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GENETIC SELECTION OF MATERNAL LINES AND DIGESTIVE EFFICIENCY IN RABBITS: LONG TERM SELECTION FOR LITTER SIZE AT WEANING *VERSUS* HYPER SELECTION FOR REPRODUCTIVE LONGEVITY

Pascual J.J., Ródenas L., Martínez E., Cervera C., Blas E., Baselga M.

Institute for Animal Science and Technology, Polytechnic University of Valencia, Camino de Vera s/n. 46071 Valencia, Spain.

Abstract: The objective of the present paper is to evaluate how long-term selection for litter size at weaning or short-term hyper selection for reproductive longevity, affect the digestive utilisation of growing and lactating rabbits. A digestibility trial was carried out during the 3rd week of lactation with a total of 27 multiparous does: 14 females came from a line selected for litter size at weaning over 32 generations (V), and 13 from a recently constituted, long lived-productive line (LP). Another digestibility trial was performed during the growing period with a total of 48 growing rabbits (24 from each line). After a 7 d adaptation period, faeces were collected individually for 4 d (from 13 to 16 d of lactation or from 49 to 53 d of age, respectively). Daily feed intake and weight gain recorded during the experimental growing period were similar for both lines (137 g of dry matter (DM)/d and 48 g/d, respectively). Growing rabbits from the V-line showed greater values for the digestibility of the DM and OM (+1 percentage point; $P<0.10$) and significantly higher values for the acid detergent fibre (+3 percentage points; $P=0.03$) than animals from the LP line. No significant differences for the apparent digestibility coefficients of crude protein, neutral detergent fibre, crude fibre and gross energy were observed between lines, these being on average 65.7, 23.0, 10.7 and 52.6%, respectively. Females from the LP line were initially heavier (+258 g of live weight; $P=0.06$), and presented a significantly greater daily feed intake (+22 g DM/d; $P=0.04$) and milk yield (+37 g/d; $P=0.01$) during the pre-experimental and faeces collection phases (from 6 to 16 d of lactation). V-line lactating does displayed greater values for digestibility for all those nutrients evaluated (from +0.9 and +3.7 percentage points for the crude protein and acid detergent fibre) compared to the LP line females, although these were only significant for the DM, organic matter and gross energy (+2.3, +2.5, +2.1 percentage points; $P<0.05$). In conclusion, rabbits selected for litter size at weaning seem to have greater efficiency for digestive utilisation than those hyper selected for reproductive longevity.

Key words: rabbits, selection, digestibility, litter size, longevity.

INTRODUCTION

There is little knowledge regarding how genetic selection used in rabbit production affects both the physiology and the use of resources available to the animals. Quevedo *et al.* (2005) observed how selection over 12 generations for litter size at weaning gave rise to crossbred does with a greater prolificacy (+2 kits born alive) which, in turn, entailed greater reproduction needs. These requirements could be covered at the cost of other components, such as maintenance needs, which may endanger the survival of the animal, or through the improved ability of these animals to obtain resources. Some previous studies have observed an improvement in the efficient use of digestible energy (DE) for foetal growth, and an increase in ingestion and milk yield at the onset of lactation (Quevedo *et al.*, 2005, 2006b) for crossbred does derived from does belonging to the most recent generations of a line selected for litter size at weaning.

Correspondence: J.J. Pascual, jupascu@dca.upv.es
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These results would support the hypothesis that selection for reproduction in rabbits could entail an improvement in the capacity to obtain resources, which would not necessarily condition other components such as lifespan. In fact, Theilgaard *et al.* (2006) observed how the selection of does for litter size at weaning did not affect their lifespan during 6 reproductive cycles, even the relative risk of culling of these does was 26% lower.

On the other hand, a new long-lived-productive line (LP) has recently been established in our Institute (Sánchez, 2006) by selecting animals which managed to produce at least 25 litters with an average size of 7.5 born alive. When this LP line was compared with another line selected over 31 generations for litter size at weaning (V line), it was observed that the LP does did indeed show a relatively smaller risk of culling at later stages. Theilgaard (2006) proposed that the greater life expectancy of LP does may be related to the larger size of these animals (+250 g average live weight) and/or their greater capacity to obtain resources (higher feed consumption).

However, the selection for reproduction criteria or the hyper selection of animals for reproductive longevity may not only affect their capacity to obtain resources, but may also be instrumental in altering digestive efficiency. This possibility must be evaluated for a better understanding of how the selection criteria used on rabbit maternal lines may influence the management of energy resources available to the animals. Therefore, the main aim of the present research is to assess how long-term selection for litter size at weaning or short-term hyper selection for reproductive longevity, affect the digestive utilisation of growing and lactating rabbits.

