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USE OF ANIMAL MODELS TO ESTIMATE THE EFFECTS OF INBREEDING ON GROWTH AND CARCASS TRAITS OF RABBITS

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ABSTRACT

Records of individual weights at 10 weeks, at slaughter, and weights of carcass, viscera, head and skin and dressing percentage of 1,181 Californian and 1,070 New Zealand White rabbits selected for 10 week weight were analyzed by a model with only fixed effects and four different animal models to estimate the effect of inbreeding on these traits. The fixed effects model included sex, breed, year/season, parity of doe and inbreeding of animal as a covariate. Because selection could bias the effect of inbreeding estimated from this model, the four different animal models were also used. In addition to the fixed effects, the animal models included: model 1 - animal, model 2- animal and litter (as permanent environment), model 3- animal, litter and maternal effects, non correlated to direct effects, model 4 - the same as in model 3, but with correlation between direct and maternal effects. The effect of inbreeding level on weights was negative and quadratic for all traits and models. Estimates of inbreeding depression with model 1 for all traits were smaller than the estimates obtained with the fixed model. The differences among estimates of inbreeding depression, with models 2, 3 and 4 were small for all traits but dressing percentage. Estimates of inbreeding depression for 10 week weight was largest with the fixed model and progressively smaller when models 4, 3, 2 and 1 were used, indicating some confounding between inbreeding and maternal or permanent environment effects. Because the estimates of fixed effects from mixed models procedures are best linear unbiased estimators and are adjusted for effects of selection, the mixed model approach should be the best to evaluate the effects of inbreeding in populations undergoing selection. Model 4 is suggested when both maternal and permanent environmental effects are considered important. When only permanent environmental effects are important, model 2 is suggested

INTRODUCTION

Inbreeding effects in rabbits are not as well estimated as in other farm animals. The theory, concepts, effects, methods of computing, importance and application of inbreeding on farm animals have been reported, for example, by Dickerson (1972), Brinks and Knapp(1975), Falconer (1981) Gillois (1988), Hartl (1989) and Wray & Thompson (1990). Brinks and Knapp (1975) found a linear decrease in performance for all growth traits in beef cattle, with increased inbreeding, although both linear and quadratic regression coefficients were important. Dickerson (1972) reported that although inbreeding could increase predicted annual response, when used in combination with individual and family selection, in chickens, pigs, sheep and cattle and for some sex limited traits, it depresses performance, particularly in components of reproductive fitness, including growth.

In rabbits, the effect of inbreeding on growth and carcass traits has not been well studied and very few papers on this topic are in the literature. Miroshnichenko (1973), working with inbred lines of Grey Giant rabbits found significant effects of inbreeding on weights at 120 and 240 days of age. Inbred animals had the lightest weights. Zelnik (1984) found significant decreases in body weights at 56 and 168 days of age in Nitra rabbits with increased inbreeding coefficients. Park et al.(1990) analyzed the effect of inbreeding on some traits of Angora rabbits and found inbred animals were lighter at 2, 4 and 7 months of age, when compared with non inbred animals. Zelnik & Granat (1973) did not find differences between inbred and non inbred lines of French Silver rabbits for body weights at 56 and 112 days of age. Miros et al. (1987) also did not find statistical differences among 90 day body weights of inbred and control lines of Soviet Chinchilla rabbits.

The majority of studies on inbreeding considered the inbreeding coefficient as a covariate in the model for analysis. However, in populations undergoing selection, the effect of selection can be confounded with the inbreeding effect. Best linear unbiased estimation (BLUE) is the method most frequently used in animal breeding for estimation of fixed effects (Weigel et al., 1991). The estimates obtained with animal models have BLUE properties. Additionally, these estimates are not biased by selection (Henderson, 1988). Kennedy et al.(1988) suggested that inbreeding coefficients should be included in animal models to account for inbreeding effects.

The objective of this study was to estimate the effects of inbreeding on individual body weights at 10 weeks of age and at slaughter, and weights of carcass, viscera, head and skin and dressing percentage of Californian and New Zealand White rabbits raised in a subtropical area of Brasil and selected for individual weight at 10 weeks.

MATERIAL AND METHODS

Data collected from 2,251 Californian and New Zealand White rabbits, born from September 1988 to December 1990, at the Rabbit Research Sector of the University of Sao Paulo, campus of Pirassununga, state of Sao Paulo, Brasil were used. Those facilities are located approximately at 22°S and 47° W and 750 m above sea level, where average temperatures range from 15°C in winter to 30°C in summer. The animals were housed in a closed building with lateral openings, where the internal temperatures varied from 18°C to 35°C. The distributions of data according to breed and inbreeding levels are shown in TABLE 1.

At weaning (28 days as an average) rabbits were identified by tattooing and their numbers, sex and weights were recorded. After weaning, the animals were raised with their littermates in metal cages (85 x 95 x 45 cm) having automatic waterers and feeders. A commercial pelleted feed (minimum of 18% crude protein and 17% fiber guaranteed), supplemented with 20% in dry matter, with green elephant grass or rami was used.
Weekly weights from weaning to slaughter were taken. Slaughter occurred at 87 days as an average. Individual weights at slaughter (IWSL), carcass weight (CWT, warm washed carcass, without head, skin and viscera), viscera weight (VISWT, all the internal organs, including the gastro- intestinal content), head weight (HEADWT, head with ears and head skin, eyes and brain, plus the paws and tail, used in crafts) and skin weight (SKINWT) were measured. Dressing percentage (DRESS%) was computed as the ratio CWT/IWSL.
The coefficients of inbreeding for each animal (F), were calculated based on the procedure of Quaas (1976) using an adaptation of DFNRM, part of K. Meyer's DFREML (Meyer, 1988a,b), using all the pedigree information available since the herd was founded in 1982.
The fixed model used was a Least Squares Model, using SAS program-GLM procedure (SAS INSTITUTE, 1985). The model was:

$Y_i = \mu + B + b_1(F) + b_2(F)^2 + b_3(\text{age}) + b_4(LSW) + b_5(LSW)^2 + E_i$, where:
Y_i = observed trait on the ith rabbit;
μ = overall mean;
B = fixed effects of sex, breed, parity of doe, and year/season fitted individually;
b_1 and b_2 = linear and quadratic regression coefficients for inbreeding of rabbit (F)
b_3 = overall linear regression coefficient for age at slaughter (age), used only for traits measured at slaughter;
b_4 and b_5 = linear and quadratic regression coefficients for adjustment of data for litter size at weaning (LSW);
E_i = the random error, $N(0, \sigma^2)$

Significance of the effects was tested at levels of $P<0.05$ (*) and $P<0.01$ (**) with the appropriate F statistic. The effects of interaction between inbreeding of the rabbit and each class of the fixed effects did not have any significance and were not included in the model reported here.
The basic form of the animal models was:

$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}\mathbf{u} + \mathbf{e}$, where:

X = incidence matrix for fixed effects;
$\boldsymbol{\beta}$ = vector of fixed effects, including sex, breed, parity, year/season, linear and quadratic regressions for inbreeding, linear regression for age at slaughter (not for IW10) and linear and quadratic regressions for litter size at weaning;
Z = incidence matrix for random effects (Model 1 : animal ; Model 2 : animal and litter as a common permanent environment effect; Model 3 : animal, litter and maternal effect, not correlated with the animal effect; Model 4 : as in Model 3, but with correlation between the direct and maternal effects);
u = vector of random effects;
e = vector of random error effects, $N(0,\sigma_e^2)$

Solutions to the mixed model equations and variance-covariance components were obtained by Restricted Maximum Likelihood (REML), using the DFREML programs (Meyer, 1988), modified to use SPARSPAK, a sparse matrix solver package (Boldman & Van Vleck, 1991). Coefficients for regression of the traits on inbreeding were plotted to illustrate the effects of inbreeding.

RESULTS AND DISCUSSION

The effects of breed, sex, parity, year, season, age at slaughter and litter size at weaning on growth and carcass traits for this data set were analyzed and discussed by Ferraz et al. (1991). The number of observations and means and standard deviations for each trait and for inbreeding coefficients are shown in TABLE 1. When the fixed model was used, the quadratic effect of inbreeding was significant for IW10 ($P<0.01$), IWSL, CWT and HEADWT ($P<0.05$), but not for VISWT, SKINWT and DRESS%. Therefore, both linear and quadratic regression coefficients are needed to describe effects of inbreeding, as reported by other authors for other species (e.g. Brinks & Knapp, 1975). The importance of inbreeding effects on growth and carcass traits found in this study agree with results of Miroshnichenko (1973) and Zelnik (1984), but are different from those reported by Zelnik & Granat (1973).

FIGURES 1 to 7 show the effects of inbreeding, expressed both in grams and in percentage of mean weight on IW10, IWSL, CWT, VISWT, HEADWT, SKINWT and DRESS%. The estimates of inbreeding effects for IW10 are progressively smaller when obtained from the fixed model and mixed models 4,3, 2 and 1. When only the fixed effects are considered, without taking account of selection effects, the estimate of the depression due to inbreeding is probably too big. When selection is accounted for, as in the mixed models, estimates of effects of inbreeding are unbiased and the effects of inbreeding are smaller. If inbreeding depresses performance as expected, effect of inbreeding, unbiased by selection, would be bigger than estimates not adjusted for selection effects, which was observed on the traits IWSL, CWT, HEADWT, SKINWT and DRESS%. However,the opposite relationship was observed for IW10 and VISWT. This result suggests that at levels of inbreeding in this population, inbred animals with better performance were selected, causing some confounding between the effects of selection and inbreeding for IW10. There was no direct selection for other traits, except as other traits are correlated to IW10 and the effects observed of those traits agree with the expectations, except for VISWT, where inbreeding effects were not important anyway.

One way to evaluate which REML model is best is to compare the logarithms of the likelihood function, as REML maximizes that function; the larger the log-likelihood, the better the model. TABLE 2 shows the log of likelihood functions for the four animal models for all traits. Model 4 was the best model for all traits, except for HEADWT, when model 3 was the best, but for HEADWT the results for models 2, 3 and 4 were similar. The regression coefficients for inbreeding effects estimated by model 1 were always smaller than those estimated by the fixed model. Model 1 did not consider the common permanent environmental effect of litters and always had the smallest log-likehood. Estimates of inbreeding effects with model 4 can be considered the best estimates and are unbiased by selection, Models 2, 3 and 4 provide similar log-likelihoods and curves of effects, so that model 2 can be used to evaluate the effects of inbreeding, without much loss of accuracy. Model 2 has the advantage of simpler analysis and fewer number of mixed model equations. TABLE 3 presents the linear and quadratic regression coefficients for all traits on inbreeding, for the model with the largest log likelihood.

