Ann Zootech (1997) 46, 255-268

Original article

Effect of dietary protein and amino acids on the performance, carcass composition and N-excretion of growing rabbits

L Maertens [1]*, F Luzi [2], G De Groote [1]

[1] *Rijksstation voor Kleinveeteelt, Burg Van Gansberghelaan 92, 9820 Merelbeke, Belgium;*
[2] *Facoltà di Medicina Veterinaria, Istituto di Zootecnica, Via Celoria 10, 20133 Milan, Italy*

(Received 9 January 1996; accepted 22 November 1996)

Summary — A total of 234 weanlings (32-day-old) were fed during 6 weeks ad libitum one of six diets, produced after progressively blending a high protein mixture with a low protein mixture, in order to obtain a series of six iso-energetic (10.4 MJ DE/kg) diets with linear decreasing protein content between 170.1 g and 137.5 g kg^{-1}. Lysine, methionine + cystine and threonine were at 1.45 times their assumed requirement in the high protein mix to avoid deficiencies of these amino acids in the experimental diets. The significant interaction ($P < 0.001$) between type of diet and weekly weight gain demonstrated an age-dependent response to the dietary protein content. A protein level below 157 g kg^{-1} resulted in a significant lower growth rate and feed intake during the first 3 weeks post weaning. However, during the finishing period (last 2 weeks) weight gain on low protein diets (< 151 g kg^{-1}) exceeded ($P < 0.05$) that of the high protein diets. Comparative slaughter techniques revealed a significant increased N-retention with increasing dietary protein dilution (from 33.9 to 41.3% of intake). N-excretion was reduced by 38% on the lowest protein diet compared to the rabbits fed the highest protein diet. However, their growth rate was 9% lower. Empty body composition showed a significant increased fat content as the protein content of the diet decreased related to the changed protein-energy ratio. Dressing out percentage was unaffected by the dietary treatment. The results suggest that dietary protein and amino acid levels of growing rabbits have to be considered into different age periods, in order to match them better with the requirements. An important reduction of the N-excretion could then be achieved without altering the performances.

rabbit / dietary protein / amino acid / performance / N-balance

Résumé — **Effet de la teneur en protéines et en acides aminés du régime sur les performances, la composition corporelle et l'excrétion azotée des lapins en croissance.** Au total, 234 lapereaux sevrés (âgés de 32 j) ont été nourris pendant 6 semaines ad libitum avec l'un des six aliments préparés en amenant progressivement un régime à haut taux protéique vers un régime à faible taux en protéines (technique de dilution). La lysine, la méthionine + cystine et la thréonine représentaient 1,45 fois la

* Correspondence and reprints

couverture des besoins dans le régime à taux protéique élevé afin d'éviter des carences en ces acides aminés dans les six régimes expérimentaux. Les régimes étaient isoénergétiques (10,4 MJ ED kg^{-1}) avec un taux décroissant linéaire de protéines de 170,1 (régime 1) à 137,5 g kg^{-1} (régime 6). L'interaction significative ($p < 0,001$) entre les valeurs de gain de poids hebdomadaire et les régimes met en évidence une réponse dépendante de l'âge des lapereaux. Un niveau protéique inférieur à 157 g kg^{-1} a entraîné une vitesse de croissance significativement ($p < 0,001$) plus faible (aliment 1 : 45,3 ; aliment 6 : 36,6 g j^{-1}) ainsi qu'une consommation alimentaire moins importante pendant les 3 premières semaines de post-sevrage. Cependant, sur la période de finition (2 dernières semaines d'engraissement), les gains de poids correspondant aux régimes à faible taux protéique (<151 g kg^{-1}) ont été plus élevés ($p < 0,05$) que ceux des régimes à fort taux protéique (aliment 1 : 45,7 ; aliment 6 : 47,1 g j^{-1}). La technique d'abattage comparatif révèle une augmentation significative de la rétention azotée liée à la dilution protéique (de 33,9 à 41,3 % de l'ingestion azotée). L'excrétion azotée était réduite de 38 % dans le régime le plus pauvre en protéines (régime 6) par rapport aux lapins alimentés avec le régime le plus riche en protéines. Cependant, la croissance globale a été réduite de 9 %. La composition corporelle a été significativement plus riche en lipide quand la teneur en protéine des régimes diminuait. Cet effet est lié au changement du rapport protéines/énergie dans les différents régimes. Les rendements d'abattage n'ont pas été influencés par les régimes alimentaires. Les résultats suggèrent que la teneur en protéines et le niveau en acides aminés des aliments doivent être pris en compte différemment selon l'âge, de manière à mieux les adapter aux besoins des lapins. On pourrait alors aboutir à une réduction de l'excrétion azotée, en tenant compte des phases d'engraissement, sans altérer les performances d'engraissement.

lapin / protéine alimentaire / acide aminé / performance / balance azotée

INTRODUCTION

Mineral pollution originating from animal production, especially from nitrogen and phosphorus in the excreta, has become a major problem in several European countries having a high density of animal production. Phosphorus requirements of rabbits are low (Lebas and Jouglar, 1990) and efforts to reduce the output of minerals were therefore focused on nitrogen. Like for other animals, reduction of the excretion is directly related to the quality and quantity of the feed given. Improvement in the efficiency of nitrogen deposition can be obtained by matching the dietary amino acid composition with the requirements for maintenance and for tissue protein accretion. The availability of commercial synthetic amino acids allows the use of low protein diets by avoiding an excess of each amino acid above the requirement. Excessive amounts of dietary protein are utilized metabolically for energetic purposes with a negative impact on the environment.

