WORLD RABBIT SCIENCE 1996, 4(1), 19-23

EFFECT OF FAT INCLUSION IN DIETS FOR RABBITS ON THE EFFICIENCY OF DIGESTIBLE ENERGY AND PROTEIN UTILIZATION

FERNÁNDEZ C.*, FRAGA M.J.

Departamento de Producción Animal, ETSI Agrónomos, Ciudad Universitaria, 28040 MADRID, Spain.

SUMMARY: Two hundred ten Californian x New Zealand White rabbits (117 males, 93 females) were used to study the influence of diet, slaughter weight (2.0, 2.25, and 2.5 kg), and sex on the efficiency of dietary digestible energy (DE) and protein (DCP) utilization determined by using the comparative slaughter technique. Seven diets were formulated to have the same ADF level (24%), diet C had no added fat, diets T, O, and S contained 3% of added beef tallow, oleins, and soybean oil, respectively. Diets TWS, OWS, and SWS contained the same level and types of fat than diets T, O, and S but included also a 18% of toasted whole soybeans to increase dietary ether extract (EE) by 3%. Neither fat addition nor slaughter weight influenced DE efficiency, but when the dietary EE level and the weight at slaughter were increased, DCP efficiency increased (P<0.001) and decreased (P<0.05), respectively. Females had a greater DE and a lower DCP efficiencies (P<0.01) than males. Diets containing soybean oil showed a higher DE efficiency than those containing oleins.

***RÉSUMÉ : Effet sur l'efficacité de l'énergie digestible et l'utilisation des protéines de l'addition de matières grasses dans le régime des lapins*.**
Deux cent dix lapins (117 mâles et 93 femelles) Californien x Néo Zélandais ont été utilisés pour étudier l'influence de l'aliment, du poids à l'abattage (2.0, 2.25 et 2.5kg) et du sexe sur l'efficacité de l'énergie digestible (DE) et sur l'utilisation des protéines digestibles (DCP), déterminée en utilisant la technique d'abattage comparé. Sept aliments ont été formulés pour obtenir le même taux d'ADF (24%): l'aliment C n'a pas de matière grasse ajoutée, aux aliments T, O et S on a respectivement ajouté 3% de suif de boeuf, d'huile d'olive ou d'huile de soja. Les aliments TWS, OWS et SWS contiennent la même matière grasse au même taux que les aliments T, O et S mais contiennent aussi 18% de soja cuit afin d'augmenter de 3% l'extractif éthéré (EE). Ni l'addition de matière grasse ni le poids à l'abattage n'ont influencé l'efficacité de DE, mais quand le taux de EE augmente l'efficacité de DCP augmente (P<0.001) ; quand le poids à l'abattage augmente l'efficacité de DCP diminue (P<0.05). L'efficacité de DE est plus grande et celle de DCP plus faible chez les femelles que chez les mâles. Les aliments contenant de l'huile de soja ont une efficacité de DE supérieure à ceux contenant de l'oléine.

INTRODUCTION

An increment in dietary fibre decreases both dietary DE content and the overall efficiency for use of DE in growing rabbits (ORTIZ *et al.*, 1989; GARCÍA *et al.*, 1992, 1993). Fat inclusion in fibrous diets can compensate the negative effect of fibre on energy digestibility (FERNÁNDEZ *et al.*, 1994). However, data on effect of fat addition on metabolic efficiency of energy are not conclusive. Thus, ORTIZ *et al.* (1989) using a calorimetric method did not observed effect of lard addition on overall efficiency of ME utilization. On the contrary, REID *et al.* (1980) using the comparative slaughter technique observed an increase in DE efficiency for growth with the addition of 5% tallow to diets at different protein levels. In the same way, studies with other animal species (JUST *et al.*, 1983) showed that fat addition increased the overall growth ME efficiency of the diet.

The aim of this work was to study the influence of fat addition to fibrous diets on digestible energy and protein efficiencies. Animals were slaughtered at different weights (2.0, 2.25, and 2.5 kg) to study how the addition of fat would affect efficiency at different periods of growth.

MATERIAL AND METHODS

Diets.

