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GROWTH OF RABBITS UNDER DIFFERENT ENVIRONMENTAL TEMPERATURES USING HIGH FAT DIETS

CERVERA C., BLAS E., FERNANDEZ-CARMONA J.

Dept. Ciencia Animal, Universidad Politécnica, 46071- VALENCIA, Spain

ABSTRACT : 686 rabbits, weaned at 35 days of age, were fed ad libitum up to 84 days of age on three diets (composition per kg dry matter: 11.0 MJ DE - 26 g EE ; 12.2 MJ DE - 117 g EE mainly from commercial tallow; 12.4 MJ DE, 99 g EE from vegetable origin) and five environments defined by the mean minimum temperatures during fattening of 10-14°C, 14-22°C, 22-26°C, 30°C constant and 33°C constant. Daily gains recorded for those temperatures were 38, 38, 33, 28, 23 g (P<0.001) and feed intake 83, 77, 70, 62, 53 g DM/kg$^{0.75}$ (P<0.001). Daily gain recorded for the three diets was 31, 32, 33 g (P<0.001) and feed intake 73, 69, 66 g DM/kg$^{0.75}$ (P<0.001). Interaction between diet and temperature was significant (P<0.001) for food intake which was similar at high temperatures while for the rest inversely related to the DE content of the diets.

RESUME** : **Croissance de lapins soumis à différentes températures ambiantes recevant de aliments riches en matières grasses.
686 lapins ont été nourris ad libitum entre 35 et 84 jours avec l'un des trois aliments expérimentaux (teneur de la matière sèche par kg: 11,0 MJ ED - 26 g matières grasses ; 12,2 MJ ED - 117 g matières grasses (suif en majorité) ; 12,4 MJ ED - 99 g matières grasses d'origine végétale) et à cinq températures ambiantes différentes correspondant soit à la température minimale moyenne pendant l'engraissement (10-14°C, 14-22°C, 22-26°C), soit à une température constante de 30°C à 33°C. Les vitesses de croissance pour les cinq températures ont été de 38, 38, 33, 28, 23 g/jour (P<0,001) et l'ingéré de 83, 77, 70, 62, 53 g MS/kg$^{0.75}$ (P<0,001). Les vitesses de croissance pour les trois aliments on été de 31, 32, 33 g/jour (P<0,001) et l'ingéré de 73, 69, 66 g MS/kg$^{0.75}$ (P<0,001). L'interaction aliment-température était significative pour l'ingéré (P<0,001). Celui-ci était indépendant de l'aliment pour les températures élevées mais il était inversement lié à la concentration en énergie digestible de l'aliment pour les températures les plus basses.

INTRODUCTION

Addition of fat to the diets increases the energy density with the general consecuences that growth of rabbits does not vary and feed efficiency improves (LEBAS, 1975). The most relevant single factor in tropical countries is a temperature 30-35°C, a critical setback for success in rearing rabbits. It has been suggested that high -fat diets could at high environmental temperatures alleviate the thermal stress, when rabbits' food intake cannot be sustained and the subsequent energy restriction severely impairs growth response. In the present work the effect of three diets with different levels of fat and digestible energy (DE) has been examined in rabbits reared at several ambient temperatures.

MATERIAL AND METHODS

Animals and housing.

The experiment was carried out in a climatic chamber at a constant temperature of 30 or 33°C and in a traditional building, where three ranges of minimum weekly temperatures of 10-14°C (12), 14-22°C (18) and 22-26°C (24) were considered, as reported in Table 1.

