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POSTWEANING PERFORMANCE OF TWO NEW ZEALAND WHITE LINES AND THEIR RECIPROCAL CROSSES FED A HIGH FORAGE DIET

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ABSTRACT : Thirty-five day old weanling rabbits from two New Zealand White genetic lines, Mexican (MX) and Oregonian (OR) and their reciprocal crosses, paternal Mexican (MO) and paternal Oregonian (OM), were used to evaluate growth performance based on high forage, alfalfa-orchard grass (AO) or commercial diet (CO). One hundred and twenty eight rabbits were used in a 4x2 factorial (genotypes x diets) repeated measurement (week) experiment. Response variables were: body weight (BW), average daily gain (ADG), feed intake (FI), feed conversion (FC), dressing weight percentage (DW) and postweaning mortality (MT). The diet effect was important for BW (P<0.01), ADG (P<0.01) and FC (P<0.05), with a superior performance by rabbits on the CO diet. Means for final 10 week BW (g), ADG (g) and FC were, 1983±45, 1722±44; 32±2, 28±2; and 3.8±6, 4.4±4, for the CO and AO diet, respectively. The genotype was not important for growth variables and showed no heterotic effect. The FI ranged from 105±5 to 112±5 g/d for genotypes, and from 107±4 to 109±4 for AO and CO diets. For DW differences were observed among genotypes, with the OR showing the poorest performance (P<0.05). Means were 49.2±1.5, 48.4±2.0, 45.6±2.2 and 43.9±2.9 for MX, OM, MO and OR. No significant differences were observed for MT, but cumulative mortality by week 10 by genotype was 12.5, 9.4, 9.4 and 6.3% for MX, OR, MO and OM. The OR and crossbreds tended to have better survival. For CO and AO diets, mortality means were not different (10.9 and 7.8%).

RESUME : Performances après sevrage de deux lignées de lapins Néo-Zélandais Blancs et de leurs croisements réciproques, nourris avec un régime riche en fourrage.
Afin d'évaluer les performances de croissance avec un régime riche en fourrage (luzerne dactyle – AO) comparé à un aliment commercial (CO), on a utilisé des lapins au sevrage, âgés de 35 jours, issus de deux lignées de Néo-Zélandais Blancs (témoin), des lapins Mexicain (MX) et d'Oregon (OR) ainsi que de leurs croisements réciproques (père Mexicain MO ; père Oregon OM). Cette expérimentation a utilisé 128 lapins selon un modèle factorielle 4 x 2 (génotype x régime). Les mesures ont été répétées chaque semaine. Les variables enregistrées ont été : le poids vif (BW), le gain moyen journalier (ADG), la consommation alimentaire(FI), l'indice de consommation (FC), le rendement à l'abattage (DW), la mortalité après sevrage (MT). Le régime riche en fourrage a particulièrement affecté le poids vif (BW ; P<0,01), le gain journalier (ADG ; P<0,01), l'efficacité alimentaire (FC ; P<0,05). Les meilleurs performances ont été enregistrées avec l'aliment du commerce (CO). A la fin de la 10^{eme} semaine, les gains de poids vif total (BW), le gain de poids journalier (ADG) et l'indice de consommation moyens, pour les régimes CO et AO respectivement, étaient de 1983 ± 45g, 1722 ± 44g ; 32 ± 2, 28 ± 2g ; 3,8 ± 6, 4,4 ± 4. Le génotype n'a guère influencé les paramètres de croissance et n'a pas montré d'effet d'hétérosis. La consommation alimentaire des différents génotypes a varié de 105 ± 5 à 112 ± 5 g/jour et de 107 ± 4 à 109 ± 9 pour les régimes AO et CO. Les rendements à l'abattage (DW) ont été différents selon les génotypes, les plus mauvais affectant les lapins Oregon (P<0,05). Les valeurs moyennes ont été 49,2 ± 1,5 ; 48,4 ± 2,0 ; 45,6 ± 2,2 et 43,9 ± 2,9 pour les lapins MX, OM, MO et OR. Il n'y a pas eu de différences significatives dans les taux de mortalité cumulée après sevrage (MT) mais la mortalité par génotype après 10 semaines a été de 12,5 ; 9,4 ; 9,4 et 6,3% pour MX, OR, MO et OM. Les lapins Oregon et leurs croisements semblent avoir un meilleur taux de survie. Les taux de mortalité ne sont pas différents pour les régimes CO et AO (10,9 et 7,8%).