Seven diets were formulated. The control diet (C) had a high level of fibre (22.3% of ADF in DM) and had no added fat (Table 1). The other six experimental diets contained 3% added fat. The added fats of diets T, O, and S were beef tallow, oleins (a by-product of the oil refining industry [mixture of soybean and sunflower oleins]), and soybean oil, respectively. The other three diets, TWS, OWS, and SWS contained the same types of fat but also 18% of toasted whole soybeans (WS) to increase dietary fat content by 3% and allow a good quality and texture of pellet. The protein concentrates were increased when fat was added to maintain constant the digestible protein:digestible energy ratio. Balance of diets was obtained using the recommended values of LEBAS (1980) for essential amino acids, calcium, phosphorus, sodium, and chlorine. Diets were supplemented with a vitamin-mineral premix (0.5%) and with a binder (0.62 to 0.80%). All diets were pelleted. Chemical analysis of diets were conducted according the methods of AOAC (1984) for DM, ether extract, and crude protein,

Table 1: Ingredient and chemical composition of diets.

		Added fat, 3%	
Ingredient, %	Control	Without whole soybean	With whole soybean
Barley grain	22	16	14
Wheat bran	8	6	3
Soybean meal (44% CP)	11	14	-
Heated whole soybeans	-	-	18
Sunflower meal (38% CP)	7	9	13
Alfalfa hay	30	30	27
Wheat straw	20	20	20
Fat (1)	-	3	3
Methionine	0.1	0.1	0.08
Limestone	0.3	0.4	0.5
Sodium chloride	0.3	0.3	0.3
Vitamin/mineral mix (2)	0.5	0.5	0.5
Bentonite (binder)	0.8	0.7	0.62
Chemical analysis, % DM(3)			
DM	93.7	93.8	94.5
CP	18.1	18.6	19.1
ADF	22.3	24.2	25.3
Ether extract	1.9	5.2	8.4
GE, kJ/g of DM	18.2	18.7	19.5
DE, kJ/g of DM(4)	10.3	10.9	11.8

(1) Fat was contributed by beef tallow, oleins, and soybean oil.
(2) Provided by Trow Ibérica S.A. to give (in mg or IU per kilogram of diet): S, 345; Mg, 261; Mn, 19.5; Zn, 58.75; I, 1.25; Fe, 107.77; Cu, 11; Co, 0.7; thiamin, 1; riboflavin, 1.9; pyridoxine, 1; nicotinic acid, 20; choline, 260; vitamin K3, 1; dl-a-tocopheryl acetate, 20; vitamin A, 8,375 IU; vitamin D3, 650 IU.
(3) The chemical analysis for the diets with added fat is the average value for the three diets within each classification.
(4) The digestible energy (DE) content of diets was determined by FERNÁNDEZ *et al.* (1994).

and that of VAN SOEST (1963) for ADF. Gross energy was determined using an adiabatic bomb calorimeter. The fatty acid composition of added fats and diets (Table 2) was determined as described by FERNÁNDEZ *et al.* (1994).

Animals and Procedures.

Ten Californian x New Zealand White rabbits were assigned at random to each combination of treatments (diet x slaughter weight), so that a total of 210 animals were used. Sex was not determined until the rabbits were slaughtered; the number of males and females were 117 and 93, respectively. Rabbits were weaned at 28 d weighing 606 g ± 45.5 (SD) and were given *ad libitum* access to feed until they reached the preestablished slaughter weight. Animals were housed individually in wired cages (24.5 cm x 61 cm x 31.5 cm). Feed intake and length of the period from weaning to slaughter were recorded for each rabbit. During the trial, rabbits were kept in a building in which the environment was partially controlled (18.6 ± 2.8°C as average temperature). The rabbits were handled according to the principles for the care of animals in experimentation.

Energy, protein, and fat contents of the body of rabbits at the beginning of the growing period were estimated using the prediction equations of body composition as a function of BW at weaning obtained at similar weights and under similar conditions by MOTTA (1990). Data of body chemical composition at the end of the experimental period were obtained by FERNÁNDEZ and FRAGA (1996). During the trial seven rabbits died; the number of rabbits used for the statistical analysis is indicated in Tables 3 and 4.

Statistical Analysis.

Data were analyzed as a completely randomized design using the GLM procedure of SAS (1985) with type of diet, sex, slaughter weight and their interactions as the main effects. Daily energy and protein retention were introduced as covariates in efficiency analyses and the data are presented as least square means. The comparative analyses among means to test dietary effects were carried out using the following orthogonal contrasts: diet C *vs* diets containing added fat (diets T, O, S, TWS, OWS, and SWS); diets containing 3% added fat without WS (diets T, O, and S) *vs* diets containing 3% added fat with WS (diets TWS, OWS, and SWS); diet with animal fat without WS (diet T) *vs* diets with vegetal fats without WS (diets O and S); diets with vegetal fats without WS (diet O vs diet S); diet with animal fat with WS (diet TWS) vs diets with vegetal fats with WS (diets OWS and SWS); and diets with vegetal fat with WS (diet OWS *vs* diet SWS). Polynomial orthogonal contrasts were used to test linear and quadratic effects of slaughter weight. The effect of sex was tested by a t-test.

