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INTRODUCTION

Early work showed that animals can tolerate high levels of fat, and from a nutritive point of view fats were recognised as having four main properties: high metabolisable energy content, high efficiency of the metabolisable energy, improved utilization of dietary protein and supply of essential fatty acids.

Differences in chain length and the number of double bonds induce relevant differences in the level of lipids and blood lipoproteins and have been studied in relation to incidence of disease, and their influence on predisposition to obesity. Dietary fat component levels are being extensively studied in relation to man, with respect to their contribution to serum cholesterol levels, and the possible effect of high fat diets on the incidence of cardiovascular, breast and colon diseases, and the rabbit has been chosen as a model in many of these works. However, this entire topic has been omitted in the present paper, where the references, breeds, productivity and management refer generally to a commercial farm of European type. Findings confirmed by research or practice have to be considered from the point of view that applying them may or may not be suitable in a given circumstance. Welfare regulations or marketing trends for instance can change current objectives, production methods or even farm structure.

The addition of fats to diets of farm animals has been relevant for the past twenty years. The main objective was traditionally to increase the energy content of diets, obtaining what some years ago was called "high-energy density" diets. Today the complex relationship between the chemical structure of fats and the lipid content and profile of blood and adipose tissue is recognised to have maximum importance.

The nutritive value of fats and oils depends on the raw material and the manufacturing process. In respect of quality, not only should the nutritional value and related chemical indicators, such as iodine or peroxide value, be measured, but also some other substances, mainly contaminants, must be assessed. After the problems that the industry has recently faced, food safety is becoming the main issue, and cost will be to some degree a lesser consideration.

The sources for animal fat rendering include mainly beef, sheep, poultry and pig fat, mixed or separated, depending on the manufacturer, and these are a substantial part of the fat included in rabbit diets. Other fats come from the edible-oil refining industry. By-products of oil manufacture, obtained by extraction from fruits, germs of cereals and seeds, are not currently used. Different intakes with similar levels of added fat could be linked to the level of free fatty acids, which in pigs seem to be less palatable than those with a high level of triglycerides. Rabbits really do accept fats or oils at a high level, but oleins (a by-product of the refining industry) seem to depress food intake at a level of 10% but not at 3% (Santoma *et* *al.*, 1987). Other work concerning the inclusion of oleins in diet (Fernández and Fraga, 1996) found this depression with a mixture of oleins and soybean oil, but not when they were included alone at the 3% level.

Besides, some non-processed raw materials, such as soyabean, or sunflower seed have substantial amounts of unsaturated high-digestible fat. Fats and oils, either present in the seed or as an independent ingredient, are mainly mixtures of triglycerides and free fatty acids. In the feed manufacturing industry oils are not used in substantial amounts for any of the main farm animals, and certainly this includes rabbits. However, in recent years the use of whole seeds, especially from soya (full-fat soybean), has substantially increased. As a result, the level of unsaturated fatty acids in the carcasses of animals fed on these products has also increased, and a consequence is the number of related papers published in recent years.

With respect to fat utilisation in the feed manufacturing industry, effective procedures for adding liquid and solid fats depend largely on the fat-handling equipment. It has always been recognised that the durability of the pellets deteriorates when a high level of fat is added. Coating the pellets with the melted fat in a vertical mixer used to be a practical method of avoiding a friable pellet. Fibre materials, such as wheat bran, lucerne and straw that are included in typical rabbit diets, probably do not allow a great percentage of fat to be added. However, particle size, the remaining ingredients, the die and roller assembly, and fat-spraying systems have traditionally been used to increase the fat level, while maintaining adequate durability of the pellet. Recently, some feed manufacturers have included a combination of expansion and extrusion before pelleting, that allows higher fat inclusion in the mix (up to 10% in rabbit diets) without a decrease in pellet durability. Moreover, the use of whole seeds of soya and sunflower as ingredients in diets allows the incorporation of a substantial amount of cellular fat, which contributes less to producing soft pellets.

Ouhayoun (1989), Fortun-Lamothe (1997) and Maertens (1998) have recently published excellent reviews of the topic and the present paper is much in debt to them. In the present review we have only considered works or references on pelleted diets. Many published works have analysed the effect of fat added to a control mash-diet. Whereas that practice seems to us of great value and sense in many countries, regions and circumstances, a comparison with results obtained with pelleted diets is usually not possible.

DIET DIGESTIBILITY

Recently, Xiccato (1998) reviewed fat digestion in rabbits thoroughly. So, in the present work we will try mainly to describe the effect of fat supplementation on diet digestibility. The principal factor affecting diet digestibility is its fibre content, but fibre measurements in general are poor predicters of gross energy digestibility (GEd) in diets based on fat, as mentioned by De Blas *et al.* (1992).

Data on the ether extract digestibility (EEd) of diets reviewed show great variability, ranging from 47 to 91% (Table 1). Xiccato (1998) suggested that this wide range could be partially due to differences in analytical methodology. Some of these studies used an analytical method of ether extract (EE) determination without hydrolysis pre-treatment, that could underestimate the faecal EE content, and consequently overestimate the EEd. The EEd is generally high and its value also depends on the added fat source (unsaturation level) and the level of structural lipids linked to cell walls (less digestible).

Table 1 - Values from the literature for the effect of dietary fat addition on the apparent digestibility coefficients of experimental diets.

Reference	Age (months)	Fat source	EE	CF	dDM	dOM	dCP	dEE	dCF	dGE
Lebas, 1975	1.5		45	106	68.1	73.3	81.8			79.9
	1.5	CO	85	106	66.7	71.8	82.5			71.6
	1.5	CO	125	106	64.2	68.6	80.9			68.2
Maertens *et al.*, 1986	2		22	172				57.1		56.3
	2	T	81	161				63.8		57.8
	2	T	133	153				52.2		55.3
	2	PL	84	159				73.8		59.6
	2	PL	136	155				71.0		61.4
	2	AF	84	163				75.3		61.0
	2	AF	136	151				73.2		61.1
	2	SO	81	162				82.8		60.1
Santomá *et al.*, 1987			31	135	58.6	60.4	66.9	64.2	16.8	60.2
		T	56	131	64.7	65.4	75.8	74.5	17.7	64.6
		PL	56	131	67.4	68.3	75.9	80.0	25.2	66.7
		SUOL	56	131	65.2	66.5	74.7	77.3	17.3	65.9
		OL	56	131	65.3	65.9	74.9	74.2	22.0	66.1
		SL	56	131	63.5	64.7	75.0	74.0	13.5	64.0
		T	84	127	64.3	65.5	73.4	76.0	21.2	65.3
		PL	84	127	63.0	63.7	73.2	75.4	20.4	63.9
		SUOL	84	127	66.1	67.7	73.3	86.7	22.8	67.6
		SL	84	127	63.7	64.7	72.7	83.8	13.3	63.8
Fraga *et al.*, 1989	2.3		29	120			76.6			64.9
	2.3	PL	66	119			79.4			70.0
Fekete *et al.*, 1990	4-5		32	149	72.0	74.0	83.0	84.0	28.0	
	4-5	AF	77	137	74.0	75.0	83.0	89.0	28.0	
	4-5	SUO	79	143	72.0	55.0	82.0	91.0	27.0	
	4-5	AF	33	254	56.0	70.0	71.0	72.0	22.0	
	4-5	AF	82	212	61.0	60.0	70.0	83.0	26.0	
	4-5	AF/SUO	83	220	64.0	64.0	71.0	79.0	45.0	
Fernández *et al.*, 1994	2.2		19		56.9	57.5	76.1	47.6	7.6	56.5
	2.2	T	52		58.0	58.1	77.9	71.9	11.7	58.4

Reference	Age (months)	Fat source	EE	CF	dDM	dOM	dCP	dEE	dCF	dGE
Fernández *et al.*, 1994 (cont.)	2.2	OL	52		58.6	59.0	77.6	71.4	15.6	59.1
	2.2	SO	84		56.6	57.2	77.4	76.1	11.9	56.9
Xiccato *et al.*, 1995	1.5		36	140	63.3	63.0	71.0	61.0	14.0	61.0
	1.5	AF	52	139	63.3	65.0	73.0	75.0	16.0	64.0
De Blas *et al.*, 1995			23	137	65.9		73.1			66.2
		PL	28	138	66.3		72.4			66.6
		PL	36	155	64.5		72.2			64.9
		PL	47	160	63.2		71.8			64.0
		PL	57	167	61.6		70.7			62.7
Falcão e Cunha *et al.*, 1996	1.2		46	102	68.6	70.0	78.3	82.2	20.1	71.8
	1.2	T	83	109	65.0	65.9	79.3	86.1	19.0	69.0
	1.2	T	113	118	66.0	66.8	79.1	84.4	26.5	69.9
	1.2		39	159	65.0	66.4	74.3	77.9	24.5	67.9
	1.2	T	66	169	60.1	61.1	72.8	73.1	21.8	63.7
	1.2	T	106	160	58.0	59.7	70.8	71.2	25.8	62.6
Perez *et al.*, 1996	1		20	194	59.9	60.1	72.3		15.9	58.6
	1	SUO	52	172	67.6	67.7	73.9		17.7	66.9
	5		20	194	56.3	56.5	65.6		10.5	54.9
	5	SUO	52	172	66.2	66.3	71.6		14.4	65.7
Nizza *et al.*, 1997	2.3		33	170	63.3	61.9	69.6	60.2		
	2.3		51	95	63.3	76.1	78.2	88.3		
Fernández-Carmona *et al.*, 1998	1.5		42	235	53.0	54.5	64.5			
	1.5	AF	111	220	54.0	55.0	66.0			
Chaabane *et al.*, 1997	1.5		39	148	68.0	63.4	68.0		22.4	
	1.5	COC	56	133	58.5	58.9	66.7		12.4	
	1.5	EOC	51	131	63.6	64.3	71.4		10.0	
	1.5	SPOC	78	148	61.0	61.3	69.7		12.3	
Pascual *et al.*, 1998a	3		26	166	62.9	64.1	72.3	49.3		61.8
	3	WS/SO	99	170	63.3	64.3	76.2	75.3		64.2
	3	AF	117	166	63.3	62.7	73.4	64.5		61.5

Fat source: CO: corn oil; T. tallow; PL: pork lard; AF: animal fat; SO: soyabean oil; SUOL: sunflower oleins; OL: oleins; SL: soyabean lecitin; SUO: sunflower oil; COC: crude oil cake; EOC: exhausted olive cake; SPOC: super press olive cake; WS: whole soyabean; EE and CF in g kg^{-1} DM; Apparent digestibility coefficients in %.

