Productive performance and carcass characteristics of New Zealand white and California rabbits and their crosses

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ABSTRACT

Objective: To evaluate the growth, performance, and carcass characteristics as well as the individual and maternal heterosis effects of New Zealand White (NZ), California (CA) rabbits and their crosses.

Design/methodology/approach: 450 offspring rabbits, from 48 females (does) mated to six stud rabbits, were evaluated, recording the weight (BLW) and litter size at birth (LSB) and weaning (LSW), as well as the weight (AWW), gain (AWG), consumption (AWC), and feed conversion (CONV) for 8 weeks post-weaning. The carcass live weight at slaughter, warm carcass weight with head, carcass yield and parts of the carcass were evaluated.

Results: The assessment showed differences (P<0.05) in LSB and LSW with values of 10.47 and 9.78 kits respectively, when NZ was used as the paternal breed, results suggest individual heterosis of 5.91% for litter size and 12.44% for the weaning weight. Regarding the productive performance and carcass characteristics, the California breed showed superiority as a paternal breed, with average values of 36.11 g in AWG and 2.90 in CONV. The average individual weight at the end of the fattening, at 70 days of age, was 2.09 kg and the carcass weight was 1.16 kg. Post-weaning heterosis for the evaluated characteristics during fattening was positive and moderate.

Limitations on study/implications: It is necessary to carry out genetic improvement studies, with different crossing systems and to evaluate results based on productive and reproductive performance.

Findings/conclusions: When using NZ as a paternal breed, the reproductive characteristics of the offspring were superior compared to the ones obtained from CA. In contrast, the reproductive variables were superior in CA breed in comparison to NZ.

Keywords: rabbit breeding, litter size, weight gain, carcass yield.

INTRODUCTION

In Mexico, rabbit breeding in family-based farms is carried out with New Zealand White (NZ), California (CA) and Chinchilla breeds, as well as a wide range of crosses, constituting a source of income and good quality protein for rural families, thus, rabbit breeding is considered an activity for ensuring food security (SAGARPA, 2010). The estimation of productive, reproductive and profitability indexes in rabbit farms can aid in the calculation of their potential performance (Lukefahr and Cheeke, 1991), besides offering useful information about pure breeds and commercial crossbreeds. NZ White and CA breeds have great potential as pure breeds, maximizing the percentage of heterosis in their crosses and used in the creation of genetic lines (Blumetto, 2007). They have good muscle conformation, high prolificity and growth rate (Ortiz and Rubio, 2001). Heterosis between crosses of these breeds is greater in reproductive characteristics than in growth characteristics, manifesting itself in a greater number of kits at weaning. This superiority is greater when the breeds differ widely in gene

frequencies with a minimum of genotype-environment interactions (Falconer and Mackay, 1996), requiring further research in local rabbit populations. The objective of this research was to evaluate the productive performance, carcass characteristics and individual heterosis of some productive traits in NZ, CA rabbits and their crosses.

MATERIALS AND METHODS
Ethical Statement
Sampling, handling, and slaughter of the animals were carried out following the Experimental Regulation Protocol and following the Mexican Official Standard (Norma Oficial Mexicana, NOM-033-ZOO-1995), which refers to the humane slaughter of domestic and wild animals; the above, approved by the Colegio de Postgraduados, Mexico.

Study site
From February to December 2019, research was conducted at the rabbit production module of the Colegio de Postgraduados, Campus Montecillo, located at 19° 27' 34.8'' LN and 98° 54' 15.8'' LO, in Texcoco, Estado de Mexico.

Feeding
Controlled commercial feed was provided to obtain the average weekly intake (AWI) in two variants; for does, with a 15.55% protein, 16.26% fiber and 2.91% fat content; for the fattening progeny with 16.5% protein, 15% fiber and 3% fat.

Experimental procedure
Data were obtained from a 48 first-calving females sample from a rabbit population of 160 females. Preweaning characteristics of NZ and CA females and their crosses were evaluated. During the first stage, NZ and CA breeders were mated with six males, three NZ and three CA, and classified into four genetic groups (treatments): T1: NZ×NZ, T2: CA×CA, T3: NZ (sire)×CA (dam) and T4: CA (sire)×NZ (dam). In the second stage, six weaned kits were selected from each female and transferred to fattening cages with an identification ear tattoo and weighed individually for five weeks. At the end of the fattening stage, 350 randomly selected animals were slaughtered to evaluate their carcass characteristics.