INTRODUCTION

In countries such as Mexico, where grains and other high energy ingredients are expensive and even scarce for most farmers; the more intensive use of forages can be an alternative for feeding the meat production rabbit, taking advantage of its ability to digest some amounts of fiber, given by an extended caecum, selective fiber excretion and caecotrophagy (CHEEKE, 1987). Also, the use of improved genetic lines have proved to be a realistic option, when animals are available to farmers from reliable suppliers (LUKEFAHR and CHEEKE, 1991).

Among different sources of forages used to feed rabbits in temperate areas, legumes and specially alfalfa have been used most. Alfalfa has been mentioned to be the largest single ingredient of commercial rabbit feeds because of its high nutritional value characteristic for the rabbit (*e.g.* high protein content) besides its desirable agronomic attributes (*e.g.* high productivity). However, is not always possible to have enough amounts of alfalfa as needed throughout the entire year. In the highlands of Central Mexico, alfalfa has been reported to have a rate of production as low as 23.35 DM $kg \times ha^{-1} \times d^{-1}$ in winter (AVENDAÑO, 1978) and because of its high demand for feeding dairy cows, it can become a very expensive alternative for feeding rabbits under some situations. This condition warrants the study of other alternatives than can be used to replace alfalfa, at least partially, as a main ingredient in rabbits diets. Although several temperate and tropical legumes and grasses have been studied in rabbit feeding by different authors (HARRIS *et al.*, 1981a; FEKETE, 1985; RAHARJO *et al.*, 1986) the information on diets using a legume–grass combination is scarce. JIMENEZ (1983) studied some agronomic properties of different legume–grass associations and found that the alfalfa–orchard grass had the highest plant growth rate and was less affected by seasonal factors. The orchard grass had an excellent persistency when harvested frequently, an intermediate production when compared with other grasses and small variability in relation to its nutritional components. Therefore, legume–grass associations are used to include a higher proportion of legume at seeding. A common proportion is 3:1.

On the other hand, the availability and use of proved genetic rabbit lines selected for specific purposes is not very common in underdeveloped countries. The New Zealand White rabbit has become, in many cases, the breeders choice for rabbit meat production, due to its availability and adaptability to different environments and management levels. Within this breed, some genetic lines have been selected for different purposes. Crossing rabbits lines intends to take advantage of both, heterosis and complementarity.

Objectives of this research were to investigate the use of a high forage diet based on alfalfa and orchard grass for feeding growing rabbits of two genetic lines, a local and an imported, including their reciprocal crosses.

MATERIAL AND METHODS

Location

This research was conducted in the Valley of Mexico, in an experimental rabbit unit located at 19°29' N and 98°53' W and 2240 m above sea level. Climatic conditions include an annual average temperature of 15°C and a rainfall of 645 mm.

Experimental animals and diets

One hundred and twenty eight animals of thirty five days old of both sexes from two New Zealand genetic lines were used for comparative purposes. An Oregon line (OR) originated from a private company in the Unites States and imported as a *Pasteurella spp* free line, and a local line (MX) subjected to genetic improvement. From these lines, crossbreeds from reciprocal crosses were also obtained and used during the trials, paternal OR (OM) and paternal MX (MO). Also, two diets were compared: a high content of combination of alfalfa and orchard grass (AO) in a 3:1 proportion and a commercial (CO), both provided as pellets. Rabbits were given *ad libitum* access to feed and water. The chemical composition analysis of forages and diets were performed according to A.O.A.C. (1980), and GOERING and VAN SOEST (1970). Aminoacid determinations were done according to GEHRKE *et al.* (1987) and KAISER *et al.* (1974). Composition and chemical analysis of diets and forages are shown in Tables 1, 2, and 3.

Experimental design and analysis

The experiment was carried out for 6 weeks from 35 to 70 days of age, when they were slaughtered. Body weight (BW), average daily gain (ADG), feed intake (FI), feed conversion (FC), dressing weight percentage (DW) and postweaning mortality (MT) were analyzed. Measurements were taken weekly for all variables, but DW was obtained considering carcass hot weight (excluding head, leg tips, liver, kidney and all other internal organs). FI and FC were measured per cage. MT was measured as a cumulative percentage and calculated by using number of rabbits dead relative to the number of initial rabbits. Four rabbits from different litters were allotted randomly per cage, in a total of 32 wire cages.