686 three-way crossbred rabbits, between 600 and 1000 g liveweight, weaned at 35 days of age were fed *ad libitum* on the same diet and housed in the same ambience as during lactation, up to 84 days of age. Food intake and liveweight were individually recorded during the following periods: 35-70 and 35-84 days; and each period was assigned to the corresponding temperature condition which was defined by the mean minimum weekly temperature during that period. Intakes were always referred to the mean metabolic weight and they were calculated by the expression

$$I*(W_{35}+W_f)^{-0.75} *2^{0.75} *d^{-1},$$

where I is the whole intake of the period (35-70 or 35-84 days) in g DM or kJ DE, W_{35} is the liveweight (kg) of rabbits at 35 days of age, W_f is the liveweight (kg) of rabbits at the end of the period and d are the days of the period (35 or 49 days).

Table 1 : Housing conditions in the experiment.

	Temperature				
	12° C	**18° C**	**24° C**	**30° C**	**33° C**
Minimum, °C	10-14[1]	14-22[1]	22-26[1]	29	32
Maximum, °C	14-18[1]	16-26[1]	25-29[1]	31	34
Months of the experiment	January-February	February-March	June to September	February-March	July-August
%RH[2]	75-80	75-80	75-80	65-70	70-75
Ventilation		static		forced	
Air speed		not appreciable		<0.5 m s^{-1}	
Location of litters before weaning		traditional building		30°C chamber	33°C chamber

[1]Range of mean minimum/maximun weekly temperatures
[2] Relative humidity

Table 2 : Ingredients (%) and composition of diets[a]

	Diet		
	C	A	V
Barley	35	20	20
Soya 44%	12	18	-
Soya full fat	-	-	24
Lucerne hay	50	50	50
Soya oil	-	-	2.5
Animal fat	-	8.5	-
DL-methionine	0.1	0.1	0.1
Calcium diphosphate	2.3	2.8	2.8
Sodium chloride	0.4	0.4	0.4
Vitamin-mineral supplement	0.2	0.2	0.2
Ash, %DM[1]	10.2	10.6	10.6
Crude protein, %DM[1]	18.0	19.0	19.8
Ether extract, %DM[1]	2.6	11.7	9.9
Acid detergent fibre, %DM[2]	19.9	19.3	19.7
Digestible energy, kJ/gDM[3]	11.0	12.2	12.4
Digestible protein, %DM[3]	13.0	14.0	15.1

[a] All diets contain (ppm) vitamin E (200), BHT (100), robenidine (66)
[1] AOAC, 1984
[2] Van Soest et al., 1991
[3] Values experimentally determined

Diets.

The ingredients and chemical composition of the diets are shown in Table 2. Starting from a control diet with 2.6 g/100 g DM of Ether Extract (C), two isoenergetic diets were formulated adding commercial tallow up to 11.7 g/100 g DM (A) and fat from soya up to 9.9 g/100 g DM (V), maintaining the same protein source (soya) and the same level of forage content (50% lucerne). Chemical analyses of diets were conducted according to the methods of AOAC (1984) and Van Soest *et al* (1991) for ADF. Gross energy was determined in an adiabatic bomb calorimeter. Apparent digestibility of the diets was measured with 15 females between 2.5 and 2.8 kg liveweight at 20-25 °C room temperature. Does were in individual metabolism cages and their feces were collected individually for 5 days after a 7-day adaptation period

Statistical analysis.

Standard analyses of variance were used for data from 686 animals with diet (C, A and V) and environmental temperature (12, 18, 24, 30 and 33°C) as independent variables, considering weaning weight and final weight as covariates, when liveweight gain and food efficiency respectively were examined. The GLM procedure for unbalanced blocks from the Statistical Analysis System package (SAS, 1989) was performed. A CHI- squared test was used to estimate the frequencies associated with mortality.

RESULTS

Regression equations were deduced for dry matter and digestible energy intake with the mean minimum temperatures during the fattening period as the independent variable.

Statistical analyses and the average results for liveweight gain, dry matter intake, energy intake and food efficiency are shown in Table 3.

Food intake and liveweight gain decreased throughout the experiment. Environmental temperature affected all indices obtained. Liveweight gain was similar at 12 and 18°C but it was significantly impaired at higher temperatures. Food intake and food efficiency also decreased as the mean daily temperature increased.

