GROWTH AND CARCASS TRAITS OF THE RABBIT
A COMPARATIVE STUDY OF THREE MODES OF FEED RATIONING DURING FATTENING

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Abstract - The effects of three modes of feed rationing were measured on 121 rabbits kept in individual cages for between 35 and 77 days. Each of the three groups received the same quantity of food rationed differently before and after 56 days.
The rabbits that received the most liberal mode of rationing after 56 days showed the best results (growth and conversion index) over the entire period of fattening. The worst results were for those with the most restrained mode of rationing after 56 days. Finally the rabbits given a consistently moderate mode of rationing between 35 and 77 days showed intermediate performances.
A feeding-up stage induced a large compensatory growth rate for those rabbits whose rationing was initially restricted. The relative growth rate of the liver, full digestive tract and adipose tissue was very significant during the feeding-up stage. The rate of skeletal development, on the other hand, was very restricted.
Restricted feeding after 56 days mainly hindered the relative growth of adipose tissue whilst preserving skeletal and muscle development.
At the end of the fattening period, the rabbits that were given increased rations after 56 days had a better carcass yield, with a smaller head proportion and lower muscle pH. However, the proportion of both the liver and the muscle/bone ratio of the carcass were higher.

INTRODUCTION

According to the bibliographical syntheses of OUHAYOUN, LEBAS and DELMAS (1986) and of OUHAYOUN (1989), most variations in carcass traits resulting from a modification of the growth rate obtained through controlled feeding can be interpreted by referring to the general laws on allometry (CANTIER et *al.*, 1969). If the growth rate is accelerated by liberal feeding, by lowering the room temperature, by greatly reducing the rate of indigestible fibres or by increasing the protein/energy ratio, a corresponding increase can be seen in the carcass yield, the muscle/bone ratio, and the adiposity of the carcass. This means that tissues which develop at a later stage (muscle tissue but also especially adipose tissue) are favoured to the detriment of precocious tissues (those of the digestive tract, skeleton and skin).Feed rationing affects the development of the digestive tract (LEBAS & LAPLACE, 1982) as well as the relative development of organs and tissues (SCHLOLAUT et *al.*, 1978 ; DE BLAS et *al.*, 1981). The compensatory growth resulting from increased feeding modifies the relative growth of tissues and the efficiency of nutritional diets (LEDIN, 1984). The aim of the present study is to evaluate the influence of rationing on production performance and carcass traits, using a feeding pattern where the global growth rate is limited by restricted feeding either immediately after weaning, or at the end of the finishing period.

MATERIALS AND METHODS

Animals used

The rabbits used in the experiment are from the GENIA selection scheme (female GENIA 67× male GENIA 95). At birth, the number of rabbits per litter were fixed at 8. At the weaning stage (35 days) the rabbits, male and female together, were reshuffled into 3 groups of 44. Care was taken to ensure that the heredity and average live weights were equal for each group. They were then placed in individual cages.

Experimental Procedure

In a preliminary study carried out on 50 rabbits bred in the same conditions as the ones anticiped for our experiment, the spontaneous weekly food consumption was estimated between 35 and 77 days. This was used as a basis to define three modes of rationing :

- mode T : Between 35 and 77 days, a ration of 80% of the spontaneous food intake per week during the fattening period, distributed three times a week (2/7, 2/7 and 3/7 of the weekly ration)
- mode BH : The same total quantity of food as above, distributed in the same way, but with a difference in rationing - a stricter ration between 35 and 56 days (70%) and a more liberal ration from 56 to 77 days (90%)
- mode HB : The same total quantity of food as above, distributed in the same way, but with an inverse rationing pattern i.e. a more liberal ration between 35 and 56 days (90%) and a stricter ration from 56 to 77 days (70%).

The feed used was well-balanced, in granule form, and contained in particular, 17,1% of crude protein, 15,4% of cellulose (Weende) and 2430 Kcal of digestible energy per kilogram.

Testing for production performance and carcass characteristics

The growth and food intake of the rabbits was controlled weekly during the entire period of fattening. At 56 days, i.e. when the ration rates of groups BH and HB were inverted, a sample of 15 rabbits, taken from each of the three groups, were slaughtered. All the other rabbits were slaughtered at 77 days. Slaughter data and that concerning the description of corporal composition were measured following the recommendations of BLASCO, OUHAYOUN and MASOERO (1993).

