rear part of the two breeds (Blanc de Termonde and Popielno White) were similar (Table 2).

The housing system significantly influenced the meat and bone weight and the fat weight in the anterior part of the carcass. The weight of the meat and bone in this part of the carcass was 610.83 g for rabbits from the battery system and 480.16 g for the box system, a difference of over 130 g. It is worth noting the pronounced difference in fat weight in the anterior part of the carcass, with values of 28.76 g and 6.58 g for the battery system and boxes, respectively (Table 2). The differences in the muscle and fat content of rabbits kept in different systems are probably due to the limited movement of animals kept in the battery system.

Significant differences ($p \leq 0.05$) were found in the weight of the meat and fat in the loin of the rabbits reared in the two systems. The average weight of the loin meat was 242.95 g in rabbits from the battery system and 198.63 g for the box system, a difference of about 44 g. The weight of the loin fat of animals from the battery system and boxes was 25.40 g and 8.42 g, respectively. There were no significant differences ($p \leq 0.05$) in the weight of the loin bone between the animals reared in the two systems. The rabbits of the two breeds did not differ significantly ($p \leq 0.05$) in terms of the weight of meat, bone and fat in the loin (Table 2).

The average meat weight in the rear part of the carcasses of rabbits from the battery system was 416.50 g, which was significantly different from the corresponding value for animals reared in boxes (349.26 g). There were no significant differences ($p \leq 0.05$) in the bone

Table 2
Effect of housing system and breed on slaughter traits in rabbits ($\bar{x}$ ±SD)

Slaughter traits	Housing system		Breed	
	battery n=42	box n=20	PB n=28	TB n=34
Weight (g):				
at slaughter	2875.12[a] ±280.61	2323.68[b] ±243.44	2741.48 ±334.35	2673.09 ±400.55
hot carcass	1538.95[a] ±153.22	1221.37[b] ±162.70	1446.30 ±167.27	1435.06 ±247.97
cold carcass	1484.52[a] ±151.79	1183.63[b] ±159.49	1391.22 ±158.79	1390.47 ±241.92
anterior part	639.60[a] ±78.26	486.74[b] ±65.72	592.89 ±85.05	591.26 ±116.30
loin	304.81[a] ±36.21	240.47[b] ±40.73	286.19 ±35.61	283.65 ±56.32
rear part	540.12[a] ±49.26	456.42[b] ±56.36	512.15 ±51.08	515.56 ±73.91
Content (g):				
meat and bones in anterior part	610.83[a] ±71.03	480.16[b] ±62.74	569.00 ±74.60	571.03 ±103.92
fat in anterior part	28.76[a] ±12.40	6.58[b] ±4.86	23.89 ±13.35	20.24 ±15.88
meat in loin	242.95[a] ±25.08	198.63[b] ±34.04	231.44 ±24.34	227.32 ±41.45
bones in loin	36.45 ±7.44	33.42 ±5.68	32.85 ±6.29	37.62 ±6.96
fat in loin	25.40[a] ±11.49	8.42[b] ±4.78	21.89 ±12.63	18.71 ±12.67
meat in rear part	416.50[a] ±42.48	349.26[b] ±43.53	395.78 ±45.11	395.38 ±58.86
bones in rear part	120.17 ±13.60	106.37 ±19.48	113.37 ±13.01	117.85 ±19.23
fat in rear part	3.45 ±3.24	0.79 ±1.08	3.00 ±2.65	2.32 ±3.28
Dressing percentage (%)				
DP 1	53.55 ±2.04	52.55 ±2.02	52.81 ±1.71	53.50 ±2.31
DP 2	51.64 ±1.99	50.93 ±2.03	50.81 ±1.70	51.83 ±2.14

PB – Popielno White
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a, b – mean values in the same row with different letters differ significantly at $p \leq 0.05$

and fat weight of the rear part of the carcasses from the two systems. The weight of the meat, bones and fat in the posterior part of the rabbits of both breeds was similar (Table 2).

Comparison of our results with those reported by Bielański and Pankowski [3] showed lower weight of the loin and its components (meat, bones and fat) as well as lower fat weight of the front and rear parts. The weight of the front and rear parts of the carcasses was higher in our research, as was the meat and bone weight in the anterior part and in the posterior part compared to the results obtained by Bielański and Pankowski [3].

An experiment conducted by Dalle Zotte et al. [8] found no significant differences in the percentage content of the anterior part, loin and rear part of the carcass or in the fat content in the carcasses of rabbits kept in cages and boxes. Pinheiro et al. [11] showed that the fat content in the carcasses of rabbits kept in open-air pens (1.66%) was lower than in the carcasses of rabbits from the standard cage system (5.29%).

The housing system and the breed had no significant effect on the hot and cold dressing percentage (Table 2). Our results are consistent with those reported by Bielański and Pankowski [3], who observed no significant differences in the dressing percentage of rabbits kept indoors and in open-air cages. Pinheiro et al. [11] came to similar conclusions, after observing no significant differences in the dressing percentage of rabbits kept in these two systems.

The last group of traits analysed was meat quality traits, i.e. its acidity and colour. The housing system and breed did not affect the acidity of the longissimus lumborum or biceps femoris muscle at 45 minutes or 24 hours after slaughter. There were no significant differences in the lightness of the colour or in the red and yellow components of the muscles depending on the housing system or breed (Table 3 and 4).