Current protein and amino acid (AA) recommendations (Lebas, 1989) for growing rabbits are based on experiments mainly performed about 20 years ago (Lebas, 1983). However, with increasing use of hybrid strains, average daily growing performances amount actually to 40–45 g instead of 30–35 g. More recently, efforts have been made to estimate AA requirements based on rabbit whole-body tissue composition (Moughan et al, 1988; Schultze et al, 1988). Their findings suggest that if a balance of essential AA relative to lysine, based on current AA recommendations is used, several of these AA will be in excess of requirement. However, in their experiments rabbits were fed on a restricted basis resulting in a low growth rate. Furthermore, in a lot of experiments, graded supplements of the amino acid under test are added to the basal diet supposed to be deficient only for that amino acid. The changed amino acid balance between diets, the uncertainty if the response can totally be ascribed to the first-limiting amino acid, especially at high levels of supplementation, and the difficulty in devising a basal diet adequate in all other indispensable AA are considered as weak points of this method (D'Mello, 1982).

The approach used in the present experiment was to study low dietary protein levels being adequate in lysine, methionine + cystine and threonine. The synthetic analogues of these AA are relatively cheap and widely used in animal feeding. By making use of the diet dilution technique (Fisher and Morris, 1970), diets with decreasing concentrations of protein with a near constant amino acid balance are obtained. A carefully formulated low-protein mixture is used to dilute a high protein summit diet in order to produce a range of iso-energetic diets.

The purpose of the present experiment was to study: 1) the effect of decreasing dietary protein content on performance; 2) age-dependent responses on zootechnical performance; and 3) the influence on carcass composition and N-excretion.

MATERIALS AND METHODS

Diets

A high protein diet (Summit mixture) was formulated to contain 10.4 MJ DE kg^{-1} (Maertens et al, 1990) and lysine, methionine + cystine and threonine levels at 1.45 times their assumed requirement (Lebas, 1989). Dietary lysine requirement was assumed to be 7.3 g kg^{-1} (Taboada et al, 1994). All other essential nutrients were at least above the recommendations of Lebas (1989) for growing rabbits. An iso-energetic low protein diet (Dilution mixture) consisting of cassava meal and animal fat as energy sources and flax chaff as fibre source was prepared. Summit and dilution mixtures were blended progressively in the ratio 90% summit + 10% dilution mix (diet 1) to 65% summit + 35% dilution (diet 6) in order to produce a series of six diets with a decreasing crude protein (CP) content between 170.1 g and 137.5 g kg^{-1} and almost constant amino acid balance. The ingredient composition of the summit and the dilution mixtures are reported in table I. The chemical and amino acid concentrations of the experimental diets (table II) were calculated using the analyzed values of the summit and dilution mix. Pelleted diets (Ø 3.2 mm) were fed ad libitum throughout the whole experimental period (42 days).

Animals and zootechnical recordings

Two hundred-and-thirty-four weanlings (32-day-old), deriving from the final cross of the Institutes' own lines (Maertens, 1992), were blocked by litter and alloted at random to the six experimental diets (sex was ignored). Only litters including at least six young rabbits, homogeneous in body weight, were used. Rabbits were caged in groups of three, so that 13 cages and 39 rabbits were assigned to each diet. The flat-deck cages, measuring 600 × 430 × 300 mm high, were equipped with a nipple drinker and an outside placed feeder. Building heating system and forced ventilation allowed the temperature to be maintained between 18 and 22°C. A cycle of 10 h of light and 14 h of darkness was used throughout the experimental period of 42 days.

Rabbits were weighed individually on a weekly basis. Feed intake was recorded each week per cage. Mortality was recorded daily. In case of mortality, weekly feed consumption of the cage was corrected taking into account the number of rabbits and the day of mortality.

N-retention and empty body composition

The comparative slaughter technique was used to determine protein accretion and retention. Twelve additional weanlings (four replicates of three rabbits) within the same weight range were killed to estimate the initial empty body (digesta-free body) composition. At the end of the growing trial, four complete replicates were killed. After cooling, the content of gut and bladder was removed and the digesta-free body weight determined. All these rabbits were frozen, ground, freeze-dried and homogenised (per pen). Nitrogen was measured by the Kjeldahl procedure. Dry matter, fat and ash were determined following AOAC (1990) methods. Dietary ADF content was determined according to the procedure of Van Soest *et al* (1991) using an amylolytic pretreatment.

Table I. Ingredients and chemical composition of summit and dilution diets.