Statistical Analysis

The growth and food intake data measured between 35 and 56 days for all the rabbits (N=121) were used to make a spectrum analysis which took into account as variables two controlled factors (age to slaughter and mode of rationing) as well as the weight at weaning (LW35) as a covariate. For each of the two ages at slaughter
(44 rabbits at 56 days and 77 at 77 days), the results of slaughter and carcass composition were analysed using only one controlled factor (the mode of rationing) and the weight at weaning (LW35) as a covariate. (S.A.S., Stat, 1990).

RESULTS AND DISCUSSION

Production performances (Table 1)

The weight at weaning has a highly significant influence (b**) on the weight of rabbits from 42 to 70 days old, and the growth rate and conversion index in the periods from 35-56 and 35-77 days. It continues to be significant (b*) on the weight at 77 days but not on the growth rate from 56-77 days. The evolution of this influence reflects the diminishing maternal effects on growth performance in relation to age. (OUHAYOUN 1978).
Here are the average production performances for groups BH and HB at different periods, expressed in percentages of group T :

	35-56 d			56-77 d			35-77 d		Body weight		
	ADG	ADC	CI	ADG	ADC	CI	ADG	ADC	CI	56 d	77 d
HB	124	115	92	60	872						
	82	93	101	107	109	96					
T	100	100	100	100	100	100	100	100	100	100	100
BH	80	89	111	135	110	123	108	99	94	92	104

ADG : average daily gain ; ADC : average daily consumption ; CI : conversion index

Table 1 : Effects of diet on the growth and feed efficiency (values adjusted for live weight of 1046 g at 35 days)

Variables	T	BH	HB	F (1)	b (1)	s_r (2)
All rabbits (no = 121)						
body weight						
42 d (g)	1199^b	1158^a	1278^c	**	**	56.5
49 d (g)	1450^b	1371^a	1557^c	**	**	68.4
56 d (g)	1674^b	1548^a	1822^c	**	**	78.4
average daily gain						
35-56 d (g/d)	29.89^b	23.89^a	36.92^c	**	**	3.733
average daily consumption						
35-56 d (g/d)	108.0^b	95.8^a	123.8^c	**	ns	7.034
conversion index						
35-56 d	3.68^b	4.09^c	3.38^a	**	**	0.393
Rabbits slaughtered at 77 d (no = 77)						
body weight						
63 d (g)	1915	1899	1938	ns	**	73.3
70 d (g)	2107	2132	2084	ns	**	91.6
77 d (g)	2302^b	2402^c	2217^a	**	*	99.8
average daily gain						
56-77 d (g/d)	29.64^b	40.05^c	17.76^a	**	ns	4.412
35-77 d (g/j)	29.88^b	32.26^c	27.87^a	**	**	2.377
average daily consumption						
56-77 (g/d)	137.3^b	151.9^c	118.8^a	**	ns	7.001
35-77 (g/d)	122.7	123.7	121.1	ns	ns	4.83
conversion index						
56-77 d	4.67	3.83	5.75	ns	ns	2.903
35-77 d	4.13^b	3.87^a	4.40^c	**	**	0.317

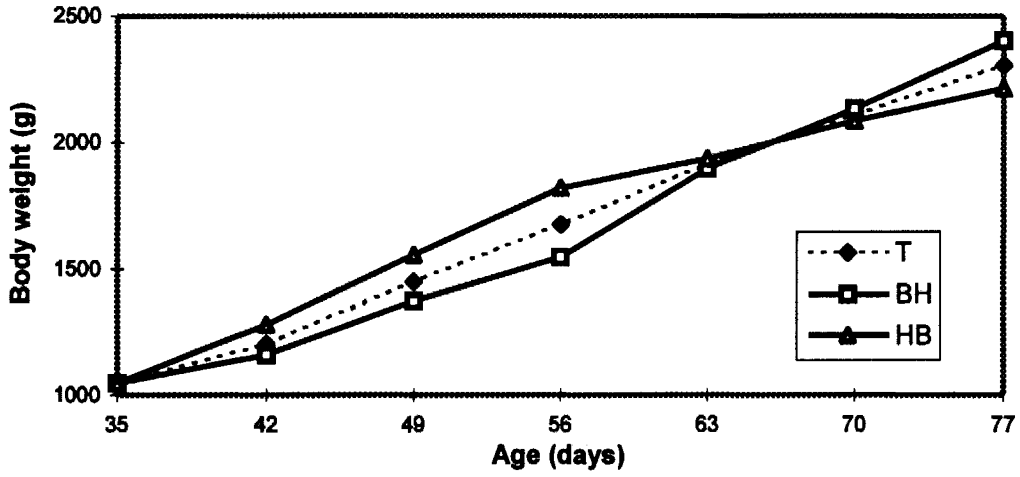
(1) ** : highly significant ($P < 0.01$) ; * : significant ($0.01 < P < 0.05$) ; ns : non significant ($P > 0.05$)
(2) s_r : residual standard deviation
Different superscript following letters indicate significantly different treatment effects ($P < 0.05$)

