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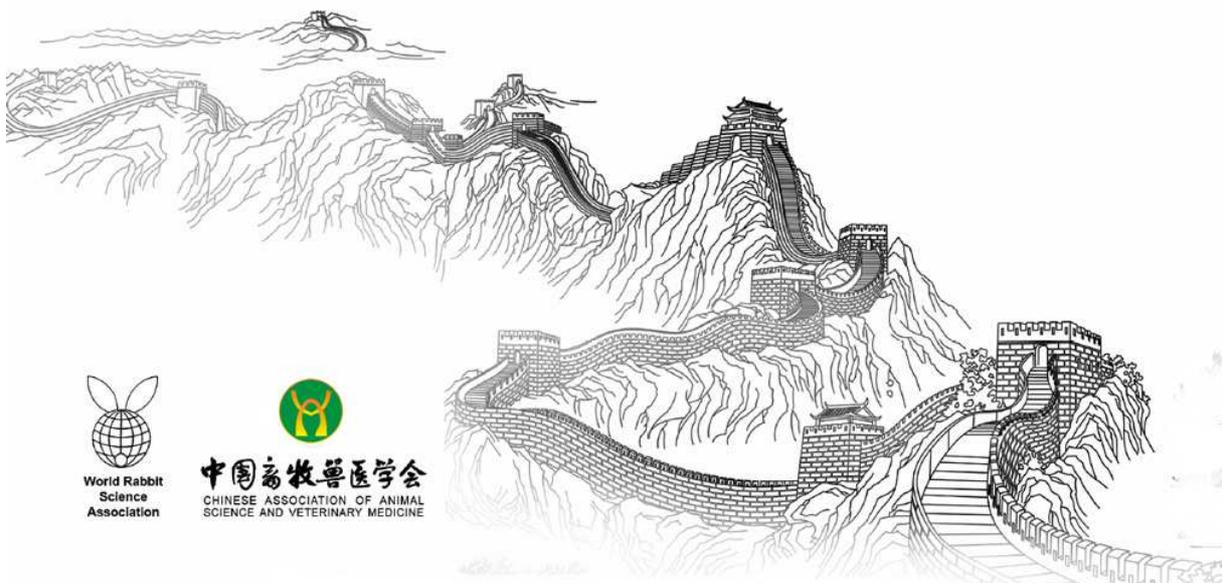**ISSN 2308-1910**

## Session
# Breeding and Genetics

## *Garreau H., Gilbert H., Molette C, Larzul C, Balmisse E., Ruesche J., Secula-Tircazes A., Gidenne T., Drouilhet L.*

## DIRECT AND CORRELATED RESPONSES TO SELECTION IN TWO LINES OF RABBITS SELECTED FOR FEED EFFICIENCY UNDER AD LIBITUM AND RESTRICTED FEEDING

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# DIRECT AND CORRELATED RESPONSES TO SELECTION IN TWO LINES OF RABBITS SELECTED FOR FEED EFFICIENCY UNDER *AD LIBITUM* AND RESTRICTED FEEDING

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## ABSTRACT

Genetic improvement of feed efficiency using two alternate traits compared to feed conversion ratio (FCR) were studied in the growing rabbit: Residual Feed Intake (RFI) in the ConsoResidual line and Average Daily Gain (ADG$_R$) under restricted feeding (80% of *ad libitum*) in the ADGrestrict line. Responses to selection for the two criteria were similar in the two lines (-0.34 genetic standard deviations ($\sigma_a$) per generation for RFI, +0.29 $\sigma_a$ per generation for ADG$_R$). Responses to selection were -0.30 $\sigma_a$ per generation on FCR in both lines. Responses to selection were null on ADG and limited on body weight at 63 days-old in the ConsoResidual line, whereas they were highly significant in the ADGrestrict line. To further examine responses to selection, in generation 9 a comparison of the two selected lines with the G0 control population (using frozen embryos) under *ad libitum* and restricted feeding was applied to 30 individuals per line and feeding level combination. As a result, both selected lines had a similar improved FCR (2.62 ± 0.02) compared to the G0 line (2.82 ± 0.02), but with a lower feed intake. In return, the ADGrestrict line showed the highest growth. Under restricted feeding, the two selected lines showed a higher ADG than the G0 line.

