# RELATIVE GROWTH OF ORGANS, TISSUES AND RETAIL CUTS IN RABBITS SELECTED FOR GROWTH RATE

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## ABSTRACT

The effect of selection for growth rate on the organs, parts and tissues of rabbit was studied in line R, a line selected for growth rate in the Polytechnic University of Valencia. Rabbits belonged to two groups. The group C was formed with the offspring of embryos recovered and vitrified when the line was in the 7th generation of selection. The group S was formed with rabbits belonging to the 18th generation of the line. Both groups were reared contemporary and under the same conditions. A total of 313 rabbits were slaughtered at 4, 9, 13, 20 and 40 weeks old (approximately 15 rabbits per group, sex and age). The weight of the different organs, parts and tissues of the carcass were related to the body weight by using the Huxley's allometric coefficient ($k$). Their degrees of maturity were related to the degree of maturity of the animal by the Butterfield's allometric coefficient ($q$). Values obtained for $k$ and $q$ coefficients led to similar patterns of growth in most of the components studied. Full gastrointestinal tract ($k$=0.75, $q$=1.92) and organs such as liver ($k$=0.70, $q$=3.18), kidneys ($k$=0.60, $q$=2.28) and thoracic viscera ($k$=0.86, $q$=1.33) were early maturing whereas the chilled ($k$=1.08, $q$=0.89) and reference carcass ($k$=1.16; $q$=0.77) where late maturing. The retail cuts of the reference carcass were isometric (forelegs, $k$ and $q$ not different from 1) or late maturing (breast and ribs, $k$=1.13 and $q$=0.74; loin, $k$=1.24 and $q$=0.74; hind legs, $k$=1.14 and $q$=0.84; abdominal walls, $k$=1.30 and $q$=0.67). Dissectible fat of the carcass ($k$=1.45; $q$=0.20) and meat of the hind leg ($k$=1.24; $q$=0.73) were late maturing and bone had an early development ($k$=0.74; $q$=1.48). Lumbar circumference ($k$=1.26; $q$=0.62) was later maturing than the carcass length ($k$=1.06; $q$=0.91). No effect of selection for growth rate on $k$, and $q$ values of any of the components studied was found.

**Key words**: Rabbit selection, Growth rate, Allometry, Huxley, Butterfield.

## INTRODUCTION

In rabbit meat production, crossbred females from two lines selected for litter size are usually mated with males from a line selected for growth rate. The selection for growth rate of the parental lines has lead to an increase of the live body weight of the rabbits along the whole growth curve (Blasco *et al*., 2003). These differences disappear when the growth curves are expressed in the metabolic scale proposed by Taylor (1980) (weight/adult weight with respect to age/adult weight$^{0.27}$). However, selection for growth rate can affect the relative growth of the different parts of the rabbit. A change in this relative growth would lead to a different carcass composition of the rabbit at a given degree of maturity.

There is some previous work about the effect of selection for growth rate on relative growth in rabbit (Deltoro and López, 1985; Blasco *et al*., 1990) using a line selected for litter size as "control" group. However, the results obtained in these works could be due to the different genetic origin of the lines. In the present work, the effect of selection for growth rate on relative growth in rabbit is studied by comparing two contemporary groups of rabbits from the same line but differing in 11 generations of selection for growth rate. The relative growth is measured by the allometric equations proposed by Huxley (1932), which relates the components weight to body weight, and Butterfield *et al*. (1983a), which relates the components weight/components adult weight to body weight/adult body weight.

## MATERIALS AND METHODS

Rabbits came from line R, a line selected for growth rate between the 4th and 9th week of age in the Polytechnic University of Valencia. Rabbits belonged to two groups: C and S. When line R was in the 7th generation of selection, some embryos were recovered and vitrified. After some generations of selection these embryos were transferred to mature does and the offspring of the rabbits obtained from the embryos formed the group C. The group S was formed with rabbits of the 18th generation of selection. Both groups were contemporary and reared under the same conditions. A total of 313 rabbits from both groups and sexes were slaughtered at 4, 9, 13, 20 and 40 weeks of age (approximately 15 rabbits per group, sex and age). Animals arriving to 40 weeks of age were weighed weekly. After slaughter, animals were bled and blood weight was calculated as the difference between live weight and bled weight. The skin and full gastrointestinal tract were removed and weighed. After 24 h at 3ºC, the chilled carcass was weighed (Blasco and Ouhayoun, 1996) and the liver, kidneys, thoracic viscera (set of lungs, thymus, esophagus and heart) were separated and weighed. The reference carcass obtained (Blasco and Ouhayoun, 1996) was weighed and the dissectible fat (perirenal and scapular fat) was removed and weighed. Dorsal length, thigh length, carcass length (dorsal plus thigh length) and lumbar circumference length were measured. The reference carcass was dissected according to the dissection used by Deltoro and López (1985), obtaining the forelegs including insertion muscles; breast and ribs cutting between the last thoracic and the first lumbar vertebra; loin including sacral vertebrae; abdominal walls and hind legs including the coxal bone. One of the hind legs was dissected to obtain its meat and bone weight. For each component, the data obtained were considered to be repeated measurements of the same "ideal rabbit"; therefore the statistical analyses were applied to the average weights of rabbits belonging to the same group-sex (S males, S females, C males, C females) and age (4, 9, 13, 20 and 40 weeks of age).