Ingredients (g kg^{-1})	*Summit diet*	*Dilution diet*
Alfalfa meal	250	
Wheat	130	
Wheat middlings	186	
Cassava meal	50	600
Sunflower meal (28%)	120	
Soybean meal	90	
Corn gluten feed (20%)	65	
Flax chaff	25	350
Animal fat	11	25
Molasses (cane)	40	
Min/vit pre-mix[1]	25	25
Coccidiostat	1	
L-Lysine HCL	3	
DL-Methionine	2.4	
L-Threonine	1.6	
Composition (g kg^{-1})		
Crude protein	183.1	52.8
ADF	155.6	155.5
Crude fat	38.5	46.5
DE (MJ kg^{-1})[2]	10.4	10.4
Ca[3]	9.1	10.1
P[3]	6.2	2.9

[1] Provided by Trouw NV and contained (g kg^{-1}): Na, 60; Ca, 115; P, 45; I, 0.02; Co, 0.03; Se, 0.012; Cu, 0.3; Mn, 1.3; Zn, 2.3; Fe, 4.0; vitamin E, 0.68; vitamin K_3, 0.012; thiamin, 0.013; choline, 4.50; riboflavin, 0.11; panthothenic acid, 0.27; pyridoxine, 0.013; nicotinic acid, 0.54; vitamin B_{12}, 0.0006; vitamin A, 320.000 IU kg^{-1}; vitamin D_3, 70.000 IU kg^{-1}. [2] Calculated (Maertens et al, 1990). [3] Calculated values, based on the Dutch feedstuffs table (CVB, 1991).

Carcass determinations

Seventy-two (12/diet) rabbits were slaughtered at the Institute for slaughter yield recordings. Out of all the remaining replicates, one or two rabbits per cage were chosen with a weight close to the average weight. Slaughterings were executed at the age of 76 days or 2 days after the end of the growth trial. During these 2 days rabbits received further their corresponding experimental diet. They were slaughtered without preceding fasting period by cervical dislocation. Carcass weights, dressing out percentages, liver, perirenal- and scapular fat weight were determined following the recommendations of Blasco et al (1993).

Statistical analysis

Zootechnical data were analyzed as a completely randomized block design by a GLM procedure, using the SAS/STAT version 6 (1990) with blocks and type of diet as main sources of vari-

Table II. Protein and amino acid composition of summit and dilution mixture and experimental diets [1] (g kg^{-1}).

	Summit (S)	*Dilution (D)*	Diets: *1* 90%S + 10%D	*2* 85%S + 15%D	*3* 80%S + 20%D	*4* 75%S + 25%D	*5* 70%S + 30%	*6* 65%S + 35%D
Crude protein	183.1	52.8	170.1	163.6	15.70	150.5	144.0	137.5
Isoleucine	7.2	1.6	6.6	6.4	6.1	*5.8* [2]	*5.5* [2]	*5.2* [2]
Leucine	12.7	2.9	11.7	11.2	10.7	*10.3* [2]	*9.8* [2]	*9.3* [2]
Lysine	10.5	1.6	9.6	9.2	8.7	8.3	7.8	7.4
Methionine + cystine	8.3	1.0	7.6	7.2	6.8	6.5	6.1	*5.7* [2]
Phenylalanine + tyrosine	13.8	3.2	12.7	12.2	*11.7* [2]	*11.2* [2]	*10.6* [2]	*10.1* [2]
Threonine	8.4	1.4	7.7	7.4	7.0	6.7	6.3	6.0
Tryptophan [3]	2.3	0.4	2.1	2.0	1.9	1.8	1.7	1.6
Valine	9.2	2.8	8.6	8.2	7.9	7.6	7.3	7.0
Arginine	11.2	3.2	10.5	10.1	9.7	9.3	*8.9* [2]	*8.5* [2]
Histidine	4.6	0.7	4.2	4.0	3.8	3.6	*3.4* [2]	*3.2* [2]

[1]Dietary protein and amino acids are based on the analysis of summit and dilution mixture. [2]Amino acids levels in italics are lower than the recommendations (Lebas, 1989). [3]Calculated values (CVB, 1991).

ation. Data are presented as least square means. Interactions between type of diet and fattening week were studied using a repeated measure analysis (SAS/STAT, 1990).

Empty body weight and live weight were used as linear covariates in the comparative slaughter trial and carcass trial analyses, respectively.

RESULTS

Zootechnical performances

The results of the fattening trial are summarised in table III. Diet composition had a highly significant effect on daily weight gain (DWG), feed intake and feed conversion (FC). Diets 1 to 3 showed high and comparable performances. From a dietary CP concentration of 150.5 g kg^{-1} (diet 4), decreased ($P < 0.05$) DWG and DFI were observed. Further dilution (diet 5 and 6) depressed DWG of the total period (6 weeks) with 6 and 9% compared to diet 1, respectively. Because the decrease in DFI was larger than in DWG, rabbits showed a more ($P < 0.05$) favourable overall FC especially on diets 5 and 6. The effect of CP concentration was age dependent (table III, fig 1). A significant interaction ($P < 0.001$) was found between type of diet and fattening week. The first 3 weeks after weaning, a decreasing CP concentration had a negative effect ($P < 0.001$) on DWG. Differences after 3 weeks of feeding between the highest and the lowest CP concentration amounted to 19%. Although diets 5 and 6 resulted in a significant lower DWG compared to diets 1 to 4, a decreasing trend was also observed from diet 1 to 4.