Interaction between diet and temperature was not significant for liveweight gain for both the 35-70 day period ($p=0.25$) and the 35-84 day period ($p=0.09$). However it was highly significant ($P<0.001$) for dry matter and DE intake which makes it necessary to consider both variables independently of each other. The overall results are shown in that way in Table 4.

Dry matter intake for fat-diets was always lower than for Diet C, significantly at 12 and 18°C, but the differences tended to be smaller when the temperature increased. With some exceptions dry matter ingestion on Diet V was lower than on Diet A. Digestible energy intake was usually higher for Diets V and A, consistently for temperatures higher than 18°C; and the effect of diet V was more evident at 24,30 and 33°C.

The three diets led to similar liveweight gains at 12 and 18°C but Diets A and V gave better figures at higher temperatures; Diet V showing again greater gains.

The general equation obtained by multiple regression for dry matter intake was :
I (g DM/kg$^{0.75}$) = 87.21 - 0.03 * T^2 (R^2 =0.69, MSE=6.29), where T is in °C. For each diet the equation were:

Diet C $I = 93.30 - 0.033 * T^2$ (R^2= 0.78, MSE= 5.90)
Diet A $I = 87.56 - 0.031 * T^2$ (R^2= 0.75, MSE= 5.56)
Diet V $I = 81.13 - 0.024 * T^2$ (R^2= 0.66, MSE= 5.42)

36% mortality was recorded at 33°C. This high rate was significantly different from those at other temperatures. About 60% of the deaths took place during the first three weeks after weaning.

DISCUSSION

The weight at weaning, discussed in some other works, depends on the feeding of does, temperature and litter size, and in the present experiment it was also conditioned by the litters included in the work performed in the climatic chamber, which depended on the number of individual cages which happened to be available.

The decrease of ingestion and liveweight gain with age of rabbits is well documented, but sometimes it has not been found, probably because in these works the

Table 3 : Effect of diet and temperature on liveweight and intake

	Significance						LS Means							
	COV	D	T	D*T	Mean	Root MSE	Diet			Temperature				
							C	A	V	12	18	24	30	33
Number of animals at 35d							230	224	232	101	125	158	216	86
Liveweight, kg														
35d		***	***	***	0.81	0.13	0.79^{a}	0.82^{b}	0.84^{b}	0.93^{a}	0.88^{b}	0.86^{b}	0.73^{c}	0.69^{d}
70d[1]	***	***	***	NS	2.00	0.15	1.97^{a}	1.99^{a}	2.05^{b}	2.23^{a}	2.20^{a}	2.11^{b}	1.86^{c}	1.61^{d}
84d[1]	***	*	***	NS	2.39	0.20	2.35^{a}	2.39^{ab}	2.42^{b}	2.70^{a}	2.66^{a}	2.45^{b}	2.17^{c}	1.94^{d}
Liveweight gain, g/d														
35-70d[1]	+	***	***	NS	34.0	4.4	32.9^{a}	33.6^{a}	35.3^{b}	40.5^{a}	39.7^{a}	36.9^{b}	29.9^{c}	22.7^{d}
35-84d[1]	NS	**	***	+	32.3	3.6	31.3^{a}	32.2^{b}	33.0^{b}	38.1^{a}	38.3^{a}	33.4^{b}	27.9^{c}	23.1^{d}
DM intake, g/kg$^{0.75}$/d														
35-70d		***	***	***	72.5	5.8	75.5^{a}	71.0^{b}	69.8^{b}	87.2^{a}	80.2^{b}	74.0^{c}	64.7^{d}	54.3^{e}
35-84d		***	***	***	70.0	5.5	72.5^{a}	68.6^{b}	66.3^{c}	83.3^{a}	77.4^{b}	70.1^{c}	61.8^{d}	53.1^{e}
DE intake, kJ/kg$^{0.75}$/d														
35-70d		***	***	***	847	68	820^{a}	849^{b}	851^{b}	1015^{a}	935^{b}	863^{c}	754^{d}	633^{e}
35-84d		***	***	**	817	65	788^{a}	820^{b}	809^{b}	969^{a}	902^{b}	818^{c}	720^{d}	619^{e}
Feed conversion ratio, gDM/g														
35-70[2]	NS	***	***	+	2.78	0.29	2.93^{a}	2.77^{b}	2.68^{c}	3.12^{a}	2.91^{b}	2.76^{c}	2.64^{d}	2.55^{e}
35-84[3]	NS	***	***	NS	3.13	0.27	3.28^{a}	3.09^{b}	3.01^{c}	3.45^{a}	3.19^{b}	3.18^{b}	2.97^{c}	2.83^{d}
Mortality, %	NS	***	***		13.5		18^{a}	8^{b}	13^{ab}	13^{a}	10^{a}	6^{a}	11^{a}	36^{b}

