World Rabbit Sci. 2023, 31: 221-228
https://doi.org/10.4995/wrs.2023.19841
WRSA, UPV, 2003

GROWTH PERFORMANCE OF THREE PATERNAL RABBIT LINES WITH DIFFERENT POTENTIAL FOR GROWTH RATE AND RESILIENCE

Catarina Peixoto-Gonçalves*, Eugenio Martínez-Paredes*, Luis Ródenas*, Juan Manuel Corpa†, Enrique Blas*, María Cambra-López*, Juan José Pascual*

*Institute of Animal Science and Technology, Universitat Politècnica de València, Camino de Vera, s/n. Valencia, 46022, Spain.
†Biomedical Research Institute (PASAPTA-Pathology Group), Facultad de Veterinaria, Universidad Cardenal Herrera-CEU, CEU Universities. C/Tirant lo Blanc 7, Alfara del Patriarca, 46115, Valencia, Spain.

Abstract: This experiment aimed to compare the growth performance, digestive efficiency and health status of three paternal lines for growing rabbits. The R line was selected by growth rate during the growing period for 37 generations; the RF line was founded by selecting a population of elite R animals (average daily gain>60 g/d); and the RFLP line was founded by backcrossing males from the RF line with females from the LP maternal line. A total of 387 weaned rabbits were used to evaluate growing performance from weaning until 63 d of age in individual cages, in three batches. Additionally, 33 animals were used to determine nutrient digestive efficiency in a digestibility trial. Body weight and feed intake were controlled at weaning (28 d), 46 and 63 d of age. Mortality and morbidity were also monitored daily. During the digestibility trial, feed intake and faeces excretion were controlled daily. Results showed no significant effects of genetic type on body weight, daily feed intake and feed conversion ratio throughout the experiment. However, RF animals had a higher average daily gain from 28 to 46 d of age (+4.4%; P<0.05) compared with R animals, but lower from 46 to 63 d of age (–4.3%; P<0.05). Regarding digestive efficiency, RF and RFLP lines showed slightly higher faecal digestibility for dry matter and gross energy of the diet compared with the R line (+1.3 percentage points; P<0.05). Mortality was higher in animals from R and RF lines compared with RFLP (on av. 25.40 *vs.* 14.06%; P<0.05). Our results suggest that the introduction of resilient genetics could be a suitable strategy to improve the digestive health of paternal lines without affecting significantly their growth performance.

Key Words: growth rate, digestibility, mortality, genetics, rabbit.

INTRODUCTION

Rabbit meat production has significantly evolved over the past few decades thanks to pertinent advances in genetic selection, reproductive management and feeding systems (Pascual, 2010). Since feed conversion ratio (FCR) and litter size are the main productive traits determining farm profitability, genetic improvement programmes should consider both paternal and maternal lines (Cartuche *et al.*, 2014). Three-way crossings are the basis for breeding programmes in commercial farms. The paternal line is usually selected for average daily gain (ADG) to provide terminal males, while two maternal lines are selected for reproductive traits and crossed to generate a commercial doe. Theoretically, this scheme provides numerous litters with heavier kits (Blasco *et al.*, 2018).

Correspondence: C. Peixoto-Gonçalves, *capeigon@upvnet.upv.es*. Received *June 2023* - Accepted *July 2023*.
https://doi.org/10.4995/wrs.2023.19841

Cite as: Peixoto-Gonçalves C., Martínez-Paredes E., Ródenas L., Corpa J.M., Blas E., Cambra-López M., Pascual J.J. 2023. Growth performance of three paternal rabbit lines with different potential for growth rate and resilience. *World Rabbit Sci., 31: 221-228. https://doi.org/10.4995/wrs.2023.19841*

Using paternal lines selected for high growth rate has widely improved growth performance in rabbit production. Consequently, growing rabbits reach a heavier weight in less time, which is associated with improved FCR (Baselga, 2004). However, the genetic selection of only specialist criteria could be related to reproductive, physiological and immunological disorders (Rauw *et al.*, 1998). Therefore, obtaining productive and functional animals in a commercial environment may be a more sustainable option in the long term (Arnau-Bonachera *et al.*, 2018).

