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EFFECT OF BIRTH WEIGHT AND LITTER SIZE ON GROWTH AND MORTALITY IN RABBITS

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ABSTRACT : Two experiments were performed with Pannon White rabbits. In the first experiment 50 litters were formed with 6, 8 or 10 rabbits of different birth weight in equal ratios (n = 380, between 39 and 70g). In the second experiment 60 litters of 6, 8 or 10 rabbits were formed (n = 456), each litter consisting of rabbits of a single weight group only (small: 39 to 43g; medium: 53 to 56 g; large: 63 to 70 g). With increasing birth weight and decreasing litter size, mortality in the suckling rabbits decreased and daily weight gain of kits and weight of rabbits up to 10 weeks of age increased significantly. These effects were weaker in experiment 2. In the extreme groups used in the experiments (10 small kits and 6 large kits) the following results were obtained : mortality between birth and 21 days was 35.3 and 8.1 % in experiment 1 and 18.0 and 5.6 % in experiment 2, daily weight gain of kits between birth and 21 days was 9.2 and 18.5 g in experiment 1 and 10.8 and 16.7 g in experiment 2, and body weight at 10 weeks of age was 1.90 and 2.58 kg in experiment 1 and 2.11 and 2.45 kg in experiment 2. In conclusion, intra-litter homogenisation of birth weight markedly reduced mortality in small rabbits and standard deviation in live weight within litters.

RÉSUMÉ : Effet du poids à la naissance et de la taille de la portée sur la croissance et la mortalité chez le lapin
Des lapins de souche Pannon White ont été utilisés pour deux expérimentations consécutives. Dans la première, il a été constitué 50 portées comprenant 6, 8 ou 10 lapereaux de poids différents à la naissance mais en proportions égales (380 lapereaux au total, pesant à la naissance entre 39 et 70g). Dans la seconde expérimentation, 60 portées ont été constituées (n = 456 lapereaux) comprenant toujours 6, 8 ou 10 lapins, mais chaque portée n'était constituée que de lapins du même groupe de poids (petit : 39 à 43 g ; moyen : 53 à 56g et gros : 63 à 70g). L'accroissement du poids à la naissance et la diminution de la taille de la portée sont associés à une réduction de la mortalité chez les lapereaux allaités et à un accroissement significatif de la vitesse de croissance des lapins et de leur poids vif jusqu'à 10 semaines. Ces effets sont atténués dans la deuxième expérimentation. Dans les groupes extrêmes ("petits" dans des portées de 10 lapereaux et "gros" dans des portées de 6) les résultats suivant ont été obtenus : mortalité entre la naissance et 21 jours : 35,3 et 8,1% dans l'expérimentation 1, mais 18,0 et 5,6% dans la 2 ; gain de poids journalier de la naissance à 21 jours : 9,2 et 18,5g pour l'exp. 1, mais 10,8 et 16,7 pour l'exp. 2 ; le poids vif à 10 semaines a été de 1,90 et 2,58kg pour l'exp. 1, mais de 2,11 et 2,45kg pour l'exp. 2. En conclusion, l'homogénéisation des portées selon le poids à la naissance réduit considérablement la mortalité pour les lapereaux les plus légers à la naissance et l'écart de poids entre les portées.

INTRODUCTION

In multiparous species, such as the rabbit, maternal effect mediated by litter size and birth weight influences both growth and mortality in suckling and growing animals. In relation to age at slaughter (10 to 12 weeks), the young rabbit spends a substantial amount of time with the mother during pregnancy and suckling. Life from the zygote stage to slaughter is 3.5 to 4 months in length : within this period 1 month is the prenatal and 1 to 1.5 month the suckling period (no solid food being eaten for up to 3 weeks). These two periods (as a main part of maternal effect) therefore amount to 25 to 30 % and 25 to 35 %, respectively, of the life of the rabbit.

Foetal and birth weight depend primarily on the number of rabbits in the uterus or the uterine horn, and also on the localisation of the young in the uterus (LEBAS, 1982; PÁLOS *et al.*, 1996). Correlation between litter size and milk intake by a kit is –0.35 (LEBAS, 1975). The negative effect of large litter size on growth rate is highest during the 3rd week after parturition (SZENDRÕ, 1986). Researchers have demonstrated a marked maternal effect only up to 6 weeks of age, with a negligible effect afterwards (BLASCO *et al.*, 1983; SZENDRÕ, 1984).

