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GENETIC EVALUATION OF FUR TRAITS IN NEW ZEALAND WHITE AND CALIFORNIAN RABBITS RAISED ON HIGH AMBIENT TEMPERATURE

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ABSTRACT: An experiment on New Zealand White (NZW) and Californian (CAL) rabbits was carried out to evaluate genetically post-weaning coat traits of these two breeds raised under hot conditions. Data on 24680 and 10549 fibers collected from 1234 NZW and 520 CAL weaned rabbits were used, respectively. At 8 and 12 weeks of age, post-weaning coat traits included average hair length in cm (HL), hair diameter (µm) in down hair (HDD) and guard hair (HDG), medulla diameter (µm) in down hair (MDD) and guard hair (MDG), and medullation percent in down hair (PMD) and guard hair (PMG). Variance components and sire heritabilities were estimated for these traits using Restricted Maximum Likelihood (REML) procedure. Transmitting abilities (TA) for these traits were estimated using a single-trait Animal Model (AM).

Most postweaning coat traits in CAL were slightly higher than those in NZW. The estimates at 8 and 12 weeks, respectively were 2.4 and 3.0 cm in NZW *vs* 2.4 and 3.1 cm in CAL for HL, 12.2 and 18.8 µm in NZW *vs* 12.2 and 18.9 µm in CAL for HDD, 62.1 and 89.1 µm in NZW *vs* 62.3 and 88.9 µm in CAL for HDG, 10.2 and 16.4 µm in NZW *vs* 10.2 and 16.4 µm in CAL for MDD, 51.4 and 78.1 µm in NZW *vs* 51.5 and 77.8 µm in CAL for MDG, 82.2 and 87.1 % in NZW *vs* 83.5 and 86.3 % in CAL for PMD, and 82.2 and 87.4 % in NZW *vs* 82.6 and 80.5 % in CAL for PMG. Percentages of phenotypic variation in NZW and CAL for coat traits at earlier ages were slightly higher than at older ages with exception of HL. Except HL and HDD in both breeds, sire heritabilities for coat traits were low or somewhat moderate. Heritabilities for all coat traits in CAL rabbits at 8 and 12 weeks of age were higher than in NZW: 0.667 and 0.775 in CAL *vs* 0.357 and 0.392 in NZW for HL, 0.326 and 0.304 in CAL *vs* 0.401 and 0.246 in NZW for HDD, 0.051 and 0.142 in CAL *vs* 0.053 and 0.116 in NZW for HDG, 0.046 and 0.356 in CAL *vs* 0.053 and 0.075 for MDD, 0.058 and 0.174 in CAL *vs* 0.057 and 0.119 in NZW for MDG, 0.008 and 0.132 in CAL *vs* 0.052 and 0.031 in NZW for PMD and 0.074 and 0.047 in CAL *vs* 0.055 and 0.048 in NZW for PMG. The largest differences in TA for most coat traits were recorded in CAL breed and the lowest differences were observed in NZW. In favor of CAL breed at 12 weeks of age, there was a large range in TA between NZW and CAL rabbits with a difference of 2.474 cm for HL, 0.755 µm for HDD, 0.906 µm for HDG, 0.818 µm for MDD, 1.181 µm for MDG, and 1.5 % for PMD. Among coat traits, the largest percent of positive TA was recorded for HDD followed by HL, MDD and MDG, while the lowest percent was recorded for HDG.

RESUME : Evaluation génétique des caractéristiques de la fourrures de lapins néo-zélandais et californiens élevés en pays chauds.

Les caractéristiques du poil, après sevrage, de lapins néo-zélandais blancs (NZW) et californiens (CAL) élevés en milieu chaud ont été génétiquement évaluées. Les résultats concernant 24680 fibres provenant de 1234 NZW sevrés et 10549 fibres provenant de 520 CAL sevrés ont été utilisés. Les caractéristiques du poil à 8 et 12 semaines sont la longueur moyenne du poil en cm (HL) le diamètre du poil (µm) du duvet (HDD) et du poil de garde (HDG), le diamètre médullaire (µm) du duvet (MDD) et du poil de garde (MDG), le pourcentage de médulation du duvet (PMD) et du poil de garde (PMG). Pour ces caractéristiques, les composantes de la variance et les héritabilités des mâles ont été estimées par la méthode du maximum de vraisemblance restreint (REML). Les capacités de transmissions (TA) ont été estimées par Modèle Animal (AM) mono-factoriel.

