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DIALLEL CROSSBREEDING EXPERIMENT IN DANISH AND HUNGARIAN MEAT RABBITS 1. REPRODUCTIVE PERFORMANCE, GROWTH, AND FEED CONVERSION

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ABSTRACT : The two rabbit meat breeds, Danish White (D), represented by a 3-way cross of 3 lines from the Danish Institute of Animal Science (DIAS), and Pannon White (H), represented by a synthetic breed from the Pannon Agricultural University (PAU) were used in a diallel crossing experiment carried out simultaneously at the two locations. In the four combinations: DD, DH, HD, and HH the male breed is mentioned first. The length of gestation and the number of young at birth were the same for the does from the two breeds, but the number of days between kindlings was smaller in H-does than in D-does. Litter number five was the largest at birth.

From weaning to the test end, the mortality for all 1,147 weaned young rabbits was only 2.7%. The largest number was seen in group (DD) with 5.4% and the smallest in group (HD) with 1.2%.
The growth rate was recorded from weaning to an age of 70 days. Highest daily gain from weaning to an age of 70 days averaged 46.1 g in group (HD). A slightly smaller growth rate, 44.2 g, was obtained in group (DD). In group (DH), the growth rate averaged 43.9 g, and in group (HH) 41.2 g. Both crossbred groups grew faster than group (HH), but only group (HD) showed a crossbred effect.

RESUME : Esssai de croisement diallèle entre lapins de chair Danois et Hongrois. 1/ Performances de reproduction, de croissance et efficacité alimentaire.
L'essai a porté sur le croisement diallèle de deux lapins de races à viande : le Danois Blanc (D) issu d'un croisement à 3 trois voies entre trois lignées provenant du Danish Institute of Animal Science et le lapin Pannon White (H) issu d'une race synthétique provenant de la Pannon Agricultural University (Hongrie), essai qui fut mené simultanément dans les deux lieux d'origine. Dans les quatre combinaisons : DD, DH, HD et HH le mâle est nommé en premier. La durée de la gestation et le nombre de lapereaux à la naissance sont identiques pour les lapines des deux races, mais le nombre de jours entre deux mise bas consécutives est plus faible pour les lapines H que pour les lapines D. La plus forte taille de portée à la naissance est enregistrée à la cinquième portée. Du sevrage jusqu'à la fin de l'expérimentation, la mortalité pour l'ensemble des 1 147 lapereaux sevrés est seulement de 2,7% (la plus importante concerne le groupe DD : 5,4% et la plus faible le groupe HD : 1,2%). La vitesse de croissance a été enregistrée du sevrage à 38 jours jusqu'à 70 jours d'âge. Le plus fort gain de poids moyen quotidien pendant cette période est de 46,1g pour le groupe HD. Un gain légèrement plus faible, 44,2g, est enregistré pour le groupe DD. Dans le groupe DH le gain moyen est de 43,9g, et dans le groupe HH de 41,2g. Les deux groupes issus du croisement grossissent plus vite que le groupe HH, mais seul le groupe HD montre un effet croisement.

INTRODUCTION

At both the Pannon Agricultural University (PAU), the Faculty of Animal Science, Kaposvár, Hungary, and the Danish Institute of Animal Science (DIAS), Foulum, Denmark, a diallel crossbreeding experiment has been carried out. 5 male and 20 female rabbits from each institute were transferred to the other institute with the purpose to test the two lines and their reciprocal crosses in both environments for reproduction, liveability, and growth rate. The report covers the results obtained at DIAS, and a similar report on the results from PAU will be published separately.

MATERIAL AND METHODS

Animals and breeding plan

The rabbits from Denmark were produced at the rabbitry at DIAS, where the breeding stock consists of three lines formed on one gene pool of Danish White breed established in 1977. For the project a 3-line cross Ix(IIxIII) was produced, and 5 6-month-old males and 20 4-month-old females were transferred to PAU on 22nd October 1991. DIAS received on 5th February 1992 a corresponding number of rabbits of the synthetic line Pannon White from PAU, and at the same time a similar group of the 3-line cross was produced at DIAS. In the following (D) is used for the Danish line cross and (H) for the Hungarian line.

