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COMPARISON OF DEGREES OF MATURITY OF RABBIT LINES SELECTED FOR DIFFERENT TRAITS

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Abstract: The aim of this work was to study whether commercial nucleus lines of rabbits selected for different traits and experimental lines bred for commercial purposes have the same degree of maturity when compared at the same slaughter age. The study was carried out with 17897 rabbits from Universitat Politècnica de València. Rabbits came from the maternal lines A (3902 rabbits; 44th generation), V (4238 rabbits; 39th generation) and LP (6115 rabbits; 9th generation), selected for litter size at weaning; the paternal line R (2023 rabbits; 34th generation), selected for growth rate between 28 and 63 d of age; the maternal line OR (586 rabbits; 11th generation) selected for ovulation rate; and the High (503 rabbits; 5th generation) and Low (530 rabbits; 5th generation) lines, from a divergent selection for high and low intramuscular fat, respectively. Rabbits were weighed at 28 (W28) and 63 (W63) d of age. Rabbit does (42, 25, 39, 94, 14, 32 and 22 from lines A, V, R, LP, OR, High and Low, respectively) were weighed between 30 and 80 wk of age to determine adult weight (AW). Line R had higher W28 and W63, growth rate between 28 and 63 d of age and AW than lines A, V and LP (5802 g *vs*. 4410, 4222, and 4391 g for AW, respectively). No relevant differences between lines in degrees of maturity at 28 and 63 d of age and time to reach 40% of degree of maturity (percentage of weight compared to AW) were found between lines A, V, R and LP, but the degree of maturity at 2000 g and the time taken to reach that weight were lower in line R (34.7% and 55.2 d) than in lines A (45.5% and 71.1 d), V (47.4% and 69.6 d), and LP (45.8% and 68.0 d). No relevant differences were found between lines OR, High and Low in the traits analysed. A robustness analysis showed that results can be extrapolated to other commercial lines and other slaughter weights. In conclusion, comparison of lines at similar slaughter age could be considered a valid approach for comparisons at the same maturity stage.

Key Words: adult weight, maturity degree, rabbit, selection.

INTRODUCTION

Comparisons between groups of rabbits (different breeds, or rabbits under different treatments) are often performed at the same commercial weight, which is the correct procedure when the aim of the experiment is to find the most economically profitable treatment, breed, etc. However, when the adult size of the groups is different, comparing at the same commercial weight implies that the groups are at a different stage of maturity (i.e., at a different proportion of adult weight; Pla *et al*., 1996 and 1998; Pascual and Pla, 2007 and 2008). In this case, the physiological ages of the groups compared are different; therefore, their carcass and meat characteristics will differ not only due to the treatments applied in the experiment, but also because carcass and meat traits change with the stage of maturity (Cantier *et al*., 1969; Pascual *et al*., 2008). For example, when comparing rabbit groups with different adult weights; as lines selected for growth rate with lines selected for litter size, the former are less mature at the same commercial weight, thus differences found in meat characteristics can be due to both selection and different stages of maturity.

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Comparisons between breeds or treatments should be done at the same stage of maturity when the objective is to discover the effect of the treatment. Unfortunately, measures of adult weight or estimates of adult weight using growth curves are scarcely available, so comparisons are often done at the same age, as an approximation to the same stage of maturity (Gondret *et al.*, 2002; Hernández *et al.*, 2004; Larzul *et al.*, 2005). However, although comparisons at the same age are closer to the same stage of maturity, the approximation may not be accurate enough. For example, Ouhayoun and Rouvier (1973) compared rabbit breeds of different adult weights, finding substantial differences in maturity stage at the same age. Nevertheless, the differences in adult weight of the breeds used by Ouhayoun and Rouvier (1973) were much larger than the current differences found in commercial lines. This raises the question of whether comparisons among current commercial rabbit lines made at the same age are affected by different stages of maturity, and the same applies to rabbit lines used for experiments in animal production. We shall present two examples in which these comparisons are feasible, and show how our results can be generalised to a wide range of lines with different adult weights through an analysis of robustness.