Covariate: liveweight [1] at 35 days [2] at 70 days [3] at 84 days
NS non significant, + $P<0.1$, * $P<0.05$, ** $P<0.01$, *** $P<0.001$
Values in the same row within diet or temperature no sharing a common superscript differ significantly with $P<0.05$

accumulated weight gains for the periods have been considered instead of succesive periods, which understimated the differences between them. In the present case the high number of rabbits being observed probably allowed small differences to be detected.

Dry matter intake decreased with digestible energy of the diet and with temperature, as has been reported when ingestion was examined in summertime and at a range of ambient temperatures from 5 to 30°C (STEPHAN 1980), 20-30°C (FERNANDEZ *et al* 1994), 10-25°C (CASAMASSIMA *et al* 1988) and 30°C (SIMPLICIO *et al* 1988, FERNANDEZ *et al.* 1994, BOITI *et al.* 1992, CHIERICATO *et al.* 1995). This last temperature was linked to a substantial decrease in both intake and growth. Some of these values have been represented in Figure 1, together with the regression lines deduced in the present work. Although the values depend on the liveweight gain, the energy of diets and the unit of temperature chosen, they follow aproximately the same pattern. For instance CHIERICATO *et al.* (1995) published values of ingestion similar to those in the present work (74 Vs 64 g DM/kg$^{0.75}$ of ingestion and 38 Vs 33 g/day liveweight gain) when comparing rabbits housed at nearly constant temperatures of 20°C and 28°C, fed on a diet of 11.8 kJ/g DE. The second of the above cited works (FERNANDEZ *et al.* 1994) found the respective values to be 86, 77, 65 g DM and 45, 37, 30 g/day at three minimum temperatures of 16, 20, 30°C for rabbits from 0.8 to 2 kg liveweight fed on a diet of 11.1 kJ/g DE.

The diet-temperature interactions followed a fairly clear pattern. At normal temperatures the lower ingestion of rabbits fed on diets A and C is a well-known fact related to their energy contents, but at high temperatures there are nearly no available references to compare with. FERNANDEZ *et al* (1994) also found that the intake for a diet with 11.1 MJ DE was higher at 16,22 and 30°C than for two others with 11.5 MJ DE, but the interaction was not significant. Using these same diets in the lactation-gestation of doe rabbits housed at 30°C, FERNANDEZ *et al* (1996) noticed a small though significant difference between the intake of diet C and the others. From our data (Table 4) it seems that this effect, very clear at 12 and 18°C, became less at higher temperatures where the difference between Diet C and the other two was not always significant, indicating the significant interaction between diet and temperature. Certainly any conclusion deduced from the results at 33°C should be viewed with caution because the standard error was relatively high, as the rabbits were affected by a high mortality rate.

From the regression equations it also becomes apparent that temperature affected the ingestion of the diets to a different degree, causing the slopes of the lines for Diets C,A and V in this order to decrease (Fig 1) and explaining the meaning of those interactions between diet and temperature which have been already mentioned.