During the last 2 weeks, the rabbits gained more weight on the lowest protein diets (< 151 g kg^{-1}CP). The weekly results were not significant, but cumulated gain between 60 and 74 days of age was higher ($P = 0.016$) both on diet 5 and 6.

Also with diluted protein concentrations, DFI decreased ($P < 0.001$). However, during the first 4 weeks this effect was very clear ($P < 0.001$), but less pronounced afterwards, respectively $P < 0.01$ and $P < 0.05$ for weeks 5 and 6. Feed conversion was not significantly different in the first half of the fattening period but favourable ($P < 0.001$) for rabbits fed on low protein diets during the second half. However, the interaction between type of diet and fattening week was not significant both for feed intake and feed conversion. Mortality was low (average of 3.8%) and a dietary effect was not observed.

N-retention

Initial empty body weight at 32 days amounted to 705 ± 46 g (mean of four replicates of three rabbits). These young rabbits had a DM content of 284.4 ± 10.8 g kg^{-1} and contained 93.9 ± 1.0 g N kg^{-1}DM. Table IV shows the empty body composition at 74 days of age and the N intake and retention during the fattening period. Because the rabbits showed significant lower weight gain on diets 4, 5 and 6, empty body weight between treatments differed significantly ($P = 0.03$). Therefore empty body weight was used as covariate in the analysis of empty body composition at 74 days. The regression coefficient of the covariate was significant for water content ($r = -0.57$, $P = 0.004$), N content ($r = -0.44$, $P = 0.03$) and fat content ($r = 0.47$, $P = 0.02$) but not for ash ($r = -0.23$, $P > 0.05$).

Fat content increased linearly ($P < 0.01$) by 18.8% from diet 1 to diet 6 and replaced water and N (table IV). The negative relationship between carcass fat (CF) content of the empty body and daily N intake was highly significant:

$$\text{CF (g kg}^{-1}\text{DM)} = 427.06 - 33.75\ \text{N intake (g DM rabbit}^{-1}\ \text{day}^{-1}) \quad r = -0.78 \quad P < 0.008 \quad n = 24$$

Nitrogen retention increased ($P < 0.001$) from 33.9% (diet 1) to 41.3% (diet 6). A significant increase of N-retention was

Table III. The performance of rabbits during the 6-week fattening period fed diets differing in CP concentration.

Diet g CP kg^{-1}	*1–170.1*	*2–163.6*	*3–157.0*	*4–150.5*	*5–144.0*	*6–137.5*	*SEM*	P
Body weight (g)								
at 32 days	809	809	798	773	802	774	6.7	0.07
at 74 days	2717^{a}	2703^{a}	2691^{a}	2567^{b}	2597^{b}	2521^{b}	28.3	<0.001
Weight gain (g day^{-1})								
0–3 weeks	45.3^{a}	44.9^{a}	43.1^{ab}	41.4^{b}	38.7^{c}	36.6^{c}	0.9	<0.001
3–6 weeks	45.7	45.1	47.2	44.9	47.1	46.5	0.9	>0.1
0–6 weeks	45.5^{a}	45.0^{a}	45.1^{a}	43.2^{b}	42.9^{b}	41.6^{c}	0.6	<0.001
Feed intake (g day^{-1})								
0–3 weeks	115.6^{a}	115.0^{a}	111.9^{a}	105.4^{bc}	100.9^{c}	96.1^{c}	1.9	<0.001
3–6 weeks	167.9^{a}	165.5^{a}	167.5^{a}	156.5^{b}	154.7^{bc}	149.6^{c}	2.5	<0.001
0–6 weeks	141.8^{a}	140.2^{a}	139.7^{a}	131.0^{b}	127.8^{bc}	122.8^{c}	1.9	<0.001
Feed conversion								
0–3 weeks	2.56	2.57	2.60	2.55	2.62	2.63	0.04	>0.1
3–6 weeks	3.69^{a}	3.69^{a}	3.56^{ab}	3.49^{b}	3.29^{c}	3.22^{c}	0.05	<0.001
0–6 weeks	3.12^{a}	3.12^{a}	3.10^{ac}	3.03^{bc}	2.98^{bd}	2.96^{d}	0.03	<0.001
Mortality	1/39	1/39	2/39	3/39	1/39	1/39	–	NS

SEM, Standard error of means (n = 13/diet). P = level of significance. Least square means followed by the same letter are not significantly different from each other at $P = 0.05$.

