DOES SELECTION FOR GROWTH RATE IMPAIR BONE RESISTANCE IN THE RABBIT?

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ABSTRACT

Two lines of rabbits divergently selected for 5 generations for live body weight at 63 days (High: rapid-growing line, n=61; Low: slow-growing line, n=74) and a cryopreserved control line (Control, n=60) were slaughtered at the same body weight (2297 ± 10 g). Average daily gain from weaning (28 d) to slaughter was 47.6, 56.0, and 65.8 g/d for Low, Control and High lines, respectively. The effects of growth rate at a fixed slaughter weight on carcass traits, morphometry and mechanical properties of bone were assessed. Selection for high body weight at fixed age had no effect on carcass traits, bone shape and bending resistance, compared to the control group when rabbits were slaughtered at the same weight. On the other hand, selection for low body weight at 63 d improved carcass weight, dressing out percentage (+2.8% for both traits) and hind part percentage (+3.6%), while adiposity remained unaffected. Femurs from Low line rabbits were lighter and thinner (lower moment of inertia) than in the other two groups resulting in a reduced bending resistance (-13.5% and -5.8% for yield and ultimate force respectively). Although tibia shape from the Low line was similar to the other two groups, its bending resistance was higher (+13.7 and +9.3% for yield and ultimate force, respectively). For both bones, elastic modulus (intrinsic stiffness) was higher in the Low line rabbits than in the other two groups. Length and whole stiffness increased with age in both bones, suggesting that these traits are good indicators of physiological maturity of the animal, independently of body weight. In conclusion, divergent selection for live body weight at 63 days affected carcass traits, morphometric characteristics and mechanical properties of bone in rabbits slaughtered at the same weight. However, an asymmetrical response to growth rate selection was observed. The effects of selection on carcass traits, morphometric characteristics and mechanical properties of bone were significant for decreased growth rate only.

Key words: bone, mechanical properties, growth rate, selection.

INTRODUCTION

Combined advances in genetics and nutrition in rabbit breeding led to a reduction in the age of the animals at the commercial slaughter weight. This reduction has been evaluated at –0.5 days per year based on the genetic progress only. In industrial slaughterhouses the frequency of broken bones in the leg can reach 10% after handling of living animals or handling of carcasses (personal data). An increased growth rate during the fattening period is often considered as responsible for the bone embrittlement elevation. At the same slaughter weight, chickens with a high growth rate also exhibited marked alterations in bone structure and bending resistance (LETERRIER and NYS, 1992). To our knowledge, previous studies on bone characteristics in rabbits have been limited to the influence of nutrition (PUSZTAI *et al.*, 1985; LEBAS *et al.*, 1998) or housing conditions (COMBES and LEBAS, 2003) and measurements were not extended. In the current study, the effects of growth rate at a fixed slaughter weight on the morphometry and mechanical properties of the bones were assessed by comparing two divergent lines of selection for body weight at 63 days and a cryopreserved control population.

MATERIAL AND METHODS

Animal selection

Rabbits were obtained from a commercial heavy sire line (Grimaud Frères). Animals were weaned at 28 days of age and were weighed at 63 days of age. For five generations, animals were selected for either a high (High line) or a low (Low line) body weight at 63 days of age, based on their BLUP breeding value (LARZUL *et al.*, 2000). Embryos from the founder population were frozen, they were thawed and implanted in female rabbits of both lines from the fourth generation, in order to be contemporary with rabbits from the fifth generation (Control group).

Carcass and bone measurements

Rabbits were slaughtered at a body weight of 2297 $\pm$ 10 g and carcasses were prepared as recommended by BLASCO *et al.* (1993). Hind legs were removed from the refrigerated carcasses, vacuum packed and frozen at -20°C until analysis. After thawing, femur and tibia were harvested, weighed and the following measurements were performed. Femur and tibia from the right leg of the animal were submitted to a three-point flexure test (COMBES *et al.*, 2001). Lengths, and inside and outside diameters were measured on the left bones using a dial calliper (0.02 mm, Mitutoyo). The area moment of inertia (MI, mm^4) was calculated from outside (B and D) and inside (b and d) diameters using the formula: $MI = (BD^3 - bd^3) x \Pi / 64)$. This parameter is an estimation of bone distribution, assuming that the bone shape is similar to a uniform elliptical hollow tube. Yield force, ultimate force, energy (area under the curve), and displacement were collected from the three-point flexure test curve, while stress, elastic modulus and strain were calculated according to the formula reported by PATTERSON *et al.* (1986).