The logarithmic form of Huxley's (1932) allometric equation $\log y = \log b + k \log x$ (logarithms in base 10) was fitted using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC), where $b$ was a parameter relating the scale of measure of live weight to the component, $k$ was the allometric coefficient, $y$ was the average weight of the component for each group-sex and age and $x$ the average live weight for each group-sex and age. When $k<1$ the component is early maturing, when $k>1$ the component is late maturing, and when $k=1$ the component and the animal mature at the same rate. The group-sex effect and its interaction with coefficient $k$ were considered. In the case of the linear measurements, $y^3$ instead of $y$ was used, to relate linear measurements with a variable of third order.

Mature live weights were estimated by fitting Gompertz's growth curve $x = A \exp[-b \exp(-k\,t)]$ to the rabbits weighed weekly from 1 to 40 weeks by a nonlinear regression using the NLIN procedure of SAS, where $x$ was the weight of the rabbit, $A$, $b$ and $k$ were the Gompertz's growth curve parameters and $t$ was the age of the rabbit. Mature live weights ($x_A$) for each group-sex were calculated as the average of $A$'s from rabbits belonging to the same group-sex. The average mature weights (except for the full gastrointestinal tract, liver, kidneys) for each group-sex ($y_A$) were obtained by setting the $x_A$'s in the previously fitted Huxley's equation $y = b\ x\ k\ CF$, considering that $y$ is $y_A$ when $x$ is $x_A$. $CF$ was the corrector factor for each group-sex to correct the bias of $y$ when Huxley's allometric equation is fitted in logarithm scale (Sprugel, 1983). Full gastrointestinal tract, liver and kidneys mature weights ($y_A$) for each group-sex were calculated as the average weight of rabbits 40 weeks old from each group-sex, because Huxley's allometric equation did not fit properly.

The allometric equation proposed by Butterfield *et al.* (1983a) $v–u^2=q(u-u^2)$ was fitted using the GLM procedure of SAS. In this equation $v$ was the degree of maturity of the component for each group-sex and age ($v=y/y_A$), $u$ the degree of maturity for each group-sex and age ($u=x/x_A$) and $q$ the Butterfields's allometric coefficient. The interaction between group-sex effect and coefficient $q$ was considered. The interpretation of $q$ is opposite to the interpretation of $k$. When $q<1$ the component is late maturing, when $q>1$ the component is early maturing and when $q=1$ the component matures at the same rate as the animal. In carcass linear measurements the equation did not fit properly, due to the adjustment of linear measurements to a variable of third order, thus $v^3$ instead of $v$ was fitted.

## RESULTS AND DISCUSSION

Exploratory analyses showed that Huxley's allometric equation did not fit properly when the component was maturing earlier (full gastrointestinal tract and kidneys) than most of the components of the rabbit and when the component achieved a weight higher than its mature weight and then decreased to raise its mature weight (liver). Butterfield's allometric coefficient fitted properly in both cases, but did not fit properly in components that were maturing later than most of the components of the animal, as it was the case of the dissectible fat of the carcass, because in these cases the slope of the curve (*q*) is close to 0. Besides, Blasco *et al.* (1990) indicated that the low $r^2$ is due to the low fat content in the rabbit carcass, which makes the analysis of fat content inaccurate in rabbit.

The relative growth of blood, skin, and gastrointestinal tract was not affected by selection for growth rate. This is in agreement with Deltoro *et al.* (1984) when comparing *k* values of two lines of rabbits selected for growth rate and litter size, respectively, and with Butterfield *et al.* (1983b) when comparing *q* values of two different strains of rams after selecting one of them for weight at one year-old for four generations. The relative growth of liver, kidneys, and thoracic viscera was not affected by selection for growth rate. In concordance, favouring growth has no effect on the same organs, either when comparing giant transgenic with non-transgenic mice (Shea *et al.*, 1987), two different strains of rams after selecting one of them for yearling weight (Butterfield *et al.*, 1983b) or two lines of rabbits selected for growth rate or litter size, respectively (Deltoro *et al.*, 1984). However, Eisen (1986), when comparing mice selected for rapid postweaning growth with a control line, found *q* values which indicated a later maturing pattern of liver and *k* and *q* values indicating earlier maturing of kidneys in the selected line. Conversely, Siddiqui *et al.* (1992) found a later maturing of kidneys in mice selected for high insulin growth factor with respect to the low line.

