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DIETARY FATTY ACID PROFILE: EFFECTS ON CAECAL FERMENTATION AND PERFORMANCE OF YOUNG AND FATTENING RABBITS

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Abstract: The present work was performed to study the effect of dietary inclusion of different fatty acid combinations (saturated, n-3 and n-6 polyunsaturated fatty acids; PUFA) on caecal fermentation activity, feed intake, growth rate and feed efficiency of young rabbits around weaning (17 to 44 d) and fattening rabbits (28 to 63 d of age). Five diets were formulated using the same raw materials and including 3% of lard (A diet, rich in saturated fat), sunflower oil (S diet, rich in n-6 PUFA), linseed oil (L diet, rich in n-3 PUFA), sunflower oil and lard at 1:1 rate (SA diet), or linseed oil and lard at 1:1 rate (LA diet). In the first trial, the effect of the 5 diets on rabbit performance was evaluated in a fattening period from 28 to 63 d of age, with 490 rabbits allocated in individual cages; mortality rates were measured with 1670 rabbits (750 allocated in individual cages and 920 in collective cages, 8 rabbits/cage). In the second trial, 120 young rabbits were used from 17 to 44 d of age, weaned at 28 d, allocated in collective cages and randomly fed with A, S or L diets, evaluating performance and gut weight and caecum fermentation activity. The use of animal fat or vegetable oil and the richness in n-3 or n-6 PUFA of vegetable oils had no significant effect on the feed intake (130 g dry matter/d) and growth rate of fattening rabbits (45.5 g/d), but the inclusion of sunflower oil in diet improved feed conversion rate (2.79 for S diet *vs.* 2.87 for the rest of diets; $P<0.01$). Mortality rate was lower when vegetable oils were included in diet (34 and 37% for S and L diets respectively *vs.* 45% for A diet; $P<0.05$). Feed intake and growth rate increased quickly from 17 to 44 d, but only small occasional differences were recorded in growth rate of young rabbits, in favour of rabbits receiving animal fat from 17 to 21 d ($P<0.05$) or sunflower oil from 28 to 30 d ($P<0.05$). Caecal traits of rabbits at 30 and 44 d of age were similar for the different dietary groups, although butyric acid concentration in caecum content at 44 d was the lowest ($P<0.05$) with L diet.

Key Words: growing rabbits, saturated fat, n-3, n-6, mortality rate.

INTRODUCTION

Human dietary recommendations often focus on reducing the consumption of saturated fatty acids (SFA) and increasing consumption of polyunsaturated fatty acids (PUFA), especially long chain n-3 PUFA, which have many known beneficial effects. However, it seems that both n-6 and n-3 PUFA have independent health effects in hepatic (Aguilera *et al.*, 2005) and cardiovascular diseases (Burdge and Calder, 2006). The absolute intake of n-3 PUFA could be much more important than n-6/n-3 ratio and further studies are required to determine whether or not n-3 fatty acids are important functional supplements with no adverse effect (Dalle Zotte and Szendrő, 2011).

Meat is one of the main sources of fat in the human diet and it has been demonstrated that its fatty acid composition can be modified by altering the fat composition of the animal diet (Hoz *et al.,* 2003; Wood *et al.,* 2003; Tres *et al.*, 2008, 2009).

Carcass fatty acid composition may be easily controlled or manipulated by dietary means because the dietary fatty acids are bound to the adipose tissue without great changes, which consequently reflects the composition of the original fats ingested (Bernardini *et al.,* 1999; Fernández-Carmona *et al.*, 2000; Ander *et al.,* 2010; Hernández and Dalle Zotte, 2010).

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Most works showed that the use of either animal or vegetable fat did not appear to have a substantial effect during the growth period, but there are some contradictory results and the issue of dietary fat type and growth performance does not yet form a clear picture (Fernández-Carmona *et al.*, 2000). Moreover, relevant changes in digestive physiology occur around weaning when solid intake begins (17-18 d old) and diet has a great influence (Soler *et al.*, 2005), although the effect of dietary fatty acids profile (Eiben et al., 2010) and oxidation level (Casado et al., 2011) seem to be moderate, and Casado *et al.* (2010) found no differences in the digestibility coefficient between diets including different PUFA sources.

To contribute knowledge on the possible effect of type of dietary fat in growing rabbits, the present work was designed to evaluate the effect of dietary inclusion of fats of different origin (vegetal or animal) on the performance and caecal traits in rabbit around weaning (17 to 44 d of age) and during fattening (28 to 63 d).