Litter size and birth weight also affect mortality in suckling rabbits (KROGMEIER and DZAPO, 1991; RAO *et al.*, 1977). In large litters rabbits are usually smaller. Where litters have not been homogenised all rabbits below 35 g birth weight have been found to die within the first week; mortality of about 50 % occurred in the young between 35 and 45 g, while above this birth weight, mortality was reduced to 7% (SZENDRÕ and BARNA, 1984).

In previous studies, however, the effect of birth weight and that of litter size were not treated separately. Maternal effect is mediated by two important traits, i.e. birth weight and litter size ; this indicates prenatal and postnatal nutrition of comparable litters. In the present work the role of these factors was evaluated both together and separately, the effect of intra-litter competition also being taken into consideration.

MATERIAL AND METHOD

The study was performed on the experimental rabbit farm of the university, in Kaposvár, with Pannon White rabbits. The animals were housed in a closed rabbitry which was heated in winter (min. temp. 14°C) and were kept in wire net, flat-deck cages. Commercial pelleted rabbit feed was fed *ad libitum* (10.3 MJ/kg DE,

16% crude protein, 15.5 % crude fibre and 2.5% crude fat). Water was supplied through valved nipples.

Rabbit does with 1 to 6 previous pregnancies were used. Parturition was induced with 1 IU/kg b.w. oxytocin on day 31 of pregnancy in the early morning. The newborn rabbits were removed from the mothers immediately, before the first suckling, for individual weighing and marking.

In the first experiment 50 litters with 6, 8 or 10 rabbits were formed to include rabbits of low, medium and high birth weight in equal ratios (Table 1). In these litters, therefore, the large rabbits had an advantage over the smaller ones for access to milk during the suckling period.

In experiment 2, litters of 6, 8 or 10 rabbits were again formed, but each litter contained rabbits of exclusively low (39 to 43g), medium (53 to 56g) or high (63 to 70g) birth weight (Table 1). In these litters the rabbits had a similar chance to suckle milk.

The first experiment was carried out in 1994 and the second in 1996. In both experiments the newborn rabbits of different weight were put into the groups independently of their original litter size.

Rabbits which died before 21 days of age were replaced with rabbits of the same age and weight originating from non-experimental litters, to keep the effect of litter size unchanged. The substitutes were not weighed. The rabbits were weaned at 5 weeks of age, after which they were kept at 6 animals per cage for the growing period. Up to the age of 6 weeks the animals were weighed weekly, in the early morning before suckling, and every 2 weeks afterwards.

The experimental data were evaluated with the STATGRAPHICS program package. The effect of birth weight and litter size on weight and weight gain was studied both separately and jointly with two-way analysis of variance or one- and two-factor linear regression. Mortality data were compared by means of chi^2 test.

The models of variance analysis applied were the following:

$$Y_{ijk} = \mu + BW_i + LS_j + (BW \times LS)_{ij} + e_{ijk}$$

where

Y_{ijk} = data of individual animals
μ = overall mean
BW_i = effect of birth weight (low, medium, high)
LS_j = effect of litter size (6, 8, 10)
$(BW \times LS)_{ij}$ = interaction of birth weight and litter size
e_{ijk} = random error

RESULTS AND DISCUSSION

Mortality

In experiment 1, when rabbits of different birth weight were kept together, 13.3% of the rabbits died before the age of 3 weeks. In litters homogenised for birth weight (experiment 2) mortality before 3 weeks was 10% (Table 2). Both birth weight and litter size affected mortality in the suckling rabbits.

Table 1 : Range of birth weight in the experimental groups

Litter size	Birth weight, g		
	First experiment (n=50 litters, 380 kits)		
6	39-70		
8	39-70		
10	39-70		
	Second experiment (n=60 litters, 456 kits)		
	low	medium	High
6	39-43	53-56	63-70
8	39-43	53-56	63-70
10	39-43	53-56	63-70

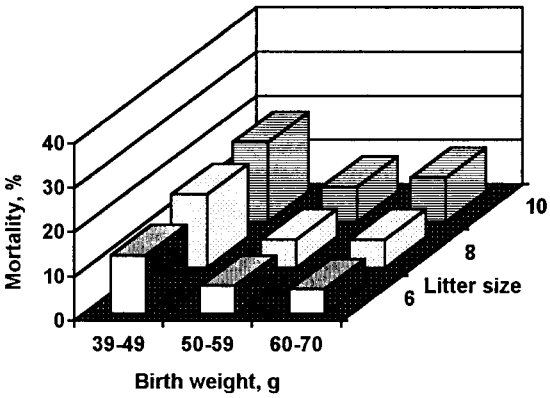
With increasing *litter size* mortality raised in both experiments. In litters of 6 and 10 rabbits 6.8 and 22.2 % (exp. 1), and 6.4 and 12 % (exp. 2), respectively, died in the first three weeks. The effect of litter size was significant ($P < 0.05$) in both experiments (Table 2).