Maertens *et al.* (1986) and Santomá *et al.* (1987) showed for different types of fat that soya bean and sunflower oils (rich in unsaturated fatty acids) presented the highest digestibility (77 to 87%), while lard and animal fat (mixed) showed a higher digestibility (71 to 75%) than beef tallow (52 to 64%). Unsaturated fats are more easily emulsified in the digestive tract and are therefore more easily absorbed than saturated fats (Hakanansson, 1974). In fact, an inverse relationship between the available energy content of fats and the saturated fatty acid content has already been demonstrated in innumerable reports in the literature on poultry and pigs. Nevertheless, Fernández *et al.* (1994) suggested that the unsaturated/saturated ratio is not the most appropriate predicter of EEd, because the digestibility of some fatty acids also depends on the fat source.

The fat digestibility of non-fat-added diets is usually low (40 to 70%), because lipids in conventional raw materials are linked to plant cell walls and are therefore poorly digested, while pure supplemented fats are more digestible. Van Manen *et al.* (1989) found high fat digestibility (90 to 98%) in semipurified diets supplemented with different levels of corn oil (20 to 160 g/kg). So, all authors (7 trials) agree that the addition of moderate quantities of fat (up to 50 to 90 g EE kg^{-1} DM) increases the EEd of diets (1.56% for each 1% increase in EE). This increase in apparent fat digestibility could also be related to the decrease in DM intake of rabbits, when levels of dietary fat that raise digestion efficiency (Xiccato, 1998) are higher, or to the fact that with increasing fat intakes the faecal excretion of endogenous fat has a diminishing effect on the calculated apparent digestibility (Van Manen *et al.,* 1989).

However, as it is shown in Table 1 and Figure 1, this linear increase may not be extrapolated for higher fat additions. Maertens *et al.* (1986), Fernández-Carmona *et al.* (1998) and Pascual *et al.* (1998a) observed higher EEd for high fat diets (more than 90 g EE kg^{-1} DM) than for their control diets, but their values were slightly lower than those observed by other authors for diets with a moderate level of fat. Xiccato (1998) attributed these lower values to the negative effect of high levels of fat on both digestive efficiency and caecal microflora activity. However, we also need take into account the source of fat used in these high fat diets, as all of those obtained from animal fat as mentioned above had lower digestibility than vegetable oils. In any case, it seems to be clear that digestibility of EE does not continue to rise with higher levels of fat.

Generally, the digestible energy (DE) content of diets with added fat is greater than that of non-added-fat diets, as a result of the influence of both GE content (principally) and energy digestibility. In fact, all the authors showed an increase of GEd when fat was added to the diet in moderate quantities, except for those diets obtained by substitution of starch for fibre+fat (De Blas *et al.,* 1995; Fernández-Carmona *et al.,* 1998) that showed a decrease of energy digestibility closely related to dietary fibre level. The lower increase of GEd when dietary EE content exceeds 90 g kg^{-1} seems to be a consequence of the lower EEd of fat used in high fat diets as mentioned above.

The addition of dietary fat is generally associated with changes in the content of other chemical measurements (e.g. an increase in CP), which may also have influence on their digestibility values. Most of the trials (Santomá *et al.*, 1987; Van Manen *et al.*, 1989; Fernández *et al.,* 1994; Xiccato *et al.,* 1995; Niza *et al.,* 1997; Pascual *et al.,* 1998a) are in agreement that an increase of dietary fat level seems to increase, at least slightly, the digestibility of dietary protein (Table 1). However, other authors have shown that level of fat does not affect crude protein digestibility (CPd) significantly (De Blas *et al.,* 1995;

Fernández-Carmona *et al.,* 1998), but this could be explained by differences in the content of dietary ADF and changes in the origin of the protein (as a proportion of forage protein), as suggested by Santomá *et al.* (1987). Pascual *et al.* (1998a), who imputed the increase of CPd of a diet with a higher content of vegetable oil (soya full-fat) to the better digestibility of full-fat soya protein than that of other proteins included in the other diets, also suggested by Fernández (1993).

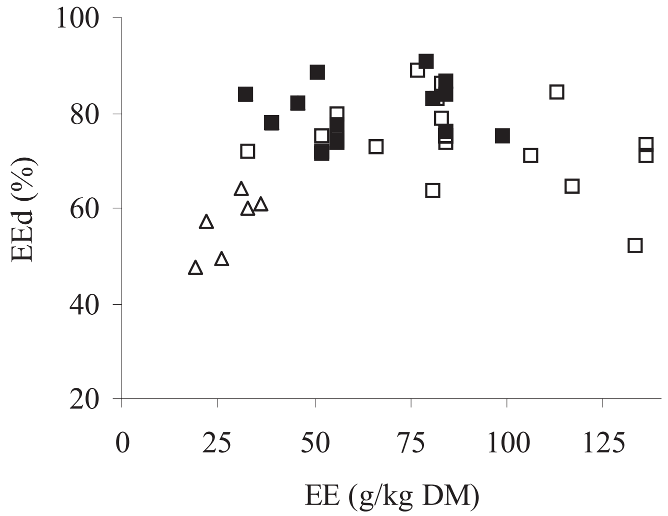

Figure 1. Effect of the EE content of experimental diets cited in Table 1 (n = 41) on the apparent digestibility coefficient of the EE, (∆ non-added fat diets, □ animal fat added diets; ■ vegetable fat added diets).

The results of effect of fat inclusion on CF digestibility (CFd) are controversial. The greater part of the authors did not find significant differences in fibre digestibility when fat was added to the diet (Barreto and de Blas, 1993; Xiccato *et al.*, 1995; Perez *et al.,* 1996). Fernández *et al.* (1994) showed that although CFd was not affected, ADF digestibility increased from 14.1 to 22.2% when fat was added to the diet. However, these differences and others shown by some authors (Fekete *et al.,* 1990; Hemid *et al.*, 1995) could be attributed more to changes in dietary fibre nature than to the addition of fat itself. In fact, Fernández *et al.* (1994) did not find differences in quantity of caecal fibre and in caecal weight in diets with added fat.

GROWING RABBITS

Growth

It is generally accepted that rabbits can regulate energy ingestion by adjusting their food intake for diets between 9.1 and 10.8 kJ/g, that correspond inversely to levels of about 24 and 13% ADF. These ranges of fibre and especially of energy can be extended when fat is added to the diet, and this has been commonly one of the main purposes of the use of fats.

Table 2. Use of fat added diets on growing rabbits: main characteristics of experimental diets found in the literature and their effect on the performance and carcass.

	Diet composition					*Rabbit performance*								
Ref.	*Diet characterisation*	*EE*	*FIBRE*	*CP*	*DE*	*no*	*IA*	*FA*	*FI*[c]	*IW*	*DWG*	*FE*	*PFW*	*D*
1	C+5% oil	53		232		9	32	137	22	353	6.5	3.34		
	C+13% oil	162		229		9	32	137	25	355	8.9	2.85		
	C+25% oil	263		241		9	32	137	22	357	8.4	2.62		
2	C	38	143[b]	199		12	49	84	118	1266	30.0	3.97	30.6	59.3
	C+5% beef tallow	92	143[b]	193		12	49	84	104	1256	29.8	3.50	34.1	60.4
	C+10% beef tallow	139	143[b]	193		12	49	84	100	1264	25.9	3.92	37.4	61.6
3	C1+2% corn oil	27		174		6	39	75	46	881	11.1	4.13		
	C1+6% corn oil	71		174		6	39	75	46	881	12.2	3.78		
	C1+10% corn oil	116		174		6	39	75	44	881	12.3	3.57		
	C1+14% corn oil	160		174		6	39	75	43	881	13.6	3.18		
	C2+2% corn oil	27		135		5	39	75	43	881	12.7	3.39		
	C2+8% corn oil	91		181		5	39	75	43	881	13.8	3.12		
	C2+14% corn oil	160		227		5	39	75	39	881	13.6	2.89		
	C3	40		173		14	39	75	72	881	17.5	4.13		
	C3+8% corn oil	127		168		14	39	75	66	881	18.4	3.60		
	C3+8% corn oil +5.7% soya protein	127		201		14	39	75	68	881	19.4	3.52		
4	C	48	115[b]	198	13.97	6	44	84	132	1101	44.5	2.97		
	C+4% corn oil	93	115[b]	200	13.14	6	44	84	138	1105	46.3	2.98		
	C+8% corn oil	136	115[b]	202	13.18	6	44	84	129	1104	43.0	3.00		
5	C	42	112[b]	211		54	28	70	72	805	19.4	3.74		
	C+5% corn oil	92	108[b]	202		54	28	70	75	806	20.4	3.67		
	C+8% corn oil	122	103[b]	194		54	28	70	79	804	21.6	3.65		
6	high energy	41	81[b]	197	12.99	18	35	93	119	919	39.4	3.02		59.7
	low energy	61	134[b]	156	11.27	18	35	96	126	792	39.4	3.20		59.3
7	C	29	162[b]	196	11.42	46	28	77	107	512	35.7	3.00	20.2	58.1
	C+34% oat	39	155[b]	157	11.42	44	28	77	102	512	35.5	2.87	30.8	58
	C+69% oat	49	153[b]	117	11.42	49	28	77		512	26.3		22.1	56.9
8	C	26	127	188	13.11	14	32	60	98	800	42.0	2.33	17.7	61.5
	C+2% soya oil	49	127	193	13.61	14	32	60	100	800	44.3	2.26		
	C+6% soya oil	96	125	188	14.61	14	32	62	97	800	43.9	2.21	27.9	62.8
	C+10% soya oil	133	124	189	15.71	14	32	57	86	800	43.2	2.01	26.4	61.7
	C+2% tallow	50	127	187	13.61	14	32	60	100	800	42.9	2.33		
	C+6% tallow	96	125	188	14.61	14	32	62	90	800	39.7	2.27	27.1	61.6
	C+10% tallow	133	124	189	15.71	14	32	57	93	800	47.1	1.97	29.0	62.3
9	C	30	198	182	10.75	18	30	71	104	570	35.1	3.04		
	C+3% pork lard	57	185	190	12.38	18	30	68	108	570	37.3	2.90		
	C+3% sunflower oil	57	185	190	12.01	18	30	70	105	570	35.7	2.84		
	C+3% soya-bean lecithin	57	185	190	11.76	18	30	69	110	570	36.6	2.83		
	C+3% beef tallow	57	185	190	11.96	18	30	69	107	570	36.4	2.94		
	C+3% (tallow+soya lecithin)	57	185	190	12.34	18	30	68	108	570	37.7	2.97		
	C+3% (pork lard+soya lecithin)	57	185	190	12.14	18	30	67	102	570	38.2	2.88		
	C+3% (tallow+sunflower olein)	57	185	190	12.38	18	30	70	104	570	36.0	2.91		
	C+3% (sunflower olein+soya lecithin)	57	185	190	12.50	18	30	73	98	570	33.6	2.97		
	C+3% sunflower olein	57	185	190	11.92	18	30	73	93	570	33.1	2.99		
	C+6% pork lard	83	202	206	12.13	18	30	69	98	570	37.0	2.61		
	C+6% sunflower oil	83	202	206	12.83	18	30	69	101	570	36.2	2.72		
	C+6% soya-bean lecithin	83	202	206	12.09	18	30	67	94	570	38.2	2.49		
	C+6% beef tallow	83	202	206	12.38	18	30	71	95	570	35.2	2.69		
	C+6% (tallow +soya lecithin)	83	202	206	11.79	18	30	71	98	570	34.9	2.76		
	C+6% (pork lard + soya lecithin)	83	202	206	12.26	18	30	71	96	570	34.5	2.84		
	C+6% (tallow + sunflower olein)	83	202	206	12.80	18	30	86	74	570	25.4	3.00		
	C+6% (sunflower olein+soya lecithin)	83	202	206	12.79	18	30	89	52	570	14.7	4.03		
	C+6% sunflower olein	83	202	206	12.26	18	30	89	34	570	10.7	4.70		
10	C	26	150[b]	158	12.28	25	35	70	111	904	37.8	2.94	14.3	57.3
	C+10% hempseed oil meal	35	158[b]	157	12.48	25	35	70	108	904	36.3	2.98	16.2	57.3
	C+20% hempseed oil meal	45	169[b]	162	11.95	25	35	70	114	904	36.3	3.14	19.7	57.6
	C+30% hempseed oil meal	55	186[b]	164	11.13	25	35	70	110	904	35.2	3.13	18.4	57.5
11	C1 (DP/DE=12.4 g/KJ)	29	192[b]	169	9.66	45	35	76	135	846	39.1	3.45		58.1
	C2 (DP/DE=14.3 g/KJ)	27	177[b]	196	10.19	45	35	76	132	837	39.6	3.33		58.4
	C1+2.9% soya oil	55	150[b]	187	11.53	45	35	76	124	857	41.3	3.00		59.7
	C2+2.9% soya oil	56	149[b]	218	12.02	45	35	76	121	829	40.7	2.97		58.7
12	C	22	100[b]	170	16.65	8	56	112	64	1540	16.1	4.00		60.7
	C+2% corn oil	44	100[b]	169	17.03	8	56	112	65	1510	20.0	3.25		60.1
	C+6% corn oil	88	100[b]	179	18.66	8	56	112	62	1520	20.7	3.00		61
	C+14% corn oil	204	100[b]	202	20.54	8	56	112	54	1530	19.1	2.80		62.3