MATERIALS AND METHODS

Experimental diets

Five isoenergetic, isoproteic and isofibrous pelleted diets were formulated according to the recommendations of De Blas and Mateos (2010), using the same raw materials and including 30 g/kg dry matter (DM) of different added fats stabilised with butyl-hydroxytoluene (100 mg/kg): lard (animal fat rich in SFA, A diet), sunflower oil (n-6 PUFA oil, S diet), linseed oil (n-3 PUFA oil; L diet), lard and sunflower oil at 1:1 rate (SA diet) or lard and linseed oil at 1:1 rate (LA diet). The ingredients and average chemical composition of the experimental diets are shown in Table 1. All diets included robenidine (66 mg/kg), except in the last week of the fattening period.

Animal and experimental procedure

Housing, husbandry and slaughtering conditions followed the current recommendation on principles of ethical care and protection of animals used for experimental purposes in the European Union (2003) and all trials were subjected to approval by the Animal Protocol Review Committee of the Polytechnic University of Valencia.

Two trials were carried out. In the first study (fattening trial) a total of 1670 (585±4 g) weaned rabbits aged 28 d were randomly housed: 750 in individual cages (150 per treatment) and 920 in collective cages (184 per treatment; 8 rabbits/cage) and had free access to one of the experimental diets from 28 to 63 d of age. Daily weight gain (DWG)

Table 1: Ingredients of basal mixture and fat included in 5 experimental diets and average chemical composition.

Ingredients	g/kg DM	Chemical composition	g/kg DM
Wheat bran	150	Dry matter (DM, g/kg)	915
Beet pulp	280	Ash	95
Alfalfa hay	250	Ether Extract	49
Sunflower meal	200	Starch	57
Soybean meal	60	Crude Protein	194
Fat (according to diet)[1]	30	Crude Fibre	181
DL-methionine	1	Neutral Detergent Fibre	454
L-lysine HCL	3	Acid Detergent Fibre	223
L-threonine	1	Acid Detergent Lignin	68
Calcium carbonate	2	Gross Energy (MJ/kg DM)	18.4
Dicalcium phosphate	12	Digestible Protein[4]	137
Sodium chloride	5	Digestible Energy (MJ/kg DM)[4]	11.0
Cycostat 66G[2]	1		
Vitamin/mineral mixture[3]	5		

[1] Diets: A, animal fat (lard); L, linseed oil; S, Sunflower oil; LA, linseed oil and lard 1:1; SA, sunflowers oil and lard 1:1.

[2] Contain: robenidine 66 g/kg.

[3] Per kg of feed: Vitamin A, 8375 IU; Vitamin D_3, 750 IU; Vitamin E, 70 mg; Vitamin K_3, 1 mg; Vitamin B_1, 1 mg; Vitamin B_2, 2 mg; Vitamin B_6, 1 mg; Nicotinic acid, 20 mg; Choline chloride, 250 mg; Mg, 290 mg; Mn, 20 mg; Zn, 60 mg; I, 1.25 mg; Fe, 26 mg; Cu, 10 mg; Co, 0.7; Butyl hydroxylanysole+ethoxiquin, 4 mg.

[4] Apparent *in vivo* digestibility coefficients obtained by Casado *et al.* (2010).

and feed intake (DFI) were recorded and feed conversion rates (FCR) calculated for 490 animals that finished the trial in individual cages. Total mortality during fattening period was calculated considering all animals. The experiment was carried out following the recommendations for applied nutrition research in rabbits described by the European Group on Rabbit Nutrition (Fernández-Carmona *et al.*, 2005).

A coetaneous trial was carried out with 120 (318±5 g) suckling rabbits from 17 to 44 d of age to evaluate the performance and caecal activity around weaning (17 to 28 d of age) and post-weaning periods (28 to 44 d). The rabbits were fed with A, S and L diets throughout the trial. At 17 d, the kits from different mothers, which were all fed with a lactating diet, were randomly distributed in 3 treatments, forming 12 mixed litters of 10 kits each (4 litters per treatment). After weaning, the animals from each litter were allocated to collective cages (50×80×32 cm high; 8 rabbit/cage) and fed *ad libitum* with the same diet. Daily feed intake of lactating and growing litters and milk supply during lactation were recorded at 21, 25, 28, 30 and 44 d. Live weight (LW) of rabbits was recorded at 17, 21, 25, 28, 30 and 44 d. Dead rabbits were removed daily and DFI of the cage was corrected according to the number of rabbits alive at all times.

Sampling of caecal content

Four rabbits per cage were slaughtered at 30 and 44 d of age, from 8 to 11 p.m., and the full gastro-intestinal tract (GIT) and caecum were weighed and sampled. After measuring the pH of caecal content (pH-meter GLP21, CRISON, Alella, Spain), aliquots of roughly 1 g were weighed and diluted with 3 mL of 2% sulphuric acid solution for ammonia nitrogen analysis (NH_3), or with 2 mL of 2% orto-phosphoric acid for volatile fatty acids analysis (VFA). Samples for VFA analysis were centrifuged at 10000*g* for 10 min and the liquid phase was collected into Eppendorf vials of 1.5 mL. Finally, all samples were stored at –80°C until analysis. The remaining caecal content was stored at –20°C until DM analysis.

