ESTIMATION OF THE GENOTYPE × ENVIRONMENT INTERACTIONS IN THE BROILER RABBITS*

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The influence of the genotype × environment interactions of two HYPLUS broiler rabbits (n = 184) crossbreeds F_1 and F_2 were analyzed for the following traits: body weight, average daily gains, average daily feed consumption and feed conversion. The rabbits from multiple litters bought in the commercial farms were weaned at the age of 34–35 days. These animals were located in the test station or in the fattening farm. The broiler rabbits were fattened during the interval from 42 to 84 days of age. The genotype × environment interaction was analyzed using the linear model with fixed effect: crossbreeds, replication, environment and interaction genotype × environment. The results of this study suggested, that the average daily feed consumption and feed conversion of rabbits were influenced by genotype × environment interaction. The genotype × environment interaction had no significant effects on the growth performance of broiler rabbits. The results showed that the crossbreds F_1 are more suitable to meat production in the fattening farm.

rabbit; genotype × environment interaction; growth; feed conversion

INTRODUCTION

Currently, the annual world market for production of rabbit meat has been estimated to about 1,300,000 tons, 60% of the whole meat production is carried out on specialized farms (Mach et al., 2001). The broiler rabbits are mostly two and four way crossbreds. The knowledge of the growth and development patterns of defined genotype is the presumption of a successful profitable production of meat animals. When the fattening abilities of broiler rabbits are tested, non-existence of the genotype × environment interaction is assumed between test station and farm conditions; this means that the growth performance and adaptability of animals or hybrid lines are the same in all environmental conditions. The existence of the genotype × environment interaction is important for the optimum use of particular genotypes in different production and breeding systems. The interaction is defined as a change in the relative value of the performance of two or more genotypes in two or more different environments. When two different genotypes were compared, the magnitude and statistical significance of this interaction was related mainly to the distinctness of genotypes or environment. In fact, we can assume the existence of this interaction whenever two or more genotypes occur in two or more environments.

According to Lin and Togashi (2002), the definitions of genotype × environment interaction can be divided into breed × environment interaction (between-breed interaction), which was investigated, e.g., by Křížek et al. (1992), and Sandelin et al. (2002), and individual × environment interaction (within-breed interaction), which was studied, e.g., by De Mattos et al. (2000). The genotype × environment interaction was studied in the Czech Republic for sheep (Křížek et al., 1992), for beef production (Vostrý et al., 2008a). The performance of rabbit meat type (purebreds and crossbreds) were analyzed by Krogmeier and Dzapo (1991), Dědková et al. (2002) and Vostrý et al. (2008b, c). Gugolek et al. (2008) analyzed effect of onions and birch twigs on the welfare of intensively reared rabbits.

The objective of this paper was to test the possibility of genotype × environment interaction existence for the growth performance, average daily feed consumption and feed conversion of the HYPLUS broiler rabbits between the test stations and the fattening farms.

MATERIAL AND METHODS

The influence of the genotype × environment interaction of two crossbreeds F_1 (♂PS59 × ♀PS19) and F_2 [(♂PS59 ×♀PS19) × (♂PS59 ×♀PS19)] (further F_1, F_2) of the HYPLUS broiler rabbits was analyzed for the following traits: body weight, average daily gains, average daily feed consumption and feed conversion. The analysis was carried out in two independent experiments, on the whole 184 animals. The rabbits from multiple litters of commercial farms weaned at the age of 34–35 days were located in a wire cage in the Experimental and demonstration stable of the Czech University of Life Science (test station) (n = 83) or in the fattening farm (n = 101). The replicate fattening was carried out within the month. The traits were recorded at weekly intervals from 42 to 84 days

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Table 1. The composition of the experimental diet

Composition	g/kg
Dry matter	904
Crude protein	171
Fat	42
Crude roughage	156
Calcium	11.5
Phosphor	7.5
Salt (NaCl)	6
Natrium (converted)	2.4

of rabbit age. The rabbits were fed with identical granulated fattening mixture in the both environments. The content of nutrients per 1 kg feeding mixture is shown in Table 1. The rabbits had *ad libitum* access to feed and water.