The relative growth of head did not differ between groups, agreeing with results found by Deltoro *et al.* (1984) when comparing rabbits selected for growth rate with respect to rabbits selected for litter size. Butterfield *et al.* (1983b) found, however, earlier development in rams selected for weight at one year old with respect to unselected animals. The patterns of growth of the retail cuts are in agreement with the waves of growth defined by Hammond (1932), who indicated a distal to proximal limb wave of growth and a head to lumbar part wave of growth. No effect of selection for growth rate on relative growth was found for the different retail cuts of the carcass, agreeing with Deltoro *et al.* (1984). We did not find any effect of the selection for growth rate on any of the carcass linear measurements studied. Deltoro *et al.* (1984) did not find differences either in the *k* values of the carcass and lumbar circumference length when comparing rabbits selected for growth and reproductive traits, respectively. In mice, Siddiqui *et al.* (1992) found an earlier growth of nose-anus measurement with respect to liveweight in females selected for high insulin growth factor with respect to the low line, although no differences were found between males.

Dissectible fat of the carcass and meat of the hind leg were late maturing with respect to the liveweight, whereas bone of the hind leg was early maturing. Fat and bone have these patterns of growth also in other species (Cantier *et al.*, 1969, in rabbit; Butterfield *et al.*, 1983a, in sheep; Evans and Kempster, 1979, in pig) but muscle of the carcass is early maturing in species with higher percentage of fat in the carcass than rabbit (Evans and Kempster, 1979, in pig; Butterfield *et al.*, 1983a, in sheep). No effect of selection for growth rate on the patterns of growth of the dissectible fat, meat of hind leg, and bone of the hind leg was found, agreeing with Deltoro *et al.* (1984) in carcass tissues of rabbits selected for growth rate compared with rabbits selected for litter size. In sheep, Butterfield *et al.* (1983a) did not find differences in these tissues in the carcass when comparing animals selected for yearling weight with an unselected strain. Thompson *et al.* (1985) did not find differences either between sheep selected for weaning weight and a random group in relative maturing patterns of muscle of the carcass, but selected animals presented earlier development of fat and later of bone. However, studies in mice show that total fat in the carcass is later maturing when selecting for post-weaning gain (Allen and McCarthy, 1980; Eisen, 1987). As conclusion, we can say that after 11 generations of selection for growth rate the relative growth of the rabbit components has not been affected.

**Table 1:** Mean values and standard errors (SE) of Huxley's *log b* and allometric coefficients *k* and Butterfield's allometric coefficients *q* for the different components with respect to liveweight, coefficient of determination ($r^2$) and difference between selected and control groups (S-C), standard errors of the difference (SED) and P-values (*P*) for *k* and *q* values