The performance of the R line can be used as an example to illustrate the reproductive and immunological problems associated with this genetic selection process. The R line is a paternal line selected for ADG during the growing period (Estany *et al.*, 1992). In the last generations, these animals have shown reproductive limitations such as inadequate responses to ovulation, foetal losses and reduced litter size (Vicente *et al.*, 2012; Naturil-Alfonso *et al.*, 2015). Such a decline in reproductive traits can affect the selection pressure, as fewer individuals are available to select, and even fewer have the desired characteristics. In addition, animals selected for ADG have shown a high prevalence of digestive disorders such as epizootic rabbit enteropathy, which results in high mortalities and increases the need for antimicrobial treatments (García-Quirós *et al.*, 2014).

Within this framework, two strategies were considered by our research team in order to explore how to improve growth performance and reduce the risk of digestive disorders: (1) selecting elite animals from the R line (ADG>60 g/d) for the foundation of an elite line called RF. (2) The introduction of resilient genetics is achieved by backcrossing these elite animals with a long-living maternal line, the LP line, thus creating the RFLP line. In a previous work, the authors studied how these new paternal lines acquire and allocate resources and their effects on the reproductive performance of female rabbits (Peixoto-Gonçalves *et al.*, 2023). While RF females showed enhanced reproductive traits in the first cycle, RFLP females' reproductive performance was more stable over time and showed an increased capacity to tackle the demands of lactation and gestation while maintaining an adequate body condition. However, to date, there is no information on the impact of these genotypes on growing rabbits' growth performance and incidence of digestive disorders.

Therefore, this study aimed to evaluate how genetic type affects growing rabbits' growth performance, digestive efficiency and health status.

MATERIAL AND METHODS

The experimental procedure was approved by the Animal Welfare Ethics Committee of the Universitat Politècnica de València (UPV; code: 015/VSC/PEA/00061) and conducted following the recommendations of the European Group on Rabbit Nutrition (Fernández-Carmona *et al.*, 2005) and the Spanish Royal Decree 53/2013 on the protection of animals used for scientific purposes.

Animals

A total of 384 weaned rabbits (28 d of age) from 3 paternal lines were used for this experiment. The animals belonged to lines R (n=125, 26 litters), RF (n=131, 27 litters) and RFLP (n=128, 27 litters), developed by the Animal Breeding and Genetics Group of the UPV in Spain. Animals came from 70 different females, from 80 litters.

The R line was a paternal line selected for growth rate during the growing period (post-weaning) for 37 generations (Estany *et al.*, 1992). The RF line was founded by selecting a population of elite R animals from two genetic selection centres, which had a high growth rate during the growing period (ADG from 28 to 63 d of life of the final population: 61.94 g/d). Finally, the RFLP line was created by backcrossing the males of the RF line with females of the maternal line LP, generating 7/8 RF and 1/8 LP animals as in other previous foundations per hyper-selection (Cifre *et al.*, 1998; Sánchez *et al.*, 2008). The LP line was founded by productive longevity criteria (minimum of 25 parturitions and 7.5 kits born alive; Sánchez *et al.*, 2008; Savietto *et al.*, 2015).

Experimental procedure

The trial was conducted in three batches of 128 animals from September 2020 to March 2021 at the experimental facilities of the Universitat Politècnica de València. Throughout the trial, the animals were kept in a controlled environment with a photoperiod of 16 h of light and 8 h of darkness, with mechanical ventilation and cooling panels. All animals were fed a commercial growing rabbit pelleted diet (161 g crude protein, 401 g neutral detergent fibre, 218 g acid detergent fibre, 36 g acid detergent lignin per kg of feed; Cunitiva Fibra, Nanta, S.A) throughout the experimental period.

The experiment lasted 35 d (from 28 to 63 d of age). At the start, weaned animals were weighed and housed in individual wired cages. Water was given *ad libitum* throughout the experiment. Feed was restricted following Gidenne *et al.* (2009) for the first 18 d, progressively increasing the offered amount until 46 d of age (35 g the first 4 d, 55 g 4 d, 70 g 3 d, 80 g 3 d and 90 g the last 4 d post-weaning). On day 46 of age, all animals were weighed again and fed ad libitum until the end of the experiment. This strategy was adopted to minimise digestive distress. Individual body weight (BW) was registered at 28, 46 and 63 d of age. Daily feed intake (DFI) was controlled in each period. Morbidity (apathy and diarrhoea) and mortality were monitored daily. In addition, animals with a severe disturbance in feed intake (under 2.5 the standard deviation of the mean) or growth (weight loss in 7 d) were considered morbid (Bennegadi *et al.*, 2000).

