

# JOURNAL OF ANIMAL SCIENCE

*The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science*

## **Breed and heterotic effects on postweaning traits in Altex and New Zealand White straightbred and crossbred rabbits**

M. F. Medellin and S. D. Lukefahr

*J Anim Sci* 2001. 79:1173-1178.

The online version of this article, along with updated information and services, is located on the World Wide Web at:

<http://jas.fass.org>



**American Society of Animal Science**

[www.asas.org](http://www.asas.org)

# Breed and heterotic effects on postweaning traits in Altex and New Zealand White straightbred and crossbred rabbits

M. F. Medellin and S. D. Lukefahr<sup>1</sup>

Department of Animal & Wildlife Sciences, Texas A&M University, Kingsville 78363

**ABSTRACT:** Postweaning data from 1,111 straightbred and reciprocally crossbred rabbits were analyzed to evaluate Altex and New Zealand White (NZW) breeds for individual growth and litter traits. The Altex is a recently developed sire breed, whereas the NZW is a popular commercial dam breed. Individual fryer growth traits were weaning (28 d; WW) and market (70 d; MW) weights and ADG. Litter traits included litter size (LSW) and total weight of litter at weaning (LWW), 28 to 70 d total feed intake (LFI), feed efficiency (LFE = total litter gain/LFI), survival rate, and within-litter MW uniformity. Least squares models consisted of fixed effects of sire breed, dam breed, season of weaning, doe parity, two- and three-way interactions, and random effects of sire within sire breed, litter within sire × dam breed, and(or) residual error (depending on whether an individual or a litter trait was analyzed). Crossbreeding parameters (direct breed additive, maternal breed, and individual heterosis) were estimated. Altex sires increased WW, ADG, and MW by 40 g ( $P < 0.10$ ), 2.5 g/d, and 152 g ( $P < 0.001$ ), respectively. Individual growth traits were not significantly influenced by the maternal breed effect. Litter size at wean-

ing and LWW means were numerically similar for Altex and NZW dams. Direct heterosis increased ADG (1.7 g/d;  $P < 0.01$ ) and MW (66 g;  $P < 0.10$ ). In straightbred Altex compared to NZW fryers, ADG and MW were increased by 3.6 g/d and 216 g, respectively ( $P < 0.001$ ). In Altex (sire) × NZW (dam) crossbred compared to NZW straightbred fryers, WW and MW were heavier (55 and 218 g;  $P < 0.10$  and  $< 0.001$ ) and ADG was more rapid (4.2 g/d;  $P < 0.001$ ). For litter traits, Altex compared to NZW sires increased LFI by 1.28 kg ( $P < 0.10$ ). Individual crossbreeding parameters did not affect ( $P > 0.05$ ) other litter traits. No relationship existed between breed type of fryer and survival status ( $\chi^2 = 2.81$ ;  $P > 0.25$ ). For litter traits, straightbred Altex had significantly greater LFI by 2.45 kg and increased LFE by 0.015 units relative to NZW. Combined direct breed additive and heterosis effects increased LFI by 1.84 kg ( $P < 0.05$ ) in Altex (sire) × NZW (dam) crossbreds compared to NZW straightbreds. Also, 25% more Altex (sire) × NZW (dam) crossbred fryers were marketable (body weight  $\geq 1.8$  kg) by 63 d of age than NZW straightbred fryers. These data suggest that crossing Altex bucks to NZW enhanced breeding efficiency of fryer growth performance.

Key Words: Breeds, Crossbreeding, Growth, Heterosis, Rabbits

©2001 American Society of Animal Science. All rights reserved.

J. Anim. Sci. 2001. 79:1173–1178

## Introduction

The New Zealand White (NZW), a breed of U. S. origin, is the most popular germplasm used in commercial rabbit production worldwide. The NZW is well recognized as a dam breed based on its outstanding maternal genetic merits for litter size, milking, and general mothering ability (Lebas et al., 1997; McNitt et al., 2000).

However, U.S. rabbit breeding experiments have documented that the commercial NZW is generally inferior

to other breeds and crosses for postweaning fryer growth, feed utilization, and carcass and lean yield traits (Ozimba and Lukefahr, 1991; Lukefahr et al., 1992; Roberts and Lukefahr, 1992). Crossbred fryers sired by Californian or Champagne d'Argent (two medium-sized breeds) bucks and reared by NZW dams have higher dressing percentages and cutability than NZW straightbred fryers. In contrast, crossbred fryers sired by Flemish Giant bucks compared to Californian, Champagne d'Argent, and NZW bucks have superior market weights but not exceptional carcass or lean yield rates.