While the liveweight gain for the whole period at moderate temperatures of 12 and 18°C was similar, it was affected from 24°C up, where it is obviously related to a low ingestion of energy, and Diets A and V led to better gains than Diet C (Table 2). In fact the interaction between diet and temperature had a probability of

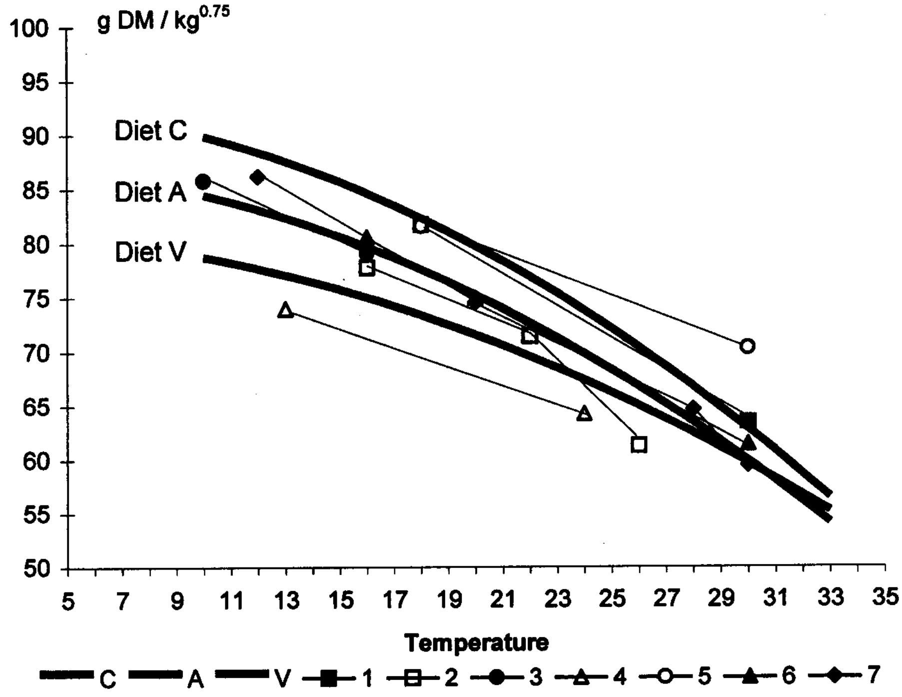

Figure 1 : C,A,V regression lines of present work. 1 STEPHAN 1980 (constant temperatures). 2 LEBAS and OUHAYOUN 1987 (mean temperatures). 3 CASAMASSIMA *et al.* 1988 (minimum temperatures). 4 NIZZA *et al.* 1992 (mean temperatures). 5 BORGIDA and DUPERRAY 1992 (mean temperatures). 6 FERNANDEZ *et al.* 1994 (minimum temperatures). 7 BOITI *et al.* 1992, CHIERICATO *et al.* 1995 (nearly constant temperatures). Only data for temperatures >10°C were considered.

$p=0.09$, so the response of liveweight gain tended to be different for the temperatures considered. Certainly there were no differences between diets for temperatures below 24°C but differences were detected from 24°C up. In this respect, we could try to explain the values of liveweight gain in terms of the DE intake, which should obviously be well-correlated to the increments of weight observed. Different dry matter intakes at 12°C (C Vs A Vs V), at 18°C (C Vs A Vs V) led to a higher DE ingestion for Diet A and consequently to higher gains for this diet, though non-significant. At 24, 30 and 33°C, as a consequence of the small differences between dry matter intake, energy intake of Diets A and especially V were much higher, so the corresponding gains showed a similar trend.