Additionally, a digestibility trial was performed according to Pérez *et al.* (1995). A total of 33 animals (49 d of age) were used in the digestibility trial (11 animals from each genetic line) from 21 different rabbit females. After a 7-day adaptation period, feeders were weighed and the cages were prepared for faeces collection at 56 d of age. In these cages, metal cones were fitted with a metal grid to retain the faeces and separate them from the urine. Feed intake was controlled and faeces were collected daily for four days and stored individually in labelled bags. The faeces were stored at –20°C until further analysis. Then they were dehydrated in an oven for 48 h at 80°C and weighed. Any feed pellet present was removed and weighed to correct dry matter intake and avoid overestimating the nutrient excretion. The dehydrated faeces and feed were ground in a 0.5 mm mesh mill before analysis.

Chemical analyses

Feed and faeces were analysed in duplicate using AOAC methods (AOAC, 2023). Dry matter (DM) was determined following AOAC official method 934.01 and crude protein (CP) following method 990.03 (Dumas method, CN628 Elemental Analyzer, LECO, St. Joseph, USA). Gross energy (GE) was determined using an adiabatic bomb calorimeter (Gallenkamp Autobomb, Loughborough, RU). Additionally, the feed was analysed for fibre fractions. Neutral detergent fibre, acid detergent fibre and acid detergent lignin were sequentially determined following the method of Van Soest *et al.* (1991), using pre-treatment with thermostable α-amylase and the nylon bag technique (Ankom, Macedon, USA).

Statistical analyses

Performance traits (BW, ADG, DFI and FCR) were analysed using a MIXED model by SAS (Statistical Analysis System) for repeated measures, considering the lack of data homoscedasticity. The model included the genetic type, age, their interaction and the batch as fixed effects and the animals as a permanent effect. Apparent faecal digestibility coefficient data were analysed using a GLM model from SAS, including the genetic type as a fixed effect. Orthogonal contrasts of interest were also obtained by comparing R with the new lines [R –½(RF+RFLP)]. The effect of genetic type on the health traits was analysed using logistic regression by the GENMOD procedure of SAS, considering a binomial distribution (logit scale). Significant differences were declared at $P<0.05$.

RESULTS

Table 1 shows the effect of genetic type on rabbits' growth performance. In general, genetic type did not affect BW, ADG (global av. 49.2 g/d), DFI (global av. 93.17 g/d) and FCR (global av. 1.96) throughout the growing period. However, rabbits from the RF line showed higher ADG from 28 and 46 d of age (+1.1±0.52 g/d; $P=0.0221$) than the R line rabbits. There were no statistically significant differences in ADG between rabbits in RF and RFLP lines.

Table 1: Effect of genetic type (R, RF and RLP) on the productive performance (mean±standard error) of growing rabbits from 28 to 63 d of age (n=271).

	Genetic type (GT)			
	R	RF	RFLP	*P*-value
From 28 to 46 d				
BW at 28	603±12	607±11	622±11	0.4204
ADG 28 to 46	27.3[a]±0.4	28.4[b]±0.4	27.5[ab]±0.3	0.0487
DFI 28 to 46	55.7±0.26	55.4±0.26	55.7±0.24	0.5635
FCR 28 to 46	2.09±0.05	2.00±0.05	2.03±0.04	0.3338
From 46 to 63 d				
BW at 46	1094±11	1118±10	1116±10	0.1865
ADG 46 to 63	72.2±1.06	69.2±1.05	70.8±0.98	0.1379
DFI 46 to 63	130±4.94	127±4.89	135±4.51	0.4787
FCR 46 to 63	1.85±0.04	1.87±0.04	1.90±0.04	0.6627
BW at 63	2321±24.1	2294±23.8	2319±22	0.6552
From 28 to 63 d				
ADG 28 to 63	49.7±0.52	48.8±0.51	49.1±0.47	0.3685
DFI 28 to 63	92.8±2.48	91.3±2.45	95.4±2.56	0.4883
FCR 28 to 63	1.97±0.02	1.93±0.02	1.97±0.02	0.1180

BW: body weight; ADG: average daily gain; DFI: daily feed intake; FCR: feed conversion ratio.
[a,b] Means not sharing superscript were significantly different at $P<0.05$.