RESULTS AND DISCUSSION

Digestible energy, digestible crude protein (DCP), and digestible ether extract (DEE) intakes were calculated from DM intake during the growing period and from digestibility of diets previously obtained (FERNÁNDEZ *et al.*, 1994).

The protein and energy retentions were calculated (see Material and Methods section) from the data of MOTTA (1990) and FERNÁNDEZ and FRAGA (1996). The efficiencies of utilization of DE and DCP for growth were adjusted by energy and protein retentions, respectively, used as covariates.

Effect of diet (Table 3).

The lack of effect of dietary ether extract level on both, DE intake (1040 kJ x $kg^{-0.75}$ x d^{-1}, as average) and energy retention (267.9 kJ x $kg^{-0.75}$ x d^{-1}, as

Table 2 : Fatty acid composition (weight, %) of ether extract of diets.

Diets(1)	C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	Free fatty acids g/kg
C	-	15.6	-	4.0	14.4	52.9	13.1	20.5
T	4.7	20.7	4.8	10.0	26.7	27.2	5.8	6.6
O	-	15.7	-	3.6	15.6	58.2	6.8	91.3
S	-	11.5	-	3.3	17.1	59.5	8.5	8.9
TWS	1.9	17.7	1.7	7.4	24.6	41.0	5.6	29.8
OWS	-	10.3	-	3.6	18.5	60.9	6.6	60.7
SWS	-	12.4	-	3.3	17.6	59.2	7.5	20.7

(1)C = Control, T = 3% beef tallow, O = 3% oleins, S = 3% soybean oil, TWS = 3% beef tallow + 18% whole soybean (WS), OWS = 3% oleins + 18% WS, SWS = 3% soybean oil + 18% WS.

average) determinates that the fat or WS addition does not affect the overall energy efficiency (25.7%, as average). This value is higher than that obtained by DE BLAS *et al.* (1985) (which varied from 17.7 to 21.3% according to the dietary fibre level) working with rabbits of Spanish Giant breed at the same weight interval using the comparative slaughter technique (CST) as in this work. The higher partial efficiency of DE for energy retention as fat rather than as protein obtained by DE BLAS *et al.* (1985) may explain this difference. Body fat content of Spanish Giant rabbits (5.7%, as average) was lower than that of the rabbits used in the present work (11.7%, FERNÁNDEZ and FRAGA, 1996) due to different maturity patterns of both breeds. On the contrary, GARCÍA *et al.* (1993) using Californian x New Zealand White rabbits with a similar body fat content to ours and using also the CST reported a value of overall energy efficiency (25%) close to that obtained in this work.

The lack of effect of fat addition to diet on overall energy efficiency was also observed by ORTIZ *et al.* (1989) with New Zealand rabbits and using an indirect calorimetric technique. The effect of dietary fat on DE efficiency for growth could be evident using partial instead overall DE efficiency. The DE ingested that was used for growth was estimated using the maintenance DE requirements value obtained by PARTRIDGE *et al.* (1989) with rabbits of Californian x New Zealand White breed and similar slaughter weight (377 $kJ \times kg^{-0.75} \times d^{-1}$). The partial DE efficiency was affected neither by fat nor by WS addition to diet (40.2% as average). On the contrary, REID *et al.* (1980) reported an increase in partial DE efficiency for growth from 39 to 53% when added 5% of beef tallow to diet. However, these values were obtained in other conditions (rabbits of New Zealand breed during a short fattening period). More data are necessary to clarify if in a specie as the rabbit, in which the body fat content is very low, the fat addition can improve digestible energy efficiency for growth.

The DCP intake decreases as the dietary ether extract content increases ($P<0.001$). As type of diet did not affect protein retention (5.15 $g \times kg^{-0.75} \times d^{-1}$, as average), the overall DCP efficiency increases ($P<0.001$) with the increase of dietary ether extract (36.8, 38.4 and 39.0% for the control diet and the diets with 3% of fat without and with WS, respectively). This fact may indicate that digestible protein:digestible

Table 3 : Effect of diet on energy, ether extract and nitrogen balance (per $kg^{0.75}$ and day) and on efficiency (%) of utilization of DE (energy retention x 100/total DE intake) and DCP (protein retention x 100/total DP intake).