A repeated measurement experimental design with a factorial arrangement was used, considering week as a repeated effect and four genotypes and two diets as factors. The

Table 1: Ingredient composition of experimental diets

Ingredient	Diet: AO[(1)] %	Diet: CO[(2)] %
Alfalfa–Orchard *	80.00	–
Alfalfa meal	–	33.62
Barley hull	–	17.90
Sorghum	5.07	1.50
Corn flour	–	24.61
Soybean meal	–	14.03
DL–methionine	–	0.40
Wheat bran	4.00	–
Molasses sugar cane	3.00	2.00
Tallow	6.00	–
Soybean oil	–	2.00
Vitamins premix	0.25	0.18
Minerals premix	0.60	0.50
Antioxidant	0.03	0.02
Antibiotic	0.05	0.02
Salt	0.50	0.84
Dicalcium phosphate	0.50	1.40
Calcium carbonate	–	0.98

(1)AO=Alfalfa–Orchard diet; (2)CO=Commercial diet.
*In a 3:1 proportion.

Table 2 : Chemical composition of the experimental diets (dry matter basis).

	Diet: AO [(1)] %	Diet: CO [(2)] %
Crude protein	17.20	19.74
Ether extract	9.98	3.67
Crude fiber	20.19	18.87
Ash	11.16	9.02
Acid detergent fiber	26.42	24.13
Neutral detergent fiber	39.20	38.61
Lignin (ADL)	5.03	4.09
Phosphorous	0.42	0.72
Calcium	1.23	1.33
Lysine	0.72	0.85
Methionine+cystine	0.52	0.75
Arginine	0.79	0.88
DE Kcal/kg (calculated)	2187.00	2284.00

(1)AO=Alfalfa–Orchard diet; (2)CO=Commercial diet.

Table 3 : Chemical composition of forages (air dry basis, %).

	Forage: Alfalfa hay	Forage: Orchard grass
Crude protein	20.00	20.00
Ether extract	32.00	45.00
Crude fiber	34.00	61.00
Aminoacids w/w (%)		
Threonine	0.70	0.78
Cystine	0.20	0.23
Methionine	0.23	0.28
Isoleucine	0.84	0.79
Leucine	1.26	1.36
Lysine	0.73	0.94
Arginine	0.80	0.87
Tryptophan	0.28	0.34
Valine	0.84	1.07
Histidine	0.32	0.38
Phenylalanine	0.79	0.99

Table 4 : Important effects on the performance of postweaning rabbits.

	Trait			
Effect	**BW**	**ADG**	**FI**	**FC**
Genotype	NS	NS	NS	NS
Diet	**	**	NS	*
Genotype*diet	NS	NS	NS	NS
Week	**	**	**	**
Genotype*week	NS	*	NS	NS
Diet*week	**	**	NS	NS
Genotype*diet*week	NS	NS	NS	NS

BW=Body weight; ADG=Average daily gain; FI=Feed intake; FC=Feed conversion; NS=Non significant; * (P<0.05); ** (P<0.01).

statistical model was:

$$Y_{ijklm} = M + G_i + D_j + GD_{ij} + C_{k(ij)} + R_{l(ijk)} + W_m + GW_{im} + DW_{jm} + GDW_{ijm} + CW_{km(ij)} + E_{ijklm}$$

where:

Y_{ijklm} is the observation of the ith genotype in the jth diet, kth cage of the lth rabbit and mth week.

M is the general constant mean.

G_i is the fixed effect of the ith genotype (i = 1,2,3,4).

D_j is the fixed effect of the jth diet (j = 1,2).

GD_{ij} is the fixed effect of the interaction genotype by diet.

$C_{k(ij)}$ is the random effect of the kth cage nested in the ith genotype and the jth diet (k = 1,2,3,4).

$R_{l(ijk)}$ is the random effect of the lth rabbit nested in the kth cage of the ith genotype and the jth diet (r = 1,2,3,4).

W_m is the fixed effect of the mth week (m = 1,2,3,4,5,6).

DW_{jm} is the fixed effect of the interaction diet by week

GW_{im} is the fixed effect of the interaction genotype by week.

GDW_{ijm} is the fixed effect of the interaction genotype by diet by week.

$CW_{km(ij)}$ is the random effect of the interaction cage by week.

E_{ijklm} is the random residual effect.