Statistical analysis

The genotype × environment interaction was analyzed by the least-squares analysis using the GLM procedure (SAS, 2005). The following linear model was used:

$$y_{ijkl} = \mu + CROSS_i + REP_{ij} + ENV_k + (CROSS \times ENV)_{ik} + e_{ijkl}$$

where: y_{ijkl} – observation, μ – overall mean, $CROSS_i$ – fixed effect of the *i*-th crossbred, $REPL_{ij}$ – fixed effect of the *j*-th replication nested in the *i*-th crossbred, ENV_k – fixed effect of the *k*-th environment, $(CROSS \times ENV)_{ik}$ – fixed effect of the *ik*-th interaction genotype × environment, e_{ijkl} – random residual error

Differences between the least-squares means were tested at the significance level (error probability) of $P < 0.05$ (*), $P < 0.01$ (**) and $P < 0.001$ (***). The effect of sex was not included into the model due to the fact that the sex dimorphism was not proved yet in the growth of broiler rabbits (Krogmeier, Dzapo, 1991).

RESULTS AND DISCUSSION

Table 2 shows the least squares means (LSM) and standard errors (SE) for body weight and feed consumption of both hybrid lines in two different environmental conditions.

Analysis of the effects

Crossbreeds

From Table 2 it is evident that the difference between the crossbreeds was significant for the almost body weight, with the exception of body weight at 77 and 84 days of age. In the whole fattening period the crossbreeds F_1 showed a lower body weight. Higher body weight of F_2 crossbreeds could be caused by higher mass selection of F_2 parents. The animals with highest body weight were selected as parents of the F_2 generation. However, all animals of F_1 generation were included in the fattening.

From the results follows that the differences between the crossbreeds in the average daily gains were significant in the intervals: 42–49 days of age ($P < 0.05$), 56–63 days of age ($P < 0.001$) and 70–77 days of age ($P < 0.05$). The differences in the determined values were in favour of the crossbreeds F_1 in the intervals 56–63 days of age and 70–77 days of age. The results showed that the crossbreeds F_1 had a significantly lower average daily feed consumption than crossbreeds F_2 in the time intervals: 42–49 days of age, 49–56 days of age, 56–63 days of age and 63–70 days of age ($P < 0.0001$). On the contrary, the crossbreeds F_2 had a significantly average daily feed consumption in the interval 70–77 days of age ($P < 0.0001$).

The lower feed conversion was recorded for the crossbreeds F_1 in comparison with the crossbreeds F_2 at the age of 70–77 days ($P < 0.0001$). In the other intervals the differences were non-significant. The crossbreeds F_1 had a lower total feed consumption ($P < 0.0001$) and average feed conversion ($P < 0.0001$) in comparison with the crossbreeds F_2. The total gain differences in the crossbreds were non-significant during the whole fattening period. Similar results for the crossbreeds 59 × 19 found Dědková et al. (2002), Metzger et al. (2006) and Vostrý et al. (2008b, c).

Environment

Table 2 shows that the differences between the environment had almost non-significant effect to body weights, with the exception at the 77 and 84 days of age ($P < 0.01$ and $P < 0.05$ respectively). The higher body weight at the age of 77 and 84 days was found in animals located in the test station. The significant differences in the average daily gain were found in the animals placed in the different environments only at the intervals 42–49 and 56–63 days of age ($P < 0.05$). The average feed consumption was significantly different in animals located in the different environments during the whole test ($P < 0.0001$). Total average feed consumption and total feed conversion (for the whole fattening period) of animals located in different environments was different. This differences were highly significant ($P < 0.0001$). The lower total average feed consumption was recorded in the test station and, on the contrary, a lower total feed conversion was recorded in the fattening farm. The differences in the total average daily gain were non-significant.

Replications

No differences between replications were found for the all trait as it was mentioned by DeLeon et al. (2002) in their paper.