**Key words**: feed efficiency, residual feed intake, growth, genetics

## INTRODUCTION

Among reproductive and productive traits, feed efficiency has the highest economic weight (Cartuche *et al.*, 2014). In order to improve feed efficiency during the growing period, two criteria have been selected: Residual Feed Intake (RFI), to select low *ad libitum* feed intake independently from production level, and Average Daily Gain (ADG) under restricted feeding (ADG$_R$) (80% of *ad libitum*), to select high ADG under limited fixed feed intake. The first objective of this study was to evaluate direct and correlated responses to selection after 9 generations of selection. The second objective was to compare performances of the two selected lines to a control line, produced from frozen embryos of the ancestor population.

## MATERIALS AND METHODS

### Creation And Management Of Lines
Two rabbit lines have been created from the INRA 1001 line (Larzul and De Rochambeau, 2005) and bred in the experimental INRA farm Pôle d'Expérimentation Cunicole Toulousain (Castanet-Tolosan, France). The ConsoResidual line was selected for RFI with *ad libitum* feeding and the ADGrestrict line was selected for ADG under restricted feeding (-20% of *ad libitum* feed intake). The two lines were conducted simultaneously in the same breeding unit (Drouilhet *et al.*, 2013) during nine generations (G0 to G9). In each batch and for each line, about 75 male and 75 female candidates to selection born from inseminations 2 and 3 (42 days interval) were tested. After weaning at 30 days and until 63 days, candidates to selection were bred in individual cages.

**Selection Criteria**
In both lines, animals were selected on their estimated breeding value (EBV) using the ASReml software (Gilmour *et al.*, 2009). In the ADGrestrict line, animals were selected for high ADG from 30 to 63 days on restricted feeding (80% of *ad libitum* feeding of a control group). In the ConsoResidual line, animals were selected for low RFI. The RFI was computed as the residual of the multiple linear regression applied at the phenotypic level of total feed consumption on average metabolic body weight (average body weight between 30 and 63 d to the power 0.75) to account for maintenance requirements and average daily weight gain between 30 and 63 days of age (ADG) to account for production requirements.

**Response to Selection**To evaluate the responses to selection, the analysis of G0 to G9 individuals included 2,538 tested animals in the ConsoResidual line and 2,404 tested animals in the ADGrestrict line. Breeding values for body weight at 63 days (BW63), ADG, feed conversion ratio (FCR) and RFI were estimated within each line with a best linear unbiased prediction (BLUP) multiple trait analysis including all traits using the ASReml software (Gilmour *et al.*, 2009). The average of the EBV for each trait were then computed for each generation in each line.

**Line Comparison**
To compare selected animals a G0 line was produced, using embryos frozen at the start of the experiment. The design comprised the three lines (G0, ConsoResidual and ADGrestrict) and two feeding levels (*ad libitum* and restricted), leading to six experimental groups with 23 to 29 animals per group. All experimental groups were raised in the same room. The same testing procedure as during selection was applied. Animals were put into individual cages at weaning (30 days of age). The same feed quantity was delivered to all restricted animals (80% of the average amount eaten by the *ad libitum* groups). The body weight at weaning (BW30) and BW63 were recorded and the ADG for this period was computed. The individual feed consumptions were measured from 30 days to 63 days by weighing distributed feed during the whole period and weighing refusals at 63 days of age. The FCR was calculated as total feed consumption divided by weight gain. The RFI was computed as described above with a multiple linear regression equation for each feeding level.

**Statistical Analyses**
Data were analysed using a linear model (GLM procedure, SAS, 2008). Fixed effects included in the model were: line (3 levels), feeding level (2 levels) and the interaction line $\times$ feeding level. Feed efficiency and growth traits of the three lines were compared using a Student *t*-test to identify significant effects ($P < 0.05$).