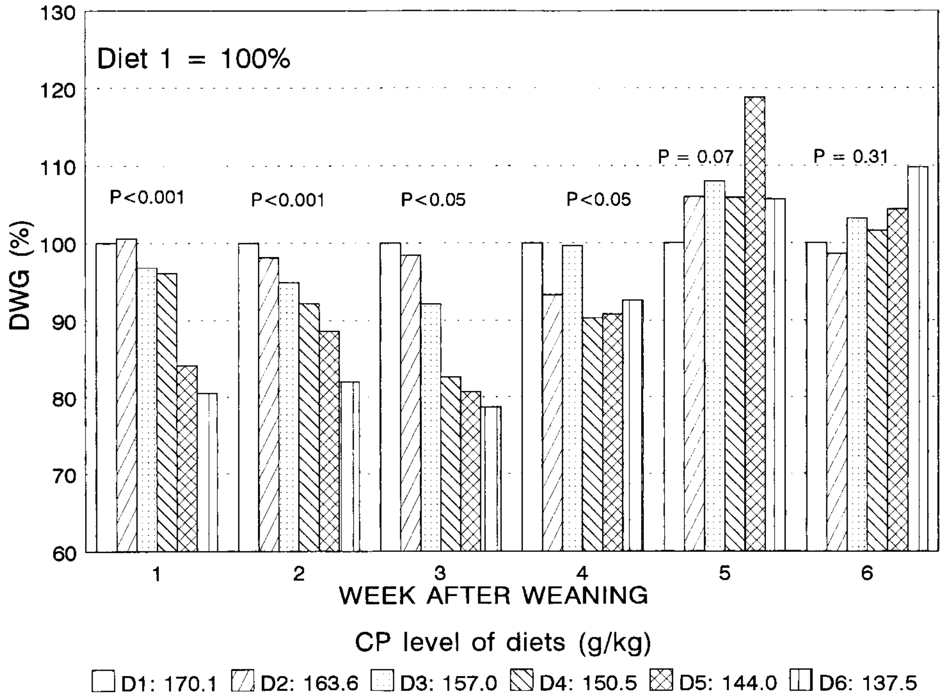

Fig 1. Effect of dietary CP level on DWG (weekly results). Expressed as percentage of the highest protein diet.

obtained from diet 4, compared to the diets with a higher CP content. The significant relationship ($r = -0.923$; $P < 0.001$) between protein intake and N-retention is given in figure 2a.

Between protein intake and N excretion a correlation coefficient of 0.993 ($P < 0.001$) was found (fig 2b). Differences in N-excretion were pronounced and reached 35% between diet 1 and 6. However, the decrease in N-excretion did not show a linear trend with CP dilution, partly due to the lower growth rate and feed intake with decreasing dietary CP content. The rabbits used for the N-balance experiment did not fully reflect the average weight and feed intake of their corresponding group (table III). Mean rabbit weight at 74 days was 70 to 80 g higher on diets 1 and 2 while for diet 3, a lower general mean was obtained. Feed intake differences were even more pronounced on these diets when comparing the overall mean with the rabbits used for the N-balance. For this reason, N-retention and excretion were also calculated using the live body weight and feed intake of all rabbits involved in the zootechnical experiment. Initial and final empty body weights per cage were calculated using the respective live body weights and the mean ratio between live and empty body weight determined in the balance trial.

N-excretion on the different diets, based on this calculation, is presented in table IV.

Table IV. Empty body composition at 74 days and N balance from 32 to 74 days of fattening.

Diet–CP (g kg^{-1})	*1–170.1*	*2–163.6*	*3–157.0*	*4–150.5*	*5–144.0*	*6–137.5*	*SEM*	*Stat signif*
Live body weight (g rabbit^{-1})[1]	2651	2624	2715	2597	2592	2522	17	0.07
Empty body weight (g rabbit^{-1})[1]	2330^{a}	2289^{abc}	2381^{ab}	2266^{c}	2252^{c}	2194^{c}	15	0.03
Empty body composition								
Water (g kg^{-1})[2]	670.0^{a}	655.9^{bc}	655.3^{bc}	659.8^{b}	658.1^{bc}	649.5^{c}	1.3	0.015
Ash (g kg^{-1}, DM)	107.6	102.4	111.2	110.6	105.5	111.3	1.9	>0.1
Nitrogen (g kg^{-1}, DM)[2]	92.1^{a}	86.4^{b}	86.3^{bc}	86.3^{b}	85.5^{b}	81.8^{c}	0.5	0.002
Fat (g kg^{-1}, DM)[2]	284.1^{a}	318.4^{b}	314.7^{b}	315.8^{b}	325.6^{b}	337.5^{b}	3.3	0.018
Daily N-intake (gDM rabbit^{-1} d^{-1})	3.72^{a}	3.63^{a}	3.49^{a}	3.13^{b}	2.94^{bc}	2.73^{c}	0.03	<0.001
N retained (g rabbit^{-1})	53.0^{a}	50.6^{ab}	52.0^{ab}	49.8^{bd}	49.2^{bd}	47.2^{cd}	0.4	0.013
N retention (percentage of intake)	33.9^{a}	33.3^{a}	34.6^{a}	37.9^{b}	39.8^{bc}	41.3^{c}	0.4	<0.001
N excretion (percentage relative of diet 1)								
– based on the killed rabbits	= 100	98.5	95.7	79.1	72.1	65.2	–	–
– based on all the rabbits[3]	= 100	94.7	89.1	78.1	69.2	61.9	–	–

Treatment means followed by the same letter are not significantly different from each other at $P = 0.05$. [1]Least square means of four cages (three rabbits per cage). [2]Least square means after covariance analysis with empty body weight as covariate. [3]Based on mean finishing weight and feed intake of all rabbits ($n = 13$ cages/diet).