(continued from Table 2)

Ref.	*Diet characterisation*	*EE*	*FIBRE*	*CP*	*DE*	*no*	*IA*	*FA*	*FI*[c]	*IW*	*DWG*	*FE*	*PFW*	*D*
	Diet composition					*Rabbit performance*								
13	C	34	161[b]	183	10.92	24	28	68	110	639	42.9	2.56	21.9	56.3
	C+3.4% animal fat	58	152[b]	216	11.13	24	28	68	111	639	44.2	2.51	28.3	56.5
13[a]	C	34	161[b]	183	10.92	24	28	68	90	639	37.3	2.41	17.6	56.4
	C+3.4% animal fat	58	152[b]	216	11.13	23	28	68	91	639	38.1	2.39	20.5	58.4
14	C	32	195	181	11.11	18	45	80	138	1125	37.8	3.65	13.8	
	C+1.5% soya oil	60	173	200	12.51	18	45	80	128	1122	39.5	3.23	19.7	
15	starch	36	180	192	12.14	8	32	60	93	774	43.9	2.11		
	soya-animal fat 2%	76	203	194	12.01	8	32	60	85	789	41.2	2.06		
16	C	19	155[b]	174	11.37	8	49	91	82	841	20.8	3.94		
	C+4% tallow	57	156[b]	172	12.73	8	49	91	105	835	29.2	3.60		
	C+3% palm oil	53	155[b]	175	12.65	8	49	91	86	826	21.5	4.00		
17	C	28	193[b]	182	10.85	12	33	84	117	841	34.4	3.40		59.3
	C+3% soya full-fat	32	190[b]	182	10.87	12	33	84	120	858	35.4	3.39		58.7
	C+6% soya full-fat	38	189[b]	178	11.23	12	33	84	121	820	36.1	3.35		58.7
18	C	45	164[b]	198	13.72	64	28	84	138	640	42.7	3.23	38	57
	C+4.5% rapeseed oil	98	168[b]	198	14.73	64	28	84	128	591	43.8	2.92	45.6	56.3
	C+9% rapeseed oil	129	169[b]	201	15.91	64	28	84	118	629	42.1	2.80	53.2	57.5
19	C1	46	123	178	13.22	10	38	73	88	914	30.0	2.93		
	C1+4% tallow	83	137	180	13.42	10	38	73	82	894	28.3	2.90		
	C1+8% tallow	113	153	184	14.02	10	38	73	70	875	19.7	3.55		
	C2	39	19.6	182	12.00	10	38	73	98	879	30.3	3.23		
	C2+4% tallow	66	209	181	11.89	10	38	73	85	846	24.1	3.53		
	C2+8% tallow	106	218	202	12.02	10	38	73	64	894	12.3	5.20		
20	C	19	223	180	10.29	30	28	73	140	606	36.4	3.83	21.9	62
	C+3% beef tallow	52	242	188	10.93	30	28	72	133	606	37.1	3.59	23.3	62.5
	C+3% oleins	52	242	189	11.06	30	28	72	135	606	37.2	3.62	25.1	62.4
	C+3% soyabean oil	52	242	186	10.65	30	28	72	135	606	37.2	3.61	27.4	62.8
	C+3% tallow+18% soya full-fat	84	253	190	11.76	30	28	73	126	606	36.2	3.45	32.1	62.8
	C+3% oleins+18% soya full-fat	84	253	191	11.59	30	28	76	117	606	34.0	3.42	36.6	63.8
	C+3% soya oil+18% soya full-fat	84	253	193	11.92	30	28	73	124	606	36.4	3.41	32.8	62.3
21	C	29	299	202	10.47	14	39	67	131	962	40.3	3.25		60.3
	C+3.8% oil	68	254	198	12.85	10	39	67	124	952	42.8	2.89		60.7
	C+4.8% oil	71	187	205	14.56	11	39	67	112	987	44.8	2.50		63.1
22	C	26	199	180	11.01	77	35	84	131	910	37.8	3.47	16.9	55.5
	C+8.5% animal fat	117	193	190	12.21	75	35	84	125	910	38.8	3.22	22.7	57.3
	C+7% soya oil	99	197	198	12.41	75	35	84	117	910	38.0	3.08	21.8	56.7
22[a]	C	26	199	180	11.01	50	35	84	108	861	32.1	3.36		
	C+8.5% animal fat	117	193	190	12.21	51	35	84	103	861	33.0	3.12		
	C+7% soya oil	99	197	180	12.41	49	35	84	107	861	35.2	3.04		
	C	26	199	180	11.01	72	35	84	88	728	27.2	3.24		
	C+8.5 animal fat	117	193	190	12.21	68	35	84	83	728	27.8	2.99		
	C+7% soya oil	99	197	198	12.41	77	35	84	84	728	28.7	2.93		
	C	26	199	180	11.01	29	35	84	67	687	21.8	3.07		
	C+8.5% animal fat	117	193	190	12.21	29	35	84	66	687	22.7	2.91		
	C+7% soya oil	99	197	198	12.41	28	35	84	71	687	24.9	2.85		
23	C	39	174	165	11.48	40	35	91	101	968	27.3	3.70	24.6	60
	C+30% crude olive cake	56	194	182	11.25	40	35	91	116	923	29.7	3.91	36.8	61.4
	C+30% exhausted olive cake	51	197	186	11.23	40	35	91	114	917	28.4	4.01	28.2	60.6
	C+30% super pressed olive cake	78	193	187	11.32	40	35	91	108	751	30.4	3.55	22.2	59.8
24	C	42	344	171	8.96	95	35	70	138	857	37.3	3.69	11.4	55.4
	C+7.9% animal fat	111	322	156	10.12	98	35	70	123	844	37.2	3.32	23.1	57.2

Diet: (C, C1, C2, C3: control diets); EE, FIBRE (ADF or CF[b]), CP in g/kg DM; DE in MJ/kg DM.
Rabbit performance: no: number of rabbits; IA: initial age; FA: final age; FI: food intake (g DM/day); IW: initial weight (g); DWG: daily weight gain (g/day); FE: feed efficiency (FI/DWG); PFW: perirrenal fat weight (g); D: dressing out (%). [c]DM for feed intake is, if not specified, assumed to be the value given in composition of diets.
Ref.: References ([a]high environmental temperatures); **1**: Thacker *et al*., 1956. Purified pellets?. It is assumed a 100% for DM intake. Only diets with 5, 15 and 25% EE are shown; **2**: Lanari *et al*., 1972 and Chiericato and Lanari, 1972; **3**: Arrington *et al.*,1974. Unusual pelleting. It is assumed diets with 90% DM; **4**: Lebas, 1975. Only control diet with 11.5% CF is shown; **5**: King, 1981. It is assumed diets with 90% DM; **6**: Ledin, 1982. FI fresh. Corrected carcass (12% Ouhayoun, 1989); **7**: Ouhayoun and Cheriet, 1983. Mean values for the two genotypes. DE calculated. EE calculated from table values. **8**: Partridge *et al.*, 1986a. Only experiments 1 and 3 are included. DE calculated. CF and ADF calculated from table values. IA assumed to be 32 days and final weight = 2000 g. Carcass corrected (6.7%, Ouhayoun, 1989); **9**: Santoma *et al.*, 1987; **10**: Lebas *et al.*, 1988. DE calculated; **11**: Maertens *et al.*, 1989. EE calculated; **12**: Van Manen *et al.*, 1989 and Beynen *et al.*, 1990. Purified diets. DE and CF calculated. DE considered ME/0.95. Restricted feeding. It is assumed diets with 90% DM; **13**: Borgida and Duperray, 1992. Composition of diets deduced from intake; **14**: Castellini and Battaglini, 1992. It is assumed that carcass traits are % of cold carcass; **15**: Peeters, 1993. Only data from non-infected strains. DE calculated; **16**: Yamani *et al.*, 1994. DE calculated. Diets with no comparable EE are not considered. Starch diet not included; **17**: Cavani *et al.*, 1996. DE calculated; **18**: Christ *et al.*, 1996a; **19**: Falcão e Cunha *et al.*, 1996. Diets with wheat bran and pea hulls; **20**: Fernández and Fraga, 1996. Mean slaughter weight; **21**: Kermauner and Struklec, 1996. Means of diets with and without probiotic. EE and DE calculated. Carcass corrected by head and chest contents (Ouhayoun, 1989); **22**: Cervera *et al.*, 1997 and Pla and Cervera, 1997. Mean values from 12 and 18 for 15ºC; **23**: Chaabane *et al.*, 1997. DE calculated; **24**: Fernández-Carmona *et al.*, 1998. Results from commercial diet not included.
Simple correlation between EE and the percentages over the control diet for FI, DWG, FE and PFW were: *FI*: r = -0. 3 (SE=8.8; P<0.001); *DWG*: r = +0.2 (SE=12.5; P<0.05); FE: r = -0.5 (SE=3.2; P<0.001); *PFW*: r = +0.6 (SE=19.7; P<0.001). No significant differences for FI, DWG, FE and significant (P<0.05) for PFW between oil and fat diets were found.