## RESULTS AND DISCUSSION

**Genetic Evolutions**
In the ConsoResidual, substantial response was achieved for the selection criteria RFI, with a genetic gain of -0.34 genetic standard deviation ($\sigma^2_a$) per generation, corresponding to a genetic gain of -3.06 $\sigma^2_a$ after nine generations of selection (Figure 1). Due to the very high positive genetic correlation between RFI and FCR (Drouilhet *et al.*, 2013), the genetic gain for FCR was in the same range (-0.30 $\sigma^2_a$ per generation).
In the ADGrestrict line the genetic gain achieved after nine generations of selection for the selection criteria $ADG_R$ was +2.58 $\sigma^2_a$ (corresponding to a genetic gain of 0.29 $\sigma^2_a$ per generation)(Figure 2). The correlated response for FCR was -0.30 $\sigma^2_a$ per generation, *i.e.* similar to the one obtained in the ConsoResidual line. Correlated responses in other traits were notably different between the lines. In the ConsoResidual line, selection for decreasing RFI resulted in a small negative correlated response on BW63, and in a null response on ADG. In two independent pig divergent selection experiments on RFI, authors reported either a null or a small correlated response in ADG (Gilbert and Dekkers, 2013). In the ADGrestrict line, on the contrary, due to the high genetic correlation between ADG and BW63 estimated in a previous study (0.81 ± 0. 17, Drouilhet *et al.*, 2013), the correlated response on BW63 was substantial (+1.59 $\sigma^2_a$). Nguyen and McPhee (2005) previously analyzed a divergent selection experiment for growth

rate under restricted feeding in pigs after four generations of selection and also reported a substantial genetic divergence in ADG and FCR.
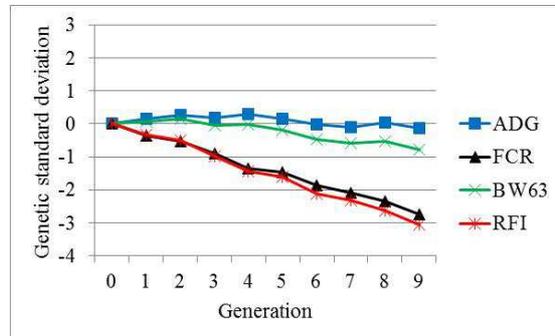


**Figure 1:** Genetic evolutions for body weight at 63 days (BW63), average daily gain (ADG), feed conversion ratio (FCR) and residual feed intake (RFI) in the ConsoResidual line over 9 generations of selection.
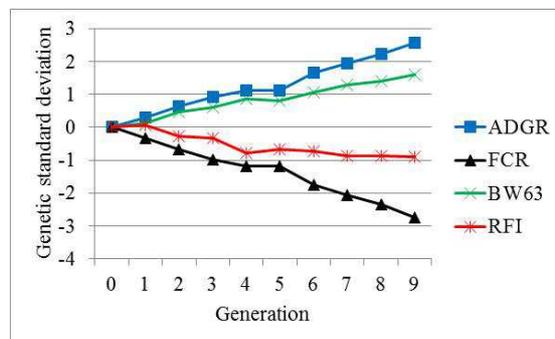


**Figure 2:** Genetic evolutions for body weight at 63 days (BW63), average daily gain (ADG$_R$), feed conversion ratio (FCR) and residual feed intake (RFI) in the ADGrestrict line over 9 generations of selection.

**Feeding Level Comparison**

Least square means (LSmeans) for the feeding level effect in generation 9 are presented in Table 1. Average feed intake of the 78 restricted rabbits was 3,273 ± 59 g, weakly variable compared to the *ad libitum* animals (4,274 ± 459 g). Among the other traits recorded during growth, only BW63 and ADG significantly differed with feeding levels. Animals with free access to feed had heavier BW63 (2,315 ± 18 *vs.* 1,944 ± 19 g, $P < 0.001$) and higher ADG (47.00 ± 0.40 *vs.* 35.81 ± 0.42 g/d, $P < 0.001$) compared with feed restricted animals. Altogether, FCR was similar in the two feeding regimens.