CONCLUSIONS

1) Inbreeding of rabbits decreased body weights at 10 weeks of age and at slaughter and weights of carcass and head,and although not statistically significant, the weights of viscera, skin and dressing percentage.
3) Quadratic as well as linear regression coefficients are needed to explain the effect of inbreeding on growth and carcass traits;
4) Mixed model procedures using animal models were most appropriate to estimate effects of inbreeding. The best results were obtained with complete models that consider as random the direct effects of the animal, the maternal and the permanent common environmental effects, as shown by the largest log-likelihood. However, the model that includes the permanent environmental effects of litter but not maternal effects gave results that are similar to the results obtained with more complex models.

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TABLE 1. **Number of records per breed, means (Mean) and standard deviations (SD) for individual weights at 10 weeks, at slaughter and for slaughter traits and distribution according to inbreeding intervals of 2,251 Californian (CAL) and New Zealand White (NZW) rabbits.**

Variable or interval	CAL	NZW	Total	Mean	SD
IW10, g	1,181	1,070	2,251	1,904.40	312.88
IWSL, g	908	823	1,731	2,251.88	354.24
CWT, g	908	823	1,731	1,170.01	205.32
VISWT, g	908	823	1,731	484.6	175.58
HEADWT, g	908	823	1,731	284.38	41.82
SKINWT, g	908	823	1,731	270.39	58.25
DRESS%, %	908	823	1,731	51.81	2.88
Inbreeding of animals					
overall mean	0.041	0.024	0.033		
no. non inbred animals	545	842	1,387		
no. of inbred animals	967	528	1,495		
mean of inbred animals	0.063	0.062	0.063		
maximum inbreeding	0.281	0.250	0.281		
no. of animals/interval of inbreeding					
$0.000 < F \leq 0.025$	291	119	410		
$0.025 < F \leq 0.050$	200	166	366		
$0.050 < F \leq 0.075$	176	91	267		
$0.075 < F \leq 0.100$	150	43	193		
$0.100 < F \leq 0.125$	39	64	103		
$0.125 < F \leq 0.150$	17	12	29		
$0.150 < F$	94	33	127		

IW10 = individual weight at 10 weeks: IWSL = individual weight at slaughter; CWT = carcass weight; VISWT = weight of viscera; HEADWT = weight of head, hands, feet and tail; SKINWT = weight of skin; DRESS% = Dressing percentage.

TABLE 2. Logarithms of likelihood functions of four different animal models used to estimate the effects of inbreeding on individual weights at 10 weeks, slaughter, carcass, viscera, head, skin and dressing percentage.

TRAIT	Model 1	Model 2	Model 3	Model 4
IW10	-13,628.387	-13,506.720	-13,503.190	-13,499.929
IWSL	-10,528.829	-10,437.610	-10,435.770	-10,434.880
CWT	- 9,564.815	- 9,485.630	- 9,483.400	- 9,482.532
VISWT	- 8,153.433	- 8,072.531	- 8,071.060	- 8,071.060
HEADWT	- 6,880.492	- 6,838.625	- 6,838.624	- 6,838.658
SKINWT	- 7,423.902	- 7,311.130	- 7,310.940	- 7,310.313
DRESS%	5,434.785	5,469.540	5,473.570	5,473.593

IW10 = individual weight at 10 weeks: IWSL = individual weight at slaughter; CWT = carcass weight; VISWT = weight of viscera; HEADWT = weight of head, hands, feet and tail; SKINWT = weight of skin; DRESS% = Dressing percentage.

TABLE 3. Linear and quadratic regression coefficients of individual weights at 10 weeks and slaughter and weights of carcass, viscera, head and skin and dressing percentage on inbreeding of rabbit.

TRAIT	regression coefficients for inbreeding linear	quadratic
IW10, g	971.24	-6,415.77
IWSL, g	814.02	-5,798.08
CWT, g	464.99	-3,617.03
VISWT, g	101.41	-586.70
HEADWT, g	88.46	-583.91
SKINWT, g	65.25	-406.53
DRESS%, %	0.002	-0.206

IW10 = individual weight at 10 weeks: IWSL = individual weight at slaughter; CWT = carcass weight; VISWT = weight of viscera; HEADWT = weight of head, hands, feet and tail; SKINWT = weight of skin; DRESS% = Dressing percentage.