Lukefahr et al. (1996) described the development of a large terminal sire breed, presently known as the Altex, which has a breed foundation of  $\frac{1}{4}$  Californian,  $\frac{1}{4}$  Champagne d'Argent, and  $\frac{1}{2}$  Flemish Giant and a history of phenotypic selection for increased 70-d mar-

<sup>1</sup>Correspondence: Campus Box 156 (phone: 361-593-3699; fax: 361-593-3788; E-mail: s-lukefahr@tamuk.edu).

Received October 6, 2000.

Accepted January 22, 2001.

ket weight. Breed complementarity and heterosis effects may be exhibited by crossbred fryers from Altex sires and NZW dams to increase economic returns in commercial rabbit operations.

Our objectives were to evaluate Altex and NZW breeds for postweaning individual growth and litter traits and to estimate direct and maternal breed additive effects and direct heterosis.

## Materials and Methods

### *Population Management and Traits Measured*

Commercial straightbred Altex and NZW populations were maintained at the rabbit research facility, Texas A&M University-Kingsville. This 1-yr study, previously approved by the institution's animal care and use committee, was initiated in the fall of 1997. Rabbits were given ad libitum access to a commercial diet (Nutrena Rabbit Pellets, Cargill-Nutrena Feeds Division, Minneapolis, MN) formulated to meet NRC nutrient requirements (NRC, 1977). Water was supplied continuously using automatic water valves. Cage dimensions were 76.2 × 61.0 × 45.7 cm (length, width, and height) for breeding bucks and 76.2 × 76.2 × 45.7 cm for breeding does and weaned litters.

Nulli- and multiparous Altex and NZW does were used to initiate the experiment. Altex and NZW does (first mated at 6 and 5 mo, respectively) were subjected to a 14-d breeding regimen, allowing a doe to produce a maximum of eight litters per annum. Pregnancy determination (by abdominal palpation) was done at 14-d after coitus, and nonpregnant does were returned to a buck's cage for service. Nest boxes were placed in the doe's cage on d 28 of pregnancy. A doe was culled if she either failed to wean at least one kit from three consecutive matings or had produced litters for an entire year (to cull aging does and/or reduce generation interval). No crossfostering of kits among litters was practiced to determine a doe's maternal ability, although crossfostering is a common commercial practice. Kits were weaned, sexed, and tattooed at 28 d of age. A weaned litter was randomly assigned to a growing cage for the 28- to 70-d postweaning period.

Performance traits used as breed evaluation criteria were individual weaning (28 d) and market (70 d) weights, and ADG. An additional growth trait was predicted age at 1.8 kg (minimum market weight), which was estimated for each fryer by regression:  $A = 28 + ADG^{-1}(1,800 - WW)$ , where A is predicted age and WW and ADG are actual weaning weight and ADG. Also included was the proportion of marketable fryers weighing ≥ 1.8 kg at 28 through 70 d involving weekly body weight data. Specifically, each fryer received a score of either 0 or 1 if body weight was < 1.8 or ≥ 1.8 kg, respectively. Litter traits included litter size and total weight of litter at weaning, 28 to 70 d total feed intake, feed efficiency (total litter gain/litter feed intake), 28 to 70 d survival rate, and within-litter unifor-

mity (coefficient of variation in market weight among littermates).

### *Experimental Mating Scheme*

A 2 × 2 factorial arrangement of sire and dam breeds was followed to produce straightbred and reciprocal crossbred litters. Specifically, the experimental mating scheme consisted of randomly assigning a doe to either an Altex or NZW buck. If a litter resulted, the same doe was randomly assigned for the next mating to a service buck of the second breed, alternating as such throughout the duration of the experiment, and vice versa for breeding bucks. The rationale for cross-classification was to balance individual sire and dam genetic and(or) maternal effects across breed types. Repeat matings and closely related matings (e.g., parent-offspring and full- or half-siblings) were avoided.