35-56 day period - The average performances resulting from the applied modes of rationing were as expected. Rabbits given the strictest ration (BH) showed the slowest growth and worst conversion index. Those on the HB diet, on the other hand, had the best performance results. Rabbits in the T group held an intermediary position. At the age of 56 days, the live weights differed significantly (HB > T > BH), an observation made by SCHLOLAUT et *al.* (1978) in similar conditions of rationing.

56-77 day period - As soon as the diets were inversed, the growth rate of the rabbits in group HB decreased, whilst it increased for group BH. In group T, the growth rhythm continued at is 35-56 day rate (29,64 *vs* 29,89 g/day). The increase in the growth rate of rabbits in group BH more than compensated for the weight deficiency accumulated in the initial period (figure 1).

The total period of fattening - The distribution of the same amount of food in three different modes resulted in different global performances. Rabbits in the BH group gained the most weight with an optimum food cost. Those in HB ranked the lowest. Rabbits in group T, subjected to a regular feeding pattern, showed an intermediate performance.

Figure 1 - Weight gain in rabbits: influence of rationing mode



Body constitution

The weights of the main body constituents are given in Table 2.

Table 2 : Effects of diet on body constitution (values adjusted for live weight of 1046 g at 35 days)

Variables	T	BH	HB	F	b	s_r
Rabbits slaughtered at 56 d (no = 44)						
slaughter weight (g)	1676^b	1551^a	1827^c	**	**	78.7
full digestive tract weight (g)	302.5^b	267.2^a	322.8^b	**	ns	40.57
skin weight (g)	250.2^b	232.8^a	277.4^c	**	**	20.25
chilled carcass weight (g)	941.0^b	880.3^a	1004.6^c	**	**	60.01
hindleg muscle weight (g)	109.2^b	101.6^a	114.2^c	**	**	8.26
hindleg bone weight (g)	21.3^b	19.9^a	21.2^b	**	**	1.13
liver weight (g)	47.8^b	43.7^a	53.5^c	**	*	4.07
renal + scapular fat weight (g)	13.86^b	10.78^a	19.44^c	**	*	3.603
Rabbits slaughtered at 77 d (no = 77)						
slaughter weight (g)	2302^b	2402^c	2217^a	**	*	99.8
full digestive tract weight (g)	390.8^a	420.3^b	375.3^a	**	ns	42.13
skin weight (g)	305.5^a	333.0^b	310.8^{ab}	*	ns	42.55
chilled carcass weight (g)	1388.5^b	1415.9^b	1334.0^a	**	**	62.99
hindleg muscle weight (g)	165.0^b	165.8^b	157.1^a	**	**	10.42
hindleg bone weight (g)	26.4	26.3	26.3	ns	ns	1.89
liver weight (g)	61.2^a	77.1^b	59.5^a	**	ns	7.46
renal + scapular fat weight (g)	31.28^{ab}	34.47^b	28.27^a	*	ns	8.739

(1) ** : highly significant ($P < 0.01$) ; * : significant ($0.01 < P < 0.05$) ; ns : non significant ($P > 0.05$)
(2) s_r : residual standard deviation
Different superscript following letters indicate significantly different treatment effects ($P < 0.05$)

The weight at weaning, and thus the maternal influence, has a significant effect (b*) on the weights of the skin, commercial carcass, muscular tissue, hindleg bone and to a lesser extent, on the liver and adipose tissue weights of 56 days-old rabbits. At 77 days, the effects of this influence can only be observed on the commercial carcass and hindleg muscle weights. Thus maternal influence diminishes with age and disappears notably on tissues

that develop early : the digestive tract at 56 days, the skin, bone and liver at 77 days. It is exceptional to find adipose tissue weight with high residual variability.
At 56 days, the classification of the feed modes in ascending order of efficiency is as follows : HB > T > BH. At 77 days, this order is reversed : BH > T > HB. As for the hindleg bone, in spite of the differences in live weight induced by the diets, its weight remains the same, as much for the T and HB groups at 56 days, as for all three groups at 77 days.