The aim of this work is to check whether comparisons at the same slaughter age are valid as an approximation to the same stage of maturity for current commercial lines and experimental lines with commercial objectives.

MATERIALS AND METHODS

Animals

The experiment was carried out with 17897 rabbits from the experimental farm of the Universitat Politècnica de València born between June 2012 and October 2013. Rabbits came from 7 lines; 4 of them were commercial lines from the selection nucleus of the Universitat Politècnica de València: maternal lines A (3902 rabbits; 44th generation), V (4238 rabbits; 39th generation) and LP (6115 rabbits; 9th generation), selected for litter size at weaning, and the paternal line R (2023 rabbits; 34th generation), selected for growth rate. The other 3 lines were derived from the V line: the maternal line OR (586 rabbits; 11th generation), selected for ovulation rate; and the lines High and Low (503 and 530 rabbits, respectively; 5th generation) from a divergent selection for high and low intramuscular fat, respectively. Lines A, V, LP and R were allocated to a different farm (farm 1) than lines OR, High, and Low (farm 2). Both farms had similar management and environmental conditions. During lactation, females and kits were fed a commercial diet (10.5 MJ digestible energy [DE], 174 g crude protein and 201 g crude fibre per kg dry matter) with a photoperiod of 16-h light: 8-h dark and controlled ventilation. After weaning at 28 d of age, rabbits were weighed (W28), allocated to collective cages and fed with another commercial diet (9.5 MJ DE, 149 g crude protein and 218 g crude fibre per kg dry matter). At 63 d of age (slaughter age under Spanish commercial conditions) rabbits were weighed (W63). Growth rate between 28 and 63 d of age [GR= (W63-W28)/35] was calculated. Rabbits selected at 63 d of age for their respective next generation of selection were reared in individual cages and received 130 g/d of the commercial diet for females described above. Females were first mated at 18 wk of age and were re-inseminated in the subsequent cycles at 11 d post-partum. After the first mating, all females received a commercial diet *ad libitum*. A total of 42, 25, 39, 94, 14, 32 and 22 females from lines A, V, R, LP, OR, High and Low, respectively, were weighed during the same week of February 2014 to determine adult weight. Females had an average age of 40.1 wk (standard deviation=3.6 wk), 63.1 (4.6), 53.4 (11.4), 50.8 (4.2), 35.9 (1.3), 43.3 (4.0), 39.6 (3.5) in lines A, V, R, LP, OR, High and Low, respectively. Physiological state was lactating in 81.0%, 64.0%, 48.7%, 60.6%, 71.4%, 81.3%, and 72.7% of the females from lines in lines A, V, R, LP, OR, High and Low, respectively.

Data analysis

Least square means for W28, W63 and GR were estimated with the 17897 rabbits cited above, using a model with line, sex and month effects.

Subsequently, W28 and W63 of all the animals were pre-corrected by the effect of month (sex was not included, as no appreciable effect was found in the former analysis), and AW of the 268 females were pre-corrected by the effect of state of lactation (2 levels; lactating and non-lactating). Line R is selected for growth rate, so their AW should be corrected to avoid bias due to selection. In each line, an approximate correction was made by multiplying AW by the generalW63/selectedW63 ratio, where generalW63 was the mean weight at 63 d of age of all rabbits and selectedW63 was the mean weight of the selected rabbits. Inadvertent selection for growth often takes place in lines selected for other traits, so the same correction was carried out for the other lines. Figure 1 shows AW after correction for state of lactation and selection *vs.* age in the different lines.

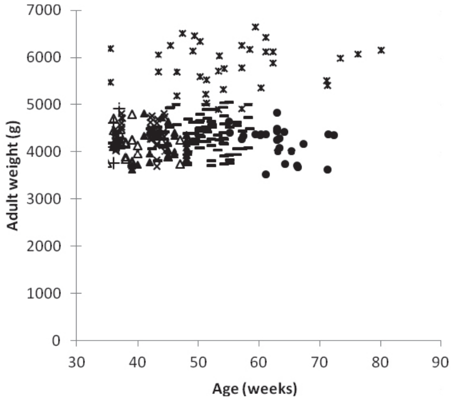

Figure 1: Adult weight corrected by lactating status and selection, *vs.* age in the different lines. x: A, •: V, ⁎: R, –: LP, +: OR, ▲: High, △: Low.