Mortality was significantly ($P < 0.05$) affected by *birth weight* in both experiments; particularly low weight exerted a marked effect. Difference in mortality up to 3 weeks of age between individuals of low and high birth weight was important : 20.0 and 7.4 % (exp. 1) and 15.6 and 7.2 % (exp. 2), respectively (Table 2).

The joint effect of *birth weight and litter size* was most marked. On comparison of mortality between weeks 0 and 3 in the two extremes, i.e. the small rabbits in the litters of 10 and the large ones in the litters of 6,

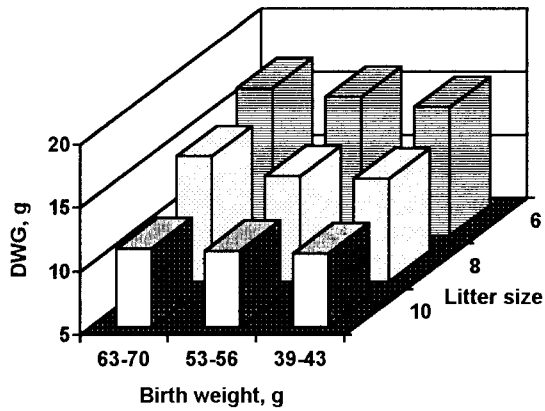
Table 2 : Effect of litter size and birth weight on mortality (%) in suckling and growing rabbits

Age weeks	Litter size			Birth weight (g)		
	Experiment 1					
	6	8	10	39-49	50-59	60-70
n	*116*	*100*	*117*	*97*	*103*	*102*
0-1	3.9^a	9.3^{ab}	13.4^b	14.7^a	7.5^{ab}	5.3^b
0-3	6.8^a	10.2^a	22.2^b	20.0^a	12.7^{ab}	7.4^b
0-10	20.4^a	16.7^a	34.7^b	31.6^a	26.9^a	12.8^b
	Experiment 2					
	6	8	10	39-43	53-56	63-70
n	*162*	*144*	*150*	*152*	*152*	*152*
0-1	5.8^a	6.6^{ab}	8.7^b	11.9^a	4.8^b	4.6^b
0-3	6.4^a	9.9^{ab}	12.0^b	15.6^a	6.8^b	7.2^b
0-10	12.8^a	15.1^a	17.3^a	23.1^a	11.6^b	9.9^b



Experiment 1

Figure 1 : Effect of birth weight and litter size on mortality in suckling rabbits between birth and 3 weeks of age



Experiment 2

Figure 2 : Effect of birth weight and litter size on daily weight gain in suckling rabbits between birth and 3 weeks of age

rates of 36.4 and 6.9 % (in exp. 1) and 18.0 and 5.5% (in exp. 2), respectively (Fig. 1), were found.

The effect of litter size on kits mortality is connected with the chance of individuals to find an available teat during the short suckling period, and on their milk intake. With increasing litter size the individual milk share is reduced (LEBAS, 1975; FERGUSON *et al.*, 1997), due to reduced access to the teat (SZENDRŐ and KAMPITS, 1985), resulting in higher mortality.

Adverse environmental effects are less well tolerated by rabbits of low birth weight and low vitality, particularly if the small ones have to struggle for the teat with stronger littermates. In several experiments (SZENDRŐ, 1978; VICENTE and GARCIA-XIMÈNEZ, 1992) all rabbits below 35 g birth weight died during the first week after parturition and half of the weight group between 35 and 45 g did not survive. Mortality in rabbits of low birth weight could be markedly reduced by transferring smaller animals to smaller litters, or decreasing weight differences within litters by homogenisation. As the results of this study show, overall mortality was decreased from 13.3 to 10% in homogeneous litters, from 36.4 to 18% in the same case in groups of small rabbits in litters of 10 and to 13% in litters of 6. Thus, mortality among small kits in litters of 6 proved the same as overall mortality in non-homogenised litters (exp. 1).