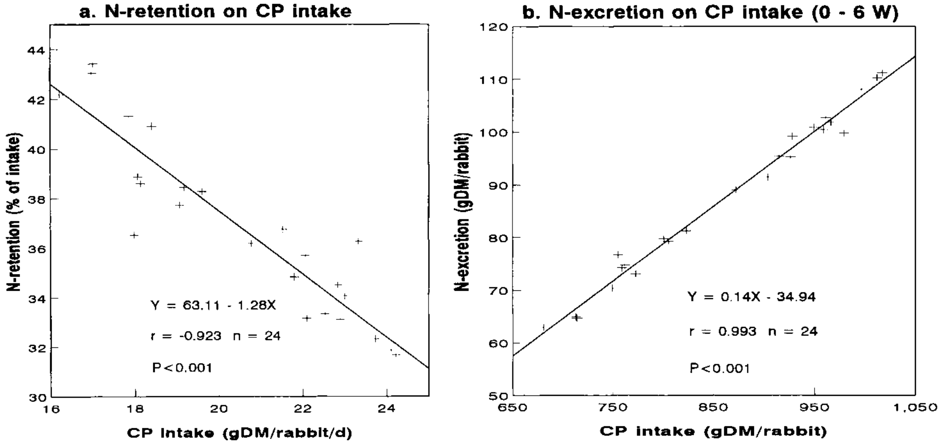

Fig 2. Effect of protein intake on N-retention (percentage of intake) and N-excretion (g/rabbit). **a.** N-retention on CP intake. **b.** N-excretion on CP intake (0–6 W).

Differences between diets were more pronounced when related to diet 1. A CP dilution of 7.7% (diet 3) reduced N-excretion with 11% without altering performances. A further dilution to a CP content of 137.5 g kg^{-1} resulted in a reduction of 38%, however, DWG worsened with 9%.

Carcass traits

Live body weight used as covariate in the analysis had a significant influence ($P < 0.001$) on the different carcass weights, skin, liver and fat weight. For these traits covariated least square means are presented in table V. However, this is not the case for the carcass dressing percentages because the covariate was not significant (P between 0.14 and 0.36). Sex had no significant effect on any of the carcass traits studied. Differences in dressing out percentages due to diet were small and not significant for most traits. Although the dissectable fat decreased with 8% from diet 1 to 6, the regression analysis did not reveal any trend with the dietary CP level. This might be partly related to the high variability of this trait and the limited number of rabbits slaughtered (n = 12/diet)

DISCUSSION

The intended high zootechnical performance level was achieved. DWG amounted to 45–45.5 g on diets with a CP content of at least 157 g kg^{-1} while FC was 3.1 between 32 and 74 days of age. Compared to other studies on the topic of protein and AA requirements, performance level in our trial was about 15% (Taboada et al, 1994) to 30% higher (Ouhayoun et al, 1979; Ouhayoun and Cheriet, 1983; Santoma et al, 1985; Lebas and Ouhayoun, 1987).

The significant interaction between the weekly DWG and dietary CP content showed that protein (amino acid) requirements of rabbits are age dependent during the post weaning period. This agrees with the only report found where the response of supplemented AA was studied in two

Table V. Effect of protein level on carcass traits at 76 days.

Diet – CP (g kg^{-1})	*1–170.1*	*2–163.6*	*3–157.0*	*4–150.5*	*5–144.0*	*6–137.5*	*SEM*	*Stat.signif*
Live body weight (g)	2997[a]	2932[ac]	2961[a]	2844[bc]	2842[bc]	2774[b]	38.4	<0.001
Skin (g)[1]	399.1[ac]	424.7[b]	412.3[bcd]	398.7[ad]	420.4[bc]	383.5[ae]	7.6	0.002
Hot carcass (g)[1]	1731	1745	1728	1726	1725	1740	10.7	>0.1
Chilled carcass (g)[1]	1680	1699	1678	1675	1681	1693	10.6	>0.1
Liver (g)[1]	108.7[ac]	95.5[b]	103.9[ab]	114.0[ac]	114.5[ac]	122.0[c]	4.4	0.003
Dissectible fat (g)[1]	94.1	97.2	96.0	91.3	91.3	86.2	4.7	>0.1
Carcass net (g)[1]	1404	1424	1401	1385	1392	1389	11.7	>0.1
Dressing percentages								
Hot carcass	59.8	60.3	59.8	59.7	59.6	60.2	0.4	>0.1
Chilled carcass	58.1	58.7	58.0	57.9	58.1	58.5	0.4	>0.1
Net carcass[2]	48.5	49.2	48.5	47.9	48.1	48.0	0.4	>0.1