Statistical analysis

Traits were analysed using the SAS GLM procedure. The model included the main effects of line (3 levels), slaughter series (2 levels), and sex (2 levels), using deviation from the average slaughter weight as a covariate. Interactions were tested but not retained in the final model because they were not significant. A principal component analysis with the variables measured or calculated for bone characteristics was performed using the SAS Princomp procedure. Results were presented graphically on a xy plane for the first 2 principal components. The further a variable is away from the two axes origin, the better it is represented on the considered plane.

RESULTS AND DISCUSSION

The increase of the growth rate (low<control<high) was associated with a reduction of 11 days of the slaughter age between the two divergent lines (Table 1). Chilled carcass weight, dressing out percentage and hind part percentage were the highest in the oldest rabbit (Low line), while adiposity did not differ between the three groups.

Table 1: Growth performance and carcass characteristics of rabbits from control and selected lines (High and Low lines). Values are ls-means ± standard deviation.

Traits	Low Line	Control	High line	std	P-line	P-sex
n	74	60	61			
Age at slaughter (d)	63.3	58.0	52.2	1.6		
Slaughter weight (g)	2375 a	2288 b	2300 b	84	***	NS
DWG (28d – slaughter)	47.6 c	56.0 b	65.8 a	2.4	***	NS
Chilled carcass weight	1363 a	1325 b	1323 b	24	***	**
Dressing out (%)	58.3 a	56.7 b	56.58 b	1.0	***	**
Perirenal fat (%)	1.69	1.74	1.65	0.42	NS	NS
Hind part (%)	31.3a	30.2 b	30.3 b	1.0	***	NS

Means in the same row with different superscripts differ: ***P <0.001; **P < 0.01; *P<.05 or NS: non-significant

Increasing post-weaning growth rate, i.e. decreasing age at the same slaughter weight led to a significant decrease in femur and tibia lengths (Table 2). This was in agreement with the classical view of bone length as an indicator of the age or physiological maturity of the animals, independently of live weight. Femurs of the Low line rabbits were the lightest ones and exhibited the lowest Inertia moment. Such reduction in the inertia moment was explained by a lower external antero-posterior diameter of the femurs in the Low line (data not shown). Femurs from the Low line rabbits were also longer but thinner and lighter than those from the 2 other groups. On the opposite, both weight and moment of inertia of the tibias did not differ between the three groups. In agreement with LETERRIER and NYS (1992), in chicken at the same slaughter weight, no difference in inertia moment of tibia was evidenced between rapid growing and slow growing lines, however tibia weight was higher in the latter line.

Post-weaning growth rate significantly affected the mechanical properties of bones (Table 3). Low line rabbits exhibited the lowest values for yield and ultimate force in femur. Those results may arise from the smaller diameters of the femur in this line. On the opposite, the yield and ultimate forces were the highest in the tibia of low line rabbits in agreement with LETERRIER and NYS (1992).

Table 2: Morphometric parameters of femur and tibia of rabbits from control and selected lines (High and Low lines) Value are ls-means and standard deviation.

Traits	Low Line	Control	High line	std	P-line	P-sex
Femur						
Wet weight (g)	10.13 b	10.69 a	10.54 a	0.78	*	NS
Length (mm)	78.2 a	76.2 b	74.2 c	1.8	***	NS
Inertia moment (mm^4)	89 b	119 a	118 a	23	***	NS
Tibia						
Wet weight (g)	8.19	8.41	8.29	0.82	NS	NS
Length (mm)	85.7 a	83.7b	80.9c	2.0	***	NS
Inertia moment (mm^4)	47	44	42	14	NS	NS

Means in the same row with different superscripts differ: ***P <0.001; **P < 0.01; *P<.05 or NS: non-significant

Our study clearly demonstrates that growth rate-related effects on yield and ultimate forces of the bone are bone specific. On the opposite, the growth-rate induced modifications of whole stiffness and elastic modulus were identical for the two bones studied. Indeed, in both femur and tibia, a decreased growth rate led to an increase in stiffness of whole bone (Low>Control>High), and in the elastic modulus (Low>Control=High).