Table 2 shows the effect of the genetic type on the apparent nutrient faecal digestibility coefficients in growing rabbits' diets from 56 to 63 d of age. The genetic type did not affect the faecal digestibility coefficient of DM (av. 54.5%), CP (av. 66.9%) and GE (54.2%). However, when comparing the original R line with the new RF and RFLP lines through contrast analysis, the new ones had higher digestibility coefficients for DM and GE (+1.30±0.55 and +1.29±0.56 percentage points, respectively; $P<0.05$).

Figure 1 shows the evolution of the cumulated mortality rates throughout the growing period, and Table 3 shows the effect of the genetic type on the health traits monitored (mortality, morbidity and SRI). Overall, global mortality throughout the experiment was 25%, highest during the first period post-weaning (28 to 46 d of age) and decreasing thereafter. All dead or morbid animals showed signs compatible with epizootic rabbit enteropathy (ERE). Animals from R and RF lines had higher mortality rates from 28 to 46 d of age than those from the RFLP line (on av. +11.3 percentage points; $P<0.05$). Although there was no significant difference between genetic types in mortality from 46 to 63 d, global mortality of the R and RF animals was higher than for RFLP animals (on av. +12.9 percentage points; $P<0.05$). As shown in Figure 1, the differences in cumulated mortality become significant between RFLP and the other genetic types from 43 d of age. On the other hand, the genetic type did not significantly affect animals'

Table 2: Effect of genetic type (R, RF and RLP) on the faecal digestibility coefficient (mean±standard error) of growing rabbits from 56 to 63 d of age (n=31).

	Genetic type (GT)			
	R	RF	RFLP	*P*-value
No. animals	10	11	10	
Feed intake (g DM/d)	193±8	182±7	180±8	0.4285
Faecal coefficients:				
Dry Matter	53.6[a]±0.5	54.9[b]±0.5	54.9[b]±0.5	0.0776
Crude Protein	66.5±0.9	67.5±0.8	66.7±0.9	0.6653
Gross Energy	53.4[a]±0.4	54.6[b]±0.4	54.7[b]±0.4	0.0907

[a,b] Orthogonal contrast analysis. RF and RFLP had higher digestibility coefficients for DM and GE (+1.30±0.55 and +1.29±0.56 percentage points, respectively; $P<0.05$).

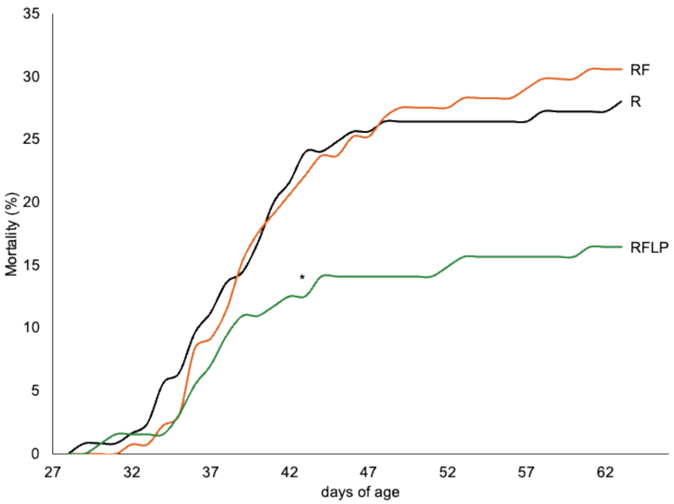

Figure 1: Cumulated mortality (%) throughout the growing period by genetic type (— R, — RF and — RFLP). * Day of age at which cumulated mortality differences become significant ($P<0.05$).

morbidity throughout the trial. Therefore, the sanitary risk index (SRI) showed a similar evolution to the mortality rate. The R and RF lines showed a higher SRI than the RFLP line from 28 to 46 d of age (on av. +12.2 percentage points; $P<0.05$) and during the global period (on av. +13.3 percentage points; $P<0.05$).