Addition of fat to the diets increases the energy density, and this has the general consequences associated with an energy increase. It may be assumed that where a lack of energy exists, e.g. the low energy of the diet does not allow compensation through a sufficiently high feed intake, the rate of growth should increase and probably the feed efficiency as well; in this case, when the fat-diet is given, the energy input is increased. However, when the initial diet is in the range mentioned above, the intake of digestible energy should be similar, because lower ingestion of the fat diets balances the energy value. The fat-added diet cannot logically increase the rate of growth, but it should improve feed efficiency, because the diet contains more energy per gram of dry matter. Certainly, the variation in response could change the results, and if the intake of digestible energy of fat-added diets is unexpectedly high, then the live-weight gain should be higher.

Summary of the data in the main available papers related to growth and feed efficiency published so far is shown in Table 2, where some of data have been calculated or have even been assumed. Some of these papers did not have the specific aim of evaluating diets with fats and oils added (Ledin, 1982; Ouhayoun and Cheriet, 1983), but in all of them the content of ether extract in the control diet is lower than in the rest. The difficulty of comparing them is inherent in the different methodology, breeds, diets and environment of the different works. It can be seen for instance that very low figures for live-weight gain were reported in the earliest works, and there is also a lack of data, as digestible energy values are sometimes not given or determined. The response to fat diets relies on the relationship between energy intake and energy retention, but it is usually assessed in terms of live-weight gain, which is always a matter of controversy, because dressing-out percentage and the deposition of carcass fat should be taken into account.

From this table some analyses and figures have been obtained, trying to find some general results. The use of either animal or vegetable fat does not appear to have a substantial effect on growth. Although in many works a higher live-weight gain can be appreciated, the figures are not related to the level of fat. In other works, unexpectedly high (Chaabane *et al.*, 1997) or low feed intakes (Falcao e Cunha *et al.*, 1996) resulted in a higher or lower growth rate respectively compared to the control diet.

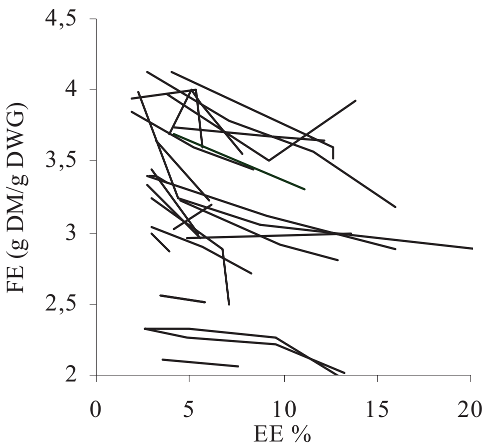

Figure 2. Effect of EE content of experimental diets cited in Table 2 (n=25) on feed efficiency in growing rabbits.

Table 2 and Figure 2 show the general improvement in feed efficiency described by Maertens (1998) in his review, being related to lower dry matter intake. Some correlations are shown in the footnote of Table 2.

The values of ADF in Table 2 are not especially high; only in three works were they about 30% or more. In the work of Kermauner and Struklec (1996) the fat-added diets had lower values of ADF than the control and live-weight gain of rabbits increased. The effect of the inclusion of fat in high-fibre diets has also been reported by Fernández-Carmona *et al.* (1998). Daily live-weight gain was similar for the two diets studied. Feed conversion ratio and dressing-out percentage were improved by the addition of fat, but perirrenal fat was almost double. Although a high level (8.9%) of animal fat was added, the performance obtained was lower when compared to a commercial diet. Nevertheless fat can be assumed to provide a significant improvement in a low energy-high fibre diet.

Carcass

Carcass traits, and particularly carcass yield, vary according to breed, environment, body weight and nutrition. Considering this last subject, dressing-out percentage has been found to be positively correlated to energy content of the diets; so very often rabbits fed on fat-added diets have higher carcass weight. Deposition of fat is a variable sensitive to variation of diet. Lanari *et al.* (1972), Raimondi *et al.* (1974 and 1975), Partridge *et al.* (1986a), Ouhayoun *et al.* (1987) and Fernández and Fraga (1996) all reported increases in perirrenal fat in rabbits fed on fat-added diets. The lumbar circumference includes the volume of fat contained in the abdominal cavity, and carcasses take a more compact shape with fat-added diets (Fernández and Fraga, 1996; Fernández-Carmona *et al.*, 1998). Carcass fat deposits are greatly affected by the ingestion of fat-added diets, although polyunsaturated fatty acids seem to increase body fat less than saturated ones. In the work of Fernández and Fraga (1996), the main carcass traits were not influenced by fat inclusion in diets, but more body perirrenal and scapular fat was found in rabbits fed on the highest fat-added diets.

Most of the studies have reported similar results (see Table 2), though sometimes the effect may be partially due to a decreased protein/energy ratio frequently linked to fat addition. That greater amount of body fat explains why an often-higher energy intake results in higher energy retention but a similar growth rate. Obviously the increase in body fat leads to a decreased content of protein and water, as some authors have consistently reported (Lanari *et al.*, 1972; Ouhayoun and Cheriet, 1983; Fernández and Fraga, 1996).

Increasing the protein level of the diet reduces the fat depots, but may have other implications such as lower efficiency and higher mortality (Askov, 1997). These relationships between protein/energy ratio and growth rate, dressing-out percentage and body composition have been also examined by Ouhayoun (1989).

The fact that fatter carcasses were obtained when starch was replaced by fat or oil on an isoenergetic basis (Maertens *et al.*, 1998) suggests a specific effect of fat itself. However, the only way to obtain leaner carcasses is reduction in the energy intake, with a subsequently lower growth rate, through the use of low density diets or a restricted-feed programme (Perrier, 1998).

The fatty acids in dietary fats do not change very much during post-absorption, and are incorporated into the adipose tissue, which consequently reflects the composition of the original fats ingested. The subject has been reviewed by Maertens (1998), where the main relationships between fatty acid composition or the degree of unsaturation and the meat fatty acids have been examined from the works of Lin *et al*. (1993), Cobos *et al.* (1994), Cavani *et al.* (1996), Christ *et al*. (1996a), Oliver *et al*. (1997) and others.

Rabbit meat has a lower content of total fat and cholesterol than other domesticated species, implying that it could have sound value in human nutrition, in addition to the possibility of controlling or manipulating its fatty acid composition by dietary means. The fatty acids synthesised *de novo* from the carbohydrate fraction of the diet are mainly palmitic (C16:0), stearic (C18:0) and oleic (C18:1) acids. This should be the approximate profile of the body fat in rabbits fed on a normal, non-fat-added diet. Dietary fat, especially fats with high content in saturated fatty acids, decreases lipolysis and *de novo* fatty acid synthesis, raising insulin resistance. The consequence should be a higher absolute amount of depot fats, which as we have already indicated, which are more like dietary fats.

Perirrrenal fat is often analysed and its acid profile reflects the dietary fatty acid composition (Raimondi *et al.*, 1975; Corino *et al.*, 1981; Ouhayoun *et al.*, 1981, 1987). Bernardini *et al*. (1999) have shown that the n-3 fatty acids content in liver, adipose tissue and muscle are correlated to the dietary n-3/n-6 ratio and linoleic acid. The adipose tissue reflects more closely the fatty acid composition of the diet. In muscle cells the influence seems to be less pronounced, and large quantities of n-3 acids were synthesised from linoleic acid in the liver.

The different effects of fats of vegetable and animal origin result from the different fatty acid profiles, and even some differences in colour and cooking losses found by Pla and Cervera (1997) can be related to this fact. Fat of low consistency or melting temperature has been associated with high levels of unsaturated fat (Wood, 1984), causing an undesirable effect on the carcass. However, Lopez-Bote *et al.* (1997) did not notice it when 3% olive and sunflower oil diets were used. Other sensory properties can be attributed to the greater lipids content of the carcass and some aromatic compounds associated with specific fats (Oliver *et al.*, 1997). In this context, unsaturated fatty acids involve a higher risk of oxidation, forming hydroperoxides, which break down, causing development of ketonic rancidity at the end of this process.

RABBIT DOES

Description of diets

Table 3 describes the main characteristics of the experimental diets found in the literature studying the effect of dietary fat addition on the performance of reproductive rabbit does. As a general rule, all these works are based on experiments where, starting from a control diet with a low EE content (2.0 to 3.6%), fat is added to the diets in moderate or high amounts, increasing both EE and DE content of diets (their effects are usually superposed). However, there are some differences in methodology between the different trials, and these could be the main cause of the variability of doe response to these diets. Most of the trials used fat coming from animal sources (mixed animal fat, pork lard or beef tallow; 15 diets), while others used vegetable fat (soya, sunflower or rapeseed oils, and whole soyabean; 10 diets). The addition of fat allows an increase in the energy content of diets without decreasing the fibre content and most of the trials used diets with a similar CF content. However, some authors studied the effect of fat inclusion on diets that presented differences in their fibre content (Maertens and De Groote, 1988; Viudes de Castro *et al.*, 1991; De Blas *et al.*, 1995). Finally, most of the trials also increased the digestible protein (DP) content of fat-added diets in order to maintain an adequate DP/DE ratio, with the exception of 4 trials (Barge *et al.*, 1991; De Blas *et al.*, 1995; Fernández-Carmona *et al.*, 2000; Pascual *et al.,* 2000b).