Pre-corrected weights were used to calculate the degree of maturity at different stages. Degrees of maturity at 28 and 63 d of age (DoM28 and DoM63, respectively) were calculated as W28/AW and W63/AW, respectively. The age at which rabbits reached 40% maturity (T40%), which is the maturity around the age of slaughter, was estimated as 28+[(0.4AW−W28)/GR]. Degree of maturity at 2000 g of live weight (DoM2000), which could be considered a Spanish commercial weight, was calculated as 2000/AW. Time taken to reach 2000 g (T2000) was calculated as 28+[(2000-W28)/GR]. Both T40% and T2000 were estimated considering that rabbits grow linearly at these ages (Blasco *et al.*, 2003). Least square means of AW, DoM28, DoM63, T40%, DoM2000 and T2000 were obtained applying a model including the line effect. Data from different farms were analysed separately. A sensitivity analysis of the robustness of the results for adult weight was performed by analysing data after increasing and decreasing AW in one standard deviation (258.1 g, 329.7 g, 483.3 g, 333.3 g, 271.8 g, 289.4 g, and 294.8 g, for lines A, V, R, LP, OR, High and Low, respectively).

RESULTS AND DISCUSSION

A key point in comparison of different rabbit lines is the moment at which the lines are compared. Changes in degree of maturity alter carcass and meat composition in rabbits (Hernández *et al.*, 2004; Pascual *et al.*, 2008). Slaughter weight is fixed by the market in intensive rabbit production, so comparisons at the same commercial weight make economic sense; however, these comparisons are drawn at different degrees of maturity, so it is not possible to know if differences observed are due to the line or to the degree of maturity. To avoid this confusion, comparing lines at the same stage of maturity has been proposed (Brody 1945; Taylor 1985; Taylor and Murray, 1987a). As adult weight is not usually available, comparisons at the same age have been used in rabbit as an approximation to the same stage of maturity (Ariño *et al.*, 2007; Hernández *et al.*, 2006). We shall now examine how accurate this approximation is.

Table 1 shows the means of the weights at 28 and 63 d of age and growth rate during this period for all lines, with coefficients of variation (CV) ranging from 0.14 to 0.20. Lines A, V and LP are currently used for producing crossbreed does and line R is commercially used as a terminal sire in the usual three-way crossbreeding scheme. The genetic composition of the lines was described by Baselga (2002) and Sánchez *et al.* (2008). Line OR was described by

Table 1: Least square means±standard error of live weight at 28 (W28, g) and 63 (W63, g) d of age, and growth rate between 28 and 63 d of age (GR, g/d) of the different rabbit lines.

	n	W28	W63	GR
Farm 1				
A	3902	601±2^{a}	1734±3^{a}	32.4±0.1^{a}
V	4238	625±3^{b}	1788±3^{b}	33.2±0.1^{b}
R	2023	771±3^{d}	2392±5^{d}	46.5±0.1^{d}
LP	6115	654±2^{c}	1836±3^{c}	33.8±0.1^{c}
Farm 2				
OR	586	494±4	1682±7^{b}	33.9±0.1^{b}
High	503	497±4	1652±8^{a}	33.0±0.2^{a}
Low	530	499±4	1687±7^{b}	33.9±0.2^{b}

Means within farm in the same column with different superscripts differ (P<0.05).