All random effects were assumed to be normal, with zero mean and respective variance. Covariances among observations of different periods in the same animal were different from zero. A sphericity test was performed for the matrix correlation among periods and degree of freedom for weeks effects were adjusted when applicable, according to the Greenhouse–Geiser epsilon. For FI, FC and MT the rabbit animal effect was eliminated from the model. For ADG, only 5 weeks were considered and for DW no week effect was employed. Data analysis were performed using the GLM procedure of SAS (SAS INSTITUTE, 1988).

RESULTS AND DISCUSSION

For BW, ADG, FI and FC results on the importance of effects are presented in Table 4. As observed, the week effect was important on all variables and no other effect was significant for FI. As a main effect, diet was important on BW, ADG and FC, and as an interaction effect with week on BW and ADG. Genotype was not important for all growth variables, but was for the interaction with week on ADG. Neither the genotype by diet interaction nor the triple interaction with week were statistically relevant.

The BW mean values per diet and genotypes through weeks are presented in Table 5. The CO was consistently superior to the AO diet throughout the experimental period, although this superiority was increasing along time with a final difference of 261 g, which represented a 15% weight advantage. Similar results were obtained by MUIR and MASSATE (1991) while evaluating diets with high and low forage content. Because diets differed in nutrient content (protein, amino acids, fiber, energy concentration, etc.) specific reasons for observed differences can not be ascertained; though the low level of methionine+cystine, as well as lysine, in the AO diet should be emphasized. SANCHEZ *et al.* (1984) found that rabbits fed a high alfalfa diet (74%) could have a good

Table 5 : Body weight by genotype and diet over weeks (Mean±SE*).

	Week age					
	5	**6**	**7**	**8**	**9**	**10**
Genotype (g)						
MX	768 ± 42	978 ± 33	1226 ± 49	1492 ± 47	1716 ± 58	1877 ± 59
OR	786 ± 32	983 ± 33	1240 ± 37	1511 ± 47	1762 ± 58	1773 ± 59
MO	836 ± 33	1058 ± 32	1300 ± 38	1574 ± 46	1748 ± 58	1886 ± 58
OM	851 ± 33	1109 ± 42	1343 ± 38	1588 ± 46	1703 ± 79	1876 ± 76
Diet (g)						
CO	849 ± 25a	1112 ± 27a	1375 ± 29a	1643 ± 36a	1832 ± 44a	1983 ± 45a
AO	772 ± 24b	952 ± 27b	1179 ± 28b	1440 ± 35b	1583 ± 43b	1722 ± 44b

MX=Mexican; OR=Oregonian; MO=Mexican*Oregonian;
OM=Oregonian*Mexican; CO=Commercial; AO=Alfalfa–Orchard.
a–b Means on the same column with no common letter are statistically different (P<0.05). *SE=Standard Error.

Table 6 : Daily gain by genotype and diet over weeks (Mean±SE*).

	Week age					
	6	7	8	9	10	Overall
Genotype (g)						
MX	30 ± 1a	35 ± 2a	38 ± 2a	31 ± 3a	23 ± 3a	31 ± 2a
OR	28 ± 1a	38 ± 2a	38 ± 2a	21 ± 3b	16 ± 3a	28 ± 2a
MO	31 ± 1a	35 ± 2a	39 ± 2a	25 ± 3a	19 ± 3a	30 ± 2a
OM	37 ± 2b	33 ± 2a	35 ± 2a	16 ± 4b	25 ± 4a	29 ± 3a
Diet (g)						
CO	37 ± 1a	38 ± 1a	38 ± 2a	27 ± 2a	22 ± 2a	32 ± 2a
AO	26 ± 1b	35 ± 1b	37 ± 1a	20 ± 2b	20 ± 2a	28 ± 2b

MX=Mexican; OR=Oregonian; MO=Mexican*Oregonian;
OM=Oregonian*Mexican; CO=Commercial; AO=Alfalfa-Orchard.
a-b Means on the same column with no common letter are statistically different (P<0.05). *SE=Standard Error.

growth rate when methionine was added to the diet. The 10-week BW was less than 2 kg in both diets, which is the usual slaughter weight in the region. For genotypes, weights were very similar across weeks.

Interestingly, no heterotic effect was observed for the OM and MO crosses. Similar results have been observed by other authors (LUKEFAHR *et al.*, 1981; ESTRADA and RAMOS, 1993). On the contrary, OETTIN *et al.* (1989) found an important superiority of crossbred animals.