Table 3. Main characteristics of different experimental diets found in the literature studying the effect of dietary fat addition on reproductive rabbit does.

Reference[1]	No	Fat added ($g\ kg^{-1}$)	Fat source[2]	EE ($g\ kg^{-1}DM$)	CF ($g\ kg^{-1}\ DM$)	DP ($g\ kg^{-1}\ DM$)	DE ($MJ\ kg^{-1}\ DM$)	DP/DE ($g\ MJ^{-1}$)
1	1	-		32	173		11.4	
	2	20	SO	52	173		11.5	
2	3	20	PL/T	5.2	170	133	11.3[3]	11.8
	4	20	WS	5.3	170	133	11.3[3]	11.8
3	5	2.4	AF	33[4]	141	114	9.7	11.8
	6	9.4	AF	39[4]	118	136	11.0	12.4
	7	17	AF	63[4]	110	153	11.9	12.9
4, 5, 6, 7	8	-		29	120	141	11.4	12.4
	9	35	PL	66	119	154	13	11.9
8	10	-	-	34	153	174	12.2	14.3
	11	20	SO	54	139	170	13.4	12.7
	12	20	SO	56	137		13.0	11.3
9	13	5	SO	32	149	125	11.1	11.3
	14	20	SO	60	140	140	12.5	11.2
10	15	-		26	169	135	9.7	13.9
	16	31	AF	66	119	159	13	12.2
11, 12, 13, 14, 15[5]	17	-	-	20	193	136	9.9	13.8
	18	30	SUO	52	177	146	12.1	12.1
16	19	-		23	137	143	11.8	12.1
	20	3	PL	28	138	138	11.9	11.6
	21	11	PL	36	155	136	12.1	11.2
	22	21	PL	47	160	136	12.3	11.1
	23	30	PL	57	167	133	12.6	10.6
17[5]	24	-		36	140	141	11.3	12.5
	25	25	AF	52	139	144	11.9	12.1
18	26	-		40				
	27	45	RO	88				
	28	90	RO	117				
19	29	-		33	133	138	10.4	13.2
	30	30	AF	60	126	148	11.2	13.2
20, 21, 22, 23, 24, 25	31	-	-	26	166	130	11.0	11.8
	32	25	WS/SO	99	170	151	12.4	12.2
	33	85	AF	117	166	140	12.2	11.5
26, 27[6]	34	10	AF	51	236	108	8.7	12.4
	35	50	AF	82	226	105	9.6	11.0

[1] References, some of them used the same diets: 1. Barge *et al.,* 1984; 2. Barge and Masoero*,* 1986; 3. Maertens and De Groote, 1988; 4. Fraga *et al.*, 1989; 5. Simplicio *et al.*, 1991; 6. Cervera *et al.*, 1993; 7. Barreto and De Blas, 1993; 8. Barge *et al.*, 1991; 9. Castellini and Battaglini, 1991; 10. Viudes de Castro *et al.*, 1991; 11. Fortun and Lebas, 1994; 12. Fortun-Lamothe and Lebas, 1996; 13. Lebas and Fortun-Lamothe, 1996; 14. Lebas *et al.*, 1996; 15. Perez *et al.*, 1996; 16. De Blas *et al.*, 1995; 17. Xiccato *et al.*, 1995; 18. Christ *et al.*, 1996b; 19. Parigi-Bini *et al.*, 1996; 20. Fernández-Carmona *et al.,* 1996; 21. Pascual *et al.*, 1996; 22. Pascual *et al.*, 1998a; 23. Pascual *et al.*, 1998b; 24. Pascual *et al.,* 1999; 25. Pascual *et al.,* 2000a; 26. Fernández-Carmona *et al.*, 2000; 27. Pascual *et al.,* 2000b.

[2] SO: soya oil; PL: pork lard; T: tallow; WS: whole soyabean; AF: animal fat; SUO: sunflower oil; RO: rapeseed oil.

[3] DE content of diets were estimated by the athors.

[4] Values of EE were estimated from the ingredients by Fortun-Lamothe (1997).

[5] Only control and fat added diets were considered (no starch added diets).

[6] Only alfalfa diet and alfalfa diet supplemented with fat were considered (no control diet).

Food and energy intake of gestating does

Although there are a lot of works on the effect of the addition of fat on the performance of lactating rabbit does, there are few that also studied their effect during gestation. In most of the experiments, animals had free access to the experimental diets at parturition, and their effect during the first gestation was not evaluated.

Pascual *et al.* (1998a) showed that nulliparous pregnant does given high fat diets showed a lower food intake than those given a control diet, which implied a decrease of the DE intake (670 and 575 kJ day^{-1} $kg^{-0.75}$ for the control and fat-added diets, respectively). These differences were mainly due to the lower DE intake with the fat-added diets compared with the control diet during the first 21 days of gestation (-126 kJ day^{-1} $kg^{-0.75}$), showing no differences in the last 10 days before partum, perhaps due to limited intake capacity during this period. However, dietary fat addition did not affect the weight gain of does during this period and the size and weight of litters at partum, parturition being reached with similar live weights for the different diets. Similar results were found by Pascual *et al.* (2000b) for nulliparous does given all-lucerne diets supplemented with 50 g of animal fat kg^{-1}.

Contrary to what is observed for the first gestation, the addition of dietary fat has no affect on the DE intake of multiparous does between weaning and the next parturition (Simplicio *et al.,* 1991; Xiccato *et al.*, 1995; Lebas and Fortun-Lamothe, 1996; Pascual *et al.,* 1998a). In spite of the high energy content of fat added diets, gestating rabbit does seem to regulate their feed intake according to the energy level of the diet.

Prolificacy

The influence of fat inclusion on prolificacy is not clear and produces conflicting results. Most of the trials did not show any significant effect of fat inclusion on litter size at birth (Partridge *et al.*, 1986b; Castellini and Battaglini, 1991; Barreto and de Blas, 1993; Cervera *et al.*, 1993; Fortun-Lamothe and Lebas, 1996; Pascual *et al.*, 1998a). However, two of these studies (Partridge *et al.,* 1986b and Cervera *et al.*, 1993) showed an increase in the litter weight alive at partum for fat-added diets (44 g and 43 g, respectively). Fortun-Lamothe and Lebas (1996) did not find any effect of dietary energy level or source on foetal or placental weight at 28 day of pregnancy, but the lipid content in the foetuses tended to increase when the does received a fat-enriched diet. The permeability of the rabbit placenta to fatty acids could explain this result (Elphick and Hull, 1977).

Partridge *et al.* (1986b) and Parigi-Bini *et al.* (1996), who showed an increase in individual weight of pups at birth for does given fat-added diets, also found an increase in pup mortality (27.5 *vs.* 8.9 %) and a decrease in litter size at birth (1.8 born alive), respectively. Likewise, Viudes de Castro *et al.* (1991) and Xiccato *et al.* (1995) showed a decrease in pups born alive (2.3 and 2.0, respectively) when fat was added to the diet. However, high doe mortality (43.5% and 40%) because of pathology was observed in both experiments. On the contrary, Maertens and de Groote (1988) showed a significant increase in litter size at partum (0.8 born alive) of does given a fat-added diet and submitted to an intensive reproduction rythm, and Fernández-Carmona *et al.* (1996) found a greater litter size at partum for does given a high fat diet with 8.5 g of animal fat and housed at 30ºC.

Although the results are controversial, they suggest that fat-added diets have to be used carefully out of lactation in the long term. Coincidentally, authors showing a high pup mortality at partum with fat-added diets (Partridge *et al.,* 1986b; Parigi-Bini *et al.*, 1996), were the only ones that reported greater DE intake of their does during pregnancy. In these cases, the higher energy intake seems to increase slightly the individual weight of pups at birth and could cause an excessive fattening of doe, which could impede foetal movement along the birth canal and so increase the probability of still-birth, as suggested by Maertens (1999). However, more such effects have not been clearly show in several long-term works, even for diets with a high level of fat (Pascual *et al.*, 1998a). In fact, the inclusion of dietary fat could be appropriate for rabbit does submitted to an intensive production rhythm (Maertens and de Groote, 1988) or under heat stress conditions (Fernández-Carmona *et al.,* 1996).

Fertility

As well-reviewed by Fortun-Lamothe (1997), data concerning the effect of dietary fat inclusion on the fertility of does are controversial. Using an intensive reproductive rhythm, Castellini and Battaglini (1991) observed an improvement in the conception rate (9%) and consequently in the interval between parturition of does, when a 20 g kg^{-1} vegetable-oil-added diet was used. However, Lebas and Fortun-Lamothe (1996) did not observe that fat addition (30 g kg^{-1} sunflower oil) had any effect on does having a low conception rate (51%) when using a similar rhythm. Results of the different experiments seem to indicate that under non-intensive reproductive rhythm (mating 10-14 days post-partum) fat inclusion has no influence on the conception rate of does (Barge *et al.,* 1984; Castellini and Battaglini, 1991).

Moreover, when we analyse the results obtained in the literature for the effect of dietary fat on the interval between parturition (Table 4), there are some works showing a slight decrease (Castellini and Battaglini, 1991; Barreto and de Blas, 1993; De Blas *et al.*, 1995) or increase (Lebas and Fortun-Lamothe, 1996; Pascual *et al.*, 1998a, 1998b and 1999) in parturition interval with a fat-added diet. There is a positive correlation between the increase in parturition interval observed for does given the fat-added diets with the ether extract content of diet ($R = 0.78$; $P<0.001$), the milk yield production ($R = 0.60$; $P<0.1$) and the weaning litter number ($R = 0.82$; $P<0.001$). Usually, an increase in EE content of diet improves milk yield and litter survival, which could affect the parturition interval in consequence.

Finally, in several long-term studies conducted in our Department the level and source of dietary fat do not seem to affect reproductive doe replacement, in agreement with the results obtained by other authors (Barreto and de Blas, 1993; De Blas *et al.,* 1995). However, Barge and Masoero (1986) found an increase in does culled, when using animal *versus* vegetable added-fat.

Food and energy intake of lactating does

Voluntary food intake of lactating rabbit does appears to be insufficient to supply their total energy requirement in certain situations, for example hyperprolific lines, primiparous does, intensive reproductive rhythms or conditions of heat stress. In these situations, high-energy diets might improve the performance of lactating rabbit does. The addition of fat is useful in this respect because it results in increasing the energy concentration of diets without decreasing the fibre content or excessively raising starch concentration (Xiccato, 1996), and also increases the digestibility of other nutritional components, as mentioned above.

The effect of dietary fat on food intake values in the literature for lactating does is also controversial (Table 4). The food intake of does usually varies greatly, according to such parameters as breed, number and weight of pups, length of reproductive cycle and environmental conditions. Also, there are some works where the food intake of does is given together with that of their litter.

