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GROWTH CURVES OF LINES SELECTED ON GROWTH RATE OR LITTER SIZE

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ABSTRACT

Two sinthetic lines of rabbits were used in the experiment. Line V, selected on litter size for 8 generations and line R, originated by mating crossbred rabbits with a Californian line which was selected on growth rate for 12 generations. 96 animals were randomly collected from 48 litters, taking a male and a female each time. Logistic, Gompertz and Richards growth curves were fitted. Gompertz curve showed to be the more appropiate curve to describe the growth of rabbits. Sexual dimorfism appeared in the line V but not in the R. b and k were similar in all curves. Maximum growth reate took place in weeks 7-8. A break due to weaning could be observed in weeks 4-5. Although there is a remarkable similarity of the values of all the parameters when only data of 20 weeks are adjusted, the higher standard errors on adult weight would make 30 weeks a more recommandable period of time to take data for liveweight growth curves.

INTRODUCTION

Considering its economic importance, there are few studies on quantitative growth in rabbits. Growth curves have been fitted by Baron et al. (1970), Lehman (1980), Fl'ak (1982) and Rudolph and Sotto (1984), but over periods never higher than 26 weeks, in which adult size is not yet reached.

The aim of this study is to fit growth curves of liveweight in two strains of rabbits which are currently selected on different objectives -Growth rate and litter size-, and to determine the number of weeks needed in a growth curve to estimate adult weight with some accuracy.

MATERIAL AND METHODS

Animals

Two sinthetic lines of rabbits were used in the experiment. Line V, selected on litter size for 8 generations, was originated by mating crossbreed males and crossbreed females of different origins. Line R was originated by mating crossbred rabbits with a Californian line which was selected on growth rate for 12 generations.

96 animals were randomly collected from 48 litters, taking a male and a female each time -following the indications of Prud'hon (1975)-. After identifying the animals, they continued in their litter untill weaning, at approximately 28 days of life. After weaning they were transferred to cages of 8 animals untill 10 weeks of age. After this date, they were transferred to individual cages untill 52 weeks of age. All animals were weekly weighed.

Animals were taken in five subsets born in February and March of 1989 and reared in a farm with controlled ventilation. The farm has an insulated double roof with fibreglass. Monthly average temperatures outside the farm varied from 10 degrees in January until 24 degrees in August.

All animals were fed *ad libitum* until 9 weeks of age. From weeks 9 to 40 animals were fed restricted, receiving 125 g of food every day. From week 40 to 52, half of the animals were fed *ad libitum* and the other half were fed restricted, with the same restriction as before, in order to produce animals with two different fat content and to define adult weight referred to a determined adult fat content (Taylor, 1985). Food was a commercial granulated feed which composition was 16.5% gross protein, 15.5% fibre, 3.4% fat. Water was free-access all over the time.

Rabbits were eliminated when they showed the first symptoms of Pasteurellosis disease or diarrhoea. The number of animals weighed each week decreased from week 1 to 52, as is shown in Table 1.

TABLE 1. Number of animals weighed from weeks 1 to 52.

Line	Sex	Week					
		1	10	20	30	40	52
R	males	25	13	11	9	6	3
	females	25	15	15	12	8	7
V	males	23	15	13	13	7	5
	females	23	11	11	9	5	5

Statistical Analysis

Logistic, Gompertz and Richards -modified by (Knizetova et al., 1983)- growth curves were fitted by nonlinear regression (table 2).

The models hitherto used to fit growth curves in rabbits have been the Logistic and Gompertz curves. These models fix the inflection point in a 50% and a 37% of the adult weight respectively, whereas Richars curve has a variable inflection point that can be determined by adjusting the data. The main inconvenients of the Richards curve are the difficulties of adjusting the data to more parameters and the lack of biological meaning of its parameters due to their dependence on the value of the parameter n which determines the inflection point (Richards 1969).

The BMDP and Statgraphics statistical packages were used. Initial values were taken from the results of López (1987). Data were weighted by dividing each set of data corresponding to a week of age by their variance.

RESULTS

Table 3 shows the results of fitting Richards curves to both lines and both sexes. When the animals were put under restricted diet it was observed that the restricted diet -usual in rabbit production- was very similar to the *ad libitum* diet. Due to this, the adjustments with animals under *ad-libitum* and restricted diet did not show any significant difference, and they are not offered.