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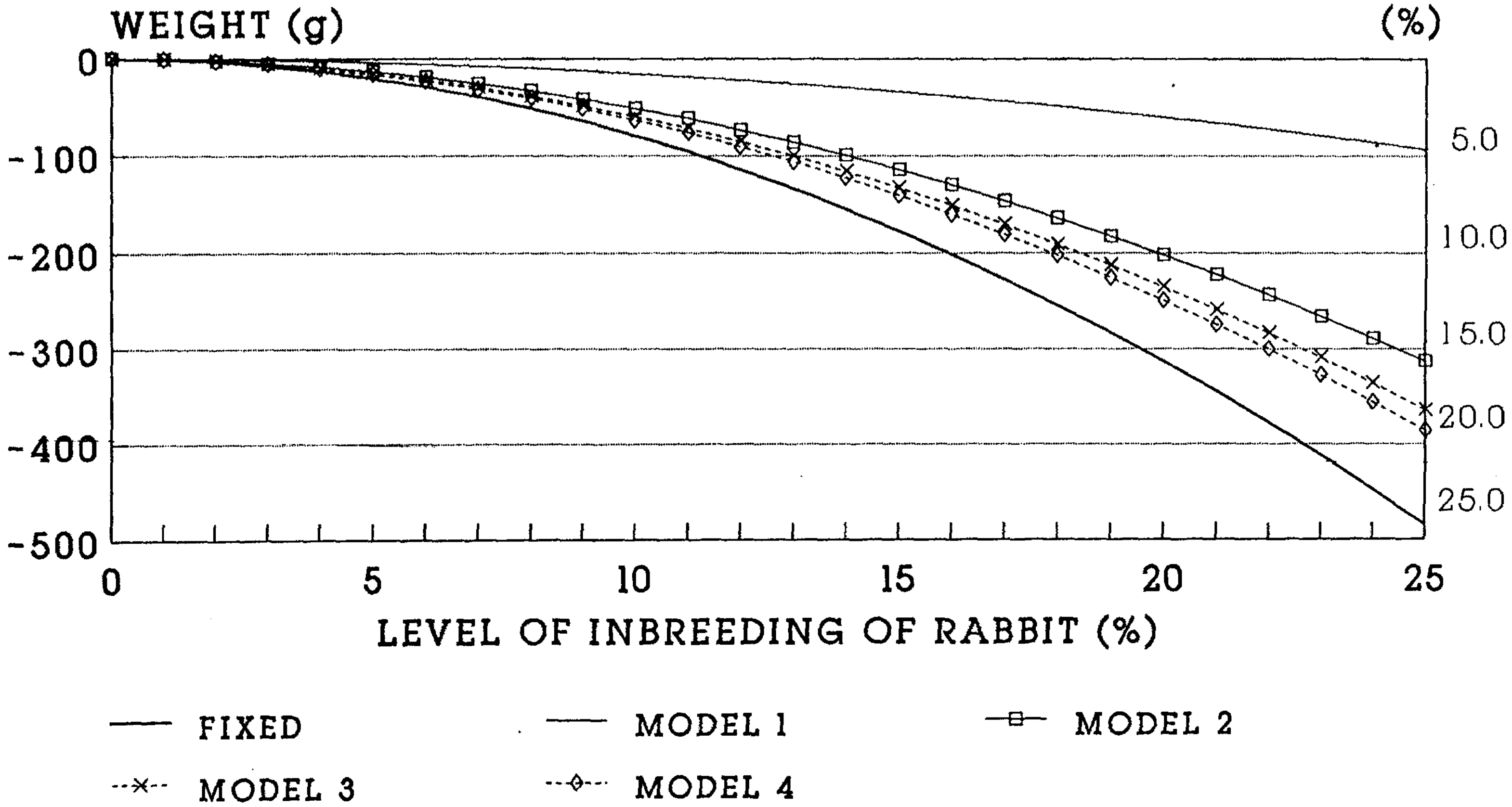
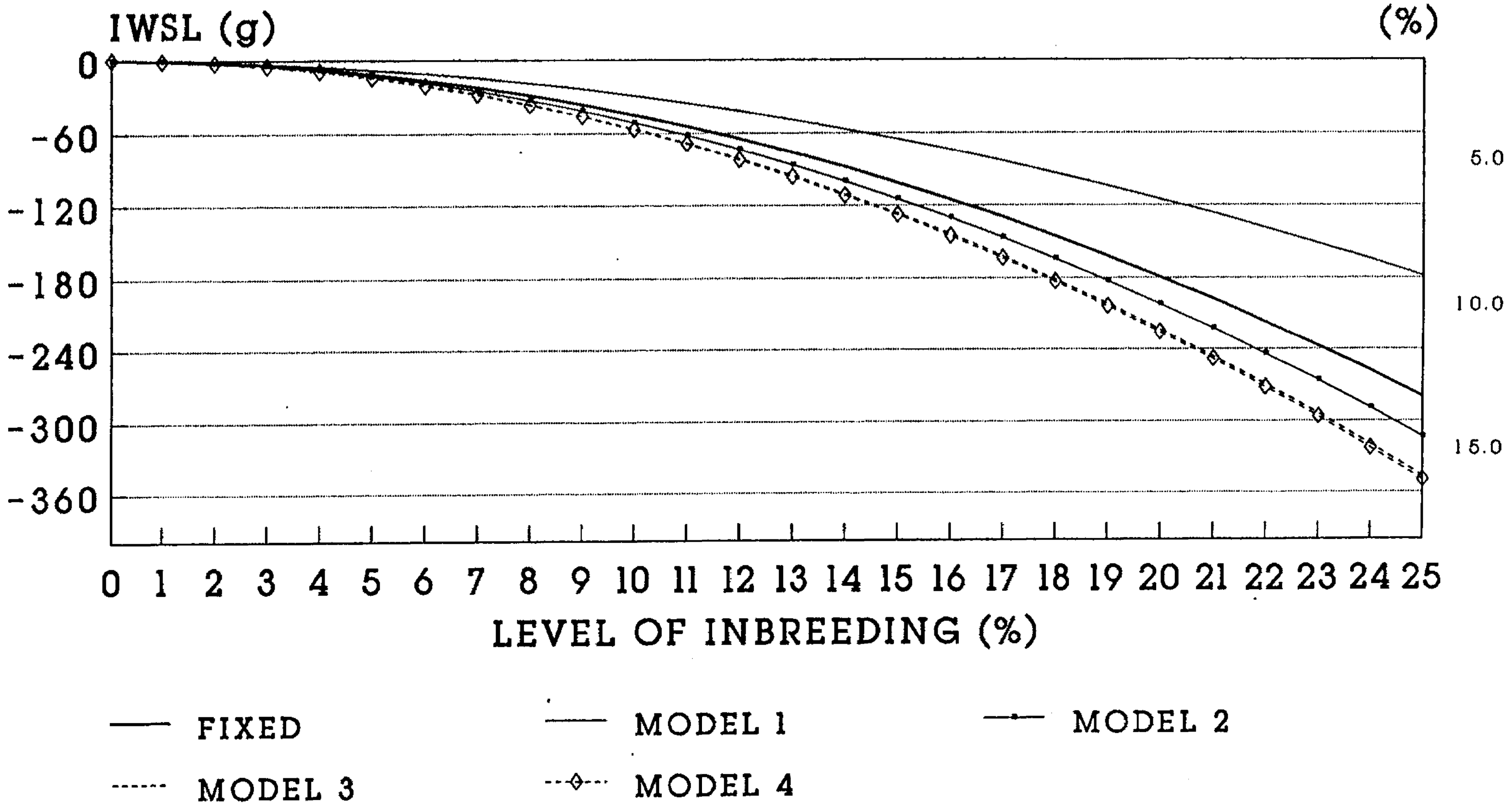
FIGURE 1. EFFECT OF INBREEDING OF RABBIT ON WEIGHT AT 10 WEEKS- COMPARISON OF FIVE METHODS OF ESTIMATION *