Table 4. Effect of fat addition on the performance of lactating rabbit does.

Ref.	RC	EE	PI	WD	DMI	DEI	MY	LWP	LWG	LN	M
2	P,M	32		21			140[2]	472	163	7.1	0.09
	P,M	52		21			156[2]	474	173	6.5	0.02
3	M	39		28	132	1447	202		166	9.6	0.19
	M	65		28	128	1521	213		174	9.4	0.16
4	M	29		28	99.9	1139	168			8.9	0.19
	M	66		28	112	1457	203			9.2	0.09
5[1]	M	29	43.0	32				330	77.2	7.1	0.45
	M	66	42.4	32				328	90.6	6.9	0.34
6	M	29		28	107	1216		421	94.9	8	0.35
	M	66		28	109	1420		464	108	8.1	0.32
7	P	29	54.8	28	88	906			118	7.7	0.16
	P	66	51.3	28	94	1115			127	8.2	0.17
8	M	34		21				470	214	8	0.14
	M	54		21				481	191	7.7	0.16
	M	56		21				470	186	7.8	0.15
9	M	32	53.8	30	125	1390			169	8.3	0.13
	M	60	51.0	30	118	1480			184	8.2	0.11
12	P	20		28			181[2]	539	121	10[3]	0.13
	P	52		28			199[2]	551	140	10[3]	0.13
13	P	20	48.8	28	124	1224	145[2]	582	146	9.0[3]	0.12
	P	52	49.2	28	112	1355	150[2]	571	150	9.0[3]	0.14
16	M	23	49.2	30	109	1285	194		164	8.4	0.15
	M	28	45.1	30	105	1245	194		173	8.1	0.20
	M	36	46.0	30	112	1357	202		176	8.7	0.16
	M	47	45.8	30	108	1323	198		164	8.6	0.19
	M	57	48.2	30	116	1467	191		159	8.6	0.15
17	P	36	35.1	30	112	1265	171	456	140	8.0[3]	0.04
	P	52	35.1	30	114	1360	191	434	147	8.0[3]	0.01
19	P	33		28	120	1244	201	443	133	8.0[3]	0.08
	P	60		28	115	1289	215	446	144	8.0[3]	0.05
20[1]	M	26		35				320	86.9	5.7	0.46
	M	99		35				340	105	5.8	0.32
	M	117		35				370	96	7.1	0.30
22	P	26	56.0	35	117	1289		460	129	8.3	0.30
	P	99	60.0	35	120	1487		465	146	8.3	0.23
	P	117	63.0	35	117	1428		459	131	8.7	0.20
	M	26	52.0	35	121	1335		477	141	9.2	0.27
	M	99	52.0	35	113	1405		501	155	8.9	0.19
	M	117	55.0	35	120	1463		482	145	9.1	0.18
24	M	26	50.5	35	119	1304	158	611	176	9.5[3]	0.33[4]
	M	99	50.9	35	118	1457	179	568	189	9.5[3]	0.18[4]
	M	117	50.4	35	122	1484	182	565	191	9.5[3]	0.13[4]
25	M	26		28	118	1296	191	581	120	8.0[3]	0.04[4]
	M	99		28	117	1445	237	552	148	8.0[3]	0.04[4]
26[1]	P,M	51	70.0	35	101	883	96	372	83.3	6.0[3]	0.14[4]
	P,M	82	71.0	35	98.4	945	115	357	112	6.0[3]	0.09[4]
27	P,M	51	57.0	28	150	1303	160	513	110	8.0[3]	0.02[4]
	P,M	82	62.0	28	133	1280	171	511	113	8.0[3]	0.02[4]

Ref.: Literature references as in Table 3; RC: reproductive cycle (P: primiparous; M: multiparous); EE: ether extract (g kg^{-1} DM); PI: parturition interval (days); WD: weaning day; DMI and DEI: calculated dry matter (g $kg^{-0.75}$ $day^{-0.75}$) and digestible energy intake (kJ $kg^{-0.75}$ $day^{-0.75}$) of doe and litter 0-28 days approximately; MY: milk yield (g day^{-1}); LWP: litter weight at partum (g) ; LWG: litter weight gain (g day^{-1}); LN: litter number at beginning of lactation; M: mortality.

[1] does at high environmental temperatures

[2] milk yield estimated from litter weight

[3] litter standardised at birth

[4] litter standardised during all lactation (dead pups were replaced daily).

A series of reports (Barge and Masoero, 1996; Maertens and De Groote, 1988; Barge *et al.*, 1991; Castellini and Battaglini, 1991; Parigi-Bini *et al.*, 1996; Fortun-Lamothe and Lebas, 1996; Lebas and Fortun-Lamothe, 1996; Fernández-Carmona *et al.*, 1996; Pascual *et al.*, 1999, 2000a) have indicated that the addition of dietary fat (20 to 120 g/kg) seems to affect slightly the food intake of lactating rabbit does, showing a non-significant decrease (0.82 g $kg^{-0.75}$ day^{-1} for each 1% EE increased). On the other hand, a far from negligible amount of works (Fraga *et al.*, 1989; Simplicio *et al.,* 1991; Cervera *et al.*, 1993; Barreto and de Blas, 1993; Xiccato *et al.*, 1995) found a slight increase when fat was added to the diet (0.80 g $kg^{-0.75}$ day^{-1} for each 1% EE increased). In these works, the higher food intake of does fed fat-added diets was mainly due to their higher DM intake during the first 3 weeks of lactation. Pascual *et al.* (1998a) found that, although primiparous does showed higher food intake with respect to the control diet during late lactation, multiparous does seem to regulate their food intake in accordance with the energy content of the diet during this period.

Usually, this increase in DM intake has been attributed to an increase in diet palatability (Cheeke, 1974; Finzi and Verità, 1976) or an improvement in nutrient balance and gut conditions (Xiccato *et al.*, 1995). However, the higher food intake shown in some works could be due to the fact that does on fat-added diets demonstrated better performance during lactation and consequently their requirements increased. In fact, while all the fat-added diets that induced an increase in food intake also improved all the litter performance traits, some fat-added diets, which induced a slight decrease in food intake of does, were also associated with a decreased number of pups at weaning with respect to the control diet (Barge and Masoero, 1986; Barge *et al.*, 1991; Lebas and Fortun-Lamothe, 1996).

In contrast to the low consensus observed in the literature for food intake, all authors showed that dietary-fat inclusion improved substantially the daily DE intake of lactating rabbit does. However, the effect of the level of EE on the DE intake observed in lactating does might be different for primiparous and multiparous does (Figure 3).

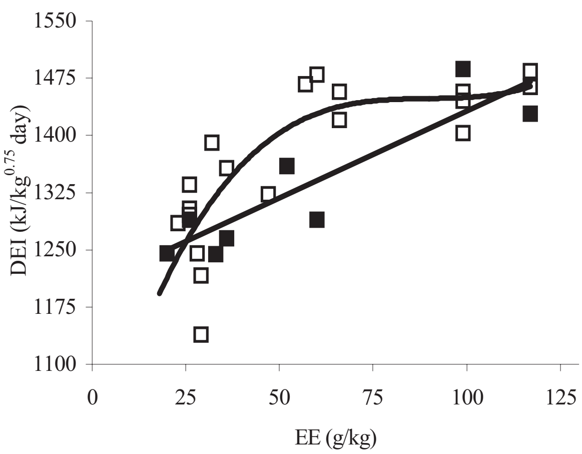

Figure 3. Effect of EE content of experimental diets cited in Table 3 (n = 36) on the digestible energy intake of primiparous (■) and multiparous (□) rabbit does (does+litter) during lactation (0-28 days).

A small addition of fat (60 to 66 g EE kg^{-1}) improved significantly the DE intake of multiparous does during lactation (Maertens and De Groote, 1988; Fraga *et al.*, 1989; Castellini and Battaglini, 1991; Cervera *et al.*, 1993), reaching values between 1420 to 1521 kJ $kg^{-0.75}$ day^{-1}. However, further addition of fat to the diet (99 to 117 g EE kg^{-1}) did not seem to result in an additional increase in DE intake (Pascual *et al.*, 1998a, 1999, 2000a), as similar values were obtained (1405 to 1484 kJ $kg^{-0.75}$ day^{-1}). In the primiparous case, although a moderate addition of dietary fat seems to increase the DE intake of does (1289 to 1360 kJ $kg^{-0.75}$ day^{-1}), this did not reach the level shown by multiparous does (Lebas and Fortun-Lamothe, 1996; Xiccato *et al.*, 1995; Parigi-Bini *et al.*, 1996). However, contrary to what was observed for multiparous does, higher fat addition (Pascual *et al.*, 1998a) implies higher further improvement of daily DE intake of primiparous does during lactation (1428 to 1487 kJ $kg^{-0.75}$ day^{-1}), reaching the level shown by multiparous does.

Most of the works on primiparous does (Parigi-Bini *et al.,* 1992; Xiccato *et al.,* 1992 and 1995; Fortun-Lamothe and Lebas, 1996; Pascual *et al.*, 1998a) showed similar food intake during lactation (aprox. 105 g DM $kg^{-0.75}$ day^{-1}) using diets with different DE content (9.9 to 12.4 MJ kg^{-1} DM) and animals with different productivity (5.8 to 9.3 weaning pups). Voluntary food intake of lactating primiparous does appears to be mainly regulated by physical factors, and seems to be insufficient to supply their total requirements even with diets supplemented with moderate amounts of fat.

Milk yield and composition

As can be seen in Figure 4, data on the effect of fat addition on the milk yield of does lead to consensus. Dietary fat inclusion results in a significant increase in milk yield of does (5 to 24%). It is appropriated to emphasize that primiparous and multiparous does did not show differences in their milk yield.

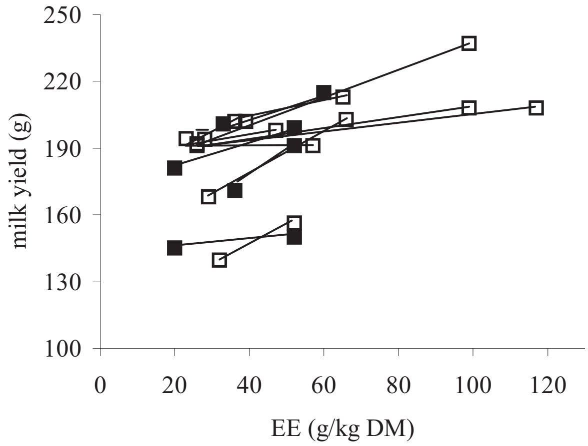

Figure 4. Effect of EE content of experimental diets cited in Table 3 (n = 28) on the milk yield of primiparous (■) and multiparous (□) rabbit does during lactation (0-28 days).