Dry matter and NH_3 in caecal contents were respectively determined by duplicate according to AOAC (2000), following procedures nº 934.01 and 973.49, respectively. Capillary gas chromatography was used for VFA determination as follows: *i)* Samples were filtered through 0.45 µm cellulose syringe filters and 0.1 mL of an internal standard solution (0.4 g of 4-methyl-valeric acid diluted in 100 mL of deionised water) was added to 0.9 mL of filtrate sample. *ii)* 1 µL from each sample was injected into a gas chromatograph (Fisons 8000 series, Milan, Italy) equipped with a split/splitless injector and a FID detector. Separation of VFA was done in a DB-FFAP capillary column (30 m×0.25 mm×0.25 µm of film thickness (J&W Scientific, Folsom, CA, USA). The carrier gas was N_2 at a constant pressure of 120 kPa. Detector and injector temperatures were set at 245°C and 150°C, respectively. The initial oven temperature was set at 115°C, held for 5 min and increased to 230°C at 8.5°C/min and finally maintained at this temperature for 10 min. VFA were identified by comparing their retention times with a standard 46975-U (Supelco®, Bellafonte, PA, USA). VFA response factors obtained from this standard were finally used to calculate the VFA concentration in samples.

Chemical analyses of diets

Feeds were analysed in duplicate using AOAC methods (AOAC, 2000) and following the recommendations of Gidenne *et al.* (2001). Dry matter was determined following AOAC official method 934.01, crude protein (CP) using a Kjeltec 2300 analyser (Foss, Höganäs, Sweden) and following AOAC official method 976.05, and ether extract and ash contents following the protocols described by AOAC methods 920.39 and 942.05, respectively. Crude fibre (CF), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) of diets were determined using filter bags and a Fiber Analyzer A220 (ANKOM, Fairport, NY, USA) and following AOAC official methods, 978.10 for CF and 973.18 for ADF and ADL (AOAC, 2000), and Mertens (2002) for NDF. Finally, gross energy (GE) content was determined by combustion in an adiabatic calorimetric pump.

Fatty acids of dietary lipid were determined in duplicate by direct derivatisation as previously described by O´Fallon *et al.* (2007). Individual fatty acids were identified by comparing their retention times with a standard of fatty acid methyl esters 47885-U from Supelco® (Bellafonte, PA, USA). The methyl esters were analysed in a Focus Gas Chromatograph (Thermo, Milan, Italy), equipped with a split/splitless injector and a flame ionisation detector. Separation was performed in an SPTM 2560 capillary column (Supelco®, Bellafonte, PA, USA) (100 m×0.25 mm×0.2 µm film) with a helium flow of 1.1 mL/min, according to the following temperature gradient: 140°C initial temperature for

5 min, followed by a linear gradient of 4°C/min until reaching 240°C, temperature which was maintained for 30 min. The detector and injector were kept at 260°C.

As expected, diets had different fatty acids profiles depending on the added fat, as shown in Table 2; consequently, the n-6/n-3 ratio varied from 19.5 to 0.8.

Statistical analysis

Data (DWG, DFI and FCR) from the fattening trial were analysed using the GLM procedure from Statistical Analysis Systems (SAS, 2002), with a model that included the diet (A, S, L, SA and LA) as fixed effect and the LW at 28 d of age as a covariate. Mean comparisons were performed using a t-test and the following contrasts were performed to analyse the effect of type of fat on performance: sunflower oil *vs.* lard [S–½(SA+A)] and sunflower oil *vs.* linseed oil [S–½(LA+L)]. A chi-squared test was used to analyse the frequencies associated with mortality.

Data on DWG of rabbits and DFI of litters around weaning were analysed using the PROC MIXED procedure (SAS, 2002), according to a repeated measures design that takes into account the variation between and within animals. Covariance structures of mixed procedure were objectively compared using the most severe criteria (Schwarz Bayesian criterion) as suggested by Littell *et al.* (1998), with the data being better fitted to an autoregressive covariance structure. The model included the control days (21, 25, 28 and 30 d), the diet (A, S and L) and their interaction as fixed effects. Random terms included the permanent effect of each animal (p) and the error term (e), both assumed to have an average of zero and variance σ_p^2 and σ_e^2, respectively. Statistical analyses of the gastro-intestinal tract and caecal traits were carried out using a GLM (SAS, 2002) as a completely randomised design with a model accounting for the fixed effect of the experimental diet (A, S and L), the age (30 and 44 d) and their interaction, and using the LW as covariate for full GIT and caecum weights. In this latter analysis, mean comparison was performed using a t-test and to analyse the effect of animal fat *vs.* vegetable oil the contrast [A–½(S+L)] was calculated.