Evaluated characteristics
Preweaning stage. Maternal ability was recorded in the parents: nest preparation, live and stillborn kits, their viability from birth to weaning, litter size and weight at birth and weaning (35 days) and mortality.

Fattening stage. Weight (AWW), weight gain (AWG), feed intake (AWC) and feed conversion (CONV) were evaluated weekly, using 112 replicates per treatment.

Carcass evaluation. After slaughter, the carcass was fractionated following the protocol by Blasco *et al*. (1992). Live weight at slaughter, carcass weight with head,

carcass yield and carcass parts (leg, loin, arms, kidney, liver, green and red viscera) were measured and classified by sex.

Individual heterosis (H) was estimated by the difference between the average of the reciprocal crosses minus the average of the parents divided by the average of the parents (Falconer and Mackay, 1996).

Statistical analysis

In the preweaning stage data, an analysis of variance was performed using the PROC GLM of SAS statistical software (SAS, 2012), with a one-way classification model. To evaluate the parents for preweaning progeny performance, two groups of treatments were formed, the first with progeny from NZ parents and the second with progeny from CA parents. For the analysis of the fattening stage, the PROC MIXED of the SAS statistical software (SAS, 2012) was used, which included the fixed effects of treatment, time and their interaction. To ascertain mean differences, a Tukey's test ($\alpha < 0.05$) was used.

$$\text{Model:} \quad Y_{ijkl} = \mu + R_i + \delta_{ji} + S_k + (RS)_{ik} + \varepsilon_{ijkl}$$

Where: Y_{ijkl}=Growth trait in the ijk-th evaluated doe; μ=Overall mean; R_i=Fixed effect of i-th genetic group; δ_{ji}=Error of j-th animal within i-th genetic group; S_k=k-th week of evaluation; $(RS)_{ik}$=Effect of genetic group × week interaction; ε_{ijkl}=Random error.

The carcass evaluation considered live weight at slaughter as a covariate, according to the model:

$$Y_{ijkl} = \mu + R_i + \beta\left(X_{ij} - \overline{X}\right) + \varepsilon_{ijkl}$$

Where: Y_{ijkl}=Carcass characteristic in ij-th evaluated rabbit; μ=Overall mean; R_i=Fixed effect of the i-th genetic group; $\beta\left(X_{ij} - \overline{X}\right)$=Effect of the covariate live weight of rabbits at slaughter ε_{ijkl}=Random error.

RESULTS AND DISCUSSION
Litter size and litter survival in the pre-weaning period

Table 1 shows differences (P<0.05) in litter size at birth (LSB) and weaning (LSW), values that concur with Piles *et al.* (2005) who indicated superiority in LSB and survival of the NZ breed and the NZ×CA crosses. Statistical analyses showed no differences (P>0.05) between breeds in birth weight (LWB). The mean number of kits per female at parturition was 10.40 and at weaning 8.94 for NZ and CA breeds, which is higher than that described by Vásquez *et al.* (2007), in the NZ breed, in the Sabana de Bogotá, Colombia.

Table 1. Analysis of pre-weaning variables of the New Zealand and California breeds and their reciprocal crosses.

Variable	Treatments			
	NZW Parents	**CA Parents**	**SEM**	**P>F**
Litter size at birth	10.47 a	10.32 b	±0.08	0.034*
Number live-born kits	9.78a	9.67a	±1.02	0.057
Mortality at birth	0.53a	0.64a	±0.56	0.054
Litter weight at birth (g)	574.87a	586.46a	±17.13	0.090
Litter size at weaning	9.03 a	8.85 b	±0.19	0.045*
Average weaning weight (g)	972.02 a	909.99 b	±31.81	0.029*
Total mortality (birth–weaning)	1.37a	1.25a	±0.36	0.331
Total percentage of mortality	12.43a	11.71a	±4.42	0.370

a,b,Means within rows with different literals are different (P < 0.05*), SEM: standard error mean. NZ: New Zealand parents, CA: California parents