For ADG during the entire experimental period, the CO diet was superior (P<0.05) over the AO (32±2 vs 28±2). However, other authors (CHEEKE and PATTON, 1978; CUEVAS, 1979; TORRES and LOPEZ, 1979; CIENFUEGOS, 1985) have reported slower growth rates for rabbits fed high forage diets. ABOUL-ELA *et al.* (1996) studied four combination of starter-finishing diets with different crude fiber levels and found that the group fed a 17.24% crude fiber level had superior gains (25.5 g/d) in the finishing period, over diets with lower and higher fiber content. The interaction effect of diet per week implied a response change through time (Table 6 and Figure 1). At weeks 6, 7 and 9 of age the superiority of the CO diet over the AO was important (P<0.05). Maximum (over 37 g/d) and minimum (below 22g/d) ADG values were obtained on weeks 8 and 10, where non significant differences between treatments occurred. The interaction effect of genotype by week was statistically important on ADG (P<0.05). This was due mainly to the atypical response of the OM genotype (Table 6 and Figure 2), which showed an initial superiority over the other genotypes in week six and the poorest response in week 9. ESPINOZA *et al.* (1992) detected an erratic performance on this trait in Mexican hybrid rabbits. In general, all genotypes performed better during the first three weeks of the experimental period.

The FI was similar for genotypes and diets (Table 7). Average FI for the entire experimental period ranged from 105±5 to 112±5 g/d for genotypes, being very similar for diets (CO=109±4 vs AO=107±4). These results differ from other studies (LEBAS, 1975; POTE *et al.*, 1980; FEKETE, 1985; CHEEKE, 1987; BLAS *et al.*, 1994; ABOUL-ELA *et al.*, 1996) in which a higher feed intake in diets based on forages was observed. Higher FI in weanling rabbits might be necessary to satisfy energy requirements. In this study, crude fiber and energy content between AO and CO diets were 20.19, 18.87% and 2187, 2284 DE Kcal/kg. However, the diet palatability and protein quality can also play an important role on lower FI when high alfalfa levels are used (KENDALL and LATH, 1976; CHEEKE *et al.*, 1977). The amount of tallow (6%) in the AO diet might have improved the apparent digestibility of some of its components (FEKETE *et al.*, 1990). Specifically, FI was increasing with time from a minimum at week 6 (less than 90 g/d) to a maximum at week 8 (over 110 g/d), with a small decline afterwards, observing a linear (P<0.01) and quadratic (P<0.05) trend.

Table 7 : Overall productive performance for some traits by genotype and diet (Mean±SE*).

	Trait			
	FI	FC	DW	MT
Genotype				
MX	108 ± 5a	4.3 ± 0.6a	49.2 ± 1.5a	12.5a
OR	105 ± 5a	3.9 ± 0.3a	43.9 ± 2.9b	9.4a
MO	112 ± a	3.9 ± 0.5a	45.6 ± 2.2ab	9.4a
OM	108 ± 5a	4.3 ± 1.3a	48.4 ± 2.1a	6.3a
Diet				
CO	109 ± 4a	3.8 ± 0.6a	47.2 ± 2.7a	10.9a
AO	107 ± 4a	4.4 ± 0.4b	46.3 ± 1.6a	7.8a

MX=Mexican; OR=Oregonian; MO=Mexican*Oregonian;
OM=Oregonian*Mexican; CO=Commercial; AO=Alfalfa-Orchard.
FI=Feed intake (g/d); FC=Feed coversion; DW=Dressing weight (%);
MT=Postweaning cumulative mortality at 70 days (%).
a-b Means on the same column with no common letter are statistically different (P<0.05). *SE=Standard Error

Diet and week effects were important on FC. This variable is a combined expression of both, live weight and feed intake by week. On average, over the entire experimental period, the rabbits fed the CO diet had a better FC than the AO diet (3.8±.6 vs 4.4±.4, Table 6; a difference of 600 g). Similar results have been found by other authors (CUEVAS,

