THE RESPONSE OF HIGHLY PRODUCTIVE RABBITS TO DIETARY THREONINE CONTENT FOR REPRODUCTION AND GROWTH

DE BLAS C.[1], TABOADA E.[2], NICODEMUS N.[1], CAMPOS R.[1], MENDEZ J.[2]

[1] Departamento de Producción Animal, ETSI Agrónomos, Universidad Politécnica de Madrid, 28040, Madrid, Spain
[2] COREN SCL, C/ Juan XXIII 33, 32003, Orense, Spain

Abstract - This study investigated the threonine requirements of rabbits. Five diets, containing from 0.54 to 0.72% crude threonine, were formulated by supplementing a basal diet with L-threonine. The apparent faecal threonine digestibility (%) was 63.8 ± 1.3 in the basal diet and 93.0 ± 6.0 for L-threonine, as estimated by the difference method. Feeding trials were carried out using 370 rabbit does and 1150 weanling rabbits slaughtered at 2 kg of body weight. Milk production was measured in 80 lactations. Carcass traits were determined in 115 rabbits.
The results indicate that a minimal dietary concentration of 0.64 and 0.43% of crude and digestible threonine, respectively, should be included to maximize performance of does and rapidly growing rabbits. Requirements were lower (0.58 and 0.38%) in the first two weeks of the fattening period and for rabbits grown in commercial cages. An excess of dietary threonine tended to impair intake and performance and to reduce fat retention. The results of this study also demonstrated the need for using digestible rather than crude units to express the threonine requirements of rabbits.

INTRODUCTION

After lysine and methionine, threonine is usually the next most limiting amino acid in diets for pigs. At present, synthetic threonine is available at a relatively low cost. As a consequence, there is an increasing interest in the feed industry for a better knowledge of threonine requirements of rabbits. Practical recommendations (LEBAS, 1987) have been established at 0.55 and 0.70% in diets for growing rabbits and lactating does, respectively.
Previous studies conducted in pigs (WANG & FULLER, 1989; FULLER *et al*, 1989) have shown a relatively high threonine requirement for maintenance. Thus, estimations based on the threonine content of the whole body might underestimate actual requirements. Other work (COLE *et al*, 1983) indicated that an excess of dietary threonine resulted in a decreased intake and performance. Furthermore, threonine digestibility depends on the source of dietary protein, as in other non ruminant species. For this reason, the recommendations should be expressed on the basis of digestible, instead of crude, threonine in the diet.
The aim of this work was to i) determine the apparent faecal digestibility of synthetic threonine as compared with that of threonine in a basal diet, and ii) measure the performance response of highly productive does and growing rabbits to an increase in dietary threonine, by using five isoenergetic diets (2420 kcal DE/kg) with crude threonine levels ranging from 0.54 to 0.72%.

MATERIAL AND METHODS

Diets

A basal diet (diet A) was formulated to meet all the essential nutrient requirements for lactating does, except for threonine, whose content was limited to 0.54% (as fed basis). Four additional diets (B, C, D and E) were made by supplementating the basal diet with L-threonine, such that threonine content was 0.58, 0.63, 0.68 and 0.72 (as-fed basis), respectively. The ingredients and chemical composition of the basal diet are shown in Table 1.

Digestibility Trial

A group of 18 New Zealand x Californian growing rabbits from 45 to 60 d of age were alloted at random to diets A and E to determine the apparent digestibility of energy, and threonine in the basal diet, and the digestibility of threonine in diet E. Following a 10-d period of adaptation to each diet, collections were made on four consecutive days.

Table 1. Ingredient and chemical composition of the basal diet

Item	
Ingredient, %	
Wheat bran	33.0
Lucerne meal	19.7
Wheat grain	14.9
Sunflower meal	13.0
Wheat straw	10.0
Molasses	3.9
Pork lard	2.0
Calcium carbonate	1.35
Dicalcium phosphate	0.82
Sodium chloride	0.50
Choline chloride	0.03
L-lysine	0.26
DL-methionine	0.14
Robenidine premix[a]	0.10
Vitamin/mineral mix[b]	0.17
Chemical analysis, % DM	
Ash	9.4
Crude protein	16.4
Threonine	0.59
Lysine	0.90
Methionine	0.44
Cystine	0.29
Starch	20.9
Ether extract	6.2
Crude fibre	15.9
Acid detergent fibre	18.3
Neutral detergent fibre	37.3
Acid detergent lignin	3.8
Calcium	1.1
Phosphorus	0.7
Gross energy, kcal/kg DM	4401

[a] 6.6% of active ingredient.