Weight gain

A significant ($P < 0.05$) relationship between *litter size* and average daily weight gain was ascertained only

Table 3 : Effect of litter size and birth weight on daily weight gain (g) in suckling and growing rabbits

Age, weeks	Litter size			Birth weight (g)		
	Experiment 1					
	6	8	10	39-49	50-59	60-70
0-3						
n	*106*	*91*	*91*	*79*	*89*	*94*
LSM	**16.5^a**	**14.4^b**	**10.6^c**	**12.6^a**	**14.6^b**	**15.4^c**
SE	0.32	0.29	0.28	0.39	0.31	0.43
3-6						
n	*97*	*88*	*86*	*74*	*83*	*91*
LSM	**42.2^a**	**39.7^b**	**34.9c**	**34.7^a**	**38.6^b**	**43.4^c**
SE	0.91	0.88	0.82	0.94	0.75	0.91
6-10						
n	*80*	*84*	*73*	*67*	*78*	*86*
LSM	**38.8^a**	**37.9^a**	**39.5^a**	**36.5^a**	**38.0^b**	**40.4^b**
SE	0.71	0.75	0.65	0.66	0.65	0.75
	Experiment 2					
	6	8	10	39-43	53-56	63-70
0-3						
n	*135*	*130*	*128*	*128*	*134*	*131*
LSM	**16.0^a**	**13.8^b**	**11.0^c**	**13.1^a**	**13.4^a**	**14.1^b**
SE	0.24	0.22	0.19	0.26	0.29	0.28
3-6						
n	*130*	*123*	*121*	*118*	*130*	*126*
LSM	**43.6^a**	**40.1^b**	**37.5^c**	**38.9^a**	**40.0^a**	**42.3^b**
SE	0.54	0.54	0.51	0.60	0.56	0.54
6-10						
n	*124*	*113*	*105*	*109*	*114*	*119*
LSM	**39.5**	**38.4**	**39.3**	**37.8^a**	**38.9^{ab}**	**40.4^b**
SE	0.56	0.68	0.71	0.65	0.67	0.60

Different letters in the same row indicate sign. ($P < 0.05$) differences

up to the age of 6 weeks (Table 3). During the first 6 weeks after parturition the rabbits grew faster in the litters of 6 than in those of 10; comparison of their daily weight gain between weeks 0 and 3 and between weeks 3 and 6 produced differences of 5.9 and 7.3 g (exp. 1) and 5.0 and 6.1 g (exp. 2), respectively.

In experiment 1 the correlation between litter size and weight gain is r = –0.63 and r = –0.31 during the first 3 weeks after parturition and between 3 and 6 weeks, respectively; afterwards the two traits were independent of each other. Similar values were obtained in experiment 2 (r = -0.63 and –0.39; Table 4).

The effect of *birth weight*, however, continues after weaning : a significant difference was found between the average daily gain of rabbits of low and high birth weight between 6 and 10 weeks (Table 3). In experiment 1 the rabbits of the highest birth weight gained 5.8, 6.7 and 3.9 g/day more during the first 3 weeks, between 3 and 6 weeks and between 6 and 10 weeks, respectively, than the small rabbits. During the same periods the correlations between the two traits were 0.42, 0.53 and 0.18, respectively, with significant regression coefficient throughout (Table 4).

In experiment 2, weight gain in rabbits of low and high birth weight did not differ as much as in experiment 1. The differences between the two groups were 1.0, 3.4 and 2.6 g/day during the first 3 weeks, between 3 and 6 weeks and between 6 and 10 weeks, respectively. The same was also shown by correlation and regression coefficients: regression lines were less steep and a weaker connection was indicated by correlation coefficients (Table 4).

Birth weight and litter size exerted a marked joint effect on daily weight gain during the suckling period (Fig. 2). Decreasing litter size and increasing birth weight enhanced daily gain. Daily weight gain of small rabbits in litters of 10 and large kits in litters of 6 were 9.3 and 17.9 g (exp. 1) and 5.9 and 8.9 g (exp. 2) during the first 3 weeks after parturition and between 3 and 6 weeks, respectively.
The two-variable functions showed that birth weight and litter size significantly affected weight gain up to 6 weeks (Table 4). In experiment 2 the slope of the line representing litter size was slightly reduced while that for birth weight decreased markedly, compared to experiment 1.

Litter size significantly affects the weight gain of suckling rabbits up to the point of weaning. The reason for this is that young rabbits consume only milk during the first 3 weeks after parturition, and individual milk share correlates (r = -0.35) with litter size (LEBAS, 1975): rabbits reared in smaller litters suckle more milk and gain more weight. During the period of transition to solid food (between 3 and 6 weeks), maternal milk still has an important nutritional role (PIATTONI *et al.*, 1998). At weaning, however, the young are separated from the doe and daily weight gain becomes independent of litter size.