DISCUSSION

The main objective of this work was to evaluate whether the foundation of two new genetic lines through the selection of elite-growth animals and the potential introduction of robust genetics could contribute to solving growth and health limitations in growing rabbits. Thus, it would be expected that the new genetic lines would improve the growth performance, digestive efficiency and intestinal health of growing rabbits.

Table 3: Effect of the genetic type (R, RF, RFLP) on the animals' health status from 28 to 63 d of age.

	Genetic Type (GT)			
	R	RF	RFLP	*P*-value
Mortality 28-46 d	25.60[b]	25.19[b]	14.06[a]	0.0394
46-63 d	3.23	7.14	2.73	0.2424
Global	28.00[b]	30.53[b]	16.41[a]	0.0204
Animals at 28 d	125	128	131	
Animals at 46 d	93	98	110	
Animals at 63 d	90	91	107	
Morbidity 28-46 d	2.40	0.76	0.78	0.4193
46-63 d	1.08	0.00	0.91	0.6086
Global	3.20	0.76	1.56	0.1757
SRI 28-46 d	28.00[b]	26.00[b]	14.80[a]	0.0268
46-63 d	4.30	7.14	3.64	0.4775
Global	31.20[b]	31.30[b]	17.97[a]	0.0216

SRI: Sanitary Risk Index.
[a,b] Means not sharing superscript were significantly different at $P<0.05$.

Feed was restricted for 18 d after weaning to avoid excessive digestive disorders. Feed restriction for the first 2-3 wk after weaning is frequently used to decrease the incidence of digestive disorders (Di Meo *et al.*, 2007). This system was preferred to the inclusion of antibiotics, as antibiotics could mask the comparison between lines on digestive disorders sensitivity. Animals under such conditions might not express their full growth potential (Blasco *et al.*, 2018). In a previous study, Marín-García *et al.* (2020) observed that R animals fed *ad libitum* during the whole growing period (with no feed restriction) presented an ADG of 64.73 g/d, a DFI of 154 g/d and BW at 63 d of 2930 g. Compared to our results, feed restriction could have reduced these traits (–23, –40% and –21%, respectively). Since the experiment took place in Spain, where the growing period is until 63 d of life, applying this restriction during the first half of the growing period does not allow compensatory growth, unlike in other countries, where the end of the growing period occurs after 70 d of life. Consequently, this could have affected our results.

Regarding the RF line, these animals showed a significantly higher ADG than the R line from 28 to 46 d of age, similar to that of RFLP. As the RF line was selected for a very high growth rate (at least 60 g/d), and selection under restricted feed intake improves resources allocation for growth (Drouilhet *et al.*, 2016; Peixoto-Gonçalves *et al.*, 2023), this could indicate that the selection of elite animals could improve the growth rate during the initial phase of the growing period under restriction conditions. However, the slight delay of R animals was significantly compensated during the second half of the growing period, when all the animals were fed *ad libitum*. Compensatory growth after restriction has been widely described in growing rabbits (Gidenne *et al.*, 2012), with no significant differences in BW between R and RF animals at the end of the growing period. Thus, overall, the foundation of a new line by introducing elite animals for growth did not improve the ADG of growing rabbits.

Regarding the RFLP line, despite RFLP animals having 1/8 LP maternal origin, which could potentially affect the animals' growth performance, there were no significant differences among the genetic types in the body weight at 63 d or in global ADG, DFI and FCR. García-Quirós *et al.* (2014) observed that, although R line animals have a higher ADG during the growing period than those of the LP line (+20%), the latter have a higher ADG than other maternal lines (+6%). This seems to be due to the larger adult size of this maternal line. In fact, Theilgaard *et al.* (2007) observed that the mean weight of LP rabbits was 4% higher than that of rabbits from another maternal line (V line). Consequently, the introduction of robust genetics through the backcrossing procedure proposed in this study did not penalise the growth potential during the growing period of the R paternal line.

When comparing digestive efficiency, animals from the newly founded lines (RF and RFLP) showed a slightly improved ability to utilise nutrients in the diet than those of the R line. Previous digestibility trials comparing genetic types have obtained contradictory results. Savietto *et al.* (2012) observed a higher digestibility of neutral detergent fibre and hemicelluloses in the diet of rabbit females from the LP line compared to the V line. However, Pascual *et al.* (2008) observed a higher digestibility of acid detergent fibre in the diet of growing rabbits from the V line with respect to the LP line. The better utilisation of the diet observed with the RFLP line could have contributed to the better resource utilisation for reproduction observed in the work of Peixoto-Gonçalves *et al.* (2023) with this line.