### *Statistical Analysis*

Individual fryer growth data were analyzed using GLMM software (Blouin and Saxton, 1990) according to the following mathematical model:

$$Y_{ijklmn} = \mu + SB_i + s_{ji} + DB_k + (SBDB)_{ik} + l_{lik} + S_m + (DBS)_{km} + \varepsilon_{ijklmn}$$

where  $Y_{ijklmn}$  = observed value of a dependent variable,  $\mu$  = overall trait mean,  $SB_i$  = fixed effect of the  $i^{\text{th}}$  sire breed,  $s_{ji}$  = random effect of the  $j^{\text{th}}$  sire nested within the  $i^{\text{th}}$  sire breed,  $DB_k$  = fixed effect of the  $k^{\text{th}}$  dam breed,  $(SBDB)_{ik}$  = fixed effect interaction of the  $i^{\text{th}}$  sire breed and the  $k^{\text{th}}$  dam breed,  $l_{lik}$  = random effect of the  $l^{\text{th}}$  litter nested within the  $i^{\text{th}}$  sire breed and the  $k^{\text{th}}$  dam breed,  $S_m$  = fixed effect of the  $m^{\text{th}}$  season of weaning of the litter (1 = January through March, 2 = April and May, 3 = June through August, 4 = September through December), fixed effect interaction of the  $k^{\text{th}}$  dam breed and the  $m^{\text{th}}$  season, and  $\varepsilon_{ijklmn}$  = the residual random error. Random effects were assumed to be uncorrelated, and trait variances were assumed to be homogeneous between breeds.

In preliminary analyses of growth traits, the gender of rabbit effect was never significant ( $P > 0.20$ ; e.g., least squares means for female and male fryer market weights were 1,960 and 1,972 g, respectively), in general agreement with the literature that sexual dimorphism in rabbits does not exist. Also, parity of doe and sire breed × season and sire breed × dam breed × season interactions never approached significance ( $P > 0.10$ ) and, likewise, were excluded from final models. Models for litter traits included the same previously described effects, except that the litter source was the residual error term. However, for litter feed intake and feed efficiency, litter size at weaning was added as a fixed main effect (classes: 1 to 11 kits) to control residual (among-litter) variation by blocking for this source.

**Table 1.** Summary statistics for individual fryer and litter postweaning traits in rabbits

Trait <sup>a</sup>	n	Mean	Minimum	Maximum	SD
WW	1,111	501	151	1,156	134
ADG	1,075	35.0	18.9	53.0	6.3
MW	1,075	1,975	1,033	3,141	353
LSW	185	6.0	1	11	2.3
LWW	181	2.97	0.59	5.21	1.04
LFI	181	28.9	3.6	53.4	11.9
LFE	181	0.296	0.178	0.476	0.037
CV	176	6.2	0.1	35.4	3.9

<sup>a</sup>Trait abbreviations: WW = individual fryer weaning weight (28 d), g; ADG = average daily gain (28 to 70 d), g/d; MW = individual fryer market weight (70 d), g; LSW = litter size weaned (28 d); LWW = total weight of litter at weaning, kg; LFI = 28- to 70-d total feed intake, kg; LFE = litter feed efficiency (total litter gain/LFI); CV = MW uniformity (coefficient of variation in MW among littermates involving litters with > 1 fryer).

Least squares means according to breed type for fryer performance traits were contrasted to estimate crossbreeding parameters: direct breed additive ( $g^I$ ), maternal breed ( $g^M$ ), and direct heterosis ( $h^I$ ), being tested at  $P < 0.05$ . An estimate of  $\frac{1}{2}g^I$  was obtained as the mean difference between Altex and NZW sire breed groups. The  $g^M$  was computed as the difference between reciprocal crossbreds from NZW vs Altex dams. The  $g^M$  parameter was a composite of possibly several maternal genetic effects (e.g., additive and non additive (grand)-maternal genetic and linkage contributions). The  $h^I$  was estimated as the mean deviation between reciprocally crossbred vs parental straightbred groups. In addition, two breed type contrasts were selected: Altex vs NZW straightbreds, and Altex (sire)  $\times$  NZW (dam) crossbreds vs NZW straightbreds. These contrasts are of biological and practical importance. However, more preplanned contrasts among breed groups were made than there were degrees of freedom, and not all contrasts were orthogonal. Thus, tests of significance for the various contrasts may be biased. These comparisons were made to test the potential merit of using Altex, in relation to traditional NZW stock, as either straightbred stock or as a terminal-sire breed in commercial herds. The random sire within sire breed source was the error line for determining the significance level for  $g^I$ . The random litter source was the error line for  $g^M$  and  $h^I$  and in testing mean differences for the two additional contrasts.