**Line Effect Comparison**

The only trait recorded that was similar between lines was BW30 (Table 1). For the *ad libitum* feeding level, feed intake LSmeans were similar in ADGrestrict and G0 lines. The LSmean of feed intake was lower for ConsoResidual line than for the two other lines ($P < 0.01$ with ADGrestrict line and $P < 0.001$ with G0 line). The G0 and the ConsoResidual lines had similar BW63 (LSmeans around 2,097 ± 22 g), lower than that in the ADGrestrict line (2,193 ± 23 g, $P < 0.01$). Similarly, the G0 and the ConsoResidual lines had similar ADG (LSmeans around 40.80 ± 0.49 g/d), lower than that in the ADGrestrict line (42.62 ± 0.51 g/d, $P < 0.01$). The FCR were similar in the two selected lines (LSmeans around 2.62 ± 0.02), significantly lower than FCR in the G0 line (2.82 ± 0.02, $P < 0.001$). The RFI, reported only for animals fed *ad libitum*, were not significantly different in the two selected lines (-137 ± 57 g for the ADGrestrict line and -176 ± 61 g for the ConsoResidual line), and significantly lower than that in the G0 line (179 ± 62 g, $P < 0.001$).

**Table 1:** Line and feeding level effects on traits measured during growth [1].

| Trait | *P* | | LSmeans feeding level effect | | LSmeans line effect | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | Feeding level | Line | restricted | Ad lib | ADGrestrict | ConsoResidual | G0 |
| FI (g)[2] | / | *** | | | $4,318 \pm 77^a$ | $4,004 \pm 77^b$ | $4,515 \pm 79^a$ |
| BW63 (g) | *** | ** | $1,944 \pm 19^a$ | $2,315 \pm 18^b$ | $2,193 \pm 23^a$ | $2,097 \pm 22^b$ | $2,098 \pm 22^b$ |
| BW30 (g) | ns | ns | $726 \pm 10$ | $722 \pm 10$ | $744 \pm 12$ | $706 \pm 12$ | $720 \pm 12$ |
| ADG (g/day) | *** | * | $35.81 \pm 0.42^a$ | $47.00 \pm 0.40^b$ | $42.62 \pm 0;51^a$ | $40;89 \pm 0.49^b$ | $40;72 \pm 0;49^b$ |
| FCR | ns | *** | $2;71 \pm 0.02$ | $2;68 \pm 0.02$ | $2;63 \pm 0;02^a$ | $2;62 \pm 0;02^a$ | $2.82 \pm 0;02^b$ |
| RFI (g)[2] | / | *** | | | $-137 \pm 57^a$ | $-176 \pm 61^a$ | $179 \pm 62^b$ |

FI: feed intake, BW63: body weight at 63 days, BW30: BW at 30 days, ADG: average daily gain, FCR: feed conversion ratio, RFI: residual feed intake. [1]*P* value and LSmeans from a linear model including the effects of line, feeding level and line*feeding level interaction. *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$. [2]The feed intake analysis concerned only animals fed ad libitum (N=85), whereas all the others traits concerned the entire experimental design (N=163). [a,b] in a row means without a common superscript differ ($P < 0.05$).

**Feeding Level And Line Interaction**

The feeding level and line interaction was only significant for ADG ($P < 0.01$). Under restricted feeding, the two selected lines had similar ADG (around $36.50 \pm 0.70$, $P = 0.82$), significantly higher than that in the control line ($34.22 \pm 0.68$, $P < 0.03$). When fed *ad libitum*, the ADGrestrict line had no significantly different ADG compared to the control line ($P = 0.19$), however the ConsoResidual line tended to have a lower ADG than the control line (P = 0.05). The two selected lines had different ADG, being higher in the ADGrestrict line than in the ConsoResidual line ($48.51 \pm 0.72$ g/d and $45.29 \pm 0.68$ g/d, respectively, *P* = 0.001).

## CONCLUSIONS

With both selection criteria, feed efficiency was improved. The selection on ADG would lead to heavier animals with no significant reduction of feed costs, whereas that on RFI leads to lower feed costs and no increase of animal weights.

## ACKNOWLEDGEMENTS

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