When n =1 Richars and Logistic curve are the same, and when n tends to zero Richards curve tends to Gompertz curve. Being n near zero, this indicates that the Gompertz curve would be more appropiate to describe rabbits growth.

Nevertheless, the high standard errors found for n shows that the growth has a period in which it is almost linear -see fig. 2-.

TABLE 2. Logistic, Gompertz and Richards equations

$$LOGISTIC \quad y = \frac{A}{1 + b \cdot e^{-kt}}$$

$$GOMPERTZ \quad y = A \cdot e^{-b e^{-kt}}$$

$$RICHARDS \quad y = A \cdot (1 \pm b \cdot e^{-kt})^{-1/n}$$

A: Adult weight. b: Constant. k: Maturity rate. n: Shape parameter

TABLE 3. Richards growth curve parameters.

	A	b	k	n	RSD
FR	4320 (28)	0.17 (0.15)	0.024 (0.001)	-0.047 (0.043)	1.0512
MR	4381 (22)	0.48 (0.07)	0.021 (0.001)	-0.153 (0.032)	1.2264
FV	4388 (35)	0.50 (0.07)	0.020 (0.001)	-0.161 (0.033)	1.1131
MV	3656 (20)	0.09 (0.12)	0.025 (0.001)	-0.024 (0.034)	1.0790

A: Adult weight. b: Constant. k: Maturity rate. n: Shape parameter. RSD: Residual standard deviation. F: Female, M:male. Lines R and V. Standard errors between brackets

TABLE 4. Rank of correlations of Richards curve parameters

	A	b	k
b	0.43 to 0.56		
k	-0.61 to -0.73	-0.91 to -0.93	
n	-0.44 to -0.57	-0.99 to -1.00	0.92 to 0.94

A: Adult weight. b: Constant. k: Maturity rate. n: Shape parameter

The rank of correlations between Richards parameters are shown in table 4. As expected, b and k are very dependent on n, and adult weight shows also a certain dependence on this parameter.

As a result of these analyses, it seemed convenient to fit the Gompertz and Logistic curves. The values of the adjusted parameters of these curves are shown in table 5. As expected by the value of n, Gompertz curve adjusts as well as Richars curve and better than the Logistic curve, being the errors of the parameters more acceptable.

An interesting result is that it does not appear sexual dimorfism in the R line. It has been accepted that the adult male rabbit weighs less than the female, although there are not many proofs about the generality of this dimorfism, found nevertheless in some experiments (see, for example, Cantier et al. 1969). b and k have similar values in all curves. Maximum growth rate occurs in weeks 7-8. A break due to weaning can be observed in weeks 4-5 (figure 1).

TABLE 5. Logistic and Gompertz growth curve parameters

		A	b	k	RSD
GOMPERTZ	FR	4305 (24)	4.068 (0.046)	0.025 (3E-4)	1.0513
	MR	4333 (20)	4.068 (0.042)	0.024 (3E-4)	1.2548
	FV	4292 (27)	4.153 (0.032)	0.023 (3E-4)	1.1390
	MV	3649 (18)	4.003 (0.036)	0.025 (3E-4)	1.0784
LOGISTIC	FR	4135 (24)	35.10 (1.37)	0.050 (8E-4)	1.2478
	MR	4172 (26)	33.98 (1.43)	0.048 (8E-4)	1.8645
	FV	3992 (30)	40.56 (1.45)	0.050 (7E-4)	1.6458
	MV	3487 (19)	31.95 (1.00)	0.052 (7E-4)	1.3770

A: Adult weight. b: Constant. k: Maturity rate. RSD: Residual standard deviation. F: Female, M:male. Lines R and V. Standard errors between brackets

Only a small part of the animals which started the experiment finished it. Although the use of all data in the experiment should not bias the results, it can be asked what would happened if only the animals arriving to the end of the experiment would have been used. This question is related to the more general question of how many weeks are needed to estimate accurate growth curves in rabbits. Table 6 shows different adjustments with all available data at 20, 30, 40 and 50 weeks of age, and table 7 shows the results of fitting Gompertz curves at 20, 30, 40 and 50 weeks of age only with the data of the rabbits which arrived to the end of the experiment.

Although there is a remarkable similarity of the values of all the parameters even when only 20 weeks are considered, the higher standard errors on adult weight would make 30 weeks a more recommandable period of time to take data for liveweight growh curves.