Table 3: Mechanical properties of femur and tibia of rabbits from control and selected lines (High and Low lines) Value are ls-means and standard deviation (std).

Traits	Low Line	Control	High line	std	P-line	P-sex
Femur						
Yield force (N)	180 b	206 a	210 a	32	***	NS
Ultimate force (N)	258 b	276 a	270 ab	35	*	NS
Stiffness (N/mm)	294 a	264 b	243 c	40	***	NS
Elastic modulus (N/mm^2)	1919 a	1327 b	1242 b	379	***	NS
Tibia						
Yield force(N)	265 a	233 b	234 b	40	***	*
Ultimate force (N)	310 a	286 b	279 b	35	***	**
Stiffness (N/mm)	404 a	363 b	337 c	39	***	*
Elastic modulus (N/mm^2)	5360 a	4836 b	4692 b	104 1	**	*

Means in the same row with different superscripts differ: ***P <0.001; **P < 0.01; *P<.05 or NS: non-significant

The results of the principal component analysis are shown in Figures 1 and 2. The first three principal components (PC) explained 55% of the total variation (24.0%, 18.4% and 12.4% for PC1, PC2, and PC3, respectively). The first PC reflected strong relationships between elastic modulus values of tibia and femur (Module F, Module T), stress at yield point and ultimate stress of tibia (Y-stress T, U-stress T). It reflected the antagonism between these variables and antero-posterior diameters of the bones (Dapo-F, Dapi-T), inertia moment and strain of the femur (MI-F, Strain-F). The second PC mainly reflected mechanical characteristics of the tibia: strain, energy and force at yield point and ultimate force. When projecting the individual animals along the first two PC axes, clear discrimination could be seen between the lines (Figure 2). The slow-growing rabbits confined to the right of the plot were thus characterised by higher elastic modulus values of tibia and femur, stress at yield point and ultimate stress of tibia. On the opposite, no clear discrimination could be seen between High Line and control group on PC1 or PC2. This underlined the asymmetrical response to selection for growth rate.