[1] Least square means after covariance analysis with live body weight as covariate (n = 12/diet). [2] Chilled carcass without head, liver, kidneys, lungs, oesophagus, trachea and heart.

weekly periods instead of considering the whole fattening period in rabbits (Parigi-Bini et al, 1988) but with numerous reports for growing pigs and broilers. Before the age of 7–8 weeks rabbits claim a dietary protein content of at least 157 g kg^{-1} under our dietary conditions. Diets with a protein content below this level resulted in significant decreased DWG and DFI although lysine, threonine and methionine + cystine were above the actual recommendations. Our results are in agreement with earlier studies, which indicated that a dietary protein content below 155 g kg^{-1} results in decreased DWG when the whole fattening period is considered (Lebas, 1983; Ouhayoun and Cheriet, 1983; Santoma *et al*, 1985; Lebas and Ouhayoun, 1987).

The increased DWG ($P < 0.05$) on diets 5 and 6, during the finishing period (last 2 weeks), indicates that the protein and AA requirements decrease with increasing age. Our results suggest that if dietary lysine, methionine + cystine and threonine levels are above the requirements, low protein diets (140–150 g kg^{-1}) can be fed without deteriorating DWG during the finishing period. However, the favourable DWG during the finishing has partly to be ascribed to compensatory growth on the lowest protein diets (diets 5 and 6). Rabbits on these diets showed 3 weeks post weaning a growth retardation of 15 (diet 5) to 20% (diet 6). The increased DWG in the finishing period can therefore not only be ascribed to the fact that the low protein (amino acid) content was less restrictive but partly by the rapid growth after the growth retardation in early fattening stage. However, DWG was still 5 (diet 4 and 5) to 9% (diet 6) lower ($P < 0.01$) compared with diet 1 at the end of the fattening period. Further experiments, using phase-feeding, are necessary to separate compensatory growth from the real AA requirements during the finishing period.

In contrast with DWG, a decreased DFI was not only observed during the first fattening weeks ($P < 0.001$) but also in the 5th ($P < 0.01$) and the 6th week ($P < 0.05$) after weaning. It is well known that diets deficient in AA result in a decreased DFI (Colin, 1974; Colin and Allain, 1978; Lebas and Ouhayoun, 1987). When we relate the dietary AA levels (table II) with the feed intake data, DFI on diets having some AA levels below the recommendations (diets 4, 5 and 6) dropped significantly. This suggests that in early fattening stage, the actual recommendations of some of these AA are close to the requirements.

Decreased DFI due to the low protein (AA) content was larger (7 to 13%) than the corresponding decreased DWG and results in a more favourable FC. However, this effect was only observed during the finishing period when rabbits on the low protein diets showed an increased DWG. At least part of this significantly decreased FC during the finishing period might be explained by the difference in live weight at 8 weeks, being significantly lower on diets 4, 5 and 6.

Dressing percentages were not significantly influenced by the dietary protein content. However, in some experiments a dietary protein content below the recommendations resulted in a reduced slaughter yield due to the decreased growth rate (Ouhayoun, 1989). Dissectible fat tended to decrease with increasing protein dilution while the fat content of the empty body significantly increased. This contradiction could be explained by the decreased DWG on the low protein diets which postponed the deposit of perirenal, inguinal and scapular fat depots (Lebas and Ouhayoun, 1987; Ouhayoun, 1989). On the other hand, protein dilution changed the protein-energy ratio. A low ratio results in decreased N content and increased lipid content in agreement with Ouhayoun and Cheriet (1983) and Fraga et al (1983). At a high ratio, the excess in amino N is degraded to uric acid, which is associated with increased heat increment and reduced net energy intake in iso-energetic (DE) diets. This explains the significant positive relationship between CP intake and carcass fat content.

Our results confirm that the N-retention (percentage of intake) of rabbits increases with decreasing dietary protein content (Colin, 1974; Castrovilli Ruffini et al, 1990). Within the framework of the present experiment, the proportion of N retained increased from 33.9 (diet 1) to 41.3% (diet 6). When related to the daily protein intake (fig 2), a linear decrease of N retention was obtained (1.28% per g increment of protein intake).

Although DWG of rabbits was altered when fed diets containing less than 157 g kg^{-1} CP, the decrease in N-excretion (g/rabbit) was much larger than could be expected by the protein dilution. Further experiments are necessary to match better the CP and AA levels to the real requirements of the rabbits during the different stages of fattening. Performances equal to high protein diets could then be achieved with important reductions of the N-excretion.

Overall, the results obtained indicate that protein and AA requirements of rabbits are age dependent during the fattening period. With the protein sources and the AA balance used in this experiment, a CP level of 157 g kg^{-1} covers the protein requirements during the first weeks after weaning, when lysine, methionine + cystine and threonine are at (or above) the requirement level. The results suggest that a further protein dilution with equal performances is possible during the finishing period. Because N-retention increased with protein dilution, a decrease of N-excretion (%) larger than the corresponding protein reduction was obvious. Finally, the results demonstrated that low protein diets hold the risk of increased carcass fat content.