La plupart des caractéristiques du poil des CAL sevrés sont légèrement supérieures à celles des NZW. Les valeurs à 8 et 12 semaines sont respectivement : HL de 2,4 et 3,0cm pour les NZW *vs* 2,4 et 3,1cm pour les CAL ; HDD de 12,2 et 18,8µm pour NZW *vs* 12,2 et 18,9µm pour les CAL ; HDG de 62,1 et 89,1µm pour NZW *vs* 62,3 et 88,9 pour CAL ; MDD de 10,2 et 16,4 µm pour NZW *vs* 10,2 et 16,4 pour CAL ; MDG de 51,4 et 78,1 µm pour NZW *vs* 51,5 et 77,8µm pour CAL ; PMD de 82,2 et 87,1% pour NZW *vs* 83,5 et 86,3% pour CAL ; PMG de 82,2 et 87,4% pour NZW *vs* 82,6 et 80,5% pour CAL. Les pourcentages de variations phénotypiques pour les caractéristiques du poil des NZW et CAL les plus jeunes sont légèrement plus élevés que pour les plus âgés excepté pour la longueur du poil. Excepté pour HL et HDD, dans les deux races l'héritabilité mâle est faible, voir modérée. Les héritabilités pour toutes les caractéristiques du poil des CAL de 8 et 12 semaines d'âge sont supérieures à celles des NZW : 0,667 et 0,775 pour les CAL *vs* 0,357 et 0,392 pour les NZW concernant HL ; 0,326 et 0,304 pour les CAL *vs* 0,401 et 0,246 pour les NZW concernant HDD ; 0,051 et 0,142 pour les CAL *vs* 0,053 et 0,116 pour les NZW concernant HDG ; 0,046 et 0,356 pour les CAL *vs* 0,053 et 0,075 pour les NZW concernant MDD ; 0,058 et 0,174 pour les CAL *vs* 0,057 et 0,119 pour les NZW concernant MDG ; 0,008 et 0,132 pour les CAL *vs* 0,052 et 0,031 pour les NZW concernant PMD ; 0,074 et 0,047 pour les CAL *vs* 0,055 et 0,048 pour les NZW concernant PMG. Concernant TA, les différences les plus grandes ont été enregistrées chez les CAL et les plus petites chez les NZW. Concernant TA il y a une grande distance entre CAL et NZW en faveur des lapins CAL, avec pour HL une différence de 2,474cm, 0,755µm pour HDD, 0,906µm pour HDG, 0,818µm pou MDD, 1,181µm pour MDG et 1,5% pour PMD. Le plus grand pourcentage de TA positives ont été enregistrés pour HDD suivi de HL, MDD et MDG, tandis que le plus bas pourcentage a été enregistré pour HDG.

INTRODUCTION

Coat traits (hair length, hair diameter and percentage of medullation) in broiler rabbits are important since heavier marketable coat constitutes a part of the economics of rabbits farms. In order to produce good-quality rabbit coats, the most important properties of the pelt must be considered. NIEDZWIADEK (1994) reported that the prices can be obtained for different rabbit coats depend upon the breed, the quality (i.e. density, length, hair diameter, strength, color, softness and brilliance) and the care with which it has been selected and handled. However, investigations carried out on coat traits in rabbits are scarce and limited (DROZDZ, 1969; MIROSHNICHENKO and UTKIN, 1972; VAS'KIN, 1973; IBRAHIM, 1980; KAWINSKA et al., 1980; PETERSEN, 1992, 1995; NIEDZWIADEK, 1994; TAO, 1994).

Table 1 : Distribution of samples, offspring, dams and sires used according to breed group and year of kindling

Item	New Zealand White			Californian		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
Number of samples	10280	7540	6860	6780	1380	2380
Number of progeny	514	377	343	339	69	112
Number of dams	30	39	30	21	9	15
Number of sires	10	13	10	7	3	5

In the last decade, new standard breeds of rabbits such as New Zealand White and Californian rabbits were imported to Egypt. These standard breeds of rabbits raised in hot environment need more attention to study their coat quality characteristics under these conditions, particularly a little attention was paid to the genetic evaluation of coat traits in rabbits. The objectives of the present study were: 1- to investigate some factors concerning post-weaning coat traits of New Zealand White (NZW) and Californian (CAL) rabbits raised in hot environment, 2- to estimate variance components and sire heritabilities for these traits, and 3- to predict the transmitting abilities of animals (TA) for these traits using an Animal Model (AM).

MATERIAL AND METHODS

The work was carried out at the experimental farm of the Faculty of Agriculture at Moshtohor, Zagazig University, Egypt. Investigation lasted for three consecutive years started in September 1989.

Animals and Breeding Plan

Two foreign breeds being New Zealand White (NZW) and Californian (CAL) rabbits were used in this study. Females within each breed were randomly grouped at the beginning of the first breeding season of the experimental period, into groups ranging from 3 to 6 does according to the available numbers. For each group of does, a buck from the same breed was assigned at random with a restriction of avoiding parent-offspring and sib matings. Each buck was given the chance to produce all his litters from the same females all over the period of the study.