Table 2: Least square means±standard error of adult weight (AW, g), degree of maturity (% weight compared to adult weight) at 28 (DoM28) and 63 (DoM63) days of age, time to reach a degree of maturity of 40% (T40%, d), degree of maturity at 2000 g of live weight (DoM2000), and time to reach 2000 g (T2000, d) of the different rabbit lines.

	n	AW	DoM28	DoM63	T40%	DoM2000	T2000
Farm 1							
A	42	4410±55[b]	13.8±0.3[b]	39.7±0.5[a]	63.8±0.6[b]	45.5±0.5[b]	71.1±0.5[c]
V	25	4222±71[a]	14.6±0.4[bc]	42.4±0.6[b]	60.1±0. 8[a]	47.4±0. 7[c]	69.6±0.7[c]
R	39	5802±57[c]	12.6±0.3[a]	41.0±0.5[ab]	62.0±0.6[a]	34.7±0.5[a]	55.2±0.6[a]
LP	94	4391±37[b]	15.2±0.2[c]	42.0±0.3[b]	60.6±0.4[a]	45.8±0.3[b]	68.0±0.4[b]
Farm 2							
OR	14	4248±77	11.2±0.5	39.7±1.0	63.5±1.3	47.3±0.9	72.3±1.1
High	32	4171±51	11.5±0.3	39.7±0.6	63.7±0.8	48.2±0.6	73.7±0.7
Low	22	4165±61	11.8±0.4	40.1±0.8	62.7±1.0	48.2±0.7	72.5±0.9

Means within farm in the same column with different superscripts differ (P<0.05).

Laborda *et al.* (2011) and the High and Low lines by Zomeño *et al.* (2013). Line R, originally formed with a population of rabbits having high growth rate, and then selected for growth rate for 34 generations, showed the highest weight at slaughter and at adult weight for all lines (table 2), which is a consequence of selection for growth rate (Blasco *et al.*, 2003).

Table 2 shows the adult weight and degrees of maturity of each line, with CV from 0.07 to 0.19. When comparing OR, High and Low lines, no differences in maturity are found either at the same commercial weight or at the same age, so comparisons can be made safely. However, when comparing degrees of maturity at slaughter commercial weight (2000 g), there is a large difference between the R line and the maternal lines A, V and LP. In consequence, line R should not be compared with other lines at slaughter weight. This will also happen if comparisons are made at other slaughter weights such as the French or Italian ones, which are around 2.5 kg live weight [Coutelet (2013) and SATA (2012) respectively]. We compared the time taken to reach maturity at 2500 g in our lines, and the result was consistent with the comparison at 2000 g (results not shown).

At slaughter time, all lines from both farms show a remarkable similarity in degree of maturity, with a maximum difference of 2.7%. The maximum difference among all lines in the time required to reach a 40% degree of maturity was 3.7 d, roughly 5% of the slaughter age. Then, lines of different adult size compared at the same age were also compared approximately at the same stage of maturity. Different results were obtained by Ouhayoun and Rouvier (1973). They compared dwarf lines with AW of 2.5 kg with crossbreed does from giant and commercial lines with 4.8 kg AW, finding different degrees of maturity at 12 wk of age (0.70% and 0.55% of adult weight, respectively). According to their results, rabbit lines with relevant differences in adult weight should not be compared at a similar age. However, in our commercial lines, the lowest and highest lines differ in 39% of their AW, whereas in the case of Ouhayoun and Rouvier the highest line was 92% heavier than the lowest line for AW. Moreover, Ouhayoun and Rouvier (1973) took adult weight as weight at 26 wk, an age too early for estimating adult weight (Blasco and Gómez, 1993), which means that the difference between low and high lines was probably higher. Therefore, their conclusions cannot be applied to the current commercial lines, because in our commercial crossbreeding programme, or in any other programme, the differences between lines for reproductive or growth purposes are much smaller. Finally, their sample size was very small (three individuals per group and week), so their results should be considered only as a first approach to the problem.

The estimates of degree of maturity may be affected by some of the approximations we made. First, we used selected animals and we corrected for the bias due to selection by considering that the ratio of weights between selected and unselected animals will be maintained from slaughter time to adult weight. This is a reasonable supposition, as all weights are correlated and selection does not modify the curve shape, as shown by Blasco *et al.* (2003). Second, adult weight was estimated in rabbit females between 30 and 80 wk of age. This should not be a problem, as Blasco and Gómez (1993), using lines V and R, showed that adult weight is stable after 30 wk of age. Figure 1 shows that adult weights are the same from week 30; moreover, preliminary analyses did not show changes in adult weight