## Results and Discussion

### Fryer and Litter Production

Descriptive statistics for individual fryer and litter traits are provided in Table 1. The breeding experiment yielded 1,111 weaned fryers from 185 litters sired by 48 bucks (31 Altex and 17 NZW) and 69 does (33 Altex and 36 NZW). Distribution of weaned fryers (litters) were 244 (43) straightbred Altex, 379 (64) Altex sire  $\times$

NZW dam, 150 (28) NZW sire  $\times$  Altex dam, and 302 (50) straightbred NZW. Although similar numbers of Altex and NZW does were represented across age and(or) parity classes, NZW does contributed more litters to the experiment than Altex does, largely due to higher observed pregnancy rate. However, it was noted that NZW buck  $\times$  Altex doe matings resulted in proportionately fewer pregnancies than straightbred Altex matings, for unknown reasons. Litter weaning weight and litter feed intake measurements were not recorded for four litters. Nine litters containing only one kit contributed no data to assess within-litter, 70-d market weight uniformity. Only 36 fryers died (3.2%) in the experiment. Chi-Square analysis revealed that no relationship existed between breed type of fryer and survival ( $\chi^2 = 2.81$ ;  $P > 0.25$ ).

### ANOVA Results for Season and Litter Size

The effect of season of weaning was highly significant ( $P < 0.01$ ) for all individual growth and litter traits studied, except for within-litter uniformity for 70-d market weight. Growth performance was reduced in the summer when high ambient temperatures, common to south Texas, greatly depressed total litter feed appetite (16.5 kg in summer compared to 30.1, 25.0, and 27.1 kg in winter, spring, and fall;  $P < 0.001$ ). Further, least squares means for the proportion of marketable fryers by d 70 was only 15.0% in summer, compared to 88.1, 61.9, and 88.6% in winter, spring, and fall. A doe breed  $\times$  season interaction was detected ( $P < 0.01$ ) for ADG and litter feed efficiency; however, numerical differences among subclass means were negligible.

As expected, for litter feed intake and feed efficiency, the fixed effect of litter size at weaning was very important ( $P < 0.001$ ). However, upon close examination, there was no clear trend across least squares means for litter size weaned because different physiological mechanisms (i.e., decelerated growth due to obesity in small litters and compensatory growth in large litters) may have occurred.

### Direct Breed Additive Effects on Individual and Litter Traits

Progeny of Altex sires were heavier at both weaning and 70 d and grew faster than progeny of NZW sires (Table 2). In an experiment conducted in Oregon, Lukefahr et al. (1983) reported total litter weights at 56 d of 9.55 and 7.86 kg for Flemish Giant-sired compared to NZW-sired fryers reared by straightbred and crossbred dams. Although litter size means at 56 d were similar (6.03 and 5.46 fryers for Flemish Giant and NZW groups), a BW difference of 144 g per fryer is calculated, which is consistent with 102 g obtained from a supplemental analysis of individual 56-d weights from the present data set. In an Alabama study, Lukefahr et al. (1992) compared fryers for postweaning growth and feed performances that were produced from mating Cal-

**Table 2.** Generalized least squares means ( $\pm$ SE), crossbreeding parameters, and selected contrasts for individual postweaning growth traits of Altex and New Zealand White (NZW) rabbits

Item	Trait <sup>a</sup>		
	WW	ADG	MW
Breed type mean <sup>b</sup>			
Altex	537 $\pm$ 22	35.2 $\pm$ 0.6	2,049 $\pm$ 39
Altex $\times$ NZW	560 $\pm$ 19	35.7 $\pm$ 0.5	2,051 $\pm$ 34
NZW $\times$ Altex	512 $\pm$ 28	34.3 $\pm$ 0.8	1,963 $\pm$ 50
NZW	505 $\pm$ 21	31.5 $\pm$ 0.6	1,833 $\pm$ 38
Crossbreeding parameter			
$\frac{1}{2}g^I_{(A-NZW)}$	40 $\pm$ 24 <sup>‡</sup>	2.5 $\pm$ 0.7***	152 $\pm$ 37***
$g^M_{(NZW-A)}$	48 $\pm$ 33	1.4 $\pm$ 0.9	88 $\pm$ 59
$h^I$	15 $\pm$ 21	1.7 $\pm$ 0.6**	66 $\pm$ 37 <sup>‡</sup>
$h^I$ , %	2.9	5.0	3.4
Breed type contrast			
Altex – NZW	32 $\pm$ 30	3.6 $\pm$ 0.9***	216 $\pm$ 55***
Altex $\times$ NZW – NZW	55 $\pm$ 21 <sup>‡</sup>	4.2 $\pm$ 0.8***	218 $\pm$ 51***

<sup>a</sup>Trait abbreviations: WW = individual fryer weaning weight (28 d), g; ADG = average daily gain (28 to 70 d), g/d; MW = individual fryer market weight (70 d), g.