Genotype × environment interaction

Table 3 shows the least squares means (LSM) and standard errors (SE) estimated for values of body weight and average daily gains of both crossbreeds stabled in the different environment. Furthermore, the genotype × envi-

Table 2. Least squares means (LSM) and standard errors (SE) for the crossbred and environment

Trait	Crossbred				Significance	Environment				Significance
	F_1		F_2			Test stations		Fattening farm		
	n = 91		*n* = 93			*n* = 83		*n* =101		
	LSM	SE	LSM	SE		LSM	SE	LSM	SE	
BW 42	1182	18	1257	18	0.0036**	1230	19	1209	17	0.3848
BW 49	1472	21	1589	20	< 0.0001***	1555	21	1506	20	0.0899
BW 56	1705	22	1850	21	< 0.0001***	1804	22	1751	21	0.0847
BW 63	1976	27	2092	40	0.0178*	2074	28	1994	36	0.0697
BW 70	2298	30	2418	29	0.0045**	2381	30	2335	28	0.2655
BW 77	2540	28	2528	45	0.8075	2615	28	2452	47	0.0048**
BW 84	2688	28	2703	31	0.7323	2737	29	2654	28	0.0412*
ADG 42-49	43	2	47	2	0.0308*	48	2	43	2	0.0188*
ADG 49-56	35	1	38	1	0.1311	38	1	35	1	0.0981
ADG 56-63	40	1	33	2	0.0072**	39	2	33	2	0.0148*
ADG 63-70	45	2	44	2	0.7205	44	2	46	2	0.2819
ADG 70-77	31	1	30	2	0.0338*	34	1	30	2	0.1359
ADG 77-84	23	1	21	1	0.1748	20	1	23	1	0.0642
AFC42_49	140	3	166	3	< 0.0001***	135	3	172	2	< 0.0001***
AFC49_56	145	3	165	3	< 0.0001***	133	3	177	3	< 0.0001***
AFC56_63	166	3	181	3	0.0001***	164	3	183	3	< 0.0001***
AFC63_70	176	3	224	3	< 0.0001***	179	3	221	3	< 0.0001***
AFC70_77	168	3	148	2	< 0.0001***	176	3	140	2	< 0.0001***
FCON42_49	3650	329	4437	319	0.0874	3084	337	5003	309	< 0.0001***
FCON49_56	5036	323	4863	312	0.7005	4435	334	5463	300	0.0229*
FCON56_63	5648	815	6835	104	0.4156	4936	843	7546	1100	0.0487*
FCON63_70	4479	204	6003	302	<0.0001***	4591	209	5891	277	0.0001***
FCON70_77	6242	784	6017	1292	0.8819	6185	805	6074	1346	0.9455
TADG	1509	22	1448	24	0.0625	1507	22	1450	23	0.0704
TAFC	4513	68	5352	79	< 0.0001***	4498	69	5367	72	< 0.0001***
TFCON	6213	71	6774	68	< 0.0001***	6263	72	6724	67	< 0.0001***

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, BW – body weight, ADG – average daily gain, ADF – average daily feed consumption, FC – feed conversion, AFC – average feed conversion, TDG – total gain, TDF – total feed consumption

ronment interaction had a significant effect on the body weight of rabbits at 42, 49, 56 and 77 days of age ($P < 0.05$). The genotype × environment interaction effect estimated for the other body weights (63, 70 and 84 days of age) was non-significant. The rabbits of crossbreeds F_1 stabled in the fattening farms showed higher body weight at 42, 49 and 56 days of age than the values estimated in the test station. In contrary, values of F_1 rabbit body weight at 63, 70, 77 and 84 days of age recorded in the test station were higher than the values recorded in the farm conditions. The rabbits of crossbreeds F_2 stabled in the test stations had higher values of body weight than the values recorded in the farm conditions at every observed interval. The genotype × environment interaction effect was non-significant in most values of average daily gain. The genotype × environment interaction significantly influenced rabbit average daily gains only in the interval from 63 to 70 days and from 77 to 84 days ($P < 0.05$). In both the above mentioned intervals higher values of rabbit average daily gain were recorded for rabbits of F_1 crossbreeds placed in the test stations than for these crossbreeds placed in the fattening farms. So the genotype × environment interaction was noticed for rabbit average daily gain in the intervals 63–70 and 77–84 days of age, when the differences between rabbit body weight were not significant.