| | Huxley's allometric equation | | | | | | | | Butterfield's allometric equation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *log b* | SE | *k* | SE | $r^2$ | S-C | SED | P | *q* | SE | $r^2$ | S-C | SED | P |
| Bl | -1.25 | 0.10 | 0.94 | 0.03 | 0.98 | 0.02 | 0.07 | 0.81 | 1.24[1] | 0.09 | 0.86 | -0.10 | 0.19 | 0.61 |
| Sk | -0.99 | 0.08 | 1.05[1] | 0.02 | 0.99 | -0.02 | 0.04 | 0.63 | 0.87 | 0.07 | 0.71 | 0.04 | 0.14 | 0.79 |
| FGT | 0.07 | 0.11 | 0.75[1] | 0.03 | 0.97 | 0.02 | 0.07 | 0.80 | 1.92[1] | 0.14 | 0.82 | -0.10 | 0.24 | 0.68 |
| CC | -0.50 | 0.02 | 1.08[1] | 0.01 | 0.99 | 0.00 | 0.01 | 0.94 | 0.89[1] | 0.02 | 0.97 | 0.01 | 0.04 | 0.84 |
| Lv | -0.57 | 0.23 | 0.70[1] | 0.07 | 0.87 | -0.03 | 0.16 | 0.85 | 3.18[1] | 0.13 | 0.97 | 0.31 | 0.25 | 0.23 |
| Ki | -0.89 | 0.10 | 0.60[1] | 0.03 | 0.97 | -0.01 | 0.07 | 0.87 | 2.28[1] | 0.06 | 0.99 | -0.15 | 0.09 | 0.12 |
| ThV | -1.46 | 0.11 | 0.86[1] | 0.03 | 0.98 | -0.02 | 0.07 | 0.78 | 1.33[1] | 0.09 | 0.84 | -0.03 | 0.20 | 0.89 |
| H | -0.38 | 0.06 | 0.73[1] | 0.02 | 0.99 | 0.02 | 0.04 | 0.63 | 1.34[1] | 0.07 | 0.84 | 0.00 | 0.14 | 0.99 |
| RC | -0.85 | 0.03 | 1.16[1] | 0.01 | 0.99 | 0.00 | 0.02 | 0.90 | 0.77[1] | 0.02 | 0.95 | 0.03 | 0.05 | 0.51 |
| FL | -1.23 | 0.04 | 0.99 | 0.01 | 0.99 | 0.02 | 0.02 | 0.38 | 0.99 | 0.03 | 0.96 | -0.04 | 0.05 | 0.48 |
| BR | -1.33 | 0.06 | 1.13[1] | 0.02 | 0.99 | -0.03 | 0.04 | 0.54 | 0.74[1] | 0.05 | 0.58 | 0.08 | 0.11 | 0.51 |
| L | -1.85 | 0.05 | 1.24[1] | 0.02 | 0.99 | 0.02 | 0.03 | 0.43 | 0.74[1] | 0.04 | 0.88 | -0.01 | 0.10 | 0.88 |
| AW | -2.53 | 0.05 | 1.30[1] | 0.01 | 0.99 | 0.00 | 0.03 | 0.95 | 0.67[1] | 0.05 | 0.84 | 0.07 | 0.11 | 0.53 |
| HL | -1.26 | 0.02 | 1.14[1] | 0.01 | 0.99 | 0.01 | 0.01 | 0.44 | 0.84[1] | 0.03 | 0.96 | -0.01 | 0.05 | 0.80 |
| DL | 3.80 | 0.04 | 1.02 | 0.01 | 0.99 | 0.02 | 0.02 | 0.32 | 0.98 | 0.03 | 0.94 | 0.02 | 0.07 | 0.82 |
| TL | 1.69 | 0.07 | 1.19[1] | 0.02 | 0.99 | 0.02 | 0.04 | 0.69 | 0.70[1] | 0.05 | 0.75 | 0.08 | 0.10 | 0.45 |
| CL | 4.01 | 0.04 | 1.06[1] | 0.01 | 0.99 | 0.02 | 0.02 | 0.33 | 0.91[1] | 0.03 | 0.94 | 0.03 | 0.07 | 0.64 |
| LCL | 2.46 | 0.06 | 1.26[1] | 0.02 | 0.99 | 0.02 | 0.03 | 0.62 | 0.62[1] | 0.04 | 0.78 | -0.07 | 0.08 | 0.37 |
| DFa | -3.35 | 0.25 | 1.45[1] | 0.07 | 0.97 | -0.06 | 0.14 | 0.69 | 0.20[1] | 0.17 | <0.01 | 0.18 | 0.36 | 0.62 |
| MHL | -1.98 | 0.04 | 1.24[1] | 0.01 | 0.99 | -0.02 | 0.02 | 0.33 | 0.73[1] | 0.03 | 0.94 | 0.02 | 0.06 | 0.73 |
| BHL | -1.04 | 0.09 | 0.74[1] | 0.03 | 0.99 | 0.09 | 0.05 | 0.08 | 1.48[1] | 0.08 | 0.88 | -0.17 | 0.17 | 0.34 |

[1] *k* or *q* was significantly different from 1 ($P<0.05$). Bl: Blood; Sk: Skin; FGT: Full gastrointestinal tract; CC: Chilled carcass; Lv: Liver; Ki: Kidneys; ThV: Thoracic viscera; H: Head; RC: Reference carcass; FL: Forelegs; BR: Breast and ribs; L: Loin; AW: Abdominal walls; HL: Hind legs; DL: Dorsal length; TL: Thigh length; CL: Carcass length; LCL: Lumbar circumference length; DFa: Dissectible fat of the carcass; MHL: Meat of the hind leg; BHL: Bone of the hind leg.

## ACKNOWLEDGEMENTS

The authors are grateful to St. Clair Taylor for his comments and advice. This experiment was supported by the Comisión Interministerial de Ciencia y Tecnología (CICYT- AGL2002-04383-02).

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