During the 4 week quarantine period, one buck and two does were lost, and the two does were replaced by two females from the first born litter, similarly two D-does were replaced due to infertility.

The breeding programme was started just after the release of the H-rabbits from the quarantine. After a doe had given birth to a litter with a buck from her own line, she was mated to a buck from the other line.

In the breeding programme described in table 1, where the male is the first mentioned in the combination, the two lines were reproduced and the two reciprocal crosses were produced in a diallel crossing.

The same breeding plan was followed at PAU. Each institute, however, used its own routine procedures. At DIAS, the does were mated by placing the doe in the cage of the buck shortly after weaning the litter at 38 days after kindling.

One day after kindling, the litters were examined; if more than 8 rabbits were found, the smallest were removed. At weaning, the young were earmarked in the left ear with successive numbers and transferred to a special rearing house

Table 1 : Breeding programme

Male line		Female line	Progeny*
Danish	X	Danish	DD
Danish	X	Hungarian	DH
Hungarian	X	Danish	HD
Hungarian	X	Hungarian	HH

* Male x Female

Table 2 : Composition of the feed mixture

Composition	%
Grass meal	30.00
Oats	30.00
Barley	15.00
Wheat bran	10.00
Sunflower meal	8.00
Soybean meal	4.00
Molasses	1.50
Lime stone	0.65
Salt	0.20
Dicalciumphosphate	0.15
Vitamin mixture	0.50
In DM, g/kg	
Crude protein	186
Ether extract	40
N-free extracts	545
Crude fibre	158
Ash	71
Dry matter	894
Calcium	8
Phosphorus	6
Digestible energy, MJ per kg feed	11.06

for the growing period.

The following individual weights were obtained; does: the day after weaning of the litter; bucks: at the time of the second litters; young: the day after weaning, 70 days of age and just before transport to the abattoir.

Compound feed and feeding

The compound feed shown in table 2 was produced at the feed mill at DIAS and pelleted in 2 or 3 mm pellets. In a balance experiment BØRSTING *et al.* (1995) measured 11.06 MJ digestible energy per kg feed. No additional hay or straw was given. Water was available from automatic watering systems with valves.

During the last part of the pregnancy as well as during the entire lactation period, the does were fed ad lib. From weaning of the litters and until the middle of the next pregnancy, the does were restricted to 130 g pellets a day with 65 g in the morning and 65 g in the evening. From 2 weeks after mating and during the entire lactation period, each doe was fed an additional 10 g of soybean oil meal per day. The young were fed the same compound feed ad libitum from 2 weeks of age to slaughter (2 mm pellets until weaning and after that 3 mm pellets).

The results of the chemical analysis in table 2 show 186 g crude protein and 158 g crude fibre per kg dry matter and 11.06 MJ digestible energy per kg feed.

Housing

All the cages were made of electroplated, welded wire net. Cages for does and bucks measured 90x45 cm and were 45 cm high. On one side of the cage a 15 cm wide and 20 cm high opening was placed in order to give the does access to the nest box. In front of the cage a valve for automatic watering and a feeding trough were placed. The cages were placed 50 cm above the concrete floor of the stable.

The nest box measured 45x45x41 cm and was placed 5 cm lower than the mother's cage. A 9 mm asphalted Masonite board of 40x40 cm formed the bottom of the nest box. The sides were made from 9 mm varnished plywood. The cover was made from 24x24 mm wire mesh upon which a Masonite board was placed. The does entered the nest box through a circular opening and the young had no access to their mothers' cages. 10 days after kindling, the circular opening was closed with a net, which was removed once a day when the does entered the nest box for suckling.

The young started to eat solid feed 12-14 days after birth at which time the nest box was replaced by a cage of the same size as the one for the does, and a wooden frame was placed in the cage and filled with straw. A valve for automatic watering and a trough for pellets were placed in front of the cage.