Rabbitry and Management

Breeding stock were individually housed in wire cages of Californian- type with dimensions of 60x50x35 cm. These cages were allocated in raw along the rabbitry with passages suitable for service. Cages of each doe were provided with metal nest boxes. Cages of bucks, does and nest boxes were regularly cleaned and disinfected before each kindling.

According to the breeding plan of the experiment, each doe was transferred to the buck's hutch to be bred. Does were weighted at each mating and palpated 10 days thereafter to detect pregnancy. Within 24 hours of kindling, litters were examined and recorded. Bunnies were weaned at five weeks of age. At weaning, litter sizes were recorded and the young rabbits were ear tagged, weighed, and housed in wire hutches (45x30x30 cm). Rabbits of nearly similar age (with a maximum number of 5 individuals) were housed in one hutch. Rabbits were fed *ad libitum* and food was offered two times daily. A commercial pellet was provided in the morning and in the afternoon. The diet contained 16.3% crude protein, 13.2% crude fiber, 2.5% crude fat (digestible energy = 2600 kcal/kg ration). The ingredients were 33% barley, 21% wheat bran, 10% soya bean meal (44% C.P.), 22% hay, 6% berseem straw (*Trifolium alexandrinum*), 3% corticated cotton seed meal, 3.3 % molasses, 1% lime stone, 0.34% table salt, 0.3% minerals and vitamins and 0.06% methionine. In winter and early spring, berseem was supplied at midday. Fresh clean water was available to rabbits at all times.

The texture of rabbits fur

1. **Structure of medulla cavity.** Under a light microscope the structure of the medulla cavity is clearly seen. Almost all hairs in rabbits are medullated. Many down hairs have a single medulla cavity, while the guard hairs always have multiple medulla cavities.

2. **Cortical cells.** The proportion of cortical cells of coat in rabbits is less than that of sheep wool; the finer the rabbit hair, the fewer the cortical cells. The proportion of medullas increases as the coat fiber becomes thicker. This feature however, can present difficulties during processing, which results in a relative low strength, stretch, elasticity and curvature of rabbit coat.

Data and model of analysis

Data of coat traits were collected during the experimental period on all offspring at 8 and 12 weeks of age. Samples were taken at 8 weeks of age due to that this age is an early slaughter age for fryer rabbits, while they were taken at 12 weeks of age since this is the broiler slaughter age in rabbits in Egypt. The distribution of data collected according to breed and year of kindling is presented in Table 1. For both ages separately, coat traits included: HL = average length of hair (in cm) calculated from length of downs and bristles, HDD = hair diameter (μm) in down hair, HDG = hair diameter (μm) in guard hair, MDD = medulla diameter (μm) in down hair, MDG = medulla diameter (μm) in guard hair, PMD = percent of medullation in down hair, and PMG = percent of medullation in guard hair.

The samples were obtained by plucking the hair from the side region of each individual for determining the hair length, diameter and medulla. The weight of each sample was about 1.5g. Measurements were taken on 20 fibers chosen randomly from each sample. The samples were used on their raw state since they were clean and did not contain any other components. The measurements of hair diameter and medullation of each hair were carried out using a projection microscope, according to the procedure described by NIKOLAEV (1962) and RYDER (1973). The percentage of medullation of each fiber was calculated by dividing medulla diameter on hair diameter multiplied by 100. Length of hair (down and guard) was measured on centimeter scale to the nearest one decimal.

Data of coat traits in NZW and CAL breeds were analyzed separately using Mixed Model Least-Squares and Maximum Likelihood Mean Weighted Program of HARVEY (1990). Post-weaning coat traits were analyzed using the following sire mixed model :

$$Y_{ijklm} = \mu + S_i + A_j + YSP_k + B_l + e_{ijklm}$$

Where

Y_{ijklm} = the observation on the ijklm rabbit,
μ = overall mean,
S_i = the random effect of the ith sire,
A_j = the fixed effect of jth sex,
YSP_k = the fixed effect of kth year-season-parity (31 classes),
B_l = the fixed effect of lth litter size at birth (10 classes),
e_{ijklm} = the random deviation of mth rabbit and assumed to be independently randomly distributed (0, $\sigma^2 e$).

The absence of records in some subclasses did not permit the inclusion of all possible interactions. Estimates of variance components ($\sigma^2 s$ & $\sigma^2 e$) were computed using REML procedure. REML is an iterative method and the random effects are estimated appropriately. Iterations are continued using the estimators of sire and error variances from the preceding round of iteration until the estimates are stabilized. In the first round of iteration a guessed value of the ratio was used. Sire heritabilities ($h^2 s$) were estimated as : 4 $^2/$ (^2s+ ^2e). The approximate standard error for h^2_S were calculated by the formula described by BECKER (1984).