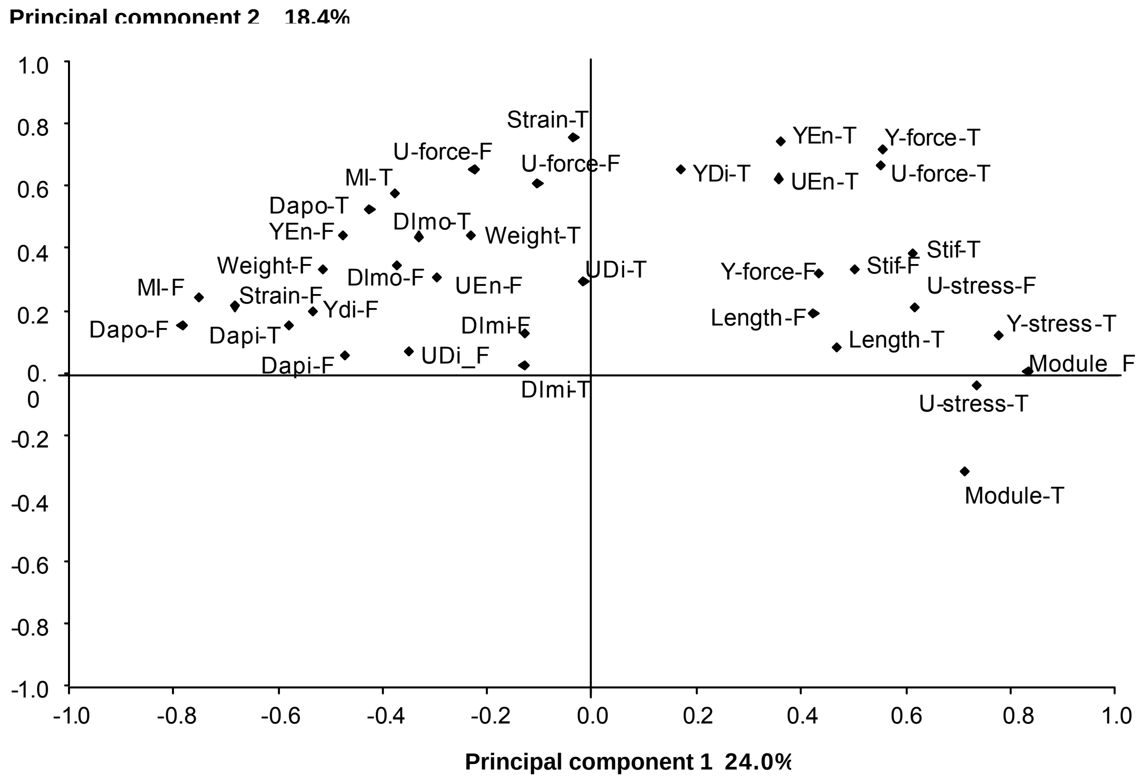

Figure 1: Projection of the variables in the plane defined by the two first principal components. Abbreviations: -T: value for tibia; -F: value for femur; DImi and DImo: inside and outside latero-medial diameter; Dapi and Dapo: inside and outside antero-posterior diameter; Length: bone length; MI: moment of inertia; Weight: bone weight; U-force: ultimate force; Y-force: yield force; YDi: displacement at yield force; UDi: displacement at ultimate force; Stif: stifness; YEn: energy at the yield force; UEn: energy at the ultimate force; U-stress: ultimate stress; Y-stress: yield stress; Strain: bone strain; Module: elastic modulus.

CONCLUSION

Divergent selection of rabbits for live body weight at 63d impaired carcass traits, morphometric characteristics and mechanical properties of bones. However, an asymmetrical response to growth rate selection was observed. Selection for a high growth rate had no effect on bone shape and bending resistance, contrary to selection for low body weight at fixed age. Reduced growth rate (1) improved carcass traits and increased intrinsic stiffness of both bones (2) led to thinner femurs resulting in a reduced bending resistance and (3) increased tibia bending resistance. The last is of great importance when carcasses are hooked on the slaughter chain.

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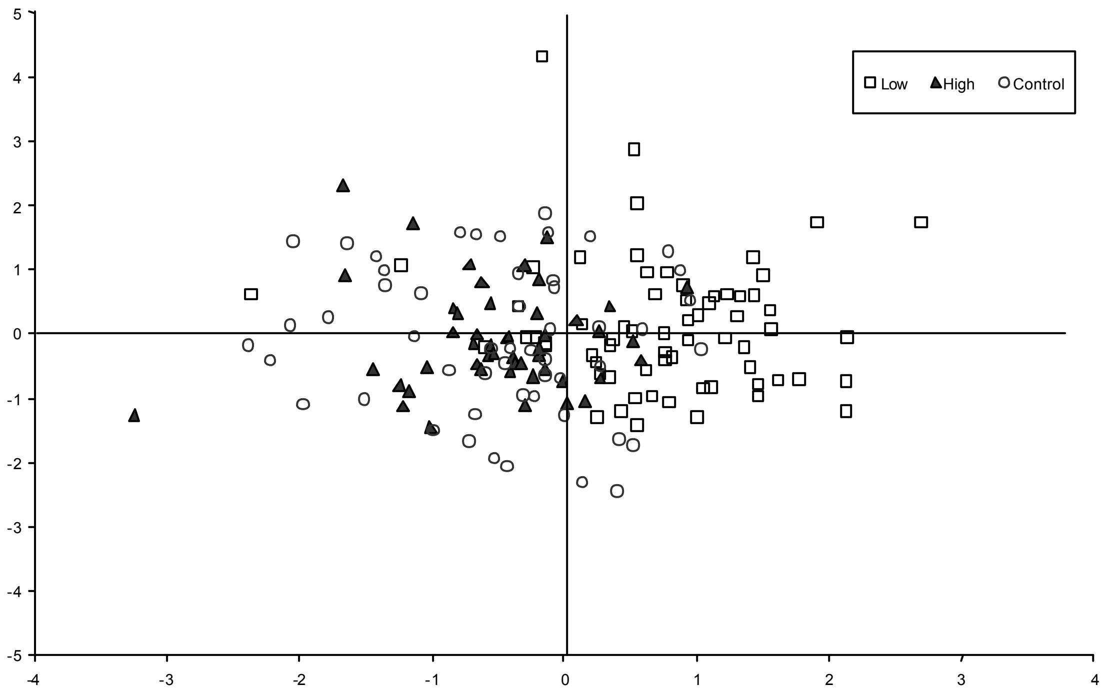

Figure 2: Projection of the data of the rabbits from control and selected lines (High and Low lines) in the plane defined by the two first principal components.

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