In terms of health status, almost all dead or sick animals presented signs of digestive distress, such as diarrhoea under the cage and dirt in the perineal area. According to Rosell and De la Fuente (2009), digestive disorders are some of rabbit farms' most common causes of mortality. To reduce post-weaning mortality, Gidenne *et al.* (2009) recommended a reduction of 20% of the feed intake for 20 d. The feed was restricted for the first 18 d of the growing period as a preventive strategy and to avoid using antimicrobials. However, the mortality rates were still abnormally high throughout the experiment. When comparing the three genetic lines, the R and RF lines had significantly higher mortality rates and, consequently, higher SRI than RFLP animals. These results agree with a previous study by García-Quirós *et al.* (2014), in which growing rabbits from the R line had a higher mortality rate than those from the LP line (16.5 *vs.* 9.5%, respectively). The results could be due to the introduction of LP genetics. These animals are more robust than other commercial lines. Past studies with reproductive rabbit females found that the LP animals could overcome adverse environmental conditions and cope better with immunological challenges than other maternal lines. Females of the LP line were less affected during the hyper-acute phase induced by an intravenous lipopolysaccharide infusion (Ferrian *et al.*, 2013). Furthermore, in a previous experiment with these same lines, it was observed that suckling kits from the RFLP line had a higher survival during the first 18 d of life (+9%) and higher feed intake than those from the other genetic lines (+47%) from 18 to 28 d of age, achieving higher weaning BW (Peixoto-Gonçalves *et al.*, 2023). Although the initial weight was similar in this study, greater maturity and previous intake of RFLP kits could also explain our results, as a higher DFI during this transitional time promotes better growth and lower mortality during the growing period (Pascual *et al.*, 2001).

CONCLUSION

The foundation of a new line with elite animals did not seem to have significantly improved the growth performance of growing rabbits. Although slight specific changes in the use of nutrients or growth were observed, the final growth performance was similar for the different lines. In addition, including LP maternal genetics through backcrossing did not penalise growth performance traits but improved the resistance to digestive disorders. These results can be helpful when creating new genetic lines or refining the characteristics of current genetic lines, overcoming the potential side effects of selecting animals only for growth criteria.

Acknowledgements: The grant for Catarina Peixoto-Gonçalves from the Department of Innovation, Universities, Science and Digital Society of the Generalitat Valenciana (GRISOLIAP/2019/149) is gratefully acknowledged. The authors would also like to thank Juan Carlos Moreno Pardo and Paula Camarena Bononad for their technical support throughout the trial.

Funding: This study was funded by the Ministry of Science, Innovation and Universities of the Government of Spain (AGL2017-85162-C2-1-R) and the General Direction of Science and Research of the Generalitat Valenciana (AICO/2012/256). The grant for Catarina Peixoto Gonçalves is also gratefully acknowledged (GRISOLIAP/2019/149; from the General Direction of Science and Research of the Generalitat Valenciana).

Authors contribution: Peixoto-Gonçalves C.: investigation, formal analysis, data curation, writing – original draft, writing – review & editing and visualization. Martínez-Paredes E.: methodology, investigation, data curation and supervision. Ródenas L.: formal analysis, investigation and methodology. Blas E.: conceptualization, methodology, investigation, supervision and funding acquisition. Cambra-López M.: writing – review & editing and investigation. Pascual J.J.: conceptualization, methodology, investigation, formal analysis, writing – review & editing, visualization, supervision, project administration and funding acquisition. Corpa J.M.: writing – review & editing, visualization and supervision.

Conflict of interest: The authors declare no conflict of interest.