The rearing house contained 290 cages in a double-tier system. Each cage contained up to 5 young rabbits and measured 90x50x45 cm. The lower cages were placed 50 cm above the manure pit covered with straw. The long side of the cage was parallel to the alley and had space for the water valve and a trough for pellets.

Statistical methods

The statistical tests of data regarding individual growth and feed consumption recorded on a litter basis were carried out according to the following model:

$Y_{ij} = m + a_i + \beta_j + e_{ij}$

where

Table 3 : Average weight of the does at weaning of the litter and weight of the bucks

Litter no	D-does n	D-does Age days	D-does Weight, kg $\bar{X} \pm S_x$	H-does n	H-does Age days	H-does Weight, kg $\bar{X} \pm S_x$
1	14	234 ± 38	4.65 ± 0.42	15	220 ± 12	4.21 ± 0.31
2	14	315 ± 45	4.74 ± 0.34	15	292 ± 13	4.25 ± 0.34
3	14	400 ± 48	4.70 ± 0.27	15	366 ± 14	4.39 ± 0.29
4	14	474 ± 46	4.79 ± 0.33	15	448 ± 25	4.53 ± 0.29
	D-bucks			H-bucks		
2	5		5.10 ± 0.29	4		4.51 ± 0.24

Table 4 : Length of pregnancy, litter size, and number of days between kindlings

	D - does				H - does			
Litter no	n	Pregnancy days	No. of young at birth	Days between kindlings	n	Pregnancy days	No. of young at birth	Days between kindlings
1	17	30.5	9.3	-	18	30.8	8.9	-
2	15	31.0	9.5	89	18	30.8	10.1	74
3	13	30.8	10.3	82	16	31.0	10.2	75
4	11	31.1	9.5	76	15	31.0	10.5	85
5	8	30.7	12.0	70	12	31.0	11.1	77
6	4	31.2	10.8	72	10	31.1	10.4	74
Total	68	30.9	10.0	80	89	31.0	10.1	77

Y_{ij} = observed individual or litter based value
m = overall means
a_i = effect of the i^{te} line or line cross i = 1 to 4
$ß_j$ = effect of being born in the j^{te} litter of a doe j = 1 to 6
e_{ij} = non-explained random effect $N(0,s^2)$

An analysis of variance was carried out using the GLM procedure of SAS (1989) taking into account that the data of the model were unbalanced and for this reason the means of the effects are estimated as Least Square Means (LSM). Statistical significance was detected by the F-test and for the line/line cross individual differences were detected by the T-test.

A test for heterosis was performed as a linear contrast of the pure lines versus their reciprocal crosses and tested against the error variances of the model.

RESULTS

Age, weight, and reproduction in the breeding stock

Kindling of the first litter took place when the Danish does were 193±30 days and the Hungarian does 187±19 days.

On an average the Danish does were born a week before the Hungarian does, therefore the kindling age of this stock was 6 days more. A higher SD (±30 days) in does from the D-line than does from the H-line certifies observations made by the attendants, who found that the Hungarian does reached sexual maturity more uniformly than the Danish does.

Corresponding observations were made in relation to the lifetime of the does. Those from the D-line were 419±136 days old when they were taken out of the experiment, whereas the does from the H-line were about three months older or 502±145 days. Apart from does which kindled only once or twice, the termination age was 478 and 564 days, respectively, or about 2 months more than the overall average including all does.

D-does were heavier than the H-does, 4.7 kg and 4.5 kg adult weight. A larger difference was obtained with the bucks, which averaged 5.1 kg and 4.5 kg, respectively. The D-does seemed to reach the adult body weight at the second litter, while H-does continued growth until they had the fourth litter, as shown in table 3. Part of the difference might be related to age, because the D-does were about 4 weeks older when kindling the fourth litter than were the H-does. At the second litter, D-does weighed 4.74 kg compared to the H-does weighing 4.25 kg.

On the average, duration of pregnancy for all litters was the same in the two groups showing 30.9 and 31.0 days. The litter size at birth was smallest at first kindling and largest at fifth kindling. The average number of days between kindling was 80 days in the D-does and 77 days in the H-does.