The evolution of carcass traits between 56 and 77 days

We studied the effects of a liberal diet (BH) or a restricted one (HB) after 56 days, by examining the relative growth of global body weight and that of the main body constituents between 56 and 77 days. We measured the disparity between body growth and that of its constituents by the ratio of the relative growth of each body element (Vre = (w77-w56)/w56) to that of the whole body (Vrc). This relative growth ratio : a = Vre/Vrc, resembles an allometric coefficient.

The results are as follows :

Variables	T	BH	HB
Vr value (1)			
live body	0,374	0,549	0,214
a values (2)			
chilled carcass	*1,27*	*1,11*	*1,53*
liver	*0,75*	*1,39*	*0,52*
full digestive tract	*0,78*	*1,04*	*0,76*
skin	*0,59*	*0,78*	*0,56*
hindleg bone	*0,64*	*0,59*	*1,13*
hindleg muscle	*1,37*	*1,15*	*1,76*
renal + scapular fat	*3,36*	*4,00*	*2,12*

(1) Vr : relative growth between 56 and 77 d of age
(2) a : ratio of organ relative growth to body relative growth between 77 and 56 d of age

Rabbits of group T, given 80% of the spontaneous food intake throughout the fattening period, have a relative organ and tissue growth rate which on the whole, tallies with the allometric relations of the species (CANTIER et *al.*, 1969). In fact, the liver, digestive tract, skin and bones have an allometrical growth of less than one (a<1), whereas that of the muscular tissue and in particular of the adipose tissue is more than one (a>1). This is also true for the commercial carcass. Between 56 and 77 days, these relations can be explained by: 1- a decrease in the proportions of the digestive tract and skin, with a corresponding increase in carcass yield, 2- a decrease in liver proportion, and an increase in adiposity and muscle/bone ratio. (Table 3).

For rabbits in group BH, the relatively fast growth observed between 56 and 77 days (Vr = 0,549), reflects a strong compensatory growth period following that of a restricted diet. All the « a » coefficients are higher than their counterparts in the T group, with the exception of those of the muscular and bone tissues. The highest coefficients are of the liver and adipose tissue. The relatively fast growth of the liver stems from an increase in its anabolical activity, in response to the increased diet. This phenomenon has already been observed by LEDIN (1984) with rabbits in a compensatory growth period. The isometric growth of the digestive tract and of the whole body (a = 1,04) is probably due to the repletion of the organ, following the increased intake after 56 days. Thus consequently, the increase in diet results in : 1- a slight increase in the proportion of the digestive tract, a moderate decrease in the proportion of skin, with a slight improvement in carcass yield, 2- an increase in the proportion of the liver, in adiposity and in the muscle/bone ratio (table 3).

Influence of the three modes of feed rationing on the final state of the rabbits (77 days)

The carcass traits of the rabbits are significantly affected by the rations given, which favour or hinder the global body growth or relative growth of tissues at given moments in function of the specific allometric relations.
Most characteristics are not influenced by the weight at 35 days, used as covariate.
In terms of global weight gain, a restricted diet for the first three weeks of fattening followed by a feeding up period enabling a rapid compensatory weight gain proves favourable : the live weight thus achieved is 4,3% greater than that of a regular, moderately restricted diet (group T). Nevertheless, such a regular diet gives the highest carcass yield (group T) as does the diet favouring liberal rationing in the initial stages of fattening (group HB). Consequently, there is hardly much difference in carcass weights for each group, and the BH group only seems significantly superior when compared to group HB.
Amongst the criteria used to assess the carcass constitution, four are significantly influenced by the three modes of rationing : the proportions of the head and liver in the carcass, the hindleg muscle/bone ratio, the final average pH in the thigh muscles. It is particularly remarkable that the adiposity of the carcasses are not

influenced by the rationing applied. Although the production of adipose tissue was greatly stimulated in rabbits who were given a liberal diet from 56-77 days (group BH), their adiposity was initially very low (at 56 days) and so at the end of the fattening period did not differ from that of the other groups.
Rabbits in group BH weighed the most due to the compensatory growth rate in the realimentation period, but showed the smallest head proportion. They also showed a more developed liver, due to the intense anabolism immediately before slaughter. Like the rabbits subjected to a stable and moderate diet (group T), they showed the best hindleg muscle/bone ratio. Lastly, it was noted that the final pH of their muscle was the lowest, probably because of a balance in the metabolism of energy favouring the glycolytic path (DALLE ZOTTE & OUHAYOUN, 1995).