RESULTS AND DISCUSSION

No significant effect of the dietary fatty acid profile on the DWG, DFI and LW at 63 d of fattening rabbits was observed, being on average 45.5 g/d, 136 g DM/d and 2167 g, respectively (Table 3). However, rabbits fed with S diet had a lower FCR in relation to SA and LA diets (–0.12; $P<0.01$). In another experiment with these same diets, Pla *et al.* (2008) noticed a 5% lower LW at 63 d with S and L diets than with A diet.

The effect of different types of fats on growth performance is controversial (Fernández-Carmona *et al.*, 2000). Several authors have found that daily feed intake and daily weight gain of rabbits seem to be unaffected by the inclusion of

Table 2: Fatty acid profile (% of total fatty acids) in experimental diets including different type of fat.

	Dietary fat inclusion (g/kg dry matter)				
Diet	S	SA	A	LA	L
Lard	0	15	30	15	0
Sunflower oil	30	15	0	0	0
Linseed oil	0	0	0	15	30
C14:0 (myristic)	0.31	1.34	2.28	1.47	0.19
C16:0 (palmitic)	12.1	18.6	25.8	19.2	12.1
C16:1 (palmitoleic)	0.18	0.91	1.64	0.96	0.11
C18:0 (stearic)	4.19	9.83	15.51	9.43	3.44
C18:1n-9 (oleic)	19.4	23.7	28.3	22.7	18.0
C18:1n-7 (vaccenic)	0.67	0.96	1.26	1.00	0.76
C18:2n-6 (linoleic)	60.2	41.5	21.9	25.6	29.3
C18:3n-3 (linolenic)	3.1	3.2	3.4	19.6	36.2
SFA	16.6	29.8	43.6	30.1	15.7
MUFA	20.2	25.5	31.1	24.6	18.8
PUFA	63.2	44.7	25.3	45.3	65.5
n-6/n-3 PUFA	19.5	13.0	6.5	1.3	0.8

SFA, saturated fatty acids [C14:0+C16:0+C18:0]; MUFA, monounsaturated fatty acids [C16:1+C18:1n-9+C18:1n-7]; PUFA, polyunsaturated fatty acids [C18:2n-6+C18:3n-3].

Table 3: Effect of type of dietary fat on live weight (LW, g), daily feed intake (DFI, g dry matter/d), daily weight gain (DWG, g/d), feed conversion rate (FCR) and mortality (%) of fattening rabbits (28 to 63 d).

	Dietary fat[1]						
	S	SA	A	LA	L	SEM	*P*-value
No.	108	98	85	90	109		
LW at 28 d	579	578	596	588	581	8	0.43
LW at 63 d[2]	2164	2160	2167	2184	2158	20	0.88
DFI[2]	128	131	129	133	130	2	0.37
DWG[2]	45.8	44.9	45.5	46.0	45.6	0.5	0.69
FCR[2, 3]	2.79[a]	2.92[b]	2.83[ab]	2.89[b]	2.86[ab]	0.03	0.003
Mortality[4]	37[b]	42[ab]	45[a]	38[ab]	34[b]		0.03

[a,b]Means in a row no sharing superscripts significantly differ at $P<0.05$.

[1] S, 3% Sunflower oil; SA, 1.5% Sunflower oil+1.5% Animal fat; A, 3% Animal fat; LA, 1.5% Linseed oil+1.5% Animal fat; L, 3% Linseed oil.

[2] Significant effect of the covariate LW at 28 d: $P<0.001$.

[3] Contrast all Sunflower oil *vs.* Animal fat [S–½(SA+A)]: $P=0.006$. Contrast all Sunflower oil *vs.* Linseed oil [S–½(LA+L)]: $P=0.009$.

[4] Measured in a population of 1670 rabbits, 750 housed in individual cages and 920 in collective cages (8 rabbits/cage).

SEM: average standard error of the means.

different rich oil seeds on the diet, such as chia (10 and 15% in rabbits from 50 to 85 d old, Peiretti and Meineri, 2008), vetch seed (10, 20 and 30% in rabbits from 35 to 77 d old, Yalcin *et al.*, 2003), flax seed (8% in rabbits 43-85 d old, Dal Bosco *et al.*, 2004), false flax seed (10 and 15% in rabbits from 70 to 120 d old, Peiretti *et al.*, 2007), or linseed (3, 6 and 9% in rabbits from 55 to 81 d old, Bianchi *et al.,* 2009). However, other authors found that DWG decreases when whole linseed (7% in rabbits from 38 to 72 d old, Colin *et al.,* 2005; 8% in rabbits from 64-87 d old, Bianchi *et al.*, 2006) or linseed oil (2% in rabbits 38 to 71 d old, Verdelhan *et al.,* 2005) were included

Table 4: Full gastro-intestinal tract (GIT) and caecum weights and caecal parameters of rabbits at 30 and 44 d of age depending on the dietary fat used.