From Table 3 it is visible, that the rabbits of crossbreeds F_1 stabled in the test station had a lower average daily feed consumption from 42 to 49 and 49 to 56 days of age than the rabbits of crossbreeds F_1 stabled in the fattening farm. In the other intervals the lower values of average daily feed consumption were estimated for the F_1 crossbreeds rabbits stabled in the fattening farm than for

Table 3. Least squares means (LSM) and standard errors (SE) for the genotype × environment interaction

Trait	F_1				F_2				Significance
	Test stations		Fattening farm		Test stations		Fattening farm		
	n = 41		*n* = 50		*n* = 42		*n* = 51		
	LSM	SE	LSM	SE	LSM	SE	LSM	SE	
BW 42	1165.35	25.83	1199.23	24.77	1295.28	26.51	1217.69	23.16	0.0275*
BW 49	1464.99	29.85	1479.36	28.61	1645.10	30.61	1531.92	26.75	0.0290*
BW 56	1695.13	31.12	1714.88	30.21	1912.47	31.93	1787.69	27.90	0.0181*
BW 63	1982.16	38.11	1970.59	37.22	2164.78	39.93	2018.24	62.67	0.1210
BW 70	2310.01	42.28	2286.28	41.85	2451.87	43.36	2383.27	37.89	0.5878
BW 77	2560.62	38.57	2519.59	38.57	2670.07	40.82	2384.25	86.22	0.0335*
BW 84	2696.43	39.95	2680.08	39.81	2778.12	41.17	2627.19	44.28	0.0998
ADG 42-49	45.31	2.29	40.01	2.15	49.98	2.30	44.89	2.00	0.9614
ADG 49-56	36.80	1.98	33.60	1.85	39.61	1.99	36.54	1.71	0.9739
ADG 56-63	42.45	2.07	36.84	1.99	35.54	2.13	29.72	3.35	0.9631
ADG 63-70	46.72	2.26	43.60	2.24	40.42	2.32	48.31	2.03	0.0137*
ADG 70-77	35.80	1.67	33.33	1.65	32.12	1.74	27.27	3.69	0.6269
ADG 77-84	23.21	1.68	22.50	1.57	17.17	1.64	23.94	1.74	0.0228*
ADF 42-49	121.72	3.55	158.99	3.40	148.45	3.64	184.07	3.18	0.8119
ADF 49-56	137.11	4.2 6	153.69	4.08	129.15	4.37	201.15	3.81	< 0.0001***
ADF 56-63	168.39	3.83	163.70	3.72	158.66	3.93	202.86	3.43	< 0.0001***
ADF 63-70	190.33	4.04	162.40	3.92	168.01	4.14	280.14	3.62	< 0.0001***
ADF 70-77	180.28	3.48	157.01	3.44	172.56	3.57	123.58	3.11	0.0002***
FC 42-49	3.13	0.48	4.17	0.45	3.04	0.48	5.83	0.42	0.0581
FC 49-56	5.16	0.47	4.90	0.44	3.70	0.47	6.02	0.40	0.0044*
FC 56-63	4.50	1.17	6.79	1.12	5.36	1.20	8.30	1.89	0.8045
FC 63-70	4.62	0.29	4.34	0.29	4.56	0.30	7.44	0.47	< 0.0001***
FC 70-77	6.02	1.11	6.45	1.10	6.35	1.16	5.68	2.46	0.7382
AFC	4.50	0.09	4.51	0.09	4.48	0.10	6.22	0.11	< 0.0001***
TDG	1531.35	30.89	1487.23	30.78	1483.28	31.86	1412.34	34.99	0.6716
TDF	6842.85	100.07	5582.59	99.06	6604.48	102.64	6942.50	89.69	< 0.0001***

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, BW – body weight, ADG – average daily gain, ADF – average daily feed consumption, FC – feed conversion, AFC – average feed conversion, TDG – total gain, TDF – total feed consumption

the F_1 crossbreeds rabbits stabled in the test station. The rabbits of crossbreeds F_2 stabled in the test station had a lower average daily feed consumption from 42 to70 days of age than the rabbits of crossbreeds F_2 stabled in the fattening farm. In the intervals form 70 to 77 days of age were estimated the lower values of average daily feed consumption for the F_2 crossbreeds rabbits stabled in the fattening farm than the rabbits of crossbreeds F_2 stabled in the test station. The average daily feed consumption was significantly ($P < 0.001$) influenced by the genotype × environment interaction in all estimated intervals with the exception of average daily feed consumption recorded in the interval from 42 to 49 days of rabbit age.