That relationship between liveweight and DE intake has been found at normal temperatures where diets with added fat have been used. When DE intake of fat-diets was higher, whether the diet was limited to give similar energy ingestions (BEYNEM *et al.* 1990) or if the decrease of DM ingestion did not compensate for the higher DE of fat-diets (PARTRIDGE 1986, MAERTENS *et al.* 1989, FERNANDEZ and FRAGA 1994), then the liveweight gain was higher. Conversely when DE intake was similar, because the lower ingestion of the fat-diets balanced their energy value, the liveweight was similar to

Table 4. Interaction between diet and temperature on liveweight gain and intake for the whole period (35-84d)

	L.S.Means														
	12			18			24			30			33		
	C	A	V	C	A	V	C	A	V	C	A	V	C	A	V
Rabbits at 35 days, no.	34	32	35	43	42	40	53	53	52	71	68	77	29	29	28
Rabbits at 84 days, no.	25	31	32	37	39	36	47	51	51	64	64	65	17	20	18
Liveweight gain[1], g/d	37.5[a]	38.6[a]	38.3[a]	38.1[a]	39.0[a]	37.6[a]	32.1[c]	33.0[c]	35.2[b]	27.2[e]	27.8[de]	28.7[d]	21.8[f]	22.7[ef]	24.9[e]
DM intake, $g/kg^{0.75}/d$	89.3[a]	83.1[b]	77.3[c]	81.9[b]	78.1[c]	72.3[d]	72.2[d]	68.7[e]	69.3[e]	64.4[f]	61.1[g]	59.7[g]	54.6[h]	51.8[h]	52.8[h]
DE intake, $kJ/kg^{0.75}/d$	971[ab]	993[a]	944[bc]	890[d]	933[c]	882[d]	785[f]	822[e]	846[e]	700[h]	731[g]	729[g]	594[j]	619[ij]	645[i]

Covariate: liveweight [1] at 35 days
Values in the same row no sharing a common superscript differ significantly with P<0.05

non-fat diets (SANTOMA *et al.* 1987, FERNANDEZ *et al* 1994) and this is the result commonly recorded in most works that have used fast-growing animals.
Diets were designed to exceed protein requirements, the actual ingestion of digestible protein being higher than 13 g daily at normal ranges of temperatures (12, 18 and 24°C) which reinforces the idea that at 24°C the lower growth rate achieved was the consequence of a limit in the energy allowance. At 33°C ingestion of DE for Diets A and V was 25 and 50 kJ higher than for Diet C, implying that 2 and 4 grams more of liveweight gain could be achieved with these diets, but the corresponding figures for DP intake (0.4 and 1.2 g) should cause lower differences in growth rate, about 1 and 3 grams respectively. The values at 30°C give similar results. In spite of the error linked to this method of theoretical assessment, a higher protein level in Diets A and V, about 1% may be supposed more likely to obtain a better response in 30 and 33°C environments, or at least to avoid the risk of an insufficient intake of protein.

Carcass yield, carcass fat and the efficiency of DE for fattening should be three factors altering the significance of liveweight gain as the only predictor of growth performance. At low and medium temperatures DE intake of the rabbits fed on fat-diets was similar, but they should use that energy more efficiently and the caloric retention could be higher with these diets.

Rather obviously, if faster growth leads to heavier carcasses linked to the degree of fatness, then any particular diet should lead to less carcass fat at a high ambient temperature. When several diets are considered, carcasses with the same weight should be compared; including carcass weight as a covariate PLA and CERVERA (1996) examined a representative sample of the carcasses of the same rabbits used here at 12 and 18°C ambient temperature recording lighter dissectable fat deposits for diet C. At 30 and 33°C DE intake of fat-diets was higher but the differences in terms of liveweight gain are small compared to that for diet C. Again PLA (1996) measured the carcass fat in those rabbits at 30°C finding much more fat, about 50% more, for diets A and V; thus justifying somehow the results in Table 3 for high ambient temperatures.

In conclusion these data suggest that the addition of fat to rabbit diets seems to improve growth performance at high environmental temperatures, although special consideration should be given to the amount of carcass fat and to the protein level of the high fat diets.

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