Table 2 : Means, standard deviations (SD) and percentages of variatio (V%) for coat traits of New Zealand White and Californian rabbits

		New Zealand White			Californian		
Trait	Age	Mean	SD	V%	Mean	SD	V%
HL (cm):							
	8 weeks	2.36	0.11	4.2	2.37	0.12	4.8
	12 weeks	3.02	0.21	6.1	3.05	0.23	6.0
HDD (μm):							
	8 weeks	12.18	2.17	17.4	12.21	2.18	17.4
	12 weeks	18.83	2.55	12.3	18.87	2.66	12.6
HDG (μm):							
	8 weeks	62.13	5.72	9.2	62.28	5.86	9.2
	12 weeks	89.12	8.56	9.4	88.87	9.13	10.0
MDD (μm):							
	8 weeks	10.15	1.94	18.5	10.17	1.89	18.0
	12 weeks	16.35	2.89	15.6	16.40	2.95	15.5
MDG (μm):							
	8 weeks	51.41	5.86	11.2	51.53	5.94	11.4
	12 weeks	78.08	8.49	10.6	77.82	8.56	10.7
PMD:							
	8 weeks	82.17	6.25	7.4	83.55	5.40	6.4
	12 weeks	87.10	5.20	5.5	86.	5.69	5.9
PMG:							
	8 weeks	82.25	3.10	3.7	82.57	2.99	3.6
	12 weeks	87.39	1.68	1.9	80.53	2.59	3.2

*HL= average hair length (calculated from length of guard and down hairs); HDD= hair diameter of down hair; HDG= hair diameter of guard hair; MDD= medulla diameter of down hair; MDG= medulla diameter of guard hair; PMD= medullation percent of down hair; PMG= medullation percent of guard hair.

Transmitting ability

A 1234 NZW and 520 CAL weaned rabbits were used for estimating transmitting abilities (TA) for post-weaning coat traits. A Single-trait

Animal Model program written by MISZTAL (1990) was used to estimate TA of different coat traits. Estimates of variance components estimated by REML were used in calculations. The linear mixed animal model used (in matrix notation) was:

$$Y = X\beta + Za + e$$

where

- Y = is an observational vector of rabbit,
- X = incidence matrix for fixed effects,
- β = vector of overall mean and fixed effects (sex, year-season-parity and litter size at birth),
- Z = incidence matrix for random effects (direct genetic effect),
- a = vector of unknown additive genetic value, i.e. animal transmitting ability,
- e = vector of unknown random error (**0**, $\sigma^2 e$).

The variance-covariance structure of the model was as follows:

$$Var\begin{bmatrix} a \\ e \end{bmatrix} = \begin{bmatrix} A\sigma^2_A & 0 \\ 0 & I\sigma^2 e \end{bmatrix}$$

Where A= the numerator relationship coefficient matrix, and I= an identity matrix with order equal to number of records per animal.

RESULTS AND DISCUSSION

Means of uncorrected records

Means, standard deviations (SD) and percentages of phenotypic variation for coat traits (hair length, hair diameter, medulla diameter and percentage of medullation) in New Zealand White (NZW) and Californian (CAL) rabbits are presented in Table 2. Means of coat traits in NZW and CAL rabbits increased with advancing age.

Hair length in CAL was similar to that of NZW breed (Table 2). Means of HL at 8 and 12 weeks in both breeds are nearly similar to those estimates reported in most of the non-Egyptian studies for Soviet Chinchilla, New Zealand White and Rex rabbits (MIROSHNICHENKO and UTKIN, 1972; TAO, 1994).

Diameters of down and guard hairs at 8 and 12 weeks of age in NZW rabbits were similar to those in CAL (Table 2). Diameter of down and guard hairs at 12 weeks in both breeds are nearly similar with the estimates reported in Baladi White, Baladi Red, Giza White and Giant rabbits at 8-month of age (IBRAHIM, 1980), while HDD and HDG at 8 and 12 weeks of age are higher than the corresponding estimates reported by other non-Egyptian studies for different breeds and ages (KAWINSKA *et al.*, 1980; NIEDZWIADEK, 1994).

Percentages of medullation of down and guard hairs at 8 and 12 weeks of age in NZW and CAL (Table 2) were higher than those estimated at 8 months of age for Bouscat, Giza White, Giant, Baladi Red and Baladi White rabbits raised in Egypt (IBRAHIM, 1980).