MATERIAL AND METHODS

The experiment was carried out in accordance with the European Union recommended principles for ethical care and protection of animals used for experimental purpose (2003) and the recommendations for applied nutrition research on rabbits as outlined by the European Group on Rabbit Nutrition (Fernández-Carmona *et al.*, 2005).

Diets

Two commercial diets for growing rabbits (G) and reproductive rabbit does (R) were used for the digestibility trial. The chemical composition of both diets is presented in Table 1. Both diets were characterised by high fibre content (228 and 218 g of acid detergent fibre (ADF) per kg of dry matter (DM) for diets G and R, respectively), the main difference being their crude protein (CP) content (149 and 174 g CP per kg DM, respectively).

Table 1: Chemical composition of the diets (G=commercial growing diet; R=commercial reproductive diet).

	Diets	
Chemical composition (g kg^{-1} DM)	G	R
Dry matter (DM; g kg^{-1})	913	903
Ash	102	98
Crude protein (CP)	149	174
Ether extract (EE)	40.8	36.9
Neutral detergent fibre (NDF)	360	396
Acid detergent fibre (ADF)	228	218
Acid detergent lignin (ADL)	39.2	36.9
Crude fibre (CF)	218	201
Gross energy (GE; MJ kg^{-1} DM)	18.1	18.1

Animals

A total of 27 multiparous does were used for the digestibility trial conducted during lactation. Fourteen females came from a line selected over 32 generations for litter size at weaning (V). The remaining 13 females were from the generation 0 of a recently constituted, long-lived productive line (LP) formed by selecting animals capable of producing a minimum of 25 litters with an average number of at least 7.5 born alive (Sánchez, 2006). The experiment was carried out over 2 experimental batches. The first one took place in January 2007, in which a total of 12 does participated (6 from each line), and a second batch was carried out in March 2007, with a total of 15 does (7 and 8 from the LP and V lines, respectively).

For the digestibility trial, performed during the growing period, a total of 48 growing rabbits (24 from each genetic line) aged 42 d with an average live weight of 1.245 kg (S.E.: 0.011 kg) were used in a single batch. One of the animals from the V line died during the trial.

Experimental procedure

Lactating does: The apparent digestibility coefficients of the DM, organic matter (OM), CP, crude fibre (CF), neutral detergent fibre (NDF), ADF, ether extract (EE) and gross energy (GE) were determined. Litters were standardised post partum to 10 kits per doe in order to maximise milk production. On day 6 of lactation, the does were housed in metabolic cages with free access to the feed and water. The females received the R diet from pregnancy confirmation at 12 d post-mating until the end of the trial. After a 7 d adaptation period, faeces were collected individually for 4 d (from 13 to 16 d of lactation) as recommended by Perez *et al.* (1995). The faeces collection period was fixed from 13 to 16 d of lactation in order to find the maximum milk yield and feed intake regularity (Pascual *et al.*, 1999; Maertens *et al*., 2006). From the moment the doe rabbits were placed in metabolic cages, both feed intake and milk yield were monitored on a daily basis. Milk yield was measured daily during this period by weighing the doe immediately prior to and following suckling.

Growing rabbits: At 42 d of age, the growing rabbits were housed in metabolic cages and feed G and water were offered ad libitum during the experimental period. Following an adaptation period of 7 d, the faeces collection lasted 4 d (Perez *et al.*, 1995). Faeces from both trials were analysed individually for DM, OM, CP, NDF, ADF and GE, while analysis for EE digestibility was determined from a pool comprising animals from the same line, trial and batch.

Analytical methods

The chemical analysis of feed and faeces was performed using the methods of the AOAC (1995) for DM, ash, EE, CP and CF, and following the recommendations of Van Soest *et al.* (1991) for the fibrous fractions (NDF, ADF and ADL), using a thermostable amylase pre-treatment. The GE was determined by combustion using an adiabatic bomb calorimeter (EGRAN, 2001).

Statistical analysis

In an experiment where the aim is to study the effect of selection in two very different settings such as long term selection for litter size and short term selection for longevity, the use of reproductive doe rabbits in the lactation phase is a necessity. This is due to the fact that lactation represents the greatest productive challenge, and it is here that differences between the two lines may occur. However, the milk yield and the condition of the does may affect the regularity of feed intake, one of the main determining factors of reliability in obtaining the apparent digestibility coefficients.