DISCUSSION

When fitting growth curves there are correlations between errors which are usually ignored, mainly due to the lack of software available to do the adjustments properly. We have tried to break these correlations by dividing the experimental group in five subsets and by fitting data of many rabbits at

TABLE 6. Gompertz curve parameters calculated with the available data at 20, 30, 40 and 50 weeks

Week		A	b	k	RSD
20	FR	4222 (114)	4.07 (0.06)	0.025 (8E-4)	1.0155
	MR	4046 (70)	4.15 (0.05)	0.027 (6E-4)	1.1086
	FV	4006 (72)	4.17 (0.03)	0.026 (5E-4)	1.0440
	MV	3628 (69)	4.05 (0.03)	0.025 (5E-4)	1.0826
30	FR	4247 (41)	4.07 (0.06)	0.025 (5E-4)	1.0139
	MR	4110 (32)	4.15 (0.04)	0.027 (4E-4)	1.0852
	FV	4023 (35)	4.17 (0.03)	0.026 (3E-4)	1.0314
	MV	3511 (27)	4.04 (0.03)	0.026 (4E-4)	1.0684
40	FR	4275 (33)	4.32 (0.04)	0.024 (4E-4)	1.1120
	MR	4268 (27)	4.08 (0.04)	0.026 (4E-4)	1.1020
	FV	4342 (27)	4.29 (0.05)	0.024 (3E-4)	1.0993
	MV	3699 (21)	4.00 (0.04)	0.025 (4E-4)	1.1129
50	FR	4305 (24)	4.07 (0.05)	0.025 (3E-4)	1.0513
	MR	4333 (27)	4.07 (0.04)	0.024 (3E-4)	1.2548
	FV	4292 (27)	4.15 (0.02)	0.023 (3E-4)	1.1390
	MV	3649 (18)	4.03 (0.04)	0.025 (3E-4)	1.0784

A: Adult weight. b: Constant. k: Maturity rate. RSD: Residual standard deviation. F: Female, M:male; lines R and V. Standard errors between brackets

TABLE 7. Gompertz adjustments of the animals which arrive to the age of 50 weeks, using subsets of their data at 20, 30, 40 and 50 weeks of age

Weeks		A	b	k	RSD
20	FR	4255 (96)	4.08 (0.05)	0.026 (7E-4)	1.0622
	MR	3998 (77)	4.12 (0.05)	0.027 (7E-4)	1.3055
	FV	4007 (79)	4.16 (0.03)	0.025 (5E-4)	1.0498
	MV	3646 (69)	4.03 (0.04)	0.027 (5E-5)	1.0622
30	FR	4221 (39)	4.08 (0.05)	0.026 (4E-4)	1.0270
	MR	4086 (38)	4.11 (0.04)	0.026 (4E-4)	1.2329
	FV	4019 (37)	4.16 (0.03)	0.025 (3E-4)	1.0360
	MV	3520 (27)	4.03 (0.04)	0.026 (4E-4)	1.0542
40	FR	4227 (27)	4.08 (0.05)	0.026 (3E-4)	1.0269
	MR	4218 (27)	4.09 (0.04)	0.025 (3E-4)	1.2272
	FV	4210 (29)	4.16 (0.03)	0.024 (3E-4)	1.1035
	MV	3606 (20)	4.01 (0.04)	0.026 (3E-4)	1.0713
50	FR	4305 (24)	4.07 (0.05)	0.025 (3E-4)	1.0513
	MR	4333 (27)	4.07 (0.04)	0.024 (3E-4)	1.2548
	FV	4292 (27)	4.15 (0.02)	0.023 (3E-4)	1.1390
	MV	3649 (18)	4.03 (0.04)	0.025 (3E-4)	1.0784

A: Adult weight. b: Constant. k: Maturity rate. RSD: Residual standard deviation. F: Female, M:male; lines R and V. Standard errors between brackets the same time, which is a usual way of avoiding this problem.

Adult weight is a difficult parameter to estimate. It seems quite clear from figure 1 that adult weight has not been still reached. As there is an asynthotic slow aproximation to adult weight, it would be needed a longer period of time to be sure that weight does not change in adult animals. However, in modern rabbit production systems the rate of replacement is around a 120% per year, which means that adult weight would be rarely reached by any animal of the farm.