Results of coat traits in NZW and CAL rabbits in the present and reviewed studies indicate that these two standard breeds could be used as effective fur-type breeds in rabbit industry in Egypt. In addition, our results obtained in NZW al CAL rabbits were comparable or slightly better than that of the literature. These standard breeds are very suitable for fur

Table 3 : f-ratios of least-squares ANOVA of factors affecting coat traits[+] in New Zealand white rabbits at 8 and 12 weeks of age

Source	D.F	HL	HDD	HDG	MDD	MDG	PMD	PMG
8-week age:								
Sire	28	25.9***	6.6***	7.6***	8.1***	8.3***	9.4***	8.4***
Year-season-parity	27	52.9***	21.3***	20.9***	23.9***	17.2***	22.8***	15.1***
Sex	1	180.***	47.0***	26.9***	46.7***	29.0***	16.9***	11.7***
Litter size at birth	8	23.2***	3.0**	8.4***	5.0***	7.1***	12.3***	10.6***
Remainder d.f	24615							
Remainder mean squares		0.01	4.49	31.47	3.55	33.23	36.79	9.31
12-week age:								
Sire	28	35.1***	11.5***	10.5***	10.1***	10.8***	5.1***	6.8***
Year-season-parity	27	138.5***	57.8***	10.4***	62.5***	10.4***	39.0***	6.0***
Sex	1	45.0***	0.0 ns	17.7***	0.0 ns	17.1***	0.0ns	6.0*
Litter size at birth	8	26.4***	7.6***	27.3***	11.7***	25.9***	19.2***	12.1***
Remainder d.f	24615							
Remainder mean squares		0.03	5.	70.03	6.52	68.91	22.68	2.77

[+] Traits as defined in Table 2.

Table 4 : F-ratios of least-squares ANOVA of factors affecting coat traits[+] in Californian rabbits at 8 and 12 weeks of age

Source	D.F	HL	HDD	HDG	MDD	MDG	PMD	PMG
8-weekage:								
Sire	15	64.8***	5.9***	6.5***	6.7***	6.7***	2.0*	5.7***
Year-season-parity	16	32.2***	13.7***	12.9***	16.8***	9.9***	10.6***	3.9***
Sex	1	74.2	1.0ns	5.2*	0.2ns	3.9*	1.0ns	0.9ns
Litter size at birth	8	54.2***	3.2**	5.1***	3.9***	4.2***	2.0*	4.7***
Remainder d.f	10499							
Remainder mean squares		0.01	4.50	33.12	3.36	34.30	28.42	8.80
12-weekage:								
Sire	15	151.2***	14.3***	8.0	16.8	9.4***	11.5***	7.0***
Year-season-parity	16	142.2***	58.7***	17.9***	80.4***	21.4***	62.2***	3.7***
Sex	1	5.5*	3.9*	0.2ns	7.1**	0.0ns	11.7***	2.2ns
Litter size at birth	8	21.4***	6.5***	5.6***	9.1***	6.7***	16.7***	3.8***
Remainder d.f	10499							
Remainder mean squares		00.03	5.61	79.20	6.47	68.85	26.18	6.60

[+] Traits as defined in Table 2.

production to be used in industry of processing and preparing of fine and inexpensive fur clothes particularly in developing countries.

Variation of uncorrected records

Estimates of phenotypic variation for coat traits in both breeds are low or relatively moderate (Table 2). These estimates are nearly similar in both breeds. The estimates for NZW and CAL averaged 4.5% for HL at 8 weeks compared with 6.1 % four weeks later. The estimates for both breeds averaged 17.4% for HDD at 8 weeks compared with 12.5% at 12 weeks, while they averaged 9.2% for HDG at 8 weeks compared with 9.7% at 12 weeks. For medulla diameter in both breeds at the two ages, MDD had higher phenotypic variation than of MDG. The estimates averaged 18.3% for down hair at 8 weeks compared with 15.6% at 12 weeks and 11.3% for guard hair at 8 weeks compared with 10.7% at 12 weeks. The phenotypic variation in medullation percent in down and guard hairs in both breeds at 8 and 12 weeks of age looks like the medulla diameter where PMD had greater phenotypic variation than of PMG.

Table 5 : Estimates of variance components and sire heritabilities ($h^2\acute{y}$) for coat traits in New Zealand White and Californian rabbits.