Because of an unusual loss among the breeding stock of D-does, the number of litters per doe became smaller than expected, and none of the does had more than 6 litters. Only 4 D-does and 10 H-does kindled 6 litters, the rest had fewer, see table 5. Totally, 166 litters were born. Data recordings of the 166 litters included 1,147 young rabbits registered in the weight

Table 5 : Distribution of number of kindlings per doe

		Number of does	
		Denmark	Hungary
No. of kindlings per doe	6	4	10
	5	2	3
	4	4	3
	3	3	0
	2	5	2
	1	3	2
	0	1	0
		22	20

Table 6 : Does removed from the test

	Danish does	Hungarian does
	Number	Number
Does slaughtered at test end	5	15
Killed before test end because of:		
Staphylococcus entermedius	10	2
Wounded legs	3	1
Snuffles	0	2
No pregnancy	2	0
Urinary inflammation	1	0
Dead, cause unknown	1	0
Total	22	20

Table 7 : Reproduction and livability

Group	DD	HD	DH	HH
No. of litters, total	36	37	45	48
No. of litters per doe	1.6	1.7	2.2	2.4
No. of young per litter at:				
Birth	9.7[a]	10.9[b]	10.1[ab]	10.8[b]
Weaning	7.0	7.6	7.4	7.4
End of test	6.6	7.3	7.3	7.2
No. of young at weaning	239	243	341	324
No. of young at end of test	226	235	337	318
Mortality, %	5.4	3.3	1.2	1.9

control after weaning.

In the group of D-does, 65 litters reached the weaning age, but further 8 litters were born in this group. Two kindlings gave stillborn young, and one litter was born outside the nest box. Five litters were killed because the mother was sick or died. The 73 kindlings were the results of 76 matings, equal to 96% fertile matings, and in the H-doe group, 98 matings resulted in 93 litters, equivalent to 94.9% fertile matings. Two litters were stillborn.

Due to the heavy attack of udder inflammation by Staphylococci 10 D-does and 2 H-does were removed. Because of other difficulties, 6 and 3 does, respectively, had to leave the test. Only one of the 42 does died.

31 of a total of 1,147 young rabbits were taken out of the test because of sickness or death. 12 died from Enteritis, 9 from Pneumonia, 4 from *Staphylococci Entermedius*, and 6 from unknown causes. The state of health in the growing period was very good with a loss of only 2.7% of a total of 1,147 young rabbits.

In the 166 weaned litters, 1,589 young rabbits were born, viz. 663 in the group of D-does and 926 in the Hungarian group. At the inspection of the nest box the day after birth, 44 and 40 young, respectively, were removed from litters including more than 8 young. Other 137 young from the Danish and 221 from the Hungarian group had to be removed before weaning, because the mother was sick or died.

Table 7 illustrates that in group (HH) 10.8 young rabbits were born per litter compared to 9.4 in group (DD); a significant difference of 1.4 young rabbits. A significant effect of the male line was observed ($P<0.05$). An average of 11.4 for line H and 9.7 for line D.

The effect of reducing the litter size at birth to a maximum of 8 young was evaluated, but only a small positive influence was noted in the line crosses. In group (HD) as well as in group (DH) the litter size at slaughter was 0.4 young rabbit larger than in the two original lines. HD gave 0.7 young rabbit more to slaughter than group (DD) did.

From weaning to slaughtering 5.4% of the young in group (DD) died. In this group a number of 239 young rabbits were weaned, but only 226 were slaughtered. In group (HH) the number of weaned animals was 324 and 318 were slaughtered, which gave a mortality rate of 1.9%. In group (HD) 3.3% died, whereas the percentage for group (DH) was 1.2%, only. The latter was lower than that of the parent groups, but (HD) was close to mean mortality. In total, the mortality was 3.4% in the progeny from the two lines, whereas it was only 2.1% in the line crossings.

After that, the recording of growth rate and feed consumption included 461 and 655 young from the two groups of does.