[b] Provided by Colborn Dawes SA. Mineral and vitamin composition (g/kg): Mn, 13.4; Zn, 40; I, 0.7; Fe, 24; Cu, 4; Co, 0.35; riboflavin, 2.1; calcium pantothenate, 7.3; nicotinic acid, 18.7; vitamin K_3, 0.65; vitamin E, 17; thiamine, 0.67; pyridoxine, 0.46; biotine, 0.04; folic acid, 0.1; vitamin B_{12}, 7 mg/kg; vitamin A, 6,700.000 IU/kg; vitamin D_3, 940,000 IU/kg.

Lactation Trial

Eighty rabbit does were used to measure milk production during one lactation. Does were separated from pups after parturition and milk production was estimated daily from weight loss of does during suckling.

Three hundred and seventy Hy Plus doe rabbits were alloted at random to the five diets. A 60-d adaptation period was allowed before recording rabbit performance. Remating interval after parturition was fixed at 7 d and weaning age at 31 d. Does that failed to conceive or lost all their pups were inmediately given the opportunity to remate. Productive traits were recorded and accumulated over a 5 month production cycle.

Animals were housed in flat-deck cages measuring 600 x 500 x 330 mm high. A cycle of 16 h light and 8 h dark was used throughout the experiment. Building heating systems and forced ventilation allowed the temperature to be maintained between 18 and 23 °C.

Growth Trial

One thousand one hundred and fifty pups from the lactation trial were blocked by litter and assigned to the same treatments. After weaning rabbits were given *ad libitum* access to the same solid feed they received during the lactation period, until they reached approximately 2 kg of body weight. Feed intake and length of the experimental period were recorded per cage. The rabbits were divided in two grups of 190 and 960 animals. The animals in the first group were placed in individual cages while the others were caged in groups (eight rabbits per cage).

One hundred and fifteen rabbits were choosen at random from the group grown in commercial cages. Once they reached the pre-established weight, they were fasted during two hours and transported to a commercial slaughterhouse. Carcass dressing percentage was measured. The total weight of primal joints (fore and hind legs, loin and kidneys) was also determined. The perirenal fat was extracted in forty carcasses.

Analytical Methods

Chemical analysis of diets was made by the method of VAN SOEST (1963) for acid detergent fibre and acid detergent lignin, ROBERTSON and VAN SOEST (1981) for neutral detergent fibre, LONGSTAFF and MCNAB (1986) for starch, and AOAC (1984) for dry matter, ash, crude protein, ether extract, and crude fibre. Gross energy was determined by adiabatic bomb calorimetry. Amino acid contents were determined using high pressure liquid chromatography (COHEN *et al*, 1989).

Statistical Analysis

Data were analysed as a completely randomized block design using the GLM procedure of SAS (1985) with initial parity number and weight of does as linear covariates in the lactation trial, and weaning and slaughter weight in the

growth and carcass trials, respectively. Type of diet was the main source of variation. Data are presented as least square means. Interactions between type of diet and day or week of lactation were studied using a repeated measures analysis. Mean comparisons were made using orthogonal contrasts.

RESULTS AND DISCUSSION

Digestibility Trial

Digestible energy content (kcal/kg feed) of the basal diet was (mean ± SE) 2420 ± 49. Faecal apparent threonine digestibility (%) in the basal diet and in diet E was 63.8 ± 1.3 and 71.4 ± 1.3, respectively. From these values, digestibility of the supplementary L-threonine was calculated by difference, obtaining an estimate of 93.0 ± 6.0.

Lactation Trial

Dietary threonine content did not affect total or maximal milk production (Table 2). However, a significant interaction (P = 0.07) was found between type of diet and period of lactation on feed intake and milk production, which were lower in diet A than for the average of the other diets in the period of maximal milk production (11-20 d). Both feed intake and growth of pups in the period 21-30 d were maximal for diet B (0.58 and 0.38% of crude and digestible threonine, respectively).