Trait[+]	New Zealand White					Californian				
	Sire		Remainder		$h^2 \pm SE$	Sire		Remainder		$h^2 \pm SE$
	σ^2_s	V%	σ^2_e	V%		σ^2_s	V%	σ^2_e	V%	
HL	0.001	9.1	0.01	90.9	0.357 ± 0.174	0.002	16.7	0.01	80.0	0.667 ± 0.025
HDD	0.50	10.0	4.49	90.0	0.401 ± 0.023	0.40	8.2	4.50	91.8	0.326 ± 0.027
HDG	0.42	1.3	31.47	98.7	0.053 ± 0.028	0.43	1.3	33.12	98.7	0.051 ± 0.037
MDD	0.05	1.3	3.53	98.7	0.053 ± 0.028	0.04	1.2	3.36	98.8	0.046 ± 0.033
MDG	0.48	1.4	33.24	98.6	0.057 ± 0.030	0.50	1.5	34.30	98.5	0.058 ± 0.042
PMD	0.48	1.3	36.79	98.8	0.052 ± 0.027	0.06	0.2	28.42	99.8	0.008 ± 0.013
PMG	0.13	1.4	9.31	98.6	0.055 ± 0.029	0.17	1.9	8.80	98.1	0.074 ± 0.053
HL	0.003	10.4	0.03	89.6	0.392 ± 0.185	0.005	19.4	0.02	80.6	0.775 ± 0.047
HDD	0.35	6.2	5.34	93.8	0.246 ± 0.043	0.46	7.6	5.61	92.4	0.304 ± 0.021
HDG	2.09	2.9	70.07	97.1	0.116 ± 0.060	2.91	3.5	79.20	96.5	0.142 ± 0.100
MDD	0.13	1.9	6.52	98.1	0.075 ± 0.040	0.63	8.9	6.47	91.1	0.356 ± 0.024
MDG	2.12	3.0	68.95	70.0	0.119 ± 0.064	3.13	4.4	68.85	95.6	0.174 ± 0.012
PMD	0.18	0.8	22.69	99.2	0.031 ± 0.011	0.89	3.3	26.18	96.7	0.132 ± 0.093
PMG	0.03	1.2	2.78	98.8	0.048 ± 0.025	0.08	1.2	6.59	98.2	0.047 ± 0.034

[+] Traits as defined in Table 2.

Table 6 : Minimum and maximum estimates of transmitting abilities (TA) for coat traits in New Zealand White and Californian rabbits.

Trait	New Zealand White				Californian			
	All animals			Top 30% of animals	All animals			Top 30% of animals
	Minimum	Maximum	Range	Range	Minimum	Maximum	Range	Range
HL (cm):								
8 weeks	-0.456	0.646	1.111	0.151	-1.137	1.489	2.626	1.054
12 weeks	-1.210	0.729	1.939	0.141	-2.685	1.728	4.413	1.045
HDD (μm):								
8 weeks	-0.468	0.249	0.717	0.270	-0.405	0.269	0.674	0.197
12 weeks	-0.694	0.561	1.255	0.242	-0.946	1.064	2.010	0.441
HDG (μm):								
8 weeks	-0.861	1.144	2.005	0.605	-0.983	1.190	2.173	0.924
12 weeks	-2.603	2.291	4.894	0.690	-3.512	2.288	5.800	1.573
MDD (μm):								
8 weeks	-0.437	0.279	0.716	0.050	-0.375	0.282	0.657	0.185
12 weeks	-0.725	0.617	1.342	0.211	-0.990	1.170	2.160	0.524
MDG (μm):								
8 weeks	-0.998	1.136	2.134	0.304	-0.844	1.112	1.956	0.744
12 weeks	-2.569	2.271	4.840	0.592	-3.619	2.402	6.021	1.584
PMD:								
8 weeks	-0.928	1.154	2.082	0.297	-0.294	0.291	0.585	0.210
12 weeks	-0.645	0.634	1.279	0.268	-1.429	1.369	2.798	0.852
PMG:								
8 weeks	-0.937	1.165	2.102	0.302	-0.956	0.271	1.227	0.031
12 weeks	-0.269	0.416	0.685	0.270	-0.323	0.306	0.629	0.199

The estimates averaged 6.9% for PMD at 8 weeks compared with 5.7% at 12 weeks and 3.7% for PMG at 8 weeks compared with 2.6% at 12 weeks. Moderate estimates of phenotypic variation for hair and medulla diameter lead to conclude that improvement of coat traits in NZW and CAL rabbits through phenotypic selection can be possible. Estimates of phenotypic variation from literature for coat traits are not available and consequently no comparisons were made with the present results.

Non-genetic aspects

Results of ANOVA given in Tables 3&4 indicate that effects of year-season-parity and litter size at birth on coat traits in NZW and CAL rabbits were significant ($P<0.001$) at both ages. High F-ratios obtained here indicate that year-season-parity of birth and litter size at birth are considered as the most important non-genetic factors influencing coat traits in these two breeds of rabbits.