			Dietary fat[1]					
		No.	A	S	L	SEM	Age	A *vs.* SL
Full GIT weight (g)[2]	30 d	16	165	167	180	8	<0.001	0.43
	44 d	15	364	352	366	9		0.64
Full caecum weight (g)[2]	30 d	16	50	53	57	4	<0.001	0.31
	44 d	15	127	121	125	4		0.44
Caecal parameters								
Dry matter (%)	30 d	16	20.2	21.3	20.0	0.5	<0.001	0.50
	44 d	15	18.3	18.2	18.5	0.6		0.96
pH value	30 d	16	5.92	5.87	5.90	0.07	0.32	0.70
	44 d	15	5.76	5.77	5.97	0.07		0.25
NH_3 (mmol/L)	30 d	16	7.13	9.02	9.48	0.91	0.72	0.06
	44 d	14	7.71	10.20	8.57	0.97		0.18
VFA (mmol/L)	30 d	16	132	139	135	12	0.43	0.75
	44 d	14	155	144	130	13		0.27
Acetic acid (mmol/L)	30 d	16	110	115	114	11	0.30	0.74
	44 d	14	132	123	113	11		0.34
Propionic acid (mmol/L)	30 d	16	8.13	9.21	8.86	0.72	<0.001	0.30
	44 d	14	7.13	6.39	5.84	0.75		0.29
Butyric acid (mmol/L)	30 d	16	12.2	13.1	10.4	1.2	0.63	0.77
	44 d	14	13.8[b]	13.5[b]	9.7[a]	1.3		0.17
Acetic/propionic rate	30 d	16	14.9	13.3	13.5	1.3	<0.001	0.32
	44 d	14	18.2	18.7	19.3	1.4		0.65

[a,b]Means in a row no sharing superscripts significantly differ at $P<0.05$.

[1] A, 3% Animal fat; S, 3% Sunflower oil; L, 3% Linseed oil.

[2] Significant effect of the covariate live weight at 17 d, $P<0.05$. No effect of the diet x age interaction was observed.

NH_3, Ammonia nitrogen in caecum content; VFA, Total volatile fatty acids in caecum content. SEM, average standard error of the means

in rabbit diets, and Eiben *et al.* (2010) found that rabbits on diets enriched with 4% linseed oil consumed 5-7% less feed between 35 to 49 d of age than rabbits on diets with 4% sunflower oil.

Fat source and level and age of rabbits seem to be responsible for differences in growth performance among trials. Dietary inclusion level of oils or whole seeds is highly variable between trials and in many cases the evaluated diets were not isoenergetic. Bianchi *et al.* (2006 and 2009) obtained contrasting results in 2 experiments for diets with similar n-6/n-3 ratio and n-3 PUFA provided by whole linseed, but including or not whole sunflowers. However, Dal Bosco *et al.* (2004) found no differences in growing-fattening rabbit performance with diets including whole flaxseed meal or whole sunflower meal (n-6/n-3 ratio: 1.6 and 5.1, respectively). Eiben *et al.* (2010) and Bianchi *et al.* (2006) found higher DWG only for 56 and 64 d old rabbits, respectively, but not during the first growing period (34 to 49 d), and Kelley *et al.* (1988) noticed differences in DWG depending on the type of oil or seed added to the diet when using older rabbits (more than 9 wk of age).

A high mortality rate was recorded due to an epizootic rabbit enteropathy event (ERE) during the fattening period (Table 3), but it was significantly lower ($P<0.05$) when vegetable oils replaced animal fat in the diet, especially for linseed oil (–11 points of percentage). Kelley *et al.* (1988) observed that the type of dietary fat markedly influenced the immune status of rabbits, as animals fed a linseed oil diet enhanced several indices of immune status compared to those fed with safflower oil (n-6 PUFA) and especially with hydrogenated soybean oil (SFA) diets. In a farm infected with ERE, Maertens *et al.* (2005) found a lower mortality in weaned rabbits fed with a diet enriched in PUFA n-3 (n-6/n-3 ratio: 1.03 *vs.* 4.22 for a diet with animal fat). However, when mortality rate was low other authors did not find any difference in mortality of fattening rabbits fed with sunflower or rapeseed and linseed oil diets (Bernardini *et al.*, 1999; Verdelhan *et al.*, 2005; Bianchi *et al.*, 2006 and 2009; Eiben *et al.*, 2010). According to Fortun-Lamothe and Boullier (2004), the amount and type of dietary fat, especially the level of n-3 and n-6 PUFAs, can modulate immune function both at systemic and intestinal levels, as fatty acids are structural components of cell membranes and signalling molecules and precursors for the synthesis of eicosanoids and either excess or deficiency of them could be harmful to the immune system. Absorption of long-chain fatty acids enhances migration of T lymphocytes and could also indirectly influence the mucosa immune system, increasing cytokine release from intestinal epithelium.