The effect of type of diet on several productive traits is shown in Table 3. Dietary threonine content did not affect average weight, live weight gain or replacement rate of does. Total feed intake (does + pups) showed a cubic trend (P = 0.05) with dietary threonine content, having a maximum for a level of 0.63 and 0.43% of crude and digestible threonine (diet C). Parturition interval, pup mortality in the period 22 d-weaning, litter size at weaning, numerical productivity, litter weight at 21 d and weaning, and feed efficiency, were quadratically affected by type of diet, showing optimal values for around 0.64 or 0.43% of crude and digestible threonine, respectively.

Table 2 : Effect of diet on average milk production and feed intake of does per lactation

Item	Diets*							Significance of comparisons**			
	A	B	C	D	E	SE[1]	P[2]	1	2	3	4
Number of lactations	17	15	17	17	17						
Total milk production per doe (kg)	5.40	5.65	5.68	5.83	5.78	0.183	NS	NS	NS	NS	NS
Milk production 1-10 days (kg)	1.72	1.71	1.65	1.78	1.68	0.07	NS	NS	NS	NS	NS
Milk production 11-20 days (kg)	2.38	2.59	2.55	2.63	2.65	0.08	NS	0.01	NS	NS	NS
Milk production 21-30 days (kg)	1.30	1.33	1.47	1.41	1.43	0.06	NS	NS	NS	NS	NS
Total feed intake per doe (g/d)	340	356	346	343	360	8.2	NS	NS	NS	NS	NS
Feed intake 1-10 days (kg)	3.17	3.37	3.08	3.10	3.30	0.12	NS	NS	NS	NS	NS
Feed intake 11-20 days (kg)	3.63	3.88	3.81	3.72	4.03	0.10	NS	0.06	NS	NS	NS
Feed intake 21-30 days (kg)	3.40	3.44	3.47	3.46	3.47	0.09	NS	NS	NS	NS	NS
N° pups weaned per litter	8.84	8.94	8.61	9.53	8.88	0.26	NS	NS	NS	0.08	NS
Feed intake of pups (g/d)	167	206	167	194	170	12.3	NS	NS	0.05	NS	NS
Pup daily gain 21-30 days (g/d)	21.4	23.9	22.1	19.7	21.7	0.98	0.08	NS	0.02	NS	NS
Maximal milk production per day (g)	277	290	287	300	300	8.96	NS	NS	NS	NS	NS
Day of lactation of maximal milk production	15.9	17.7	17.6	17.4	18.2	0.54	0.08	0.006	NS	NS	NS

* Threonine contents of diets A, B, C, D, E = 0.54, 0.58, 0.63, 0.68 and 0.72 respectively
** 1 = Diet A vs the other diets. 2 = Diet B vs diets C, D, E. 3 = Diet C vs diets D, E. 4 = Diet D vs diet E
[1] SE = Standard error of means (n = 17) ; [2] P = Level of significance ; NS = Non significant (P > 0.10)

Table 3 : Effect of dietary threonine level on productive traits of doe rabbits

Item	Diet*							Significance of comparisons**			
	A	B	C	D	E	SE[1]	P[2]	1	2	3	4
Number of litters	126	120	129	120	114						
Average weight of does (kg)	4.17	4.14	4.15	4.19	4.14	0.03	NS	NS	NS	NS	NS
Live weight gain (g/d)	-0.53	-0.89	-0.78	-0.29	-0.89	0.36	NS	NS	NS	NS	NS
Feed intake (g/d)[d]	342	356	381	369	356	9.55	0.04	0.02	NS	NS	NS
Parturition interval (d)[a]	49.0	49.7	48.3	46.6	50.8	1.56	NS	NS	NS	NS	0.06
No. born total per litter[d]	11.39	10.67	10.70	10.86	11.31	0.26	NS	0.08	NS	NS	NS
No. born alive per litter	10.79	10.01	10.19	10.17	10.04	0.28	NS	0.03	NS	NS	NS
No. pups dead 1-21 days per litter[a]	2.83	1.54	1.31	1.41	1.87	0.29	0.001	0.0001	NS	NS	NS
No. pups dead 22° d-weaning per litter[a]	0.34	0.39	0.18	0.21	0.38	0.07	NS	NS	NS	NS	NS
No. weaned per litter[c]	7.62	8.07	8.69	8.55	7.79	0.26	0,01	0.02	NS	0.10	0.04
No. weaned per cage and year[c]	60.3	62.1	69.5	69.9	57.6	2.73	0.003	NS	NS	0.08	0.002
Litter weight at 21 d (kg)[b]	2.68	2.80	2.93	2.89	2.66	0.08	0.06	0.10	NS	NS	0.05
Litter weight at weaning (kg)[b]	4.83	5.17	5.49	5.41	5.03	0.16	0.02	0.01	NS	NS	NS
Feed efficiency (kg weaned/kg feed)[a]	0.299	0.305	0.315	0.326	0.292	0.01	NS	NS	NS	NS	0.03
Feed efficiency (No. weaned/kg feed)[c]	0.471	0.479	0.499	0.513	0.443	0.02	0.03	NS	NS	NS	0.003
Replacement rate per doe and year (%)	116.6	94.1	90.7	139.5	107.7	21.4	NS	NS	NS	NS	NS