De Blas *et al.* (1995) did not find an increase in the milk production of does when dietary starch was replaced by fat and fibre, because does used in the milk production trial also showed low DE intake. Moreover, Pascual *et al.* (1996) showed that, when the experimental procedure only monitored does able to wean a fixed number of pups, DE intake of control and two high fat diets was found to be the same, with no differences in milk yield. So, the increase in milk yield with the inclusion of dietary fat was due more to higher DE intake than to dietary fat itself.

With respect to the effect of dietary fat on the composition of does´milk, data from the literature lead to different results (Table 5). We must take into account that these differences could be mainly due to methodological differences: sampling day (1 to 28), where sample comes from (pup stomach or mammary gland), type of sampling method (stomach tube, vacuum machine, manually by gentle massage), or the analytical method used (e.g. Soxhlet or Gerber method for milk fat determination). Furthermore, some of the traits were assessed with a low number (4 or 5) of observations.

Table 5. Effect of dietary fat addition on chemical composition of does' milk in the studies reviewed.

	Milk sampling method[2]					Milk composition[3]				Milk fat composition[4]		
Ref.[1]	Day	From	no	By	EE[5]	Total solids	Fat	Protein	Energy	SCFA	MCFA	LCFA
4	15-19	pup stomach	5	tube	29	28.8	13.9	11.8	8.03	0.71	43.0	56.3
					66	28.9	14.1	11.6	8.11	0.68	41.5	57.8
16	15	pup stomach	16	tube	23	27.9	13.1	11.6				
					28	27.3	13.6	10.7				
					36	28.1	13.6	10.6				
					47	28.1	14.5	11.0				
					57	28.7	13.8	10.9				
14	16-17	mammary gland	17	vacuum oxytocin	20	27.8	9.5	13.5		0.52[6]	62.8	40.41
					52	26.1	9.8	11.67		0.30[6]	53.6	49.7
17	22	mammary gland	4	vacuum oxytocin	36	31.0	14.6	10.7	8.38			
					52	30.9	14.5	10.7	8.36			
18[7]	1	pup stom.	16	tube	40		15.9			-	31.1[8]	57.2
	21	mammary gland		vacuum oxytocin	88		16.8			-	17.6[8]	71.6
					117		17.7			-	13.9[8]	75.4
21, 24	7	mammary gland	62	manual oxytocin	26	33.8	16.5	13.5	9.4	0.53	53.5	44.8
	21				99	34.6	18.3	12.3	10.0	0.52	39.5	58.2
	28				117	36.6	19.7	12.8	10.6	0.63	40.5	57.3

[1] References as in Table 3.
[2] Day: milk sampling days; From: milk was sampled from pup stomach or does mammary gland; no: number of observations for each treatment; By: milk was sampled by stomach tube, vacuum machine or manually by gently massaging.
[3] Total solids, fat and protein in % fresh milk; energy in MJ/kg fresh milk.
[4] Fatty acids composition in % of total fatty acids; SCFA: short-chain fatty acids (C4:0 to C7:0); MCFA: medium-chain fatty acids (C8:0 to C12:0); LCFA: long-chain fatty acids (C14:0 to C22:1).
[5] EE of experimental diets in g/kg DM.
[6] only value of C6:0.
[7] milk samples were obtained from pup stomach at 1st day and from mamary gland at 21st day of lactation.
[8] C12:0 content is not given by the authors.

Inclusion of moderate quantities of fat in the diet (Fraga *et al.,* 1989; De Blas *et al.*, 1995; Xiccato *et al.*, 1995) does not seem to affect the milk fat content. Only Lebas *et al.* (1996) showed that milk fat tended to be slightly higher. However, the use of high-fat diets (>88 g

EE kg^{-1} DM; Christ *et al.,* 1996b; Pascual *et al.*, 1999) increases significantly the milk fat content (0.27% for each 1% increase in EE; $P<0.01$, $r = 0.83$), especially at the beginning of lactation.

Similarly, all authors showed clear modifications in milk fat composition after a dietary fat addition (Fraga *et al.*, 1989; Lebas *et al.*, 1996; Christ *et al.*, 1996b; Pascual *et al.*, 1999), increasing the proportion of long-chain fatty acids (LCFA) and decreasing that of medium-chain fatty acids (MCFA). In non-ruminant animals, glucose is the main source of acetyl-CoA for milk fatty acid synthesis and, during milk fatty acid synthesis, chain elongation stops when the growing chain is eight to ten atoms long (Dils, 1986); and consequently longer milk fatty acids must come from dietary fat. Therefore, it seems that does given control diets (with a relatively greater starch content) had a higher proportion of MCFA and the proportion of LCFA was higher in the milk of does given fat-added diets. LCFA uptake directly from the blood should be responsible for the higher milk fat content. Fat inclusion in the diet could not have affected daily milk MCFA production (originating in the main from *de novo* synthesis) but may have increased the milk LCFA uptake coming mainly from the blood.

Different dietary fat levels and sources should be the main reasons for the differences observed in the proportion of milk fatty acids, when the different diets in the literature are examined. All these studies indicate that the percentage of milk fatty acids reflected the fatty acid composition of diets. Vegetable fat addition to the diet increased the polyunsaturated fatty acids proportion in milk fat, as a consequence of the high content of C18:2 and C18:3 in sunflower and soya oils (Lebas *et al.*, 1996; Pascual *et al.*, 1999). Accordingly, the addition of animal fat or rapeseed oil to the diet increased the monounsaturated fatty acids proportion in milk fat (Fraga *et al.*, 1989; Christ *et al.*, 1996b; Pascual *et al.*, 1999), due to their greater C18:1 content.

Lebas *et al.* (1996) and Pascual *et al.* (1999) found a decrease of odd-chain fatty acids in the milk of does fed with soya-oil-added diets. Taking into account that odd-chain fatty acids have a bacterial origin, the caecal fermentation activity of lactating rabbit does could have been affected by the greater proportion of polyunsaturated fatty acids in soya oil.

Lebas *et al.* (1996) and Pascual *et al.* (1999) found a decrease in milk protein content of does given fat-added diets (5.2 to 13.6%). Other authors (Fraga *et al.*, 1989; De Blas *et al.,* 1995; Xiccato *et al.*, 1995) did not find any significant effect, although most of them showed lower values for fat-added diets. Lebas *et al.* (1996) proposed that this decrease could be explained by the lower DP/DE ratio of the fat-added diets. However, Pascual *et al.* (1999) suggested that it could be partly explained by a dilution effect due to the greater milk fat content when diets had a balanced DP/DE ratio, because daily milk protein production observed in this work was similar for the three experimental diets (21.4, 22.0 and 23.2 g kg^{-1} for control, vegetable and animal fat diets, respectively). An alternative hypothesis is that the different milk protein content might result from some changes in caecal activity that could decrease the milk protein obtained from caecal micro-organism protein.

As a consequence of the differences in the results obtained in the different studies, while Fraga *et al.* (1989) and Xiccato *et al.* (1995) did not show any effect of fat addition on milk energy content, Pascual *et al.* (1999) found higher values for does given high fat diets, related to the high level of milk fat. Finally, some authors (Lebas *et al.*, 1996; Pascual *et al.*, 1999) found a greater value of milk ash content when vegetable oil was added to the diet, but the differences were not always significant.

Efficiency of utilisation of energy for milk production
Xiccato (1996) proposed a reduction in the digestive and metabolic utilisation of dietary energy when DE intake of does increases as a consequence of higher DM intake, which leads to faster digestive transit. However, the addition of dietary fat permits higher DE intake of does, without an increase in their food intake.

Most authors have indicated that the addition of fat could improve the efficiency of utilisation of DE in milk production (Partridge *et al.*, 1983; Fraga *et al.*, 1989; Xiccato *et al.*, 1995; Pascual *et al.*, 1998b, 1999, 2000a). Some research studies conducted in our department on the use of high fat diets (Pascual *et al.*, 1998b, 1999, 2000a) seem to indicate that these diets could increase this efficiency significantly (7 to 12%). In fact, the relationship between the DE intake used for milk production and the milk energy obtained from the DE intake using data from does given a high-fat diet showed a slightly better efficiency than that from does given a control diet (Figure 5).

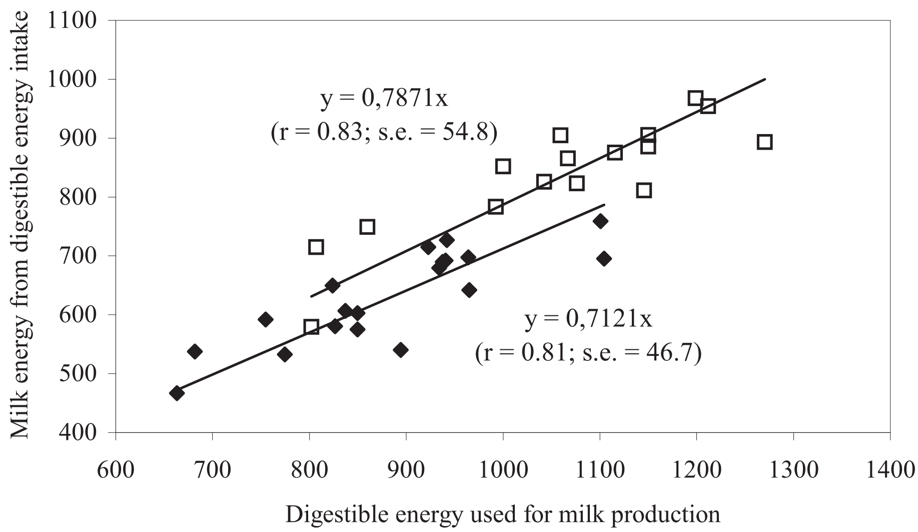

Figure 5. Relationship between the digestible energy intake used for milk production and the milk energy obtained from the digestible energy intake in does (unit of energy: kJ kg$^{-0.75}$ day^{-1}) given a moderate energy diet (υ) or a high fat diet (☐) (from Pascual *et al.*, 2000a).

The improvement shown in the efficiency could be related to the fact that the synthesis of milk fat from fatty acids coming directly from the high-fat diets seems to be more efficient than that from fatty acids obtained by synthesis *de novo* in the mammary gland, or in body fat mobilization of does given fat-added diets observed by some studies at late lactation.