Growth performance of rabbits from 17 to 44 d was similar for all the dietary groups (Figure 1). DFI and DWG increased quickly ($P<0.001$) from 17 to 44 d. Young rabbits (17 to 21 d) on A diet showed higher DWG than those on L diet (+5.6±2.0 g/d; $P<0.05$), and recently weaned rabbits (28 to 30 d) on diet S showed higher DWG than those on A diet (+9.9±2.1 g/d; $P<0.05$), which should be related with the higher milk production of does recorded with A diet from 14 to 28 d (27, 23 and 22±1 g/d for each kit on A, S and L diets, respectively; $P<0.05$). Eiben *et al.* (2010) and Maertens *et al.* (2005) found no differences in litter performance during lactation related to dietary sunflower and linseed oil supplementation.

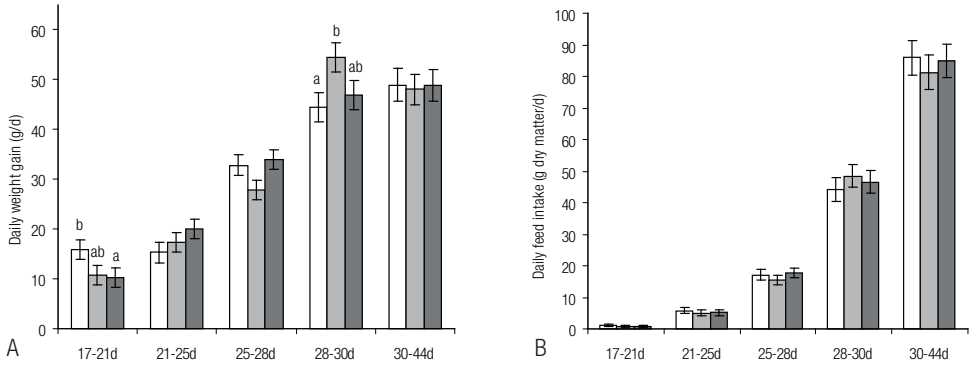

Figure 1: Evolution of A) daily weight gain and B) daily feed intake of young rabbits (17 to 44 d) depending on the dietary fat used: animal fat (□), sunflower oil (▒) and linseed oil (■). [ab] Bars at each time period differing in superscript were significantly different at $P<0.05$.

Full GIT and caecum weights increased from 30 to 44 d ($P<0.001$) and 30 d old rabbits had a higher DM caecum content and lower acetic/propionic rate ($P<0.001$) than rabbits 44 d old (Table 4). However, weights, caecal pH and other caecal fermentation traits of 30 or 44 d old rabbits were similar among dietary groups; only butyric acid concentration in caecal content at 44 d was lower (–3.9±1.2; $P<0.05$) with L compared to A and S diets. The effect of dietary fat on fermentation or fibrolytic activity in the caecum leads to contradictory results (see Fernández-Carmona *et al.*, 2000) and may interact with fibre source. Falcão-e-Cunha *et al.* (2004) observed higher acetic acid and lower butyric acid concentration in caecal content of rabbits given a diet with sunflower oil when fibre was mainly provided from beet pulp *vs.* wheat bran and intermediate when from alfalfa hay, but the same authors in a previous research work (Falcão-e-Cunha *et al.*, 2000) found opposite results.

In conclusion, these results indicate that the dietary use of vegetable oils rich in PUFA could help to improve the viability of rabbits in an ERE context and does not seem to affect the feeding behaviour, growth performance and caecal fermentation activity of young rabbits before and after weaning.

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REFERENCES

Aguilera C.M., Ramírez-Tortosa C.L., Quiles J.L., Yago M.D., Martínez-Burgos M.A., Martínez-Victoria E., Gil A., Ramírez-Tortosa M.C. 2005. Monounsaturated and ω-3 but not ω-6 polyunsaturated fatty acids improve hepatic fibrosis in hypercholesterolemic rabbits. *Nutrition, 21: 363-371. doi:10.1016/j.nut.2004.06.029*

Ander B.P., Edel A.L., McCullough R., Rodriguez-Leyva D., Rampersad P., Gilchrist J.S.C., Lukas A., Pierce G.N. 2010. Distribution of omega-3 fatty acids in tissues of rabbits fed a flaxseed-supplemented diet. *Metabolism, 59: 620-627. doi:10.1016/j.metabol.2009.09.005*

AOAC. 2000. Official methods of analysis of the Association of Official Agricultural Chemists (18th ed.). *AOAC International, Arlington, VA, USA (5th revision).*