Table 3: Least square means±standard error for adult weight (AW, g), degree of maturity (% weight compared to adult weight) at 28 (DoM28) and 63 (DoM63) d of age, time to reach a degree of maturity of 40% (T40%, d), degree of maturity at 2000 g of live weight (DoM2000, d), and time to reach 2000 g (T2000, d) when increasing (AW +1 s.d.) and decreasing (AW–1 s.d.) adult weight in one standard deviation in females from lines A, V, R and LP.

	n	AW	DoM28	DoM63	T40%	DoM2000	T2000
Robustness analysis AW–1 s.d.							
A	42	4152±55[b]	14.7±0.4[ab]	42.2±0.6[a]	60.6±0.6[b]	48.4±0.6[b]	71.1±0.5[c]
V	25	3892±71[a]	15.8±0.5[bc]	46.1±0.7[b]	56.1±0.8[a]	51.8±0.8[c]	69.6±0.7[c]
R	39	5319±57[c]	13.7±0.4[a]	45.4±0.4[b]	57.9±0.6[a]	37.9±0.6[a]	55.2±0.6[a]
LP	94	4058±37[b]	16.5±0.2[c]	44.8±0.6[b]	56.6±0.4[a]	49.6±0.4[b]	68.0±0.4[b]
Robustness analysis AW+1 s.d.							
A	42	4631±58[ab]	13.2±0.3[b]	37.9±0.5[a]	66.5±0.7[b]	43.4±0.5[bc]	71.1±0.5[c]
V	25	4520±76[a]	13.6±0.4[bc]	39.5±0.6[b]	63.8±0.8[a]	44.5±0.6[c]	69.6±0.7[c]
R	39	6325±61[c]	11.6±0.3[a]	37.7±0.5[a]	66.5±0.7[b]	31.8±0.5[a]	55.2±0.6[a]
LP	94	4713±40[b]	14.2±0.2[c]	39.1±0.3[b]	64.5±0.4[a]	42.7±0.3[b]	68.0±0.4[b]

Means within farm in the same column with different superscripts differ (P<0.05). s.d.: standard deviation.

from 30 to 80 wk, as the regressions slopes of adult weight against age did not differ from zero. Third, females were at different moments of gestation and lactation, showing lactating and non-lactating females and average of 4553 and 4893 g of AW respectively (results not shown), and the effect was partially corrected by pre-correcting AW by lactation effect. Fourth, we used only females to estimate the adult weight, when it is well known that rabbit lines can present sexual dimorphism (Blasco and Gómez, 1993, for lines V; Pascual *et al.*, 2008, in line R). All these issues are common in maturity studies, in which males are a very small proportion of all adult animals and females are in different physiological states (Thiessen *et al.*, 1984; Taylor and Murray, 1987b). We did not consider the different litter size of the lines, as this trait is a property of each line, thus litter size is not corrected when comparing growth of lines, or in meat quality studies. Line R is a terminal sire and its litter size is irrelevant for the use of the line in the three-way cross.

These approximations make a robustness analysis appropriate to assess how errors in the estimation of adult weight affect the estimates of maturity. We decided to consider possible errors in adult weight by augmenting or decreasing the estimated AW by one standard deviation. In a normal distribution, one standard deviation includes 67% of the individuals, thus the interval we have taken for the robustness analysis represents a large possible error in AW. Tables 3 and 4 show the result of the robustness analysis. After increasing or decreasing AW, the differences in AW are large, reaching more than 1 kg in the R line. The figures of degrees of maturity and time to reach maturity change when changing AW; however, it is noticeable that all the conclusions of this work remain: degree of maturity of line R is

Table 4: Least square means±standard error for adult weight (AW, g), degree of maturity (% weight compared to adult weight) at 28 (DoM28) and 63 (DoM63) days of age, time to reach a degree of maturity of 40% (T40%, d), degree of maturity at 2000 g of live weight (DoM2000, d), and time to reach 2000 g (T2000, d) when decreasing (AW +1 s.d.) and decreasing (AW–1 s.d.) adult weight in one standard deviation in females from lines OR, High and Low.