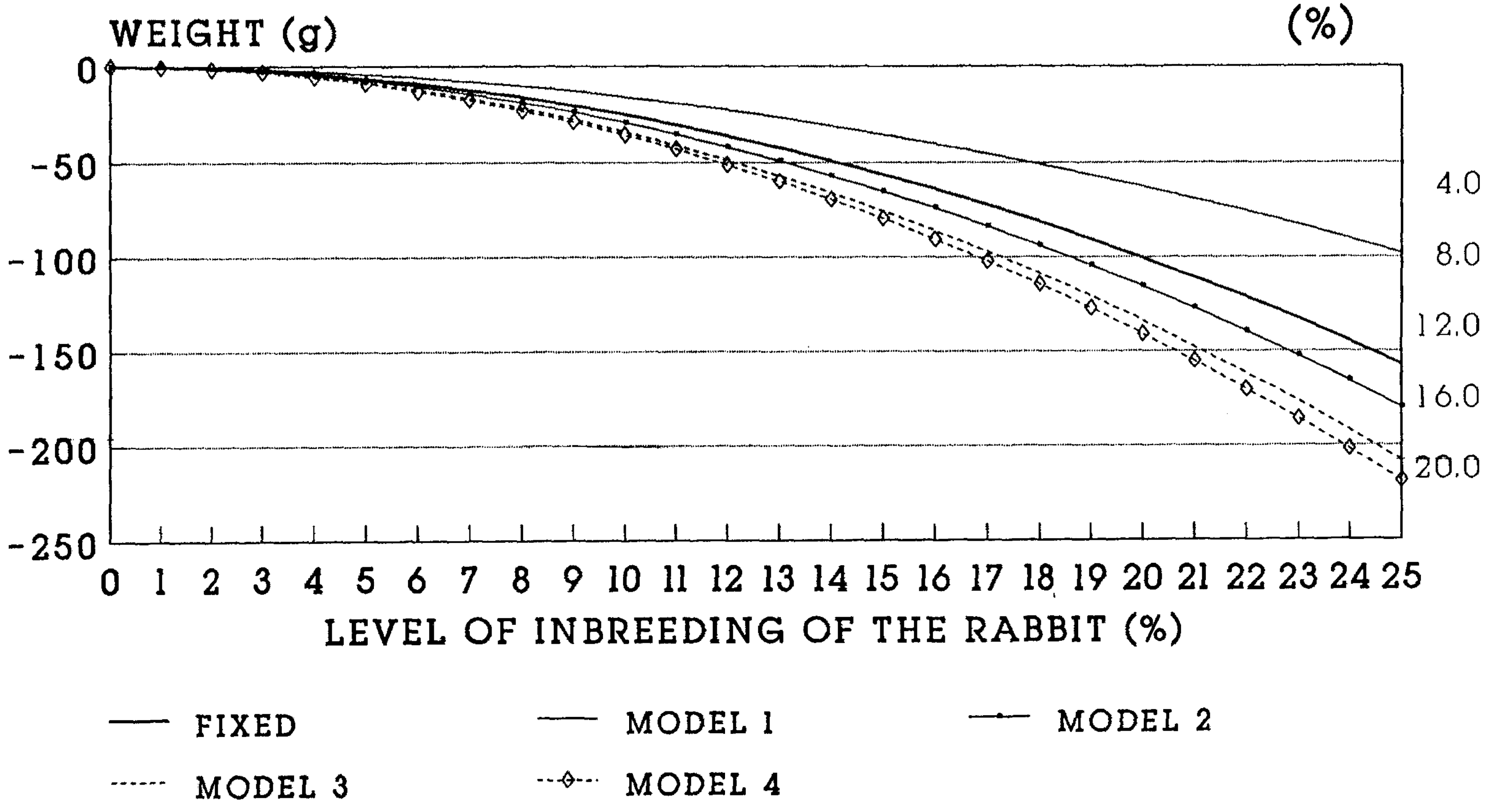
(*)- Fixed model and four different animal models