The line crossing HD reached slaughter weight 2.69 kg in 79.0 days, which was shorter than the two lines, whereas the reciprocal crossing DH reached the slaughter weight in 79.5 days or similar to line DD; but the HH-line obtained the slaughter weight in 81.7 days.

Growth rate

In group (DD) the average weight at weaning was 950 g and 957 g in group (HH). The calculation is shown in table 8, which also shows that both groups of line crosses were heavier than those from the two breeds. Group (HD) averaged 1002 g and group (DH) 968 g. A significant interaction ($P<0.001$) between the male line and the female line was found. The group (HD) reached the highest weight at weaning, which was 13% above the average of the two parent lines, and the reciprocal cross (DH) was 6% above this average.

(HD) averaged 2.36 kg, (DH) 2.30 kg, (DD) 2.29 kg, and (HH) 2.19 kg from weaning to day 70. The young in group (HD) grew faster than those from the other groups. The average daily live weight gain of group (HD) was 43.3 g, group (DD) 42.1 g, group (DH) 42.4 g, and group (HH) 38.9 g. A significant effect of the female line was found ($P<0.001$), but the interaction between the male and the female line was not significant. The cross (HD) had 11% higher daily gain than the average of the parental lines, and it was not significantly different from the parental line (DD).

When the weight control was finished at slaughter, the weight of group (HD) averaged 2.69±0.01 kg, and at that time

Table 8 : Growth rate and feed conversion

Group	DD	HD	DH	HH
Age at weaning, days	38.1	38.5	38.5	38.2
Age at slaughter, days	79.5	79.0	79.5	81.7
Weight at weaning[1], g	950	1002	968	957
Weight at 70 days, kg	2.29[b]	2.36[c]	2.30[b]	2.19[a]
Average daily gain[1], g	42.1[b]	43.3[b]	42.4[b]	38.9[a]
Weight at slaughter[1], kg	2.66	2.69[a]	2.66[a]	2.63[b]
Pellets per kg gain[1], kg	3.49	3.45	3.49	3.53
Digestible energy, MJ per kg gain	37.43	36.60	37.80	37.85
Feed consumed per young/day[1], g	149[a]	151[a]	145[a]	138[b]

Means within a row with no common superscript differ significantly ($P<.05$)
[1] Least square means

the average age was 79.0 days. An average of group (DD) was 2.66±0.06 kg and of group (DH) 2.66±0.07 kg. In each of those two groups the average age was 79.5 and 79.8 days, respectively. Group (HH) had a significantly slower growth rate, weighing 2.59±0.08 kg at the age of 81.7 days.

Feed consumption

From weaning to the end of the test, the (DD) group consumed 149 g pellets per day, which was 11 g more than group (HH) consuming 138 g per day - a significant difference. The groups (HD) and (DH) consumed 151 g and 145 g, respectively, and did not differ from the (DD) group.

Calculated as kg feed per kg live weight gain, the feed conversion in group (HD) was 3.45 kg/kg and for group (DH) 3.49 kg/kg, and both were lower than the average of the two parent lines. The feed conversion was highest in the (DD) group. Calculated in MJ digestible energy, the overall average for the four groups was 37.48 MJ per kg live weight gain.

Heterosis

Heterosis is often referred to as the difference between the crosses and the mid-parent value as a percentage of the mid-parent. Among the traits in table 8, weight at 70 days, daily gain, and feed consumption per day showed statistically significant heterosis of 4.2%, 5.9%, and 3.2%, respectively.

As to the effect of reciprocal crosses, it is seen from table 8 that 70 days' weight is significantly higher for the crosses (HD) than the reverse, although both have higher values than the parent breed with the highest values.

DISCUSSION

Crossbreeding of a Danish and a Hungarian line of meat rabbits increased litter size at birth in relation to the Danish line, but no heterosis effect was observed, for the crosses (HD) and (DH) did not give larger litters than the average of the parent groups. Litter size in the crossing groups was intermediate between the parent groups.