Birth weight depends on, among other parameters, litter size and intrauterine localisation: foetuses situated closer to the ovary are larger than those closer to the cervix (LEBAS, 1982; PÁLOS *et al.*, 1996). Foetuses showing faster development may gain at rates above average during the postnatal period. The results of this study show that up to 6 weeks of age both traits affected weight gain: it is advantageous for rabbits to be born with higher weight or to be reared in a smaller litter. After 6 weeks, however, only the effect of birth weight was prevalent. The additive effect of genes is

Table 4 : Equations for prediction of live weight and daily weight gain in rabbits

Y	Experiment 1		Experiment 2	
	Equation a+bX	r	Equation a+bX	r
Daily weight gain (g)				
0-3 weeks	28.6-1.52 LS	-0.63***	23.5-1.2 LS	-0.63***
3-6 weeks	52.4-1.74 LS	-0.31***	52.6-1.5 LS	-0.39***
6-10 weeks	36.6+0.21 LS	- 0.05NS	39.5-0.06 LS	-0.02NS
0-3 weeks	6.3+0.18 BW	0.42***	10.5+0.06 BW	0.17***
3-6 weeks	14.4+0.44 BW	0.53***	32.3+0.15 BW	0.22***
6-10 weeks	28.4+0.18 BW	0.18***	32.9+0.11 BW	0.16***
Weight at (g)				
3 weeks	604-32.1 LS	-0.64***	549-26.1 LS	-0.61***
6 weeks	1695-67.5 LS	-0.45***	1657-58.7 LS	-0.53***
10 weeks	2731-61.3 LS	-0.28***	2747-57.7 LS	-0.34***
3 weeks	120+4.2 BW	0.40***	221+2.2 BW	0.30***
6 weeks	436+13.1 BW	0.42***	895+5.4 BW	0.29***
10 weeks	1215+18.7 BW	0.42***	1868+7.8 BW	0.27***
	$a + b x_1 + c x_2$	R^2	$a + b x_1 + c x_2$	R^2
Daily weight gain (g)				
0-3 weeks	17.9+0.2 BW-1.57 LS	0.74***	20.5+0.06 BW -1.2 LS	0.43***
3-6 weeks	28.1+0.45 BW-1.82 LS	0.49***	44.6+0.15 BW -1.5 LS	0.20***
6-10 weeks	27.0+0.18 BW-0.18 LS	0.04NS	33.4+0.11 BW -0.06 LS	0.02NS
Weight at (g)				
3 weeks	365+4.5 BW-33.1 LS	0.77***	431+2.2BW -26 LS	0.46***
6 weeks	962+13.7 BW-69.9 LS	0.62***	1366+5..3 BW -58 LS	0.36***
10 weeks	1701+19.2 BW-64.9 LS	0.51***	2324+7.7 BW -58 LS	0.18***

*** : P≤ 0.01; BW: birth weight; LS: litter size

Table 5 : Effect of litter size and birth weight on live weight (g) in suckling and growing rabbits

Age	Litter size			Birth weight (g)		
	Experiment 1					
birth weight	6	8	10	39-49	50-59	60-70
n	*116*	*100*	*117*	*97*	*103*	*102*
LSM	**54.8**	**54.6**	**54.6**	**45.0a**	**54.0b**	**64.3c**
SE	0.75	0.81	0.74	0.31	0.24	0.32
at 3 weeks						
n	*108*	*91*	*92*	*79*	*91*	*95*
LSM	**399^a**	**358^b**	**276^c**	**310^a**	**356^b**	**386^c**
SE	7.4	6.6	6.3	8.4	6.9	9.2
at 6 weeks						
n	*100*	*88*	*88*	*74*	*84*	*94*
LSM	**1276^a**	**1193^b**	**1003^c**	**1031^a**	**1169^b**	**1282^c**
SE	24	22	22	27	20	25
at 10 weeks						
n	*94*	*85*	*78*	*68*	*78*	*90*
LSM	**2368^a**	**2250^b**	**2111^c**	**2050^a**	**2250^b**	**2404^c**
SE	38	36	34	38	30	38
	Experiment 2					
	6	8	10	39-43	53-56	63-70
birth weight						
n	*156*	*152*	*150*	*160*	*146*	*152*
LSM	**54.2^a**	**54.2^b**	**54.1^a**	**42.4^a**	**54.6^b**	**65.6^c**
SE	0.79	0.79	0.80	0.15	0.10	0.18
at 3 weeks						
nb	*135*	*130*	*128*	*128*	*134*	*131*
LSM	**390^a**	**344^b**	**286^c**	**318^a**	**336^b**	**368^c**
SE	5.3	4.9	4.1	5.5	6.1	5.8
at 6 weeks						
n	*130*	*123*	*121*	*118*	*130*	*126*
LSM	**1306^a**	**1188^b**	**1072^c**	**1135^a**	**1177^b**	**1258^c**
SE	13	14	14	16	16	14
at 10 weeks						
n	*124*	*113*	*105*	*109*	*114*	*119*
LSM	**2408**	**2270**	**2179**	**2209^a**	**2275^b**	**2385^c**
SE	24	25	26	24	27	24