A remarkable result is that no sexual dimorfism appeared in line R. Although it is generally admitted that females are heavier than males, there are not many proofs about whether this happens in all breeds or not. Data from breed contests cannot be considered because as sexual dimorfism is usually included in breed standards, farmers bring heavier females to these contests. It can be argued that there is a sampling problem in the experiment because only 3 males and 7 females of line R arrived to 52 weeks of age, but the results of the adjustments at 20 and 30 weeks (table 5), made with more rabbits, show that if this sexual dimorfism exists it should be much smaller for line R than for line V. It should also be considered that when the analyses were made with the whole set of data (table 3) no sexual dimorfism appeared in line R. Whether or not this is an effect of the selection for growth rate is difficult to say. Embryos of both lines have been now frozen, which will make possible to assess the effect of selection in the near futur.

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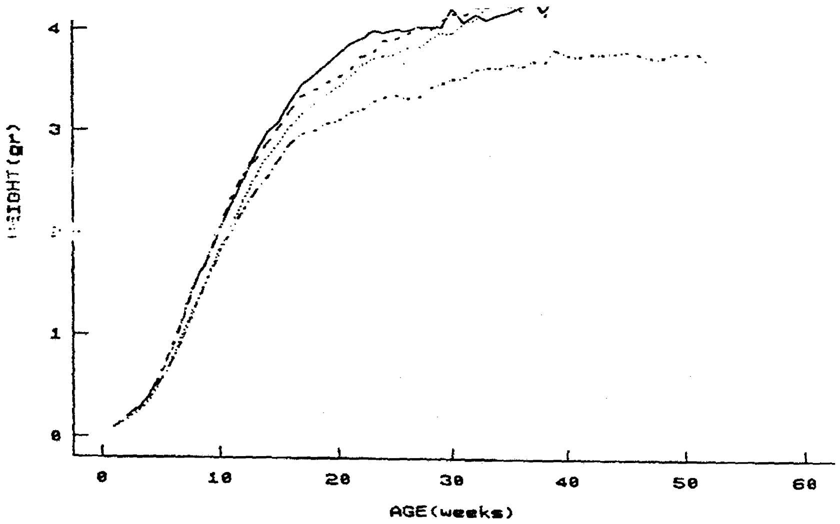
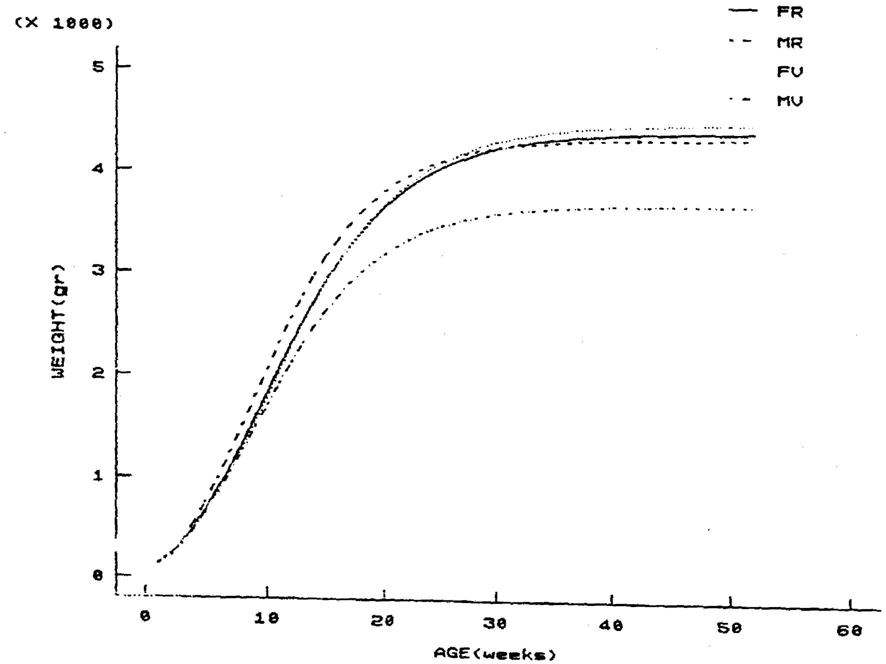

4
3
1
0
0
10
20
30
40
50
60
AGE(weeks)

FIGURE 2


(X 1000)
FR
MR
FV
MV
5
4
3
2
1
0
WEIGHT(gr)
0
10
20
30
40
50
60
AGE(weeks)