<sup>b</sup>Sire breed precedes dam breed for crossbreds.

<sup>‡</sup> $P < 0.10$ .

\* $P < 0.01$ .

\*\*\* $P < 0.001$ .

ifornian, Champagne d'Argent, Palomino, and NZW bucks to NZW does. Californian and Champagne d'Argent crossbred fryers were 74 and 146 g heavier at 70 d than NZW straightbred fryers, consistent with the present results. These cited values provide estimates of one-half fractions of breed additive effects if negligible heterosis existed.

Direct breed additive effects were generally not significant for litter traits (Table 3). One exception was that litter feed intake increased by 1.28 kg ( $P < 0.10$ ) in Altex compared to NZW sire breed groups. This agrees with 1.3-kg increased litter feed intake reported

by Khan and Lukefahr (1996) in an Alabama study involving earlier generations of Altex bucks compared to the combined mean performance of Californian and NZW bucks that were mated to Californian and NZW straightbred and crossbred does. However, in a commercial operation, fryers are marketed as early as possible (i.e., at a minimum 1.8 kg body weight). On this basis, according to present findings, Altex-sired offspring would have been marketed earlier, hence there actually could have been some feed savings. In retrospect, a more useful approach to assess litter feed intake may have been to remove from the litter those individ-

**Table 3.** Generalized least squares means ( $\pm$ SE), crossbreeding parameters, and selected contrasts for litter postweaning traits<sup>a</sup> of Altex and New Zealand White (NZW) rabbits

Item	LSW	LWW	LFI	LFE	CV
Breed type mean <sup>b</sup>					
Altex	5.8 $\pm$ 0.3	3.04 $\pm$ 0.16	24.8 $\pm$ 0.7	0.299 $\pm$ 0.006	6.5 $\pm$ 0.7
Altex $\times$ NZW	6.0 $\pm$ 0.3	3.02 $\pm$ 0.14	24.2 $\pm$ 0.6	0.291 $\pm$ 0.005	5.5 $\pm$ 0.6
NZW $\times$ Altex	6.0 $\pm$ 0.5	2.92 $\pm$ 0.19	24.1 $\pm$ 0.8	0.296 $\pm$ 0.006	6.2 $\pm$ 0.8
NZW	6.3 $\pm$ 0.4	2.99 $\pm$ 0.15	22.4 $\pm$ 0.6	0.285 $\pm$ 0.005	6.5 $\pm$ 0.6
Crossbreeding parameter					
$\frac{1}{2}g^I_{(A-NZW)}$	-0.2 $\pm$ 0.4	0.08 $\pm$ 0.18	1.28 $\pm$ 0.66 <sup>‡</sup>	0.005 $\pm$ 0.006	-0.3 $\pm$ 0.7
$g^M_{(NZW-A)}$	0.0 $\pm$ 0.5	0.11 $\pm$ 0.23	0.11 $\pm$ 0.95	-0.005 $\pm$ 0.008	0.3 $\pm$ 0.6
$h^I$	-0.0 $\pm$ 0.3	-0.04 $\pm$ 0.14	0.56 $\pm$ 0.65	0.001 $\pm$ 0.004	-0.6 $\pm$ 0.6
$h^I$ , %	-0.0	-1.5	2.8	0.5	-9.3
Breed type contrast					
Altex – NZW	-0.4 $\pm$ 0.5	0.05 $\pm$ 0.22	2.45 $\pm$ 0.91**	0.015 $\pm$ 0.007*	-0.0 $\pm$ 0.9
Altex $\times$ NZW – NZW	-0.2 $\pm$ 0.5	0.03 $\pm$ 0.21	1.84 $\pm$ 0.80*	0.006 $\pm$ 0.007	-0.9 $\pm$ 0.8

<sup>a</sup>Trait abbreviations: LSW = litter size weaned (28 d); LWW = total weight of litter at weaning, kg; LFI = 28- to 70-d total feed intake, kg; LFE = litter feed efficiency (total litter gain/LFI); CV = market weight uniformity (coefficient of variation in market weight among littermates involving litters with > 1 fryer).

<sup>b</sup>Sire breed precedes dam breed for crossbreds.

<sup>‡</sup> $P < 0.10$ .

\* $P < 0.05$ .