Different letters in the same row indicate sign. ($P < 0.05$) differences

probably the same in the pre- and postnatal periods. More important is the fact that heavier kits have an advantage over smaller ones in the competition for suckling, and they can consume more milk. Comparison of the results of the two experiments shows that reduction in competition within the litters equalises the chances for the rabbits to obtain a proportionate share of milk, resulting in more equal growth. This indicates the positive effect of intra-litter homogenisation.

Live weight

Throughout the duration of the life of the rabbits (up to the age of 10 weeks) significant negative correlation was ascertained between *litter size* and live weight; this correlation became weaker with advancing age (Table 4). Rabbits of similar birth weight reared in litters of 6 and 10 showed 123, 273 and 257 g weight difference (exp. 1) and 104, 234 and 229 g difference (exp. 2) at 3, 6 and 10 weeks of age, respectively. At 10 weeks no compensatory growth was observed (Table 5). The slope of regression lines increased more than twofold between 3 and 6 weeks in both experiments, but changed little afterwards (Table 4). Correlations between live weight and litter size were $r = -0.64$ and $r = -0.61$ at 3 weeks and $r = -0.28$ and $r = -0.34$ at 10 weeks in experiments 1 and 2, respectively. With advancing age the correlation coefficients showed decreasing connections, but the correlation was still significant ($P < 0.05$) at 10 weeks.

Correlation between *birth weight* and weight at 3, 6 or 10 weeks ranged from $r = 0.40$ to 0.42 and from $r = 0.27$ to 0.30 ($P < 0.05$) in experiments 1 and 2, respectively; the slope of the regression line became steeper, while the closeness of the relationship remained unchanged (Table 4). Difference between the smallest and the largest rabbits born was more marked in experiment 1 (difference of 76, 251 and 354 g at 3, 6 and 10 weeks, respectively) than in experiment 2 (difference of 50, 123 and 176 g; Table 5).

With decreasing *litter size* and increasing *birth weight* live weights increased in each of the age periods (Fig. 3). The two-factor regression lines show a significant relationship up to 10 weeks, although the slope determined by litter size did not change after 6 weeks. It was observed that the slope determined by birth weight in experiment 2, was reduced to half in comparison with experiment 1 (Table 4).

Researchers have obtained correlations between litter size and live weight similar to those ascertained in this study: -0.59 at 3 weeks and -0.51 at 8 weeks (ROUVIER *et al.*, 1973); -0.1 at 8 and 10 weeks (ZIMMERMANN *et al.*, 1988); -0.43 at 8 weeks (LUKEFAHR *et al.*, 1990); -0.3 at 10 weeks (FERGUSON *et al.*, 1997). The results of this study are not fully comparable with those of the above researchers, since in

the present experiments rabbits that died during the period studied were replaced with others.

Differences between rabbits reared in the most favourable conditions (in a litter of 6 of high birth weight) and the least favourable (in a litter of 10 of low birth weight) were smaller in each of the age periods in experiment 2 than in experiment 1. This indicates that weight homogenisation at birth produces more homogeneous weight at slaughter.

CONCLUSIONS

Maternal effect is mediated primarily by birth weight and litter size, both jointly and separately. The effect of low birth weight on mortality and growth can be reduced markedly by means of intra-litter homogenisation, which results in more efficient growth in rabbits of low birth weight.

In the knowledge of the effect of litter size, birth weight and homogenisation it can be calculated that to reach slaughter weight simultaneously, rabbits of birth weight of 60 to 70 g, 50 to 60 g and 40 to 50 g should be reared in litters of 10, 8 to 9 and 6 to 7, respectively. Improved weight homogeneity is advantageous both to the producer and to the slaughterhouse.

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