Table 3 : Effects of diet on body constitution (values adjusted for live weight of 35 days)

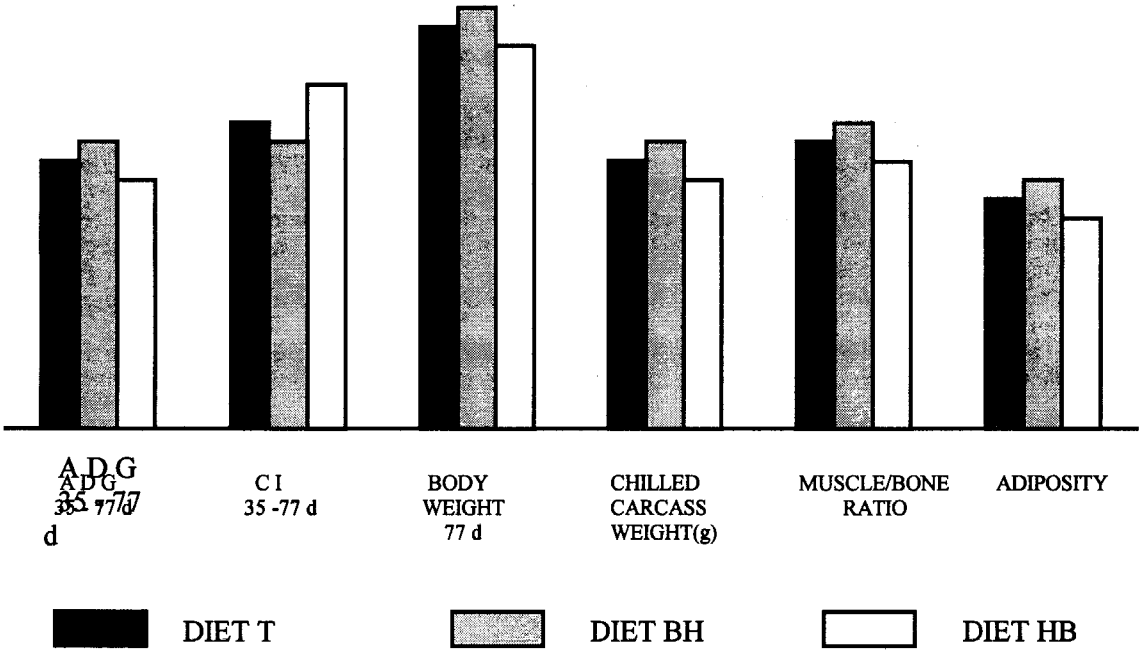
Variables	T	BH	HB	F	b	s_r
Rabbits slaughtered at 56 d (no = 44)						
As % of slaughter weight						
full digestive tract	18.2	17.4	18.1	ns	**	2.78
skin	15.0	15.1	15.4	ns	ns	0.84
chilled carcass	56.4	57.3	55.7	ns	**	2.23
As % of warm carcass weight						
drip loss	2.82	2.62	2.77	ns	ns	0.674
As % of chilled carcass weight						
head	9.93	10.06	9.58	ns	**	0.590
liver	5.12^{ab}	4.96^{b}	5.35^{a}	*	*	0.457
As % of reference carcass weight						
fore part	30.1	30.2	29.8	ns	ns	0.78
intermediate part	30.7^{a}	30.4^{a}	32.2^{b}	**	*	0.90
hind part	39.0^{b}	39.3^{b}	38.1^{a}	**	ns	0.80
renal and scapular fat	1.79^{a}	1.51^{a}	2.37^{b}	**	ns	0.411
Hindleg characteristics						
muscle/bone ratio	5.12	5.11	5.39	ns	**	0.433
cooking loss (%)	24.48	24.58	24.12	ns	ns	1.492
average ultimate pH	5.85	5.87	5.84	ns	*	0.052
Rabbits slaughtered at 77 d (no = 77)						
As % of slaughter weight						
full digestive tract	17.0	17.5	17.0	ns	**	1.71
skin	13.3	13.9	14.0	ns	ns	1.81
chilled carcass	60.3^{b}	59.0^{a}	60.1^{b}	**	**	1.67
As % of hot carcass weight						
drip loss	2.96	3.04	3.02	ns	ns	0.380
As % of chilled carcass weight						
head	9.28^{b}	8.98^{a}	9.40^{b}	**	ns	0.488
liver	4.41^{a}	5.45^{b}	4.48^{a}	**	*	0.550
As % of reference carcass weight						
fore part	29.0	29.2	29.3	ns	ns	0.86
intermediate part	32.5	32.7	32.2	ns	ns	1.04
hind part	38.4	38.2	38.6	ns	ns	0.98
renal + scapular fat	2.69	2.96	2.53	ns	ns	0.734
Hindleg characteristics						
muscle/bone ratio	6.28^{b}	6.32^{b}	5.98^{a}	*	ns	0.498
cooking loss (%)	25.99	25.94	24.80	ns	ns	2.014
average ultimate pH	5.77^{b}	5.73^{a}	5.77^{b}	*	ns	0.079