Bernardini M., Dal Bosco A., Castellini C. 1999. Effect of dietary n-3/n-6 ratio on fatty acid composition of liver, meat and perirrenal fat in rabbits. *Anim. Sci., 68: 647-654.*

Bianchi M., Petracci M., Cavani C. 2006. Effects of dietary inclusion of dehydrated lucerne and whole linseed on rabbit meat quality. *World Rabbit Sci., 14: 247-258. doi:10.4995/wrs.2006.562*

Bianchi M., Petracci M., Cavani C. 2009. The influence of linseed on rabbit meat quality. *World Rabbit Sci., 17: 97-107. doi:10.4995/wrs.2009.663*

Burdge G.C., Calder P.C. 2006. Dietary α-linolenic acid and health-related outcomes: a metabolic perspective. *Nutr. Res. Rev., 19: 26-52. doi:10.1079/NRR2005113*

Casado C., Moya V.J., Fernández C., Pascual J.J., Blas E., Cervera C. 2010. Diet digestibility in growing rabbits: effect of origin and oxidation level of dietary fat and vitamin E supplementation. *World Rabbit Sci., 18: 57-63. doi:10.4995/wrs.2010.18.08*

Casado C., Moya V.J., Pascual J.J., Blas E., Cervera C. 2011. Effect of oxidation state of dietary sunflower oil and dietary zinc and α-tocopheryl acetate supplementation on performance of fattening rabbits. *World Rabbit Sci., 19: 191-202. doi:10.4995/wrs.2011.940*

Colin M., Raguenes N., Le Berre G., Charrier S., Prigent A.Y., Perrin G. 2005. Influence d´un enrichissement de l´aliment en acides gras omega 3 provenant de grains de line extrudées sur les lipides et les caractéristiques de la viande de lapin. *In Proc.: 11emes Journées de la Recherche Cunicole, 29-30 Novembre, 2005, Paris, France, 163-166.*

Dal Bosco A., Castellini C., Bianchi L., Mugnai C. 2004. Effect of dietary α-linolenic acid and vitamin E on the fatty acid composition, storage stability and sensory traits of rabbit meat. *Meat Sci., 66: 407-413. doi:10.1016/S0309-1740(03)00127-X*

Dalle Zotte A., Szendrő Zs. 2011. The role of rabbit meat as functional food. *Meat Sci., 88: 319-331. doi:10.1016/j.meatsci.2011.02.017*

De Blas C., Mateos G.G. 2010. Feed formulation. *In: De Blas C., Wiseman J. (eds). Nutrition of the rabbit. 2nd ed. CABI Publishing, Wallingford, UK, 222-232. doi:10.1079/9781845936693.0222*

Eiben Cs., Végi B., Virág Gy., Gódor-Surmann K., Maró A., Odermatt M., Zsédely E., Tóth T., Schmidt J. 2010. Effect of different dietary ratios of sunflower and linseed oils on growth and carcass traits of rabbits. *Livest. Sci., 131: 15-22. doi:10.1016/j.livsci.2010.02.017*

European Union. 2003. Protection of animals used for experimental purposes. *Council Directive 86/609/EEC of 24 November 1986, amended 16.9.2003.*

Falcão-e-Cunha L., Jorge J., Freire J.P.B., Perez H. 2000. Fat addition to feeds for growing rabbits, differing in fiber level and nature: effects on growth rate, digestibility and caecal fermentation patterns. *World Rabbit Sci., 8, Supp 1, Vol C: 191-198.*

Falcão-e-Cunha L., Peres H., Freire J.P.B., Castro-Solla L. 2004. Effects of alfalfa, wheat bran or beet pulp, with or without sunflowers oil, on caecal fermentation and on digestibility in the rabbit. *Anim. Feed Sci. Technol., 117: 131-149. doi:10.1016/j.anifeedsci.2004.07.014*

Fernández-Carmona J., Pascual J.J., Cervera C. 2000. The use of fat in rabbit diets. *World Rabbit Sci., 8, Supp 1, Vol C: 29-59.*

Fernández-Carmona J., Blas E., Pascual J.J., Maertens L., Gidenne T., Xiccato G., García J. 2005. Recommendations and guidelines for applied nutrition experiments in rabbits. *World Rabbit Sci.,13: 209-228. doi:10.4995/wrs.2005.516*

Fortun-Lamothe L., Boullier S. 2004. Interactions between gut microflora and digestive mucosal immunity and strategies to improve digestive health in young rabbits. *In Proc.: 8th World Rabbit Congress, 7-10 September, 2004, Puebla, Mexico, 1035-1067.*

Gidenne T., Perez J.M., Xiccato G., Trocino A., Carabaño R., Villamide M.J., Blas E., Cervera C., Falcão-e-Cunha L., Maertens L. 2001. Technical note: Attempts to harmonize chemical analyses of feeds and faeces for rabbit feed evaluation. *World Rabbit Sci.,9: 57-64. doi:10.4995/wrs.2001.446*