Table 3
Effect of housing system and breed on meat acidity ($\bar{x}$ ±SD)

Acidity	Housing system		Breed	
	battery n=42	box n=20	PB n=28	TB n=34
m. biceps femoris				
pH_{45}	6.73 ±0.26	6.86 ±0.35	6.73 ±0.26	6.80 ±0.32
pH_{24}	6.00 ±0.14	6.08 ±0.14	5.93 ±0.07	6.10 ±0.15
m. longissimus lumborum				
pH_{45}	6.81 ±0.27	6.92 ±0.32	6.90 ±0.20	6.79 ±0.34
pH_{24}	5.88 ±0.17	5.92 ±0.07	5.80 ±0.09	5.97 ±0.14

PB – Popielno White
TB – Blanc de Termonde
a, b – mean values in the same row with different letters differ significantly at $p \leq 0.05$

Table 4
Effect of housing system and breed on meat colour ($\bar{x}$ ±SD)

Colour	Housing system		Breed	
	battery n=42	box n=20	PB n=28	TB n=34
m. biceps femoris				
L^*_{45}	53.17 ±3,29	53.11 ±3.34	53.14 ±3.39	53.16 ±3.24
a^*_{45}	2.38 ±0.96	2.67 ±1.25	1.95 ±0.85	2.89 ±1.03
b^*_{45}	–0.86 ±1.40	0.01 ±1.21	–0.82 ±1.55	–0.40 ±1.25
L^*_{24}	57.55 ±1.99	57.68 ±1.88	57.75 ±1.24	57.46 ±2.37
a^*_{24}	3.38 ±1.13	3.63 ±1.11	3.25 ±1.05	3.63 ±1.16
b^*_{24}	2.64 ±1.49	3.41 ±0.71	3.25 ±0.91	2.58 ±1.56
m. longissimus lumborum				
L^*_{45}	59.35 ±4.26	60.66 ±4.55	58.31 ±4.03	60.91 ±4.32
a^*_{45}	1.86 ±3.04	1.34 ±2.95	3.78 ±2.96	0.05 ±1.77
b^*_{45}	–0.81 ±3.72	–4.19 ±4.41	1.03 ±3.47	–4.16 ±3.25
L^*_{24}	57.43 ±3.46	57.31 ±1.95	57.87 ±1.86	57.01 ±3.73
a^*_{24}	4.55 ±1.58	4.31 ±1.01	4.39 ±1.31	4.54 ±1.52
b^*_{24}	1.78 ±2.07	1.77 ±1.28	2.42 ±1.55	1.26 ±1.93

PB – Popielno White
TB – Blanc de Termonde
a, b – mean values in the same row with different letters differ significantly at $p \leq 0.05$

In a study by Chwastowska-Siwiecka et al. [7], in which Californian and New Zealand White rabbits were kept on deep litter in the open air, the pH of the Californian rabbits measured 45 minutes and 24 hours after slaughter was 6.76 and 5.9, respectively, while that of the femoral muscles of New Zealand White rabbits was 6.79 and 5.97. Dalle Zotte et al. [8] found that the rabbit housing system affected the pH of the biceps femoris muscle and the colour parameters of both the longissimus lumborum and biceps femoris. The acidity of the biceps femoris of rabbits kept in a cage system (5.65) was higher than for rabbits reared in a box system (5.58). The colour parameters of the longissimus lumborum muscle of rabbits kept in cages were L* = 54.80, a* = 7.67, b* = 3.87, compared to L* = 56.80, a* = 6.56 and b* = 2.99 for rabbits kept in boxes. The authors [8] found significant differences in the a* and b* parameters of the femoris biceps muscle. The meat of rabbits kept in cages had a red component of a* = 3.58 and a yellow component of b* = −0.01. The values of these parameters were higher than those obtained for rabbits kept in boxes. Pinheiro et al. [11] found that the housing system only affected the lightness of rabbit meat. The meat of rabbits kept in open-air pens (L* = 50.72) was darker than that of rabbits kept in cages (L* = 53.12).

The observations made during rearing showed that although the rabbits in both systems were fed identical diets, the weight gain in individual periods after weaning was highly varied. The lower weight gain in rabbits kept in boxes can be assumed to be due to housing of the animals in groups (4–5 animals) and the resulting hierarchy, which led to unequal access to feed. Furthermore, the larger area per rabbit enabled greater physical activity, resulting in energy losses. These observations inspire behavioural research aimed at determining the optimal area per rabbit in a box, which would meet welfare requirements while also minimizing energy losses.

Summing up, it can be concluded from the research that the breed of rabbit does not influence growth (from weeks 1 to 12) or slaughter performance. Rabbits kept in the battery system had faster growth from the moment of weaning and higher values for carcass parameters. The housing system and breed did not affect the acidity or colour of the meat, which means that the meat of Popielno White and Blanc de Termonde rabbits reared in different systems was equally suitable for processing. The study indicates that the effectiveness of rabbit rearing (body weight and daily weight gains) differs considerably in the battery system and the box system, which suggests the need for economic analyses to determine the costs of meat procurement.

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