\*\* $P < 0.01$ .

ual fryers on the day that 1.8 kg body weight was attained and continue recording feed intake until either all fryers reached 1.8 kg or an age limit occurred (e.g., 70 d).

#### Maternal Breed Effects on Individual and Litter Traits

The maternal breed effect was never significant for individual growth or litter traits. Least squares means for both litter size and weight at weaning were similar for Altex and NZW dams (Table 3). Although milk production was not measured, total litter weight at 21 d, which is highly correlated with total milk production, did not differ ( $P = 0.746$ ) between dam breeds. Hence, although NZW compared to Altex dams produced proportionately more litters (from total matings) in the experiment, there were no significant differences in average litter size or weight at weaning ( $P > 0.10$ ), which perhaps best explains why breed type means were similar for litter traits.

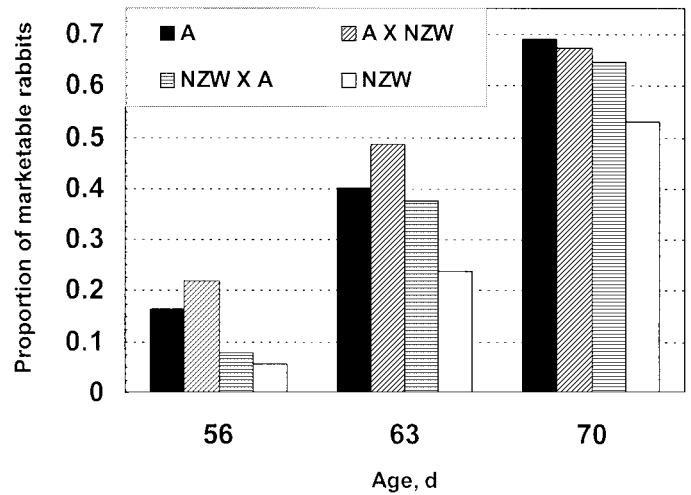
In agreement, studies by Carregal (1980) and Lukefahr et al. (1986), involving similar large- and medium-sized breeds, reported that additive breed effects were more important than maternal breed or direct and maternal heterotic effects on individual market weight at 56 or 70 d. In studies involving only medium-sized breeds, maternal breed effects have been shown to be comparable to or more important than additive breed effects for growth and litter traits (Brun and Ouhayoun, 1989; Afifi et al., 1994; Abdel-Ghany et al., 2000).

#### Direct Heterotic Effects on Individual and Litter Traits

Estimates of direct heterosis for growth and litter traits were small (e.g.,  $< 10\%$ ; Tables 2 and 3), despite using divergent parental breeds in founding the Altex compared to NZW. Individual heterosis positively influenced ADG by 1.7 g/d ( $P < 0.01$ ) and 70-d market weight by 66 g ( $P < 0.10$ ). Present heterosis estimates generally confirm numerous literature values. The least reported trait, within-litter uniformity in 70-d market weight, had a direct heterosis estimate of  $-9.3\%$ , which differs from the  $10.5\%$  estimate reported by Khan and Lukefahr (1996) involving Californian and NZW parental breeds and crosses; however, neither estimate was significantly different from zero ( $P > 0.05$ ). Using an individual animal model to estimate additive and dominance genetic variances for fryer market weights in a NZW population, Lukefahr et al. (2000) reported a range of 7 to 17% influence attributable to dominance effects, also in agreement with present results reflecting minor nonadditive genetic effects on growth traits.

#### Predicted Market Age and Proportion of Marketable Fryers Analyses

For predicted age at minimum market weight of 1.8 kg, least squares means by breed type were 65.2, 65.1,



**Figure 1.** Proportion of marketable fryers (weight  $\geq 1.8$  kg) by breed type and age. Breed types: Altex (A), New Zealand White (NZW). For crossbreds, sire breed precedes dam breed.

66.8, and 70.1 d, respectively, for Altex, Altex (sire)  $\times$  NZW (dam), NZW (sire)  $\times$  Altex (dam), and NZW fryers. These findings suggest that NZW fryers would have required more days of feeding to achieve market weight. Specifically, estimates of breed additive (Altex minus NZW sire groups), breed maternal (NZW minus Altex dams between reciprocal crosses), and direct heterosis for predicted age were  $-3.3 \pm 1.0$  ( $P = 0.003$ ),  $-1.7 \pm 1.5$  ( $P = 0.270$ ), and  $-1.8 \pm 1.0$  d ( $P = 0.082$ ), respectively. In addition, least squares means by season were 60.5, 67.9, 77.4, and 61.4 d for winter, spring, summer, and fall, respectively.