In agreement with the Danish results, ROUVIER *et al.* (1973) found a small paternal effect on litter size at birth by crossing. By crossing New Zealand White and German Giant, WILLEKE *et al.* (1981) found larger litter size at birth by crossing than in the two breeds. ESTANY *et al.* (1988) increased the litter size at birth with 0.16 kids by crossing two NZW-lines. AFIFI *et al.* (1990) and PARTRIDGE *et al.* (1981) showed highly significant heterosis effect on litter size at birth as well as at weaning. KROGMEIER *et al.* (1994) noticed that selection for litter size resulted in a larger size and also in larger litter weight at later ages.

The lack of heterosis effect in the Danish experiment might be due to the fact that the Hungarian group (HH) is a synthetic breed based on Californian and New Zealand White. But on the other hand, BRUN *et al.* (1992) recorded significant, maternal crossing effect on litter size in a two-line crossbred experiment with does, which were crossing between the two breeds.

The weaning weight at 39 days of the offspring was larger in the two crossbred groups (HD) and (DH) than in the parent lines (DD) and (HH). The smallest weaning weight was noted in the inbred Danish line (DD). Maternal effect was slightly larger than paternal effect. KHALIL *et al.* (1986) reported an analogous result and found the largest maternal effect in the young's first lifetime, decreasing about weaning and raising again after weaning.

ORAVCOVA *et al.* (1991) found a larger weaning weight in an inbred line of New Zealand White than in a non-inbred line or in crosses between the two lines. But the crossbred offspring grew faster from weaning to killing than the offspring of the parent lines. This result of line crossing is also noted by SMITH (1964) as well as OETTING *et al.* (1989).

In the Danish-Hungarian project the fastest growing offspring group was (HD), which had Hungarian bucks and Danish does as parents. This group grew faster than the other groups at the age interval of 39-70 days. Progeny of Danish bucks and Hungarian does grew intermediate between the parent lines (DD) and (HH). Group (HD) grew 10% faster than group (HH). This difference was significant, $P<0.01$.

ROUVIER (1991) found that crossing two lines after 13 generations of inbreeding gave a maternal heterosis effect of 15.9% in daily live weight gain. KROGMEIER and DZAPO (1991) noted that crossing two equal breeds only gave a small heterosis effect on growth rate between the reciprocal crosses. The difference was significant as was the difference between groups (HD) and (DH) in the Danish-Hungarian project.

Among the four groups in the project only a small difference was observed in feed conversion. Per kg live weight gain groups (HH) and (DH) consumed 3.42 kg pellets or 3.2 and 1.2%, respectively, more than the two other groups. Calculated as g pellets eaten per day from weaning to slaughtering, group (DD) consumed 5.9% more than group (HH).

Group (HD) had the best feed efficiency consuming 36.60 MJ digestible energy per kg live weight gain, or 2.8% less than the parent average. In contrast to this, the other crossbred group (DH) consumed 0.4% MJ digestible energy more per kg live weight gain than the parent average. The difference between groups (HD) and (DH) indicates a maternal effect, which may be why BRUN and OUHAYOUN (1989) found that crosses between Californian and New Zealand White had a poorer feed efficiency than the average of the parent breeds.

Heterotic effects of crossing lines are dependent on the type of traits involved. SHERIDAN (1981) illustrated in a review article that regarding growth related traits most authors came up with heterotic effects of 3% to 6% in farm animals, which are found also in the present work.

The asymmetric effect of heterosis in which the (HD) crosses are larger than the reverse is often seen in diallel crosses and FALCONER (1989) termed that as 'specific combining ability', the rationale of which is to choose the right combination of the two parent breeds.

CONCLUSION

Crossing equally bred and inbred lines in a breed, meat production may increase. The Danish-Hungarian crossbreeding project illustrated the importance of selecting the proper breed or line as female or male line.

In this project, the litter size at birth as well as at weaning was higher using bucks from the Hungarian line (HH) and does from the Danish line (DD) than seen in the reciprocal crossing (DH). The (HD)-group also had a better growth rate, feed efficiency, carcass conformation, and fleshiness than the basic breed (HH) and the two other groups (DH) and (DD). The vitality was intermediate and the carcass length in both crossbred groups was at the same level as both of the parent breeds.

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