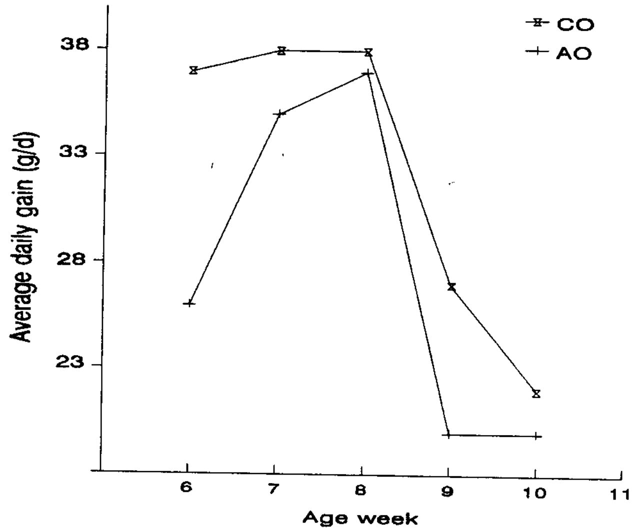

Figure 1 : Average daily gain by week of weanling rabbits under two different forage content diets. CO=Commercial ; AO = Alfalfa-Orchard

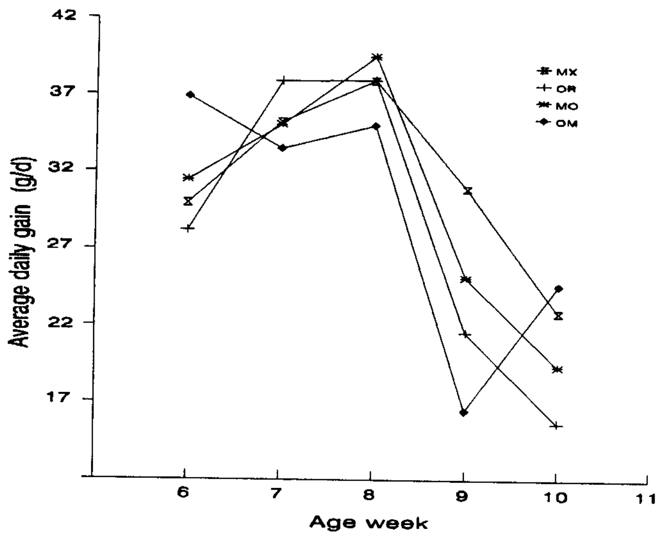

Figure 2 : Average daily gain by genotype and week. MX=Mexican; OR=Oregonian; MO=Mexican*Oregonian; OM=Oregonian*Mexican

1979; HARRIS *et al.*, 1981b; ORTIZ *et al.*, 1989; ABOUL-ELA *et al.*, 1996). Superior FC has been obtained (from 2.27 to 2.55) when crude fiber levels are moderate (from 11.6 to 15.3) and crossbred animals were used (BLAS *et al.*, 1994). The effect of week on FC consistently increased (P<0.01), although at different rates, (linear, quadratic and cubic effects were all important). DE BLAS (1989) pointed out that in fattening rabbits FC increased in older and heavier animals due to a differential body composition in which more fat tissue is present and less protein tissue and water. Genotypes performed similar for FC, in agreement with results by LUKEFAHR *et al.* (1981) and CHIERICATO and FILOTTO (1989).

For DW differences were observed among genotypes (Table 7), with the OR and MO showing the poorest performance (P<0.05). LUKEFAHR *et al.* (1981) and CHIERICATO and FILOTTO (1989) did not find important differences between pure and hybrid lines for DW. The OR line has been selected to be a *Pasteurella spp* free line, rather than to meat production performance. However, no diet effect was found. These results are in disagreement with DE BLAS (1989) who showed that rabbits fed a high forage diet had a lower DW, suggesting that fiber caused an increase on weight in the empty digestive tract and its content. Other studies (LEBAS, 1975; DE BLAS *et al.*, 1986) reported that feeds with a low fiber content stayed longer in the digestive tract which resulted in an enlarged caecum, and a lower DW. The diets means were very similar 47.2±2.7 vs 46.3±1.6, for CO and AO.

Although, no significant differences were observed in MT (Table 7), the OR and crossbreeds tended to have better survival, and these differences could be economically important for the producer. For diets, means were similar; 10.9 and 7.8% for CO and AO. Major mortality problems are found when weanling rabbits are fed low fiber diets. In this study, fiber content of both diets was over 18%. In diets high in alfalfa an important reduction in mortality has been reported (CHEEKE and PATTON, 1978; POTE *et al.*, 1980; HARRIS *et al.*, 1981b).

In this research, genotype effects were non important for traits studied, except for DW. These results showed that for rabbits fed the AO diet, BW, ADG and FC performances were poorer. FI and MT were not affected by genotype or diet. Additional research to evaluate other local forages and economic aspects, of growing rabbits fed high forage diets seems warranted.

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