For proportion of marketable fryers weighing 1.8 kg or heavier, no fryers attained this weight on d 28, 35, or 42, and at d 49 the overall figure was  $< 1\%$ . However, for d 56, 63, and 70, marketability analyses revealed cumulative and overall estimates of 0.129, 0.373, and 0.634, respectively. Results by breed type are shown in Figure 1. The breed additive contribution of Altex vs NZW sires was significant ( $P < 0.05$ ) at d 56, 63, and 70 (differences of 0.045, 0.057, and 0.095). In contrast, the maternal breed influence was significant ( $P = 0.035$ ) only at d 56, with a 0.140 difference in favor of NZW dams. Direct heterosis positively affected marketability by 0.112 only at 63 d ( $P < 0.05$ ). However, neither maternal breed nor direct heterosis effects were important ( $P \geq 0.24$ ) at 70 d. In addition, Altex compared to NZW straightbreds had higher marketability values by 0.110 ( $P < 0.10$ ), 0.162 ( $P < 0.05$ ), and 0.161 ( $P < 0.01$ ) at d 56, 63, and 70. Altex (sires)  $\times$  NZW (dam) crossbreds compared to NZW straightbreds showed larger and more significant differences of 0.163 ( $P < 0.01$ ) and 0.247 ( $P < 0.001$ ) at 56 and 63 d than those observed in the previous contrast, although the difference of 0.144 ( $P < 0.01$ ) at 70 d was similar. Hence, approximately 25% more fryers were marketable by 63 d in Altex-sired fryers from NZW dams than for NZW straightbreds.

### *Breed Type Comparisons for Individual and Litter Traits*

Straightbred Altex fryers had greater ADG by 3.6 g/d and heavier 70-d market weight by 216 g than straightbred NZW fryers ( $P < 0.001$ ; Table 2), although weaning weight did not differ significantly ( $P = 0.291$ ). Altex litters also consumed more feed (a difference of 2.45 kg;  $P < 0.01$ ) than NZW litters (Table 3). Straightbred NZW litters had lower feed efficiency of 0.285 vs 0.299 in straightbred Altex litters ( $P < 0.05$ ). Lukefahr et al. (1984) also reported heavier market weights at 56 d by 0.35 kg in Flemish Giant compared to NZW straightbred fryers. However, in the cited study, litter feed intake was comparable because litter size was larger by 1.7 kits at weaning in NZW litters; also, litter feed efficiency was similar. In agreement with present results, Ozimba and Lukefahr (1991) observed Flemish Giant-sired, crossbred litters to have heavier 70-d market weights and higher litter feed intake than NZW, although litter feed efficiency did not differ.

Altex-sired fryers from NZW dams had heavier weaning weights by 55 g ( $P < 0.10$ ), faster ADG by 4.2 g/d ( $P < 0.001$ ), and heavier 70-d market weights by 218 g ( $P < 0.001$ ) compared to NZW straightbreds, due to favorable breed additive (transmitted by Altex sires) and positive heterotic effects (Table 2). These effects, and the +88 g ( $P = 0.142$ ) g<sup>M</sup> contribution of NZW dams, resulted in this terminal-cross having a nearly identical mean 70-d market weight (2,051 vs 2,049 g) compared to straightbred Altex fryers. In Louisiana, McNitt (2000) reported that Altex-sired fryers from NZW dams had consistently heavier postweaning weekly body weights than NZW fryers, although differences were smaller than those observed in the present experiment. The only litter trait found to differ significantly ( $P < 0.10$ ) was litter feed intake, whereby Altex (sire) × NZW (dam) crossbreds consumed 1.84 kg more feed than NZW straightbreds. However, economic returns associated with heavier body weights in crossbreds (218 g per fryer × 6 fryers per litter × market price) would well exceed higher feed costs if fryers were all marketed at 70 d, assuming that purchase cost of Altex was comparable to NZW bucks.

### **Implications**

In the U.S. meat rabbit industry, there is a need to develop sire breeds and(or) lines to cross to available dam breeds to potentially enhance breed complementarity and heterosis benefits on postweaning fryer performance. This breeding experiment evaluated a new sire breed, the Altex, and a popular dam breed, the New Zealand White. Overall, results showed that growth traits measured in progeny were superior for Altex compared to New Zealand White sires. However, maternal effects tended not to be important. Direct het-

erosis positively influenced fryer average daily gain and market weight at 70 d. Genetic differences for litter traits were minor between Altex and New Zealand White breeds. Altex (sire) × New Zealand White (dam) crossbred fryers had greater postweaning growth performance than New Zealand White fryers, thus classifying the Altex as a commercial sire breed.