FIGURE 2. EFFECT OF INBREEDING OF RABBIT ON WEIGHT AT SLAUGHTER - COMPARISON OF FIVE METHODS OF ESTIMATION. *



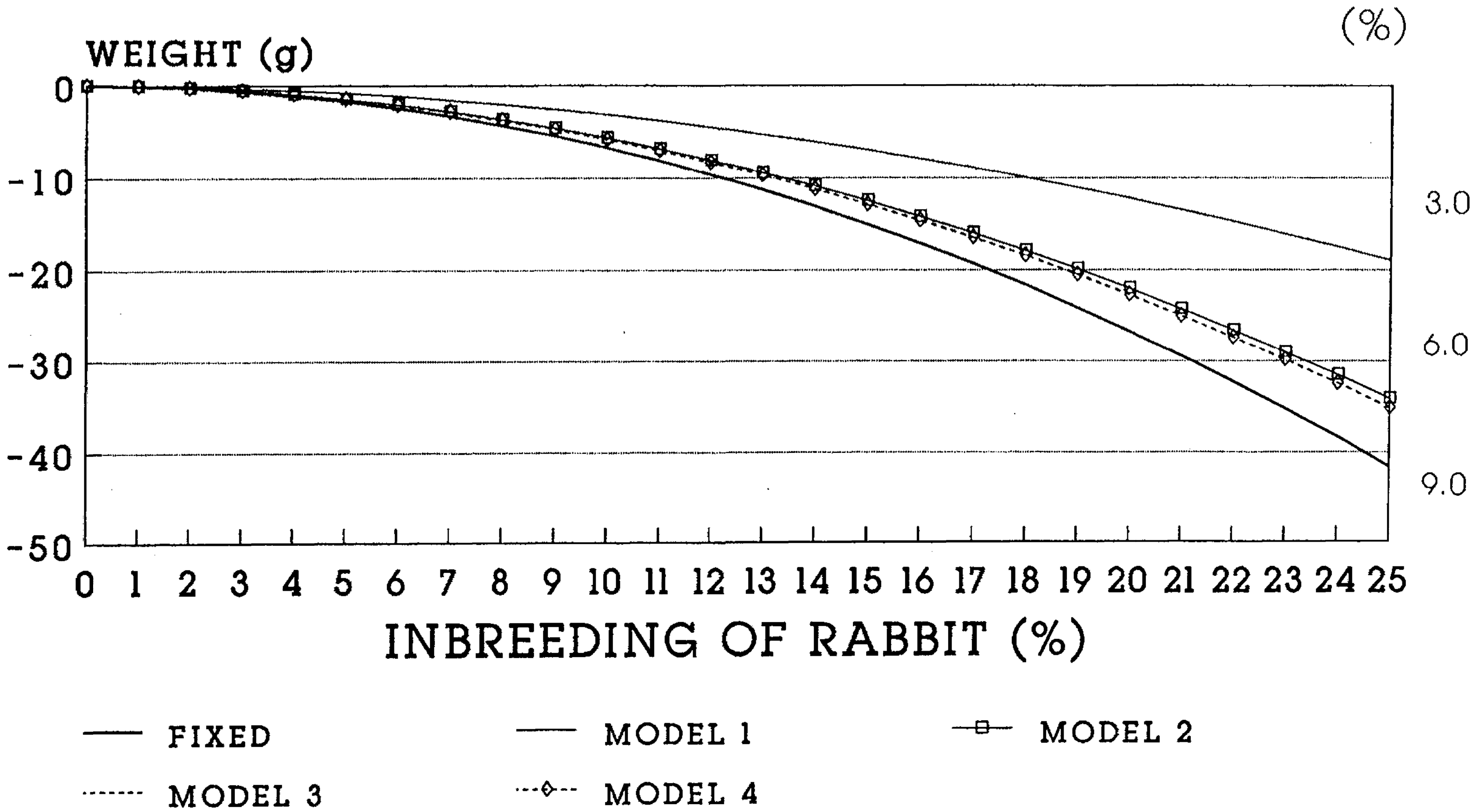
(*)- Fixed model and four different animal models