REFERENCES

AOAC 2002. Official methods of analysis, 17th ed. *Association of Official Analytical Chemists, Gaithersburg, MD, USA.*

Arnau-Bonachera A., Savietto D., Pascual J.J. 2018. Long-term implications of feed energy source in different genetic types of reproductive rabbit females: III. Fitness and productivity. *Animal, 12: 1886-1894. https://doi.org/10.1017/S1751731117003305*

Baselga M. 2004. Genetic improvement of meat rabbits. Programmes and diffusion. *In Proc.:8th World Rabbit Congress, 7-10 September 2004, Puebla, Mexico, 1-13.*

Blasco A., Nagy I., Hernández P. 2018. Genetics of growth, carcass and meat quality in rabbits. *Meat Sci., 145: 178-185. https://doi.org/10.1016/j.meatsci.2018.06.030*

Bennegadi N., Gidenne T., Licois D. 2000. Non-specific enteritis in the growing rabbit: detailed description and incidence according to fibre deficiency and sanitary status. *In Proc.: 7th World Rabbit Congress, 4-7 July 2000, Valencia, Spain, Vol. A: 109-117.*

Cartuche L., Pascual M., Gómez E.A., Blasco A. 2014. Economic weights in rabbit meat production. *World Rabbit Sci., 22: 165-177. https://doi.org/10.4995/wrs.2014.1747*

Cifre J., Baselga M., García-Ximénez F., Vicente J.S. 1998. Performance of a hyperprolific rabbit line. I. Litter size traits. *J. Anim. Breed. Gen., 115: 131-138. https://doi.org/10.1111/j.1439-0388.1998.tb00336.x*

Di Meo D., Bovera F., Marono S., Vella N., Nizza A. 2007. Effect of feed restriction on performance and feed digestibility in rabbits. *Ital. J. Anim. Sci., 6: 765-767. https://doi.org/10.4081/ijas.2007.1s.765*

Drouilhet L., Achard C.S., Zemb O., Molette C., Gidenne T., Larzul C., Ruesche J., Tircazes A., Segura M., Bouchez T., Theau-Clément M., Joly T., Balmisse E., Garreau H., Gilbert H. 2016. Direct and correlated responses to selection in two lines of rabbits selected for feed efficiency under ad libitum and restricted feeding: I. Production traits and gut microbiota characteristics. *J. Anim. Sci., 94: 38-48. https://doi.org/10.2527/jas.2015-9402*

Estany J., Camacho J., Baselga M., Blasco A. 1992. Selection response of growth rate in rabbits for meat production. *Genet. Sel. Evol., 24: 527–537. https://doi.org/10.1186/1297-9686-24-6-527*

Fernández-Carmona J., Blas E., Pascual J.J., Maertens L., Gidenne T., Xiccato G., García J. 2005. Recommendations and guidelines for applied nutrition experiments in rabbits. *World Rabbit Sci., 13, 209-228. https://doi.org/10.4995/wrs.2005.516*

Ferrian S., Blas E., Larsen T., Sánchez J.P., Friggens N.C., Corpa J.M., Baselga M., Pascual J.J. 2013. Comparison of immune response to lipopolysaccharide of rabbit does selected for litter size at weaning or founded for reproductive longevity. *Res. Vet. Sci., 94: 518-525. https://doi.org/10.1016/j.rvsc.2013.01.008*

García-Quirós A., Arnau-Bonachera A., Penadés M., Cervera C., Martinez-Paredes E., Ródenas L., Selva L., Viana D., Corpa J.M., Pascual J.J. 2014. A robust rabbit line increases leucocyte counts at weaning and reduces mortality by digestive disorder during fattening. *Vet. Immunol. Immunop., 161: 123-131. https://doi.org/10.1016/j.vetimm.2014.07.005*

Gidenne T., Combes S., Feugier A., Jehl N., Arveux P., Boisot P., Briens C., Corrent E., Fortune H., Montessuy S., Verdelhan S. 2009. Feed restriction strategy in the growing rabbit. 2. Impact on digestive health, growth and carcass characteristics. *Animal, 3: 509-515. https://doi.org/10.1017/S1751731108003790*

Gidenne T., Combes S., Fortun-Lamothe L. 2012. Feed intake limitation strategies for the growing rabbit: Effect on feeding behaviour, welfare, performance, digestive physiology and health: A review. *Animal, 6: 1407-1419. https://doi.org/10.1017/S1751731112000389*

Gidenne T., Lebas F., Fortun-Lamothe L. 2020. Feeding behaviour of rabbits. *Nutrition of the Rabbit*, 254-274. *CABI Books. CABI International. https://doi.org/10.1079/9781789241273.0254*