Litter weight at birth and weaning

The average litter weight at birth (LWB) was 580.66 g, with an individual weight of 56.1 g, and an average individual weaning weight of 941 g (Table 1). The results at birth are similar to those of Diaz (2006), who reported birth weights of 50 to 75 g in the NZ breed and crossbred progeny. The present results are higher than those reported by Ponce de León *et al.* (2002) who reported birth weights of 562.22 g for NZ parents. Contrastingly, Gallego (2016) reported that the offspring of NZ parents reached a higher weight at weaning than the progeny of CA parents, attributable to the additive effects of NZW males and the individual heterosis possessed in this trait; contrary to what was obtained in the LWB variable. Offspring from CA parents at weaning obtained a lower average weight (909.99 g), similar to the values reported by Lukefahr *et al.* (2000). New Zealand White females were superior to CA females in their reproductive traits. The contribution of maternal effects was higher in the NZ breed (Table 1).

The heterosis obtained for live births and survival during the preweaning period, within the four genetic groups, was positively superior by 5.91 and 4.99%, respectively, from the crossbred progeny (Table 2), coinciding with Brun and Baselga (2005), that report positive heterosis effects of the crossbred progeny and values with a 6% superiority. The heterosis found in birth weight was 5.29%, a value lower than that reported by Youssef (2004) who indicates a 6% superiority in the birth weight of the NZ breed and reciprocal crosses with CA.

Table 2. Direct effects of heterosis on litter size at birth, survival rate, birth and weaning weight and percentage of heterosis in rabbit breed.

Maternal breed	Litter size at birth	Survival rate (%)	Birth weight (g)	Weaning weight (g)
California	10.36 b	92.32 a	574.46 a	962.98 b
New Zealand White	10.44 a	94.73 a	589.07 a	919.42 a
Heterosis (%)	5.91	4.99	5.29	12.44

a,b, Means within columns with different literals are different (P<0.05*).

The progeny of the NZ×CA cross showed a superior weaning weight (12.44%) in relation to its parental breeds which, complemented with litter survival at birth, demonstrates it was the cross with the best performance of the evaluated genetic groups. This heterosis is considered of medium and moderate impact on the productivity in breeding systems and concurs with Gallego (2016) and Youssef (2004) who report similar results with a 13% value.

Fattening phase

Table 3 shows the means of the evaluated breeds in the fattening phase. The CA progeny had a higher increase (P<0.05) in AWG, with a mean of 35.99 g and a ratio of 2.90 kg feed per kg live weight, compared to offspring from NZ parents. However, there were no differences between breeds for weight and weekly feed intake variables.

Table 3. Analysis of fattening stage variables (g) in the New Zealand (NZ), California (CA) rabbit breeds and their crossbreeds.

Variable		AWG	AWW	AWC	CONV
Treatment (T)	(NZ)	33.62 b	1914.96 a	104.58a	3.22 b
	(CA)	35.99 a	1970.57a	101.97a	2.90 a
	NZ×CA	34.54 ab	1946.49a	104.97a	3.03 ab
	CA×NZ	36.11 a	1979.39a	103.22a	3.00 ab
	SEM	±0.67	±54.13	±3.09	±0.12
Week (W)	ONE	33.98a	941.20a	60.90a	1.81a
	TWO	35.97a	1184.06a	81.46a	2.28a
	THREE	37.11a	1466.61a	110.45a	3.06a
	FOUR	33.52a	1724.06a	121.31a	3.81a
	FIVE	34.76a	1968.92a	143.30a	4.22a
	SEM	±0.78	±31.96	±2.31	±0.11
Interactión (p>F) T×W			0.0049**	0.8228	0.6675	0.0359*

a,b, Means within columns with different literals are different (P<0.05* y P<0.01**). AWG: average weekly gain, AWW: average weekly weight, AWC: average weekly consumption and CONV: average feed conversion.

These results coincide with those by Piles *et al*. (2005) where the superiority of the CA compared to NZ regarding weight gain and feed conversion was reported and no differences were found in feed intake and final weight.