To evaluate the possible effects of female feed intake regularity and milk yield during the pre-experimental and faeces collecting phases on the reliability of determining the DM digestibility coefficient (dDM), this coefficient was determined individually (dDM_i). Subsequently, by means of a full-cross validation procedure, a dDM reference value (dDM_r) was obtained for each animal on the basis of the individual

DM digestibility values of all the animals from the same genetic line and batch, except for that of the individual in question. The difference between both values resulted in a residue, which in absolute value can be an indicator of the reliability of the reliability of determining each dDM value. The correlation between the standard deviations of feed intake (SDI) and milk yield (SDM) per animal during the 4 d prior to and the 4 d following faeces collection with the absolute values of the residues ($|dDM_r - dDM_i|$) was conducted using the CORR procedure of SAS (Statistical Analysis System, 1996). Using this analysis a positive and significant correlation was observed between doe SDI in the 4 d prior to the faeces collection phase ($SDI4d_i$) and the reliability in the determination of dDM (r = +0.52; $P<0.01$). Therefore, $SDI4d_i$ was used to improve reliability in determining the different digestibility coefficients for the females. This was made possible by introducing the relative percentage of this standard deviation (PSD_i), as a weight variable, calculated as:

$$PSD_i\ (\%) = [SDI4d_{max} - SDI4d_i] / SDI4d_{max} \times 100$$

where $SDI4d_{max}$ was the maximum $SDI4d_i$ observed in this experiment. In the analysis, this variable (PSD_i) provides a relatively greater weight to those values obtained from females with a lower variability on their previous feed intake; as opposed to those with a higher feed intake variability.

Data from both digestibility trials were analysed statistically by means of a GLM procedure from SAS (1996). The analyses were performed using fixed models. The genetic line was the only factor considered in the growing trial, and the genetic line, the experimental batch, in addition to any interaction between lines in the lactation trial.

RESULTS

Table 2 shows the results obtained during the digestibility trial performed using the growing rabbits. The daily feed intake and weight gain recorded during the experimental period (49 to 53 d of age) was similar for both lines (137 g DM/d and 48 g/d, respectively). Growing rabbits from the V-line displayed greater values for the digestibility of the dietary DM (+1 percentage point; P=0.08) and OM (+1 percentage point;

Table 2: Effect of genetic line on the apparent digestibility coefficients of feed in growing rabbits.

	Genetic line		
	LP	V	*P*-value
No. of animals	24	23	
Daily feed intake (g DM/d)	138.0±2.0	135.4±2.1	0.380
Daily weight gain (g/d)	47.0±1.3	48.5±1.4	0.451
Apparent digestibility coefficients (%)[1]:			
DM	51.54±0.40	52.60±0.42	0.077
OM	51.82±0.40	52.77±0.40	0.099
CP	65.66±0.63	65.67±0.64	0.987
NDF	23.77±1.79	22.25±1.88	0.560
ADF	13.08±0.92	16.08±0.94	0.028
CF	10.52±0.94	10.94±0.96	0.759
GE	52.23±0.39	52.90±0.40	0.235
EE	71.81	72.33	

[1] Abbreviations as in Table 1.

P=0.10) than those animals from the LP line. This was due to their significantly higher digestibility values for the ADF (+3 percentage points; *P*=0.03). No significant differences for the apparent digestibility coefficients of CP, NDF, CF and GE were observed between lines, these being on average 65.7, 23.0, 10.7 and 52.6%, respectively. The dietary EE digestibility, determined from a pool of faeces, was also similar for both lines (average: 72.1%).

Table 3 gives the results obtained during the digestibility trial performed with the lactating rabbits. LP females were initially heavier (+258 g of LW; *P*=0.06), and presented a significantly greater daily feed intake (+22 g DM/d; *P*=0.04) and milk yield (+37 g/d; *P*=0.01) during the pre-experimental and faeces collection phases (from 6 to 16 d of lactation). V does returned greater digestibility values for all the nutrients evaluated (from +0.9 to +3.7 percentage points for the CP and ADF, respectively) than the LP females, although these were only significant for the DM, OM and GE nutrients (+2.3, +2.5, +2.1 percentage points, respectively; *P*<0.05).

DISCUSSION

The daily weight gain and feed intake observed for the growing rabbits during the digestibility trial were not only similar for both types of animals, but were also similar to those values obtained in previous trials on the same experimental farm. For example, Pascual *et al.* (2007) reported 122 g DM/d of feed intake and 48 g/d of weight gain for three-way crossbred rabbits during a similar period. However, females from the different lines presented clear differences in initial live weight, feed intake and milk yield which could slightly affect the interpretation of the obtained results.

As previously observed by Theilgaard *et al.* (2007, 2009), in our study LP females show a greater LW than V females (+6%), which, in part, could be explained by the greater daily feed intake of LP (+6%). When the daily feed intake is adjusted per kilogram of animal metabolic weight the difference almost disappears

Table 3: Effect of genetic line on the apparent digestibility coefficients of feed in lactating rabbit does.