Variance components

For NZW and CAL breeds, differences in most coat traits due to sire effect were high and significant ($P<0.05$ or $P<0.001$) at both ages of the study (Tables 3&4). The variance components in addition to the percentages of variation (V%) attributed to the sire and remainder for coat traits in NZW and CAL rabbits are shown in Table 5. Except HL and HDD, percentage of variation due to sire for most coat traits in both breeds were low or relatively moderate (Table 5). The estimates for NZW rabbits at 8 and 12 weeks of age averaged 9.8 % for HL, 8.1 % for HDD, 2.1 % for HDG, 1.6 % for MDD, 2.2 % for MDG, 1.1 % for PMD and 1.3 % for PMG. The corresponding estimates for CAL rabbits at 8 and 12 weeks of age averaged 18.1 % for HL, 7.9% for HDD, 2.4% for HDG, 5.1% for MDD, 2.9% for MDG, 1.8% for PMD and 1.6% for PMG. These estimates showed that percentages of variance (V%) attributed to the sire effect for most coat traits in CAL rabbits were generally larger than those estimates obtained for NZW rabbits.

Sire heritabilities

Sire heritabilities for most coat traits in NZW and CAL rabbits are given in Table 5. In general, heritability estimates increased with advancing age in both breeds of the study. For HL and HDG in both breeds, heritabilities were moderate or high. This indicates that improvement of these two traits could be achieved through sire selection. Moderate or high heritabilities obtained here for HL are in agreement with

Table 7 : Percentages of positive transmitting ability (TA) for coat traits in New Zealand White and Californian rabbits.

Trait	New Zealand White		Californian	
	8-week	12-week	8-week	12-week
HL	48.3	51.7	43.8	56.3
HDD	58.6	48.3	56.3	43.8
HDG	37.9	48.3	50.0	43.8
MDD	34.8	45.8	52.0	48.0
MDG	34.5	48.3	56.3	50.0
PMD	44.8	51.7	43.8	62.5
PMG	44.8	41.4	68.8	43.8

those estimates reported by some investigators for mink and foxes (JAKOVENKO and KUZNECOV, 1970; CHOIEWA, 1978; REITEN, 1977; MACILJOWSKI *et al.*, 1980; EINARSSON, 1988; JEZEWSKA and MACIEJOWSKI, 1991; BERG, 1993). For other traits (HDG, MDG, PMD and PMG), heritabilities estimated in NZW and CAL rabbits at 8 and 12 weeks of age were low in most cases. REITEN (1977) with mink and JEZEWSKA and MACIEJOWSKI (1991) with foxes reported that heritabilities for hair diameter were moderate: the estimates were 0.2 and 0.25, respectively.

Although all estimates of heritability are generally low, estimates for all coat traits (hair length, hair diameter and hair medullation) in CAL rabbits are higher than the corresponding values in NZW rabbits (Table 5). For both breeds at both ages, heritabilities ranged from 0.357 to 0.775 for HL, 0.246 to 0.304 for HDD, 0.051 to 0.142 for HDG, 0.046 to 0.356 for MDD, 0.057 to 0.174 for MDG, 0.008 to 0.132 for PMD, and 0.047 to 0.074 for PMG. Unfortunately, relevant literature of sire heritabilities for post-weaning coat traits are not available in rabbits.

Transmitting ability

Using an Animal Model procedure, transmitting abilities (TA) predicted for coat traits in NZW and CAL animals are given in Table 6. For most coat traits, the largest differences between minimum and maximum values of TA were recorded by CAL rabbits and the lowest differences were observed by NZW. In comparison between the two breeds for TA, there was a large range in TA with a difference of 1.111 cm in NZW *vs* 2.626 cm in CAL for HL at 8 weeks, 1.939 cm in NZW *vs* 4.413 cm in CAL for HL at 12 weeks, 0.717 µm in NZW *vs* 0.674 µm in CAL for HDD at 8 weeks, 1.255 µm in NZW *vs* 2.01 µm in CAL for HDD at 12 weeks, 2.005 µm in NZW *vs* 2.173 µm in CAL for HDG at 8 weeks, 4.894 µm in NZW *vs* 5.8 µm in CAL for HDG at 12 weeks, 0.716 µm in NZW *vs* 0.657 µm in CAL for MDD at 8 weeks, 1.342 µm in NZW *vs* 2.16 µm in CAL for MDD at 8 weeks, 2.134 µm in NZW *vs* 1.956 µm in CAL for MDG, 4.84 µm in NZW *vs* 6.021 µm in CAL for MDG, 2.08% in NZW *vs* 0.585 % in CAL for PMD at 8 weeks, 1.3 % in NZW *vs* 2.8 % in CAL for PMD at 8 weeks, 2.1% in NZW *vs* 1.2 % in CAL for PMG at 8 weeks and 0.7% in NZW *vs* 0.6 % in CAL for PMG at 12 weeks of age. When considering the top 30% of animals (Table 6), the differences between maximum and minimum values in TA were smaller than that when considering all the animals list.