Marín-García P.J., Ródenas L., Martínez-Paredes E., Cambra-López M., Blas E., Pascual J.J. 2020. A moderate protein diet does not cover the requirements of growing rabbits with high growth rate. *Anim. Feed Sci. Technol., 264: 114495. https://doi.org/10.1016/j.anifeedsci.2020.114495*

Naturil-Alfonso C., Marco-Jiménez F., Jiménez-Trigos E., Saenz-de-Juano M.D., Viudes-de-Castro M.P., Lavara R., Vicente J.S. 2015. Role of embryonic and maternal genotype on prenatal survival and foetal growth in rabbit. *Reprod. Domest. Anim., 50: 312-320. https://doi.org/10.1111/rda.12493*

Pascual J.J. 2001. Early weaning of young rabbits: a review. *World Rabbit Sci., 9: 165-170. https://doi.org/10.4995/wrs.2001.461*

Pascual J.J. 2010. The role of body condition on new feeding and breeding programmes for reproductive rabbit does. *In Proc.: 22nd Hungarian Confer. Rabbit Prod. Kaposvár, Hungary, 11-32.*

Pascual J.J., Ródenas L., Martínez E., Cervera C., Blas E., Baselga M. 2008. Genetic selection of maternal lines and digestive efficiency in rabbits: long term selection for litter size at weaning versus hyper selection for reproductive longevity. *World Rabbit Sci., 16: 165-171. https://doi.org/10.4995/wrs.2008.625*

Peixoto-Gonçalves, C., Martínez-Paredes, E., Ródenas, L., Larsen, T., Corpa, J.M., Blas, E., Cambra-López, M., Pascual, J.J. 2023. Reproductive performance of rabbit females from three paternal lines with a different potential for growth rate and resilience. *Animal, 100729. https://doi.org/10.1016/j.animal.2023.100729*

Perez J.M., Lebas F., Gidenne T., Maertens L., Xiccato G., Parigi-Bini R., Dalle Zotte A., Cossu M.E., Carazzolo A., Villamide M.J., Carabaño R., Fraga M.J., Ramos M.A., Cervera C., Blas E., Fernandez J., Falcão e Cunha L., Bengala Freire J. 1995. European reference method for in vivo determination of diet digestibility in rabbits. *World Rabbit Sci., 3: 41-43. https://doi.org/10.4995/wrs.1995.239*

Rauw W.M., Kanis E., Noordhuizen-Stassen E.N., Grommers F.J. 1998. Undesirable side effects of selection for high production efficiency in farm animals: a review. *Livest. Prod. Sci., 56: 15-33. https://doi.org/10.1016/S0301-6226(98)00147-X*

Rosell J.M., De la Fuente L.F. 2009. Culling and mortality in breeding rabbits. *Prev. Vet. Med., 88: 120-127. https://doi.org/10.1016/j.prevetmed.2008.08.003*

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. https://doi.org/10.2527/jas.2007-0217*

Savietto D., Blas E., Cervera M., Baselga M., Friggens N.C., Larsen T., Pascual J.J. 2012. Digestive efficiency in rabbit does according to environment and genetic type. *World Rabbit Sci., 20: 131-139. https://doi.org/10.4995/wrs.2012.1152*

Savietto D., Friggens N.C. Pascual J.J. 2015. Reproductive robustness differs between generalist and specialist maternal rabbit lines: the role of acquisition and allocation of resources. *Genet. Sel. Evol., 47: 1-12. https://doi.org/10.1186/s12711-014-0073-5*

SAS 2009. SAS/STAT ® 9.2 User's guide. *SAS Inst. Inc., Cary NC, USA.*

Theilgaard P., Sánchez, J.P., Pascual J.J., Berg P., Friggens N.C., Baselga M. 2007. Late reproductive senescence in a rabbit line hyper selected for reproductive longevity, and its association with body reserves. *Genet. Sel. Evol., 39: 207-223. https://doi.org/10.1186/1297-9686-39-2-207*

Van Soest P.J., Robertson J.R., Lewis B.A. 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci., 74: 3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2*

Vicente J.S., Llobat L., Viudes-de-Castro M.P., Lavara R., Baselga M., Marco-Jiménez F. 2012. Gestational losses in a rabbit line selected for growth rate. *Theriogenology, 77: 81-88. https://doi.org/10.1016/j.theriogenology.2011.07.019*