	Diets(1)								
	C	T	O	S	TWS	OWS	SWS	SEM	Contr.(2,3)
n	29	29	29	28	29	30	29		
Digestible energy intake, kJ	1043	1036	1043	1006	1068	1016	1069	9.92	NS
Digestible protein intake, g	14.3	13.7	13.6	13.6	13.1	12.7	13.2	0.21	A***,B**
Digestible ether extract intake, g	0.97	3.43	3.37	3.61	5.81	5.79	5.93	0.06	A***,B***,D*
Energy retention, kJ	271.6	260.4	257.9	269.2	275.5	262.5	278.7	4.63	NS
Protein retention, g	5.28	5.30	5.23	5.19	5.03	4.96	5.05	0.16	NS
Fat retention, g	3.56	3.38	3.68	3.86	4.02	3.68	4.30	0.06	B*, F*
Digestible energy efficiency for growth, %(4)	26.1	25.1	24.8	26.7	25.7	25.8	26.0	0.33	D*
Digestible crude protein efficiency for growth, %(5)	36.8	38.6	38.4	38.3	39.0	39.4	38.6	0.48	A***,B***

(1)C = Control, T = 3% beef tallow, O = 3% oleins, S = 3% soybean oil, TWS = 3% beef tallow + 18% whole soybean (WS), OWS = 3% oleins + 18% WS, SWS = 3% soybean oil + 18% WS.
(2)Contrasts: A: Diet C *vs* diets containing added fat; B: Diets containing 3% added fat without WS *vs* diets containing 3% added fat with WS; D: Diet O *vs* Diet S; F: Diet OWS *vs* Diet SWS.
(3)Levels of significance: * $P<0.05$; ** $P<0.01$; *** $P<0.001$.
(4)Energy retention x 100/total digestible energy intake.
(5)Protein retention x 100/total digestible crude protein intake.

Table 4: Effect of slaughter weight and sex on energy, ether extract and nitrogen balance (per $kg^{0.75}$ and day) and on efficiency of utilization of DE (energy retention x 100/total DE intake) and DCP (protein retention x 100/total DCP intake).

	Slaughter weight, kg				Sex		
	2.0	2.25	2.50	SEM	Male	Female	SEM
n	67	68	68		113	90	
Digestible energy intake, kJ(1,2)	1072	1031	1028	9.86	1056	1017	10.30
Digestible protein intake, g(1,2)	13.8	13.3	13.3	0.13	13.7	13.2	0.12
Digestible ether extract intake, g(1,2)	4.35	4.12	4.07	0.04	4.24	4.11	0.01
Energy retention, kJ	282.5	260.8	265.4	4.60	269.5	265.5	4.60
Protein retention, g(3,4)	5.42	5.13	4.71	0.10	5.21	4.82	0.09
Fat retention, g(5)	3.85	3.53	3.98	0.14	3.78	3.83	0.01
Digestible energy efficiency for growth, %(6)	26.3	25.3	25.8	0.21	25.4	26.2	0.19
Digestible crude protein efficiency for growth, %(6,7)	39.2	38.5	35.4	0.57	38.1	36.6	0.27

(1,3,7) Linear effect of slaughter weight (P<0.1, 0.001 and 0.05, respectively).
(2,4,6) Effect of sex (P 0.05, 0.001 and 0.01, respectively).
(5) Quadratic effect of slaughter weight (P<0.05).

energy ratios of control diet (13.7 g $\times$ MJ^{-1}) and of diets with 3% of added fat (13.2 g $\times$ MJ^{-1}, as average) are high to promove the best results in terms of DCP utilization.

Digestible ether extract intake increased (P<0.001) with fat and WS addition, but retained fat only increased (P<0.05) with WS addition.

There was no difference between animal and vegetal fat utilization in DE efficiency, in spite of the diets T and TWS contained higher levels of C14:0, C16:0 and C16:1 than the other diets (Table 2). However, the diets with oleins (that contained high free fatty acid values) presented lower values than those with soybean oil. Both, DEE intake and DE efficiency for growth were lower (P<0.05) in the diet with 3% olein (diet O) than in diet with 3% soybean oil (diet S). The retention of fat was lower in the diet with olein and WS (diet OWS) than in the diet with soybean oil and WS (diet SWS).

Effect of weight at slaughter and sex (Table 4).