	n	AW	DoM28	DoM63	T40%	DoM2000	T2000
Robustness analysis AW - 1 s.d.							
OR	14	3976±77	12.0±0.5	42.5±1.1	60.4±1.2	50.5±1.0	72.3±1.1
High	32	3882±51	12.4±0.3	42.7±0.7	60.2±0.8	51.8±0.7	73.7±0.7
Low	22	3870±61	12.7±0.4	43.9±0.9	59.2±1.0	52.0±0.8	72.5±0.9
Robustness analysis AW + 1 s.d.							
OR	14	4435±94	10.5±0.6	37.5±1.1	66.4±1.7	45.2±0.9	72.3±1.1
High	32	4461±50	10.8±0.3	37.1±0.6	67.1±0.9	45.0±0.5	73.7±0.7
Low	22	4459±60	11.0±0.4	38.0±0.7	66.2±1.1	45.0±0.6	72.5±0.9

s.d.: standard deviation.

much smaller than the degrees of the other lines at 2000 g of live weight, but differences in maturity disappear when compared at the same slaughter age, and again comparisons between OR, High and Low lines can be made at the same weight or age. These results confirm that possible deviations due to the approximations considered would not affect the conclusions. Besides, the differences between males and females are lower than one standard deviation (Blasco and Gómez, 1993), so the conclusions remain valid even when using only females in the comparison.

Another important issue is that our results can be generalised to other commercial lines and experimental lines used for commercial purposes that will be around the adult size of the lines used in this experiment. This means that the stage of maturity at a fixed age should be similar in all lines, within the limits of adult size for commercial lines and research in lines with commercial purposes (i.e., excluding, for example, dwarf rabbit lines). Thus, in other markets in which commercial weight is higher, comparisons should be made at an age that will approximate commercial weight; for example 11 wk in the case of the French or Italian market.

CONCLUSIONS

There are substantial differences in degree of maturity at a fixed commercial weight when comparing lines of different adult size, but the differences disappear when comparing the lines at the same slaughter age. Comparisons between lines or groups of different adult size should be carried out at the same age and not at the same weight, in order to disentangle the line effect from the effect of maturity stage.

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REFERENCES

Ariño B., Hernandez P., Pla P., Blasco A. 2007. Comparison between rabbit lines for sensory meat quality. *Meat Sci., 75: 494-498. doi:10.1016/j.meatsci.2006.08.013*

Baselga M. 2002. Rabbit Genetic Resources in Mediterranean Countries. 1st ed. Options mediterraneenes, serie B: Etudes et recherches, Zaragoza, Spain.

Blasco A., Gómez E. 1993. A note on growth curves of rabbit lines selected on growth rate or litter size. *Anim. Prod., 57:332-334. doi:10.1017/S000335610000698X*

Blasco A., Piles M., Varona L. 2003. A Bayesian analysis of the effect of selection for growth rate on growth curves in rabbits. *Genet. Sel. Evol., 35: 21-41. doi:10.1186/1297-9686-35-1-21*

Brody S. 1945. Bioenergetics and growth. Ed. London, Hafner Press.

Cantier A., Vezinhet R., Rouvier R., Dauzier L. 1969. Allométrie de croissance chez le lapin (*Oryctolagus cuniculus*). 1. Principaux organes et tissues. *Ann. Biol. Anim. Bioch. Biophys., 9: 5-39. doi:10.1051/rnd:19690101*

Coutelet, G. 2013. Résultats technico-économiques des éleveurs de lapins de chair en France en 2012. *In Proc.: 15èmes Journées de la Recherche Cunicole, 19-20 novembre 2013. Le Mans, France. 1: 111-113.*

Gondret F., Combes S., Larzul C., Rochambeau H. 2002. Effects of divergent selection for body weight at a fixed age on histological, chemical and rheological characteristics of rabbits muscles. *Liv. Prod. Sci., 76: 81-89. doi:10.1016/S0301-6226(02)00003-9*

Hernández P., Aliaga S., Pla M., Blasco A. 2004. The effect of selection for growth rate and slaughter age on carcass composition and meat quality traits in rabbits. *J. Anim. Sci., 82: 3138-8143.*