FIGURE 3. EFFECT OF INBREEDING ON WEIGHT OF CARCASSES OF RABBITS- COMPARISON OF FIVE METHODS OF ESTIMATION.*



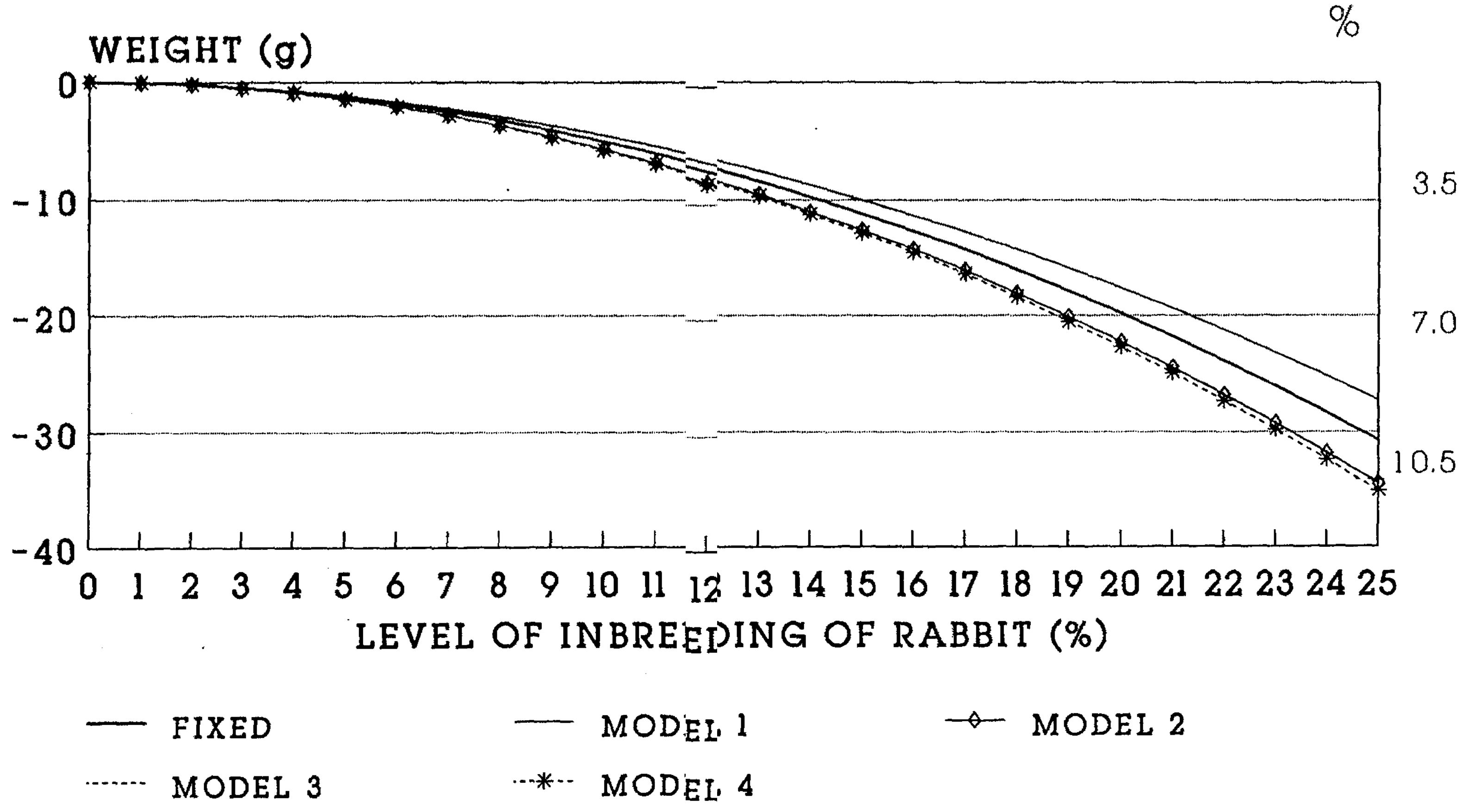
(*)Fixed model and four different animal models

FIGURE 4. EFFECT OF INBREEDING OF RABBIT ON WEIGHT OF VISCERA - COMPARISON OF FIVE METHODS OF ESTIMATION *



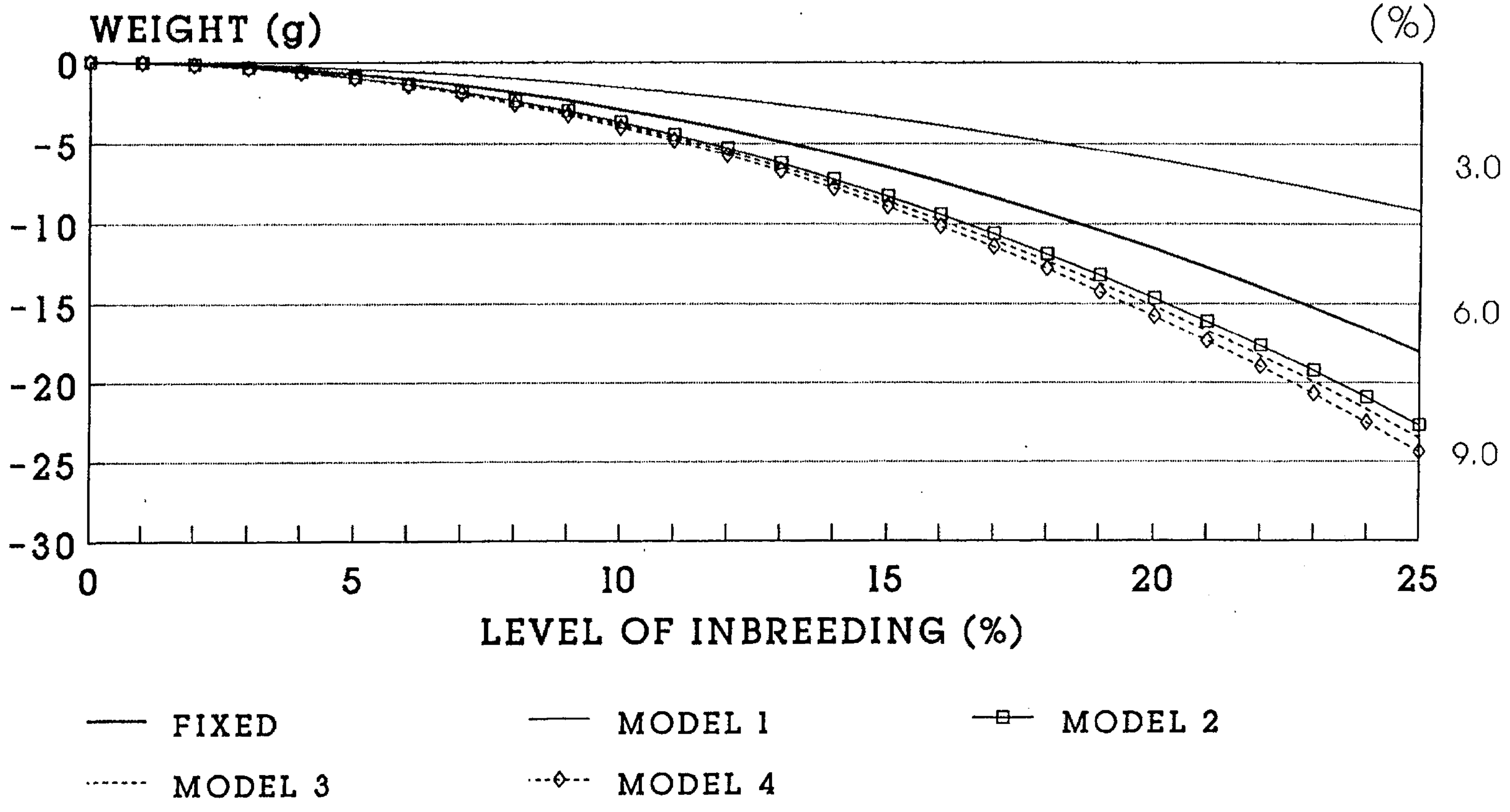
(*)Fixed model and four different animal models