* Threonine contents of diets A, B, C, D, E = 0.54, 0.58, 0.63, 0.68 and 0.72 respectively
** 1 = Diet A vs the other diets. 2 = Diet B vs diets C, D, E. 3 = Diet C vs diets D, E. 4 = Diet D vs diet E
[1] SE = Standard error of means (n = 48 except n = 74 in replacement rate) ; [2] P = Level of significance ; NS = Non significant < (P > 0.10)
[a] Quadratic response to dietary threonine content ($P < 0.05$) ; [b] Quadratic response to dietary threonine content ($P < 0.01$)
[c] Quadratic response to dietary threonine content ($P < 0.005$) ; [c] Cubic response to dietary threonine content ($P < 0.08$)
[d] Cubic response to dietary threonine content ($P < 0.01$)

Growth Trial

The effect of diet on growth and carcass traits is shown in Table 4. Rate of growth was significantly higher ($P < 0.001$) when rabbits were grown in individual *vs* commercial cages (42.2 *vs* 36.2 g/d, SE 0.41), but no interaction was found between type of diet and cage density.

Table 4 : Effect of dietary threonine level on growth and carcass traits

Item	Diets*					SE [1]	P [2]	Significance of comparisons**			
	A	B	C	D	E			1	2	3	4
Two-weeks after weaning period											
Average daily gain (g)	41.9	44.1	42.9	43.5	42.5	0.68	NS	0.08	NS	NS	NS
Feed intake (g/d)	86.5	90.9	86.4	86.4	85.2	1.52	0.09	NS	0.007	NS	NS
Feed efficiency (g gain/g feed)	0.491	0.486	0.500	0.505	0.499	0.006	NS	NS	0.005	NS	NS
Whole individual fattening period											
Average daily gain (g)	41.3	42.7	43.2	41.8	41.9	0.58	NS	NS	NS	0.06	NS
Feed intake (g/d)	117	120	117	117	116	1.36	NS	NS	0.02	NS	NS
Feed efficiency (g gain/g feed)	0.354	0.355	0.370	0.355	0.361	0.004	0.06	NS	NS	0.03	NS
Collective fattening period											
Average daily gain (g)	36.1	37.4	36.2	35.8	35.5	0.48	0.06	NS	0.005	NS	NS
Feed intake (g/d)	109.5	113.2	112.8	107.2	108.3	2.02	NS	NS	NS	0.04	NS
Feed efficiency (g gain/g feed)	0.320	0.323	0.310	0.321	0.317	0.006	NS	NS	NS	NS	NS
Total mortality (%)	6.25	8.33	7.29	7.81	6.77	0.02	NS	NS	NS	NS	NS
Carcass traits											
Carcass dressing percentage (%)	57.1	57.1	57.4	57.9	57.4	0.37	NS	NS	NS	NS	NS
Perirenal fat (%)	16.9	16.8	19.7	12.1	14.6	1.58	0.01	NS	NS	0.002	NS
Proportion of primal joints in dressed carcass (%)	81.2	81.5	81.6	80.9	81.2	0.28	NS	NS	NS	NS	NS