Hernández P., Dalle Zotte A. 2010. Influence of diet on rabbit meat quality. *In: De Blas, C., Wiseman, J. (eds). Nutrition of the rabbit. 2nd ed. CABI Publishing,Wallingford, UK, 163-178. doi:10.1079/9781845936693.0163*

Hoz L., López-Bote C.J., Cambero M.I., D´Arrigo M., Pin C., Santos C., Ordóñez J.A. 2003. Effect of dietary linseed oil and α–tocopherol on pork tenderloin (*Psoas major)* muscle. *Meat Sci., 65: 1039-1044. doi:10.1016/S0309-1740(02)00322-4*

Kelley D.S., Nelson G.J., Serrato C.M., Schmidt P.C., Branch L.B. 1988. Effects of type of dietary fat on indices of immune status of rabbits. *J. Nutr., 118: 1376-1384.*

Littell R.C., Henry P.R., Ammerman C.B. 1998. Statistical analysis of repeated measures data using SAS procedures. *J. Anim. Sci., 76: 1216-1231.*

Maertens L., Aerts J.M., De Brabander D.L. 2005. Effet d´un aliment riche en acides gras omega-3 sur les performances et la composition du lait de lapines et la viabilité de leur descendance. *In Proc.: 11emes Journées de la Recherche Cunicole, 29-30 Novembre, 2005, Paris, France, 205-208.*

Mertens D.R. 2002. Gravimetric determination of amylase-treated neutral detergent fibre in feeds with refluxing beakers or crucibles: collaborative study. *J. AOAC Int., 85: 1217-1240.*

O´Fallon J.V., Busboom J.R., Nelson M.L., Gaskins C.T. 2007. A direct method for fatty acid methyl ester synthesis: Application to wet meat tissues, oils, and feedstuffs. *J. Anim. Sci. 85: 1511-1521. doi:10.2527/jas.2006-491*

Peiretti P.G., Meineri G. 2008. Effects on growth performance, carcass characteristics, and the fat and meat fatty acid profile of rabbits fed diets with chia (*Salvia hispanica* L.) seed supplements. *Meat Sci., 80: 1116-1121. doi:10.1016/j.meatsci.2008.05.003*

Peiretti P.G., Mussa P.P., Prola L., Meineri G. 2007. Use of different levels of false flax (*Camelina sativa* L.) seed in diets for fattening rabbits. *Livest. Sci., 107: 192-198. doi:10.1016/j.livsci.2006.09.015*

Pla M., Zomeño C., Hernández P. 2008. Effect of the dietary n-3 and n-6 fatty acids on rabbit carcass and meat quality. *In Proc.: 9th World Rabbit Congress, 10-13 June, 2008, Verona, Italy, 1425-1429.*

SAS. 2002. User's guide statistic (Release 9.2). *Statistical Analysis System Institute Inc, Cary, NC. USA.*

Soler M.D., Blas E., Cervera C., Biglia S., Casado C., Fernández-Carmona J. 2005. Ingestión de pienso en gazapos lactantes: efecto estacional y relación con la ingestión de leche. *In Proc.: XXX Symposium de Cunicultura. 19-20 May, 2005, Valladolid, Spain, 129-133.*

Tres A., Bou R., Codony R., Guardiola F. 2008. Influence of different dietary doses of n-3 or n-6-rich vegetable fats and α–tocopheryl acetate supplementation on raw and coocked rabbit meat composition and oxidative stability. *J. Agric. Food Chem., 56: 7243-7253. doi:10.1021/jf800736w*

Tres A., Bou R., Codony R., Guardiola F. 2009. Dietary n-6- or n-3-rich vegetable fats and α-tocopheryl acetate: effects on fatty acid composition and stability of rabbit plasma, liver and meat. *Animal, 3: 1408-1419. doi:10.1017/S1751731109990334*

Verdelhan S., Bourdillon A., Renouf B., Audoin E. 2005. Effect de l´incorporation de 2% d´huile de lin dans l´aliment sue les performances zootechniques et sanitaires de lapins en croissance. *In Proc. : 11emes Journées de la Recherche Cunicole, 29-30 Novembre, 2005, Paris, France, 209-211.*

Wood J.D., Richardson R.I., Nute G.R., Fisher A.V., Campo M.M., Kasapidou E., Sheard P.R., Enser M. 2003. Effects of fatty acids on meat quality: a review. *Meat Sci., 66: 21-32. doi:10.1016/S0309-1740(03)00022-6*

Yalçin S., Tuncer I., Yalçin S., Onbaşılar E.E. 2003. The use of different levels of common vetch seed (*Vicia sativa* L.) in diets for fattening rabbits. *Livest. Prod. Sci., 84: 93-97. doi:10.1016/S0301-6226(03)00048-4*