During the whole fattening period the effect of genotype × environment interaction on rabbit feed conversion was in most rabbit age intervals non-significant with the exception of intervals from 49 to 56 days ($P < 0.05$) and from 63 to 70 days ($P < 0.001$). In most observations the lower values of rabbit feed conversion were estimated in the test stations. Only in the intervals form 70 to 77 days the rabbits of crossbreeds F_2 showed the lower values of feed conversion in the fattening farm than in the test station. Similarly, in the intervals from 49 to 56 days and 63 to 70 days the rabbits of crossbreeds F_1 showed the lower values of feed conversion in the fattening farm than in the test station. From the results it follows that the lower values of average feed conversion were found in the rabbits of both crossbreeds (F_1, F_2) stabled in the test stations than the rabbits stabled in the fattening farms. On the contrary, both crossbreeds (F_1, F_2) stabled in the test station had higher total gain than rabbits stabled in the fattening farm. The lower value of total feed consumption showed the crossbreeds F_1 stabled in the fattening farm and the crossbreeds F_2 stabled in the test station. The genotype × environment interaction significantly influenced only the average feed conversion ($P < 0.0001$) and total feed consumption ($P < 0.0001$).

These results demonstrate that the average daily feed consumption and feed conversion were influenced by genotype × environment interaction. The effect of interaction is expressed by covariance when a change in environment influences the differences between the expected values of crossbreeds. The genotype × environment interaction had no significant effect on growth performance of broiler rabbits. The results correspond to the definition of genotype × environment interaction according to Lynch and Walsh (1998).

CONCLUSIONS

Results of this study support a theory that the average daily feed consumption and feed conversion were influenced by genotype × environment interaction ($P < 0.0001$). The effect of interaction was expressed by a covariance when the environmental changes induce the differences between the expected rabbit performance values of particular crossbreeds. In most rabbit age intervals the genotype × environment interaction had no significant effect on the growth performance (body weight and average daily gains) of broiler rabbits.

Furthermore, according to the results of our trials we can conclude that in the first part of fattening period the animals of crossbreeds F_2 were much better adapted to environmental condition in the fattening farm than the animals of crossbreeds F_1.

The results of total value (average feed conversion, total gain and total feed consumption) showed that crossbreds F_2 stabled in the fattening farm had considerably worse performance than crossbred F_1 ($P < 0.0001$). Therefore the crossbreds F_1 should be preferably used for meat production than crossbreds F_2 on the fattening farm.

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Odhad interakce genotyp × prostředí u brojlerových králíků.

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U dvou typů finálních hybridů brojlerového králíka HYPLUS (F_1 a F_2) byl pro vlastnosti živá hmotnost, průměrné denní přírůstky, průměrná denní spotřeba krmiva a konverze krmiva zjišťován vliv interakce genotyp × prostředí. Hybridi pocházející z vícečetných vrhů a odstavení ve 34–35 dnech věku byli získáni z faremního chovu. Hybridi pocházející ze stejného vrhu byli rozděleni a ustájeni v testační stanici či ve faremním chovu. Tito jedinci byli vykrmováni od 42. do 84. dne věku. Vliv interakce genotyp × prostředí byl zkoumán pomocí lineárního modelu zahrnujícího fixní efekty: typ hybrida, opakování, prostředí a interakce genotyp × prostředí. Z výsledků vyplývá, že průměrná denní spotřeba krmiva a konverze krmiva byly ovlivněny interakcí genotyp × prostředí. Avšak interakce genotyp × prostředí neměla prokazatelný vliv na růstové schopnosti hybridů. Z výsledků dále vyplývá, že hybridi F_1 v porovnání s hybridy F_2 vykazovali lepší růstové schopnosti ve faremním chovu.

králík; interakce genotyp × prostředí; růst; konverze krmiva

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