	Genetic line		
	LP	V	*P*-value
No. of females	13	14	
Initial live weight (g)[1]	4302±94	4044±95	0.060
Daily feed intake (g DM/d)[2]	395.1±12.8	373.1±10.8	0.044
Daily milk yield (g/d)[2]	253.7±9.4	216.3±9.2	0.008
Apparent digestibility coefficients (%)[3]:			
DM	57.35±0.69	59.67±0.61	0.018
OM	57.41±0.71	59.91±0.62	0.014
CP	70.90±0.72	71.77±0.63	0.373
NDF	26.59±1.76	29.59±1.56	0.216
ADF	22.13±1.84	25.86±1.63	0.144
CF	20.12±1.53	23.42±1.43	0.128
GE	56.83±0.68	58.96±0.60	0.027
EE	74.43	76.09	

[1] Live weight at day 6 of lactation (beginning of the pre-experimental period).
[2] Mean values from day 6 to day 16 of lactation.
[3] Abbreviations as in Table 1

(132 and 131 g DM/kg $LW^{0.75}$/d for LP and V females, respectively; P=0.08). These results also concur with those obtained by Theilgaard *et al.* (2009) for these same lines during the second lactation period, where LP females were heavier (+153 g at 10 d of lactation) and displayed a greater daily feed intake (+25 g DM/d) and milk yield (+21 g/d) from 7 to 30 d of lactation.

The greater feed consumption of LP females could partly explain their lower apparent digestibility coefficients for the DM, OM and GE in comparison with the V does, (−2.3, −2.5 and −2.1 percentage points, respectively; P<0.05). However, a 6% change in ingestion cannot completely account for this effect on the apparent digestibility coefficients, especially if we consider that the feed intake per kilogram of metabolic weight was the same and the effects observed for the apparent digestibility coefficients in the trial with growing rabbits - with the same daily feed intake - were similar to those observed for the females.

In general, the values obtained for the apparent digestibility coefficients of nutrients were similar to those obtained for both growing and lactating rabbits by other authors (Maertens and De Groote, 1982; De Blas *et al.*, 1995; Perez *et al.*, 1996).

Regarding the effect of the genetic line on the digestive efficiency of rabbits, animals from the V-line seemed to have a greater digestive efficiency (higher DM, OM and GE digestibility coefficients) than animals from the LP line. Fifty percent of this enhanced digestive efficiency was due to their efficient digestibility of fibre components, −although other components such as EE digestibility were also improved−, albeit without any significant effect on protein digestibility.

With regards to cattle, there are many studies demonstrating the existence of genetic variability for digestive efficiency, which have obtained clear differences between breeds vis-á-vis the digestibility of some dietary constituents (Ikhatua and Olubajo, 1981; Holloway *et al.*, 1985; Beaver *et al.*, 1989; Givens and Moss, 1994). However, the very few projects conducted on multiparous species [rabbits: Maertens and De Groote (1982); pigs: Panaiotov (1986), Sartor *et al.* (2006)] did not discover any effect on the digestive efficiency of the main nutrients which may have been caused by breed or commercial line used.

Furthermore, knowledge concerning the effect of genetic selection on digestive efficiency is also scarce. Selection for lean growth efficiency has been linked to an improvement in dietary protein digestibility and higher protein retention in pigs (Yen *et al.*, 1983; Kiani *et al.*, 2004), supporting the concept of higher amino acid requirements for pigs with increased lean growth potential. In a similar manner, Feki (1994) compared the feed efficiency of a line selected over 20 generations for post-weaning growth rate (R line) with the V line (that used in the present study, but at generation 14) and the A line (also selected over 18 generations for litter size at weaning). The results revealed that rabbits from the R line had a greater protein digestibility than the other 2 lines, especially when the quality of dietary protein was low (+3%; P<0.05). Langerkvist and Tauson (1993), when comparing minks selected for litter size over 5 generations with an unselected line, observed that although the digestibility of dietary protein was not affected, selection for litter size increased the fat digestibility of the diet (main dietary energy source).

Quevedo *et al.* (2006a) reported how selection over 12 generations for litter size at weaning in two maternal lines led to crossbred does being more efficient during gestation, achieving an improvement of 0.04 (from 0.29 to 0.33) in the efficiency of DE utilisation for foetal growth. In another study, the same authors (Quevedo *et al.*, 2006b) observed that V-line does from the most advanced generations of selection for litter size at weaning showed a greater ingestion capacity at early lactation which led to an increase in milk yield and improved litter survival during this period.

In conclusion, when considering these results and those found in the present work, we can hypothesise that selection for litter size at weaning in rabbits may have led to the production of animals which are

more proficient in their use of the available energy resources, thereby achieving greater reproduction-linked results (foetal growth and milk yield) from the same resources (feed) through, for example, the improvement in the efficiency of digestive utilisation.

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