(1) ** : highly significant ($P < 0.01$) ; * : significant ($0.01 < P < 0.05$) ; ns : non significant ($P > 0.05$)
(2) s_r : residual standard deviation
Different superscript following letters indicate significantly different treatment effects ($P < 0.05$)

CONCLUSION

There is a difference in efficiency of production and body constitution of rabbits given the same quantity of feed (122g/day) during fattening (35-77 days) i.e. 80% of the *ad libitum* consumption but rationed out differently before and after 56 days using three modes : 80-80% (T), 70-90% (BH) and 90-70% (HB).

Figure 2 : Production performance and carcass characteristics in rabbits : influence of rationing mode



Rabbits given diet T performed intermediately in terms of weight gain and feed efficiency. The evolution of their body constitution, surveyed between 56 and 77 days, globally conforms to the allometric relations established for the species by CANTIER et *al.* (1969). In terms of carcass traits, this is essentially reflected by an improvement in carcass yield, in the adiposity and muscle/bone ratio and a reduction of the liver proportions. Rabbits given the HB diet are lighter at 77 days and have a higher conversion index. The carcass yield obtained is the same but the carcass is lighter. Also, the muscle/bone ratio is lower.

Finally, rabbits given the BH diet, who show signs of a great compensatory rate between 56 and 77 days, are characterised by a better weight gain, and global feed efficiency. The carcass traits of this group are no worse, although the carcass yield is lower.

It therefore seems possible to restrict the diet of rabbits at the early stages of fattening if a liberal feeding period ensues, without damaging the carcass characteristics and thus reducing feed costs.

Nevertheless, further studies are required to observe the combined effects of the time length and quantity of this rationing before it may be applied to commercial breeding.

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Croissance et qualité de la carcasse chez le lapin : étude comparative de 3 modes de rationnement durant l'engraissement - Les effets de trois modes de rationnement alimentaire ont été mesurés sur 121 lapins élevés en cages individuelles entre 35 et 77 j. Chacun des trois lots a reçu la même quantité d'aliment répartie différemment avant et après 56 j.
Les lapins réalimentés plus libéralement après 56 j expriment les meilleures performances (croissance et indice de consommation) sur l'ensemble de la durée d'engraissement. A l'inverse, les plus restreints après 56 j ont les performances les moins bonnes. Ceux, rationnés modérément selon le même niveau entre 35 et 77 j ont des performances intermédiaires.
La réalimentation des lapins restreints en première période induit une forte croissance compensatrice.La croissance relative du foie, du tractus digestif plein et du tissu adipeux est très active durant la phase de réalimentation. A l'inverse,celle du squelette est très modérée.
La restriction alimentaire appliquée après 56 j pénalise principalement la croissance relative du tissu adipeux tout en préservant celle du squelette et du muscle.
A l'issue de la période d'engraissement, les animaux réalimentés après 56 j ont un rendement à l'abattage, une proportion de tête et un Ph musculaire plus faible. Par contre, la proportion de foie et le rapport muscle/os de leur carcasse sont plus élevés.