ACKNOWLEDGMENTS

The authors are very grateful to A Vermeulen for his skilful technical assistance and to R Lemmens for carrying the rabbits. They are also grateful to Techna animal nutrition (France) for a working grant to F Luzi.

REFERENCES

AOAC (1990) Official Methods of Analysis. *Association of Official Analytical Chemists* (15th edn), Washington DC, USA, 1, 1230 p

Blasco A, Ouhayoun J, Masoero G (1993) Harmonization of criteria and terminology in rabbit meat research. *World Rabbit Sci* 1, 3–10

Castrovilli Ruffini C, Rigamonti A, Serrantoni M (1990) Studio della escrezione azotata nel coniglio. *Riv di Conigl* 27, 33–36

Colin M (1974) Supplémentation en lysine d'un régime à base de tourteau de sésame chez le lapin. Effets sur les performances de croissance et le bilan azoté estimé par deux methodes. *Ann Zootech* 23, 119–132

Colin M, Allain D (1978) Étude du besoin en lysine du lapin en croissance en relation avec la concentration énergétique de l'aliment. *Ann Zootech* 27, 17–31

CVB (1991) *Veevoedertabel. Gegevens over voederwaarde, verteerbaarheid en samenstelling.* CVB Lelystad, The Netherlands, 422 p

D'Mello JP (1982) A comparison of two empirical methods of determining amino acid requirements. *World's Poultry Sci J* 38, 114–119

Fisher C, Morris TR (1970) The determination of the methionine requirement of laying pullets by a diet dilution technique. *Br Poultry Sci* 11, 67–82

Fraga MJ, De Blas JC, Perez E, Rodriguez JM, Perez CJ, Galvez JF (1983) Effect of diet on chemical composition of rabbits slaughtered at fixed body weights. *J Anim Sci* 56, 1097–1104

Lebas F (1983) Bases physiologiques du besoin proteique des lapins. Analyse critique des recommandations. *Cuni Sci* 1, 16–27

Lebas F (1989) Besoins nutritionnels des lapins : revue bibliographique et perspectives. *Cuni Sci* 5, 1–28

Lebas F, Ouhayoun J (1987) Incidence du niveau protéique de l'aliment, du milieu d'élevage et de la saison sur la croissance et les qualités bouchères du lapin. *Ann Zootech* 36, 421–432

Lebas F, Jouglar JY (1990) Influence du taux de phosphore alimentaire sur les performances de lapines reproductrices. In: *5es Journées Rech Cunicole en France, Paris 12-13 décembre 1990. ITAVI Ed.* Communication 48

Maertens L (1992) Selection scheme, performance level and comparative test of two lines of meat rabbits. *Proc. 5th WRSA Congress, Oregon (Corvallis). Int J Appl Rabbit Res* 15, 206–212

Maertens L, Janssen WMMA, Steenland EM, Wolters DF, Branje HEB, Jager F (1990) Tables de composition, de digestibilité et de valeur énergétique des matières premières pour lapins. In: *5^es^ Journées Rech Cunicole en France, Paris, 12–13 décembre, 1990. ITAVI Ed.* Communication 57

Moughan PJ, Schultze WH, Smith WC(1988) Amino acid requirements of the growing meat rabbit. 1. The amino acid composition of rabbit whole-body tissue. A theoretical estimate of ideal amino acid balance. *Anim Prod* 47, 297–301

Ouhayoun J (1989) La composition corporelle du lapin. *Inra Prod Anim* 2, 215–226

Ouhayoun J, Delmas D, Lebas F (1979) Influence du taux protéique de la ration sur la composition corporelle du lapin. *Ann Zootech* 28, 453–458

Ouhayoun J, Cheriet S, (1983) Valorisation comparée d'aliments à niveaux protéiques différents, par des lapins sélectionnés sur la vitesse de croissance et par des lapins provenant d'élevages traditionnels. I. Étude des performances de croissance et de la composition du gain de poids. *Ann Zootech* 32, 257–276

Parigi-Bini R, Xiccato G, Cinetto M (1988) Integrazione con metionina e lisina di sintesi di un mangime per conigli in accrescimento. *Riv di Conigl* 25, 33–38

Sas/Stat (1990) User's Guide, Version 6, Fourth Ed. *SAS Institute Inc. Cary, NC, USA.*

Santoma G, Galvez JF, Garcia P, Perez de Ayala P (1985) Nota sobre las necesidades e inclusion de lisina en dietas de conejos en cebo. *Anales del Instituto Nacional de Investigaciones Agrarias-Serie: Ganadera* 22, 83–91

Schultze WH, Smith WC, Moughan PJ (1988) Amino acid requirements of the growing meat rabbit. 2. Comparative growth performance on practical diets of equal lysine concentration but decreasing levels of other amino acids. *Anim Prod* 47, 303–310

Taboada E, Mendez J, Mateos GG, De Blas JC (1994) The response of highly productive rabbits to dietary lysine content. *Livest Prod Sci* 40, 329–337

Van Soest PJ, Robertson JB, Lewis BA (1991) Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. *J Dairy Sci* 74, 3583–3597