### **Literature Cited**

- Abdel-Ghany, A. M., N. S. Hassan, and A. A. Amin. 2000. Heterosis, direct and maternal abilities of post-weaning daily gain in weight traits of two Egyptian native breeds on account of crossing with New Zealand White rabbits. In: Proc. 7th World Rabbit Cong., Valencia, Spain. pp 325–331.
- Affi, E. A., M. H. Khalil, A. F. Khadr, and Y. M. K. Youssef. 1994. Heterosis, maternal and direct effects for postweaning growth traits and carcass performance in rabbit crosses. *J. Anim. Breed. Genet.* 111:138–147.
- Blouin, D. C., and A. M. Saxton. 1990. General Linear Mixed Models (GLMM) User's Manual. Louisiana State Univ., Baton Rouge.
- Brun, J. M., and J. Ouhayoun. 1989. Growth performances and carcass traits in three strains of rabbits and their two-way crosses. *Ann. Zootech. (Paris)* 38:171–179.
- Carregal, R. D. 1980. Evaluacion de la heterosis de la capacidad de combinacion y de los efectos maternos y reciprocos en conejos. In: Proc. 2nd World Rabbit Cong., Barcelona, Spain. pp 213–220.
- Khan, M. A., and S. D. Lukefahr. 1996. Breed type comparisons for postweaning litter traits in rabbits. In: Proc. 6th World Rabbit Cong., Toulouse, France. pp 299–304.
- Lebas, F., P. Courdert, H. de Rochambeau, and R. G. Thébault. 1997. *The Rabbit: Husbandry, Health and Production*. 2nd ed. Food and Agriculture Organization of the United Nations, Rome.
- Lukefahr, S. D., P. R. Cheeke, N. M. Patton, and M. A. Grobner. 1986. Genetic, maternal and seasonal factors affecting 56-day market weights in rabbits. *J. Anim. Sci.* 63(Suppl. 1):195 (Abstr.).
- Lukefahr, S., W. D. Hohenboken, P. R. Cheeke, and N. M. Patton. 1983. Breed, heterotic and diet effects on postweaning litter growth and mortality in rabbits. *J. Anim. Sci.* 57:1108–1116.
- Lukefahr, S. D., W. D. Hohenboken, P. R. Cheeke, and N. M. Patton. 1984. Genetic effects on maternal performance and litter preweaning and post-weaning traits in rabbits. *Anim. Prod.* 38:293–300.
- Lukefahr, S. D., J. I. McNitt, M. Duangjinda, and I. Mitzal. 2000. Additive and dominance genetic effects on post-weaning growth in New Zealand White rabbits. In: Proc. 7th World Rabbit Cong., Valencia, Spain. pp 457–462.
- Lukefahr, S. D., H. B. Odi, and J. K. A. Atakora. 1996. Mass selection for 70-day body weight in rabbits. *J. Anim. Sci.* 74:1481–1489.
- Lukefahr, S. D., J. D. Roberts, J. K. A. Atakora, and H. H. Hamilton. 1992. Evaluation of Californian, Champagne D'Argent, New Zealand White and Palomino as potential sire breeds: II. Carcass yield and lean cutability traits. *J. Appl. Rabbit Res.* 15:287–298.
- McNitt, J. I. 2000. Evaluation of two weaning methods for rabbits. In: Proc. 7th World Rabbit Cong., Valencia, Spain. pp 441–446.
- McNitt, J. I., N. M. Patton, S. D. Lukefahr, and P. R. Cheeke. 2000. *Rabbit Production*. 8th ed. Interstate Publishers, Danville, IL.
- NRC. 1977. *Nutrient Requirements of Rabbits*. 2nd ed. National Academy Press, Washington, DC.
- Ozimba, C. E., and S. D. Lukefahr. 1991. Comparison of rabbit breed types for postweaning litter growth, feed efficiency, and survival performance traits. *J. Anim. Sci.* 69:3494–3500.
- Roberts, J. D., and S. D. Lukefahr. 1992. Evaluation of Californian, Champagne D'Argent, New Zealand White and Palomino as potential sire breeds: I. Postweaning litter traits. *J. Appl. Rabbit Res.* 15:274–286.

**Citations**

This article has been cited by 1 HighWire-hosted articles:  
<http://jas.fass.org#otherarticles>