Litter performance
Generally, most of the studies reviewed (13 trials) found a small (2-5%) or a large (10-30%) improvement in the survival index of pups during lactation, when does were fed with fat-added diets. Only 4 trials found a slightly higher mortality of pups on fat diets (1-3%). The positive effect of dietary fat on the pup survival index seems to be mainly related to greater

milk energy resources (higher milk yield and energy content mentioned above) during the first days of lactation. Some authors have related this improvement to the modification of milk fatty acid composition of does. D'Ambola *et al.* (1991) found that suckling rabbits have better defences against pulmonary diseases with diets supplemented with fish and safflower oils rich in ω-3 fatty acids (C18:2 and C18:3). Fat-added diets seem to increased the milk fat content, and consequently the total C18:2 and C18:3 content in the milk could explain the better pup survival index obtained with fat-added diets. However, Pascual *et al.* (1999) found that the content of these fatty acids was higher for does given a soya-oil-added diet than for those given an animal-fat-added diet, and improvement in pup survival was found with both diets. Therefore the lower mortality shown with inclusion of fat seems to be more closely connected with the resulting higher energy intake of pups during the first days of lactation.

As a consequence of the positive effect of fat diets on the yield and composition of does´ milk, all the authors found a clear improvement in litter growth during the first 21 days of lactation (with the exception of Barge *et al.*, 1991), since they consume almost only maternal milk throughout this period. However, during the last days of lactation most of the studies that controlled the food intake of litters (De Blas *et al.*, 1995; Xiccato *et al.*, 1995; Pascual *et al.*, 1998, 1999, 2000a, 2000b; Fernandez-Carmona *et al.*, 2000) found that litters on fat diets consumed less pelleted food than litters on control diets (approx. 21%). So, litters on a control diet were able to compensate for lower milk energy ingestion with a higher intake of pelleted food, resulting in similar litter growth rates at that stage. Consequently, although litter weight at weaning is usually higher for litters given fat-added diets, the differences with respect to the control diet are less evident than those observed at 21st day of lactation.

Doe live weight and body reserve mobilisation

As a general rule, dietary-fat addition did not seem to affect the live weight of reproductive does in most of the studies reviewed. Although there is some long-term work (Castellini and Battaglini, 1991) showing a significantly higher weight at partum (3.1%) when does were fed with a fat-supplemented diet, this increase is not relevant and it has not been corroborated by other long-term works (Lebas and Fortun-Lamothe, 1996), even with high-fat diets (Pascual *et al.*, 1998a). All authors state that rabbit does greatly increase their live weight during the first 21 days of lactation, later showing a slight decrease in their weight until weaning. Contrary to results when moderate levels of fat were included in the diet, Pascual *et al.* (1998a) observed that primiparous does given high fat diets had a similar DE intake to multiparous does (Figure 1), and did not show live weight losses in spite of their greater productivity. However, live weight change is a poor indicator of body tissue mobilization in the doe (Partridge *et al.*, 1983), and such changes could also be linked to variations in gut contents resulting from food intake differences or water concentration in the body (Xiccato *et al.*, 1995).

All energy balance experiments have reported a clear energy deficiency during the first lactation period of reproductive rabbit does (Partridge *et al.*, 1983; Xiccato *et al.,* 1995; Parigi-Bini *et al.*, 1992, 1996; Fortun-Lamothe and Lebas 1996); which lose weight and mobilise body tissue. The balance seems to further deteriorate when does are currently pregnant (Parigi-Bini *et al.,* 1992, 1996; Xiccato *et al.,* 1995). Protein mobilisation appears to be less predictable and relevant in primiparous does, and little difference has been detected between pregnant and non-pregnant lactating does (Parigi-Bini *et al.,* 1992; Xiccato *et al.,* 1995). Milk production seems to be one of the main factors in mobilisation of body protein, as well as energy. However, the N mobilisation doesn't seem to be directly related to the addition of dietary fat, and the body-protein catabolism shown during lactation was usually poor in all the studies reviewed, the lost N being easily recovered.

The results from the literature for the effect of fat diets on the energy balance of rabbit does are controversial. Fortun-Lamothe and Lebas (1996) have found that fat-enriched diets seem to have little influence on the body composition of primiparous rabbit does, but others suggest that fat diets could accentuate their body reserve mobilisation, as they stimulate milk yield primarily (Xiccato *et al.,* 1995; Parigi-Bini *et al.,* 1996). In fact, Fortun-Lamothe and Lebas (1996) and Pascual *et al.* (2000a) showed a negative correlation between the milk yield and the body condition of does (r = -0.24 and -0.60, respectively), showing that does that exhibited lower body-fat losses also gave a lower milk yield. Pascual *et al.* (2000a) observed that high-fat diets were not able to solve the energy deficit problems of lactating does, which showed a similar body condition to does given a commercial diet at the end of the second lactation. However, Lebas and Fortun-Lamothe (1996) found a higher weight of adipose tissues (60%) in does given a fat-added diet, with respect to those given a moderate-energy diet after four successive reproductive cycles, suggesting that highly energetic diets (fat or starch) could improve does´body condition in the long term (Fortun-Lamothe, 1997).

Nevertheless, no study has taken into account the source of fat used. In rats, some authors have also found different responses in adipose tissue mobilisation as a function of different fat sources (Van Amelsvoort *et al.,* 1988; Field *et al.*, 1989). Fat diets rich in saturated fatty acids usually tend to orient the ingested fat to non-adipose tissues and to prevent excessive fat storage in adipose tissues, but diets rich in polyunsaturated fatty acids increased the insulin action on incorporation of glucose into adipose tissue lipids in rats. There was the coincidence that authors showing a decrease of corporal reserves in does given fat diets (Xiccato *et al.*, 1995; Parigi-Bini *et al.*, 1996) used pork lard rich in saturated fatty acids, while those that did not show any clear diet-related difference (Fortun-Lamothe and Lebas, 1996; Lebas and Fortun-Lamothe, 1996; Pascual *et al.*, 2000a) used sunflower and soya oils rich in polyunsaturated fatty acids.

On the other hand, Pascual *et al.* (2000a) found that not all does presented a negative energy balance during lactation. Does given a fat-enriched diet that showed a higher negative energy balance were those that also showed higher live weight at partum and higher live weight loss during lactation. So, body fat losses during lactation could be partially related to the initial body condition of the animals, it being necessary to use *in vivo* methods to study the body changes of particular animals over time, such as magnetic-resonance-imaging tomography (Kover *et al.*, 1996, 1998) or ultrasound (Pascual *et al.*, 2000c). However, the effects of both fat source and initial corporal condition on the body mobilisation of does are yet to be clarified, and specific and long-term studies are needed to establish them.

HIGH ENVIRONMENTAL TEMPERATURE

At high environmental temperatures rabbit food intake can be extremely low and the energy restriction severely impairs rate of growth. It is generally accepted that feed intake starts to decrease at about 25ºC, depending on the ventilation rate and the relative humidity conditions. The use of fat addition to the diets has been one of the means to alleviate thermal stress, although the interaction of diet and temperature in growing rabbits has only been studied in two works (Borgida and Duperray, 1992; Cervera *et al.*, 1997).

Borgida and Duperray (1992) showed that the use of a fat-supplemented diet resulted in similar growth rate to that observed for rabbits given a moderate-energy diet during summertime. However, Cervera *et al.* (1997) observed that the use of high-fat diets (more than 9% EE content) slightly improved the growth performance of rabbits placed in a climatic chamber at constant temperatures of 24, 30 and 33ºC, as a consequence of small differences in feed intake compared with the control diet. As live-weight gain alone is a poor predictor of growth performance, carcass yield and carcass fat should be taken into account. Carcass yield improved in the work of Borgida and Duperray (1992), but much of the difference was due to the greater dissectable fat deposit linked to the ingestion of high-fat diets (Pla and Cervera, 1997).

The effect of dietary fat on the reproductive performance of rabbit does under severe environmental conditions has been only studied in 3 trials (Simplicio *et al*., 1991; Fernández-Carmona *et al.*, 1996 and 2000), where does were housed in a climatic chamber at a constant temperature of 30ºC.

At high environmental temperature, animals decrease their food intake in order to reduce the production of heat linked to digestion, usually having a similar DM intake. All trials showed an improvement of the DE intake of does given fat-added diets, and Fernández-Carmona *et al.* (2000) found an increase in their milk yield (115 *vs.* 96 g/day) when 5% fat was added to a high-fibre diet. Consequently, and as described for other situations where the voluntary food intake was also limited, in all the trials reviewed the addition of dietary fat had a positive effect on litter performance at high temperature, showing higher live weight gain and pup survival during lactation. Additionally, Fernández-Carmona *et al.* (1996) reported 1.4 more pups alive at birth when does were fed with a high-animal-fat-added diet in a long-term experiment. So, the inclusion of fat seems to be advisable in high temperature conditions, and does not appear to affect adversely the long-term performance of reproductive rabbit does.

CONCLUSIONS

Finally, we could conclude from the works reviewed that as a general rule:

1) The use of fat-added diets leads to an improvement of the conversion index in growing rabbits, related to their lower feed intake. However, an increase of main fat depots is usually found, and some care in their use from a meat-quality point of view is required.
2) Gestating rabbit does seem to regulate their feed intake as a function of the energy level of the diet, but a high DE intake during gestation has been related to an increase in pup mortality at partum.
3) Dietary fat inclusion does not seem to affect greatly the feed intake of lactating rabbit does, and consequently permits a higher energy intake.
4) As a consequence of higher DE intake, fat-added diets improve litter growth and survival, in comparison with less-concentrated commercial diets.
5) This positive effect on litter performance is mainly related to the large increase in milk yield of does, but the inclusion of fat in the diet also seems to increase milk fat and energy contents, especially during the first days of lactation, and induces modification of milk fatty acid composition, related to the dietary fatty acids.
6) The positive effects observed on survival index seemed to be more related to higher energy intake of pups than to changes in the content of milk fatty acids.

7) However, the effect of dietary fat on the body condition of lactating does continues to be controversial. In general, fat inclusion does not seem to reduce the body mobilisation of does during lactation.

In this respect, it could be interesting for future further research to study:
1) The reduction of fat deposition in growing rabbits as a result of nutritional strategies or by the use of certain additives.
2) The use of high fat diets allowing primiparous does to obtain a similar DE intake to multiparous does, but no energy balance study has been made in this respect.
3) The effect of fat addition on gestating rabbit does. In fact, there are some unknown factors in this respect: such as the appropriate moment to be fed on fat-added diets (mating, the end of gestation, the beginning of lactation), the transfer of fatty acids from mother to foetus and the problems associated with lipid peroxidation.
4) The protein level and some specific aminoacids in fat-added diets.

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