FIGURE 5. EFFECT OF INBREEDING OF RABBIT ON WEIGHT OF HEAD AND PAWS- COMPARISON OF FIVE METHODS OF ESTIMATION *



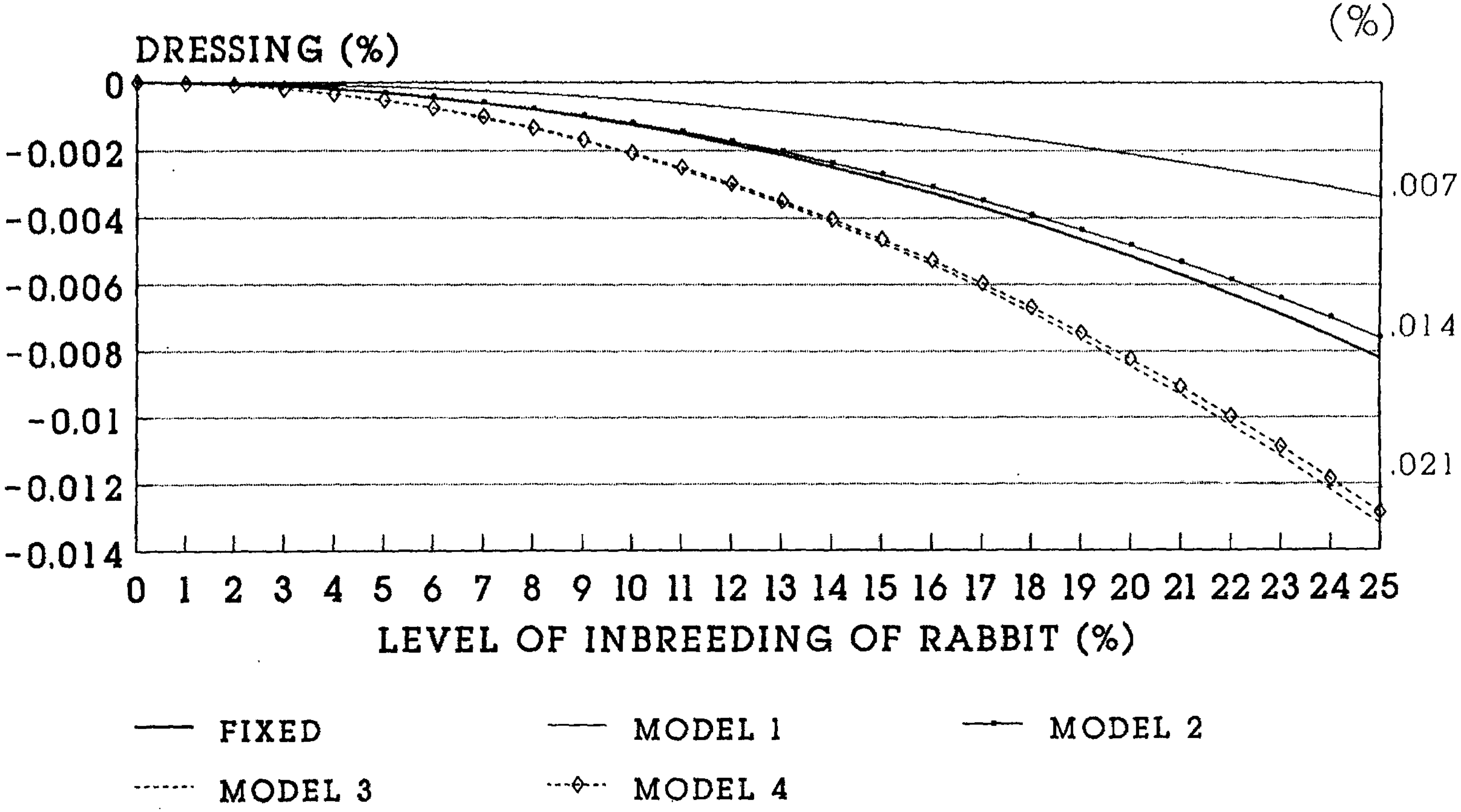
(*) Fixed model and four different animal models

FIGURE 6. EFFECT OF INBREEDING OF THE RABBIT ON SKIN WEIGHT- COMPARISON OF FIVE METHODS OF ESTIMATION *



(*)-Fixed model and four animal models

FIGURE 7. EFFECT OF INBREEDING OF RABBIT ON DRESSING PERCENTAGE- COMPARISON OF FIVE METHODS OF ESTIMATION *



(*)- Fixed model and four different animal models