Among all animals, percentages of animals with positive estimates of TA are given in Table 7. At both ages, the percentages of positive estimates of TA obtained for NZW and CAL animals, respectively averaged 50 % and 50.1 for HL, 53.4 % and 50.1 % for HDD, 43.1 and 46.9 % for HDG, 40.3 and 50 % for MDD, 41.4 and 53.2 % for MDG, 48.2 and 53.2 % for PMD and 43.1 and 56.3 % for PMG. These percentages indicate that animals with positive TA for coat traits in CAL breed are higher than that in NZW. Among all coat traits, the largest percent of positive TA was recorded for HDD followed by HL, MDD and MDG, while the lowest percent was recorded for HDG.

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REFERENCES

BECKER, W.A. 1984: Manual of quantitative genetics. (Fourth Edition) *Academic Enterprises, Pullmon, W.A., USA.*

BERG P. 1993: Variation between and within populations of mink. II. Skin and fur characteristics. *Acta Agric., Scandinavica, Section A, Animal Science, **43(3)**: 158-164. (A.B.A., Vol., 3, No. 1476).*

CHOIEWA, R. 1978: The effect of heritability of production characters on the effectiveness of measures in a group of Arctic foxes. *Roczniki Akademii Rolniczej w Poznaniu **101**: 39-43. (A.B.A., 48, No 1307).*

DROZDZ A. 1969: Chinchillas, exotic fur animals. *Wszechswiat, **3**: 60-63. (A.B.A., 40, No. 2176).*

EINARSSON E.J. 1988: Selection for litter size in mink. IV. Effect on postweaning growth and fur characteristics. *Norwegian Journal of Agric. Sci., **2(1)**: 1-20.*

HARVEY W.R. 1990: User's Guide for **LSMLMW**. Mixed model least squares and maximum likelihood computer program. *PC - Version 2 . Ohio State University, Columbus, USA (mimeograph).*

IBRAHIM M.K. 1980: Some hair characteristics of different native and standard rabbit breeds. *Annals of Agric. Sci., Moshtouhor, Zagazig University, Egypt (Abstract).*

JAKOVENKO A. V., KUZNECOV G. A. 1970: Inheritance of some colour and pelt characters in silver-black foxes. *Zverovod. Krolikoved., **9**: 45-49. (A.B.A. Vol. 39, No., 5000)*

JEZEWSKA G., MACIEJOWSKI J. 1991: The characteristic of the zonal pigmentation of hair in pastel foxes. *Roczniki Nauk*

Rolinczych. Seria B, Zootechnicza ***106 (1-2)****, 149-154. (A.B.A., 61, No., 3756).*

KAWINSKA J., NIEDZWIADEK S., TUCZYNSKA J. 1980: Studies on the fur quality of French Silvery rabbits. *Roczniki Naukowe Zootechniki,* ***7(2)****: 157-166 (A.B.A., 50, No. 7419).*

MACILJOWSKI J., JEZEWSKA G., SLAWON J. 1980: The heritability of hair length in standard mink. *Prace i Materialy Zootechniczne* ***21****: 67-75. (A.B.A. 50, No., 2137)*

MIROSHNICHENKO T.K., UTKIN L.G. 1972: Changes in fur density in rabbits at different ages. *Nauchno-Issledovatel'skii Institut pushnogo Zverovodstva i Krolikovodstva,* ***11****: 114-118. (A.B.A., 42, No. 2275).*

MISZTAL I. 1990: Mixed model program using iteration on data with support for Animal Model. *PC Version, University of Illinois, USA, (mimeograph).*

NIEDZWIADEK S. 1994: Improvement of pelts of rabbit fur breeds in Poland. *Egyptian Journal of Rabbit Sci.,* ***4(2)****:191-193.*

NIKOLAEV A.I. 1962: Science of wool technology. *Isdtel. Union Center Press. Moscow*

PETERSEN A. 1992: Effect of age on priming and fur quality of the rabbit Castor Rex. *Journal of Applied Rabbit Research,* ***15:1599-1605****, USA.*

PETERSEN A. 1995. The influence of feeding on the chemical composition of carcasses and on pelt quality in the Castor Rex rabbit. *World Rabbit Science,* ***3(3)****: 141-145.*

REITEN J. 1977: Heritability estimates for pelt size and characters in standard mink. *Nores Landbrukshogskole* ***56*** *(16), 12 pp (A.B.A., 47, No. 4980).*

RYDER M. 1973: Hair studies in biology. No. 41, Edward Arnold, London.

TAO Y. R. 1994: Studies on the quality of Rex rabbits fur. *World Rabbit Science,* ***2(1)****: 21-24.*

VAS'KIN A.N. 1973: Comparative characteristics of fur development on the foot in different rabbit breeds. *In Konferentsiya Molodykh Uchenykh po Zverovodstvu i Krolikovodstvu. Vypusk I. Moscow, USSR, NIIPZK. 73-77 (A.B.A., 42, No. 3303).*