The obtained values in this study for the evaluated crosses are higher than those reported by Palmieri (2006) who crossed CA with NZ breeds and reported post-weaning weight gains of 30 g per day. Blumetto (2007) recorded a daily weight gain of 35.54 to 36.51 g, similar to those reported in the present study. The heterosis in weight gain and final weight in the four genetic groups was 33.33 and 24.75%, respectively (Table 4). These are of high heritability and higher than those found by Zaghloul *et al*. (2019) and Khalil and Al-Homidan (2014) who report heterosis of 18 to 34% in weight gain and 19 to 20% at final weight.

Table 4. Direct effects of individual heterosis on progeny characteristics in the fattening phase of rabbit breeds.

Paternal breed	Weight gain	Final weight	Feed consumption	Feed conversion
California	36.05 a	1974.98a	102.59a	2.95 a
New Zealand White	34.08 b	1930.72a	104.77 b	3.12 b
% Heterosis	33.33	24.75	22.58	23.44

a,b. Means within columns with different literals are different (P<0.05*).

Regard feed consumption and CONV, the heterosis found was 22.58% and 23.44%, respectively, which are of moderate tendency. The results described here were superior to those found by Youssef (2004) and Piles *et al*. (2004) who reported a 20% heterosis in the feed intake and 22% in CONV.

Table 5 shows the superiority of the progeny from CA breed parents in live weight at slaughter (2094.87 g) and carcass weight (1164.21 g); no differences were found in yield and carcass parts (P>0.05).

Carcass characteristics

Gender did not influence the evaluated characteristics. Trocino *et al*. (2003) indicate that sex influences the weight and parts of the carcass at slaughter when the live weight is greater than 2.5 kg. Barrón *et al*. (2004) indicate that rabbits are slaughtered before puberty with an average weight of 2.1 kg. The results obtained are similar to those reported by Boicoc (2002), who registered a slaughter weight of 1998 g for NZ and 2040 g for CA breeds beds and shows the importance of heterosis in the crossbreeding of rabbits, whose reported weights were 2160 g at the end of fattening in a CA×NZ cross.

Table 5. Analysis of the carcass characteristics in New Zealand (NZ) and California (CA) rabbit breeds and their crosses.

Treatment	Live weight (g)	Carcass weight (g)	Dressing percentage (%)	Loin(g)	Legs (g)	Arms (g)	Kidney (g)	Liver (g)
NZ	1920.74b	1055.97b	55.23a	172.18a	273.48a	139.74a	21.81a	70.44a
CA	2078.54a	1156.18a	55.51a	176.81a	272.50a	145.49a	21.90a	70.62a
NZ×CA	1964.75b	1083.65b	55.29a	175.75a	274.97a	138.19a	21.93a	70.56a
CA×NZ	2111.20a	1172.24a	55.52a	178.50a	273.00a	150.71a	21.73a	70.56a
SEM	130.38	±86.92	±1.96	±31.02	±28.01	±19.81	±1.48	±2.55
P>F	0.0028**	0.0312*	0.7900	0.7911	0.9859	0.7323	0.9073	0.9816
By sex								
Males	2029.16a	1120.60a	52.20a	175.94a	277.14a	144.44a	21.92a	70.34a
Females	1994.05a	1107.90a	55.53a	175.04a	269.58a	142.17a	21.77a	70.74a
SEM	±155.17	±103.43	±2.33	±36.91	±33.33	±23.57	±1.76	±3.03
P>F	0.1246	0.3798	0.2561	0.8477	0.0959	0.3962	0.4293	0.2164

a,b. Means within columns with different literals are different (P<0.05*).

In carcass yield, a general average of 55.38% was obtained for all the crosses, higher than the 52% reported by Boicoc (2002) in the progeny of NZ males with CA female crosses.

Regarding carcass parts, the loin and legs are the most economically important, representing 40% of the carcass, of which 16% is the loin and 24% the legs. There were no differences (P>0.05) between parental breeds.

CONCLUSIONS

The crosses between NZ parental breed rabbits showed better reproductive performance and viability in litter size at birth and weaning. Offspring from CA parents reported higher birth weights than the offspring from NZ parents. The results on the productive behavior of the CA×NZ cross progeny indicate that they are better when CA is used as the parental breed, with higher weekly weight gain and better feed conversion.

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