* Threonine contents of diets A, B, C, D, E = 0.54, 0.58, 0.63, 0.68 and 0.72 respectively
** 1 = Diet A vs the other diets. 2 = Diet B vs diets C, D, E. 3 = Diet C vs diets D, E. 4 = Diet D vs diet E
[1] SE = Standard error of means (n = 38 for individual growth traits, n = 24 for collective growth traits except n = 200 for mortality, n = 21 for carcass traits and n = 8 for fat trait) ; [2] P = Level of significance ; NS = Non significant ($P > 0.10$)

Both low and high dietary threonine contents impaired average daily gain, feed intake and feed efficiency, which showed maximal values at levels of 0.58 and 0.38, and 0.63 and 0.43% of crude and digestible threonine, for the two-weeks after weaning and the collective fattening period, and for the whole individual fattening period, respectively. Perirenal fat was maximal for diet C, decreasing sharply at higher threonine levels. Neither the carcass dressing percentage, nor the proportion of primal joints in the dressed carcass, were affected by type of diet.

REFERENCES

AOAC (1984) Official Methods of Analysis (14th Ed). Association of Official Analytical Chemists, Arlington, USA

COLE DJA, SPARKES GM, LEWIS D (1983) The influence of dietary protein on voluntary feed intake in pigs. In PION R, ARNAL M, BONIN D: *The Voluntary Feed Intake of Pigs*, Publ No 13, pp 61-70. Br Soc Anim Prod. London.

COHEN SA, MEYS M, TARVIN TL (1989) The pico tag method. A manual of advanced techniques for amino acid analysis. Millipore Corp, Bedford, USA.

FULLER MF, Mc WILLIAM R, WANG TC, GILES LR (1989) The optimum dietary amino acid pattern for growing pigs. 2. Requirements for maintenance and tissue protein accretion. *Br J Nutr* 62, 255-267.

LEBAS F (1987) Feeding conditions for top performances in the rabbit. Commision of European Communities. Report EUR 10983. pp 27-40. Luxembourg.

LONGSTAFF M, Mc NAB JM (1986) Influence of site and variety of starch, hemicellulose and cellulose composition of wheats and their digestibilities by adult cockerels. *Br Poultry Sci* 27, 435-449.

ROBERTSON JB, VAN SOEST PJ (1981) The detergent system of analysis and its applications to human foods. In JAMES WPT, THEANDER, O: *The Analysis of Dietary Fiber in Foods* pp 123-158, Marcel Decker, New York.

STATISTICAL ANALYTICAL SYSTEMS INSTITUTE (1985) SAS User's guide: Statistics. SAS Institute, Cary, USA

VAN SOEST PJ (1963) Use of detergents in the analysis of fibrous feeds. 2. A rapid method for the determination of fibre and lignin. *J Assoc Anal Chem* 46, 828-835.

WANG TC, FULLER MF (1989) The optimum dietary amino acid pattern for growing pigs. 1. Experiments by amino acid deletion. *Brit J Nutr* 62, 77-89.

Respuesta al contenido en treonina de ladieta en reproduccion y crecimiento de conejos altamente productivos - El objeto de este estudio ha sido investigar las necesidades de treonina en conejos. Para ello, se formularon cinco dietas que contenían entre 0.54 y 0.72% de treonina, suplementando una dieta basal con L-treonina. La digestibilidad aparente de la treonina (%) fue 63.8 ± 1.3 en la dieta basal y 93.0 ± 6.0 para la L-treonina, estimada por diferencia. Se realizaron ensayos de alimentación utilizando 370 conejas y 1150 conejos destetados sacrificados a los 2 kg de peso. La producción de leche se midió en 80 lactaciones. Para medir los parámetros de la canal se emplearon 115 conejos.

Los resultados indicaron que se requiere una concentración mínima de 0.64 y 0.43% de treonina bruta y digestible en la dieta para obtener rendimientos máximos en conejas y gazapos de crecimiento rápido. Las necesidades fueron más bajas (0.58 y 0.38%) en las dos primeras semanas de engorde y en gazapos criados en jaulas comerciales. Un exceso de treonina en la dieta tendió a empeorar la ingestión y los rendimientos y a reducir el grado de engrasamiento. Los resultados del trabajo también demuestran la necesidad de usar valores digestibles, en vez de brutos, para expresar las necesidades de treonina de los conejos.