Digestible energy, DCP, and DEE intakes tended (P<0.1) to decrease as the weight at slaughter increased. Neither the retained energy, nor the efficiency of DE for growth were affected by the slaughter weight. The lack of influence of slaughter weight (between 2.0 and 2.5 kg) on overall efficiency of DE was also reported by GARCÍA *et al.* (1992, 1993). Protein retention linearly decreased (from 5.4 to 4.7 g $\times$ $kg^{-0.75}$ $\times$ d^{-1}, P<0.001) when slaughter weight increased, showing the lower ability for protein synthesis in the later stages of the growing period. As a consequence, the efficiency of crude protein utilization decreased continuously (from 39.2 to 35.4%) as slaughter weight increased. The same result was obtained by DE BLAS *et al.* (1985) and GARCÍA *et al.* (1992, 1993).

Digestible energy, DCP, and DEE intakes were higher (P<0.05) in males than in females. Males retained more protein (P<0.001) and were more efficient in the protein utilization for growth (P<0.01) than females. Sex of animals did not affect the retention of energy, and as consequence energy efficiency for growth was higher (P<0.01) in females. There is not previous information about the influence of sex on feed utilization, but these results agree with the reports of the effect of sex on body composition (FRAGA *et al.*, 1983, FERNÁNDEZ and FRAGA, 1996).

Acknowledgments: The authors are grateful to Dr. J.C. DE BLAS for his help during the preparation of this paper. Financial support was provided by the Spanish Comisión Interministerial de Ciencia y Tecnología (ALI89-0386).

Received :June 26, 1995
Accepted :February 20, 1996.

BIBLIOGRAPHY

AOAC, 1984. Official Methods of Analysis (14th Ed.). *Association of Official Analytical Chemists, Washington, DC.*

DE BLAS J.C., FRAGA M.J., RODRÍGUEZ J.M., 1985. Units for feed evaluation and requirements for commercially grown rabbits. *J. Anim. Sci., 60, 1021-1028.*

FERNÁNDEZ C., FRAGA M.J., 1996. The effect of fat inclusion on growth performance, carcass characteristics, and chemical composition of rabbits. *J. Anim. Sci. (in press).*

FERNÁNDEZ C., COBOS A., FRAGA M.J., 1994. The effect of fat inclusion on diet digestibility in growing rabbits. *J. Anim. Sci., 72, 1508-1515.*

FRAGA M.J., DE BLAS J.C., PÉREZ E., RODRÍGUEZ J.M., PÉREZ C.J. GÁLVEZ J.F., 1983. Effect of diet on chemical composition of rabbits slaughtered at fixed body weights. *J.Anim. Sci. 56, 1097-1104.*

GARCÍA G., GÁLVEZ J.F., DE BLAS J.C., 1992. Substitution of barley grain by sugar-beet pulp in diets for finishing rabbits. 1. Effect on energy and nitrogen balance. *J. Appl. Rabbit Res., **15**, 1008-1016.*

GARCÍA G., GÁLVEZ J.F., DE BLAS J.C., 1993. Effect of substitution of sugar-beet pulp for barley in diets for finishing rabbits on growth performance and on energy and nitrogen efficiency. *J. Anim. Sci., 71, 1823-1830.*

JUST A., JORGENSEN H., FERNÁNDEZ J.A., 1983. Maintenance requirements and the net energy value of different diets for growth in pigs. *Liv. Prod. Sci., **10**, 487-506.*

LEBAS F., 1980. Les recherches sur l'alimentation du lapin: Evolution au cours des 20 dernières années et perspectives d'avenir. *Proc. II World Rabbit Congr., Barcelona, vol. **II**, 1-17.*

MOTTA W., 1990. Efecto de la sustitución parcial de heno de alfalfa por orujo de uva o pulpa de remolacha sobre la utilización de la dieta y los rendimientos productivos en conejos en crecimiento. *Ph.D. Dissertation. Universidad Politécnica de Madrid.*

ORTIZ V., DE BLAS J.C., SANZ E., 1989. Effect of dietary fibre and fat content on energy balance in fattening rabbits. *J. Appl. Rabbit Res., 12, 159-162.*

PARTRIDGE G.G., GARTHWAITE P.H., FINDLAY M., 1989. Protein and energy retention by growing rabbits offered diets with increasing proportions of fibre. *J. Agric. Sci., Camb., **112**, 171-178.*

REID B.L., MAIORINO R.M., PARKER D.J., SCHURG W.A., 1980. Estimates of energy needs for protein and fat deposition in growing rabbits. *Nutr. Rep. Int., 21, 157-162.*

SAS, 1985. SAS User's Guide: Statistics (Version 5 Ed.). *SAS Inst. Inc., Cary NC, USA.*

VAN SOEST P.J., 1963. Use of detergents in the analysis of fibrous feeds. 2. A rapid method for the determination of fibre and lignin. *J. Assoc. Off. Anal. Chem., **46**, 829-835.*