Hernández P., Ariño B., Grimal A., Blasco A. 2006. Comparison of carcass and meat characteristics of three rabbit lines selected for litter size or growth rate. *Meat Sci., 73: 645-650. doi:10.1016/j.meatsci.2006.03.007*

Laborda P., Moce L., Santacreu M.A., Blasco A. 2011. Selection for ovulation rate in rabbits: Genetic parameters, direct response, and correlated response on litter size. *J. Anim. Sci., 89: 2981-2987. doi:10.2527/jas.2011-3906*

Larzul C., Gondret F., Combes S., Rochambeau H. 2005. Divergent selection on 63-day body weight in the rabbit: response on growth, carcass and muscle traits. *Genet. Sel. Evol., 37: 105-122. doi:10.1186/1297-9686-37-1-105*

Ouhayoun J., Rouvier R. 1973. Composition corporelle et degré de maturité en poids de lapereaux de plusieurs génotypes. *J. Rech. Avic. Cunic., Paris.*

Pascual M., Pla M. 2007. Changes in carcass composition and meat quality when selecting rabbits for growth rate. *Meat Sci., 77: 474-481. doi:10.1016/j.meatsci.2007.04.009*

Pascual M., Pla M. 2008. Changes in collagen, texture and sensory properties of meat when selecting rabbits for growth rate. *Meat Sci., 78: 375-380. doi:10.1016/j.meatsci.2007.07.009*

Pascual M., Pla M., Blasco A. 2008. Effect of selection for growth rate on relative growth in rabbits. *J. Anim. Sci., 86: 3409-3417. doi:10.2527/jas.2008-0976*

Pla M., Guerrero L., Guardia D., Oliver M.A., Blasco A. 1998. Carcass characteristics and meat quality of rabbit lines selected for different objectives: I. Between lines comparison. *Livest. Prod. Sci., 54: 115-123. doi:10.1016/S0301-6226(97)00179-6*

Pla M., Hernández P., Blasco A. 1996. Carcass composition and meat characteristics of two rabbit breeds of different degree of maturity. *Meat Sci., 44: 85-92. doi:10.1016/S0309-1740(96)00079-4*

Sánchez J. P., Theilgaard P., Mínguez C., Baselga M. 2008. Constitution and evaluation of a long-lived productive rabbit line. *J. Anim. Sci., 86:515-525. doi:10.2527/jas.2007-0217*

SATA. 2012. Relazione dell'attività tecnica Sezione Conigli. Anno 2012. *Servizio di Assistenza Tecnica agli Allevamenti. Available at: http://www.m.regione.lombardia.it/shared/ccurl/433/175/REL.TEC.4%20-%20CONIGLI.pdf*. Accessed June 2015.

Serrano P., Pascual M., Lavara R., Gómez E. A. 2012. Analysis of management techniques on productivity indicators using the bdcuni Spanish database. *In Proc.: 10th World Rabbit Congress, Sharm El Sheik - Egipto. 1: 803-807.*

Taylor C. S. 1985. Use of genetic size-scaling in evaluation of animal growth. *J. Anim. Sci., 61: 118-143.*

Taylor C. S., Murray J.I. 1987a. Genetic aspects of mammalian growth and survival in relation to body size. *In: Academic Press, 1987: 58.*

Taylor C. S., Murray J.I. 1987b. Voluntary food intake of cattle differing in breed size in a time-controlled feeding system. *Anim. Prod., 45, 433-452. doi:10.1017/S0003356100002920*

Thiessen R. B., Hnizdo E., Maxwell D. A. G., Gibson D. Taylor C. S. 1984. Multibreed comparisons of British cattle. Variation in body weight, growth rate and food intake. *Anim. Prod. 38: 323-340. doi:10.1017/S0003356100041520*

Zomeño C., Hernandez P., Blasco A. 2013. Divergent selection for intramuscular fat content in rabbits. I. Direct response to selection. *J. Anim. Sci., 91: 4526-4531. doi:10.2527/jas.2013-6361*