

FATS IN RABBIT NUTRITION : A REVIEW*

L. MAERTENS

Ministry of Small Enterprises, Trade and Agriculture, Center for Agricultural Research - Ghent,
Department of Animal Nutrition and Husbandry, Burg. Van Gansberghelaan, 92, 9820 MERELBEKE - Belgium

Abstract : Effects of inclusion of fat oil or full-fat seeds in rabbit diets are reviewed. Rabbits kits are able to ingest and to efficiently digest large quantities of milk lipids. About 40% of the milk fat consists of medium-chain fatty acids (C8:0 and C10:0). Rabbits digest dietary lipids in a way comparable to other monogastric animals. With the exception of tallow, added fat or oil is nearly 100% digestible, especially at low levels of inclusion. The dietary inclusion of fats or full-fat soybeans is well accepted by the rabbits and does not provoke palatability problems. Growth rate of fryers is commonly not influenced by dietary fat addition but, due to the increased energy density, a more favorable feed efficiency is obtained. However, a replacement of starch by fat, on an iso-energetic basis, increases the carcass lipid content. In

lactating does, dietary fat addition leads to a higher daily DE intake (+5%/1% of fat). This additional energy intake is primarily used for increased milk production. Fat addition modifies milk composition and carcass lipids of fryers. The dietary fatty acid pattern has a regulating effect on meat fatty acid content. The major interest for the use of fats is to increase the energy concentration of the fibrous rabbit diets. However, fat-added diets are only economically acceptable in intensive rabbit meat production systems to favour feed efficiency. Under practical feeding conditions, fat addition is limited to 2-3% in order to maintain the durability of the pellets. Finally, fats also show some potential to reduce thermal stress because under hot environmental temperatures, energy intake tends to be higher.

RESUME : Revue sur les matières grasses dans l'alimentation du lapin.

Les effets de l'incorporation d'huiles ou d'oléagineux dans l'alimentation du lapin sont passés en revue. Les lapereaux sont capables d'ingérer et de digérer efficacement la grande quantité de lipides du lait. Environ 40% des lipides du lait sont constitués d'acides gras à chaîne moyenne (C8:0 et C10:0). Les lapins adultes digèrent les lipides de l'aliment de manière comparable à celle des autres monogastriques. A l'exception du suif, la matière grasse ou l'huile ajoutées sont digérées à presque 100%, surtout lorsque les taux d'incorporation sont bas. L'incorporation dans le régime des matières grasses ou de graines entières de soja est bien acceptée par le lapin et ne provoque pas de problème de d'appétence. La vitesse de croissance des lapins de chair n'est pas influencée par l'incorporation de matières grasses mais, à cause de l'augmentation de l'énergie disponible, on obtient une meilleure efficacité alimentaire. Cependant, si on remplace sur une base iso-énergétique l'amidon par une matière grasse, on obtient des carcasses plus grasses. Chez la lapine allaitante, l'incorporation de matières grasses

dans l'aliment provoque une augmentation de l'ingestion quotidienne d'énergie digestible (+5%/1% de matière grasse). Ce surplus d'énergie ingérée est principalement utilisé à accroître la production laitière. L'addition de matières grasses modifie la composition des lipides du lait et ceux des lapins de chair. La composition en acides gras du régime a un effet régulateur sur la composition en acides gras de la viande. Le principal intérêt de l'incorporation de matières grasses est d'augmenter l'énergie digestible des régimes riches en fibres. Cependant, les régimes supplémentés en matière grasses ne sont économiquement acceptables que dans les systèmes de production intensive de lapin de chair afin d'optimiser l'efficacité alimentaire. Dans les conditions pratiques d'alimentation, l'addition de matières grasses doit être limitée à 2-3% en raison de son effet négatif sur la durabilité des granulés. De plus, l'accroissement de la teneur en matières grasses semble aussi être capable de réduire le stress dû à la chaleur, parce dans un environnement chaud, la quantité d'énergie ingérée tend à se maintenir.

INTRODUCTION

Fats are very energy dense raw materials. Their gross energy content is nearly three times as high as that of other feedstuffs. Therefore high levels of feed grade fats are mainly used to produce high energy diets for broilers and to a lesser extent for pigs and milk cows. The voluntary feed intake of rapidly growing broilers (2.0 kg in less than 6 weeks) or of highly productive lactating animals is often insufficient to supply their needs. Furthermore, energy represents the largest cost in diet formulation and fats are competitive as an energy source. For these reasons, the use of fats, fat blends, oils or oil containing raw materials is a common practice in compounding diets for nonruminants.

The use of fats in rabbit feeding is limited for a number of reasons: (i) pellets are widely preferable to meal, (ii) rabbit feed intake capacity is high, (iii) the performance level is not increased as in other animal production systems, and (iv) it would seem that its

addition is only economically justified under highly intensive conditions. In fact, during the last three decades, the performance of rabbits increased only slowly compared to poultry and pigs. However, quite recently high performance hybrid rabbit lines were developed showing an average litter size of 10 young instead of 8 for the common pure commercial breeds (De ROCHAMBEAU, 1998). In specialized male lines, daily weight gain amounts more than 50 g and greatly exceeds the growth potential of the New Zealand White or Californian (RAMON *et al.*, 1996).

Research efforts dealing with the use of fats in rabbit nutrition were limited before 1980 and conflicting results have been presented (see the review by LANG, 1981). Increasing use of high performance stock held under intensive rearing conditions has led to interest in the use of concentrated rabbit diets. Because rabbit diets normally have a fibrous nature, fats show potential for increasing energy concentration. Since the 1980's

significant progress has been made in the knowledge of dietary fat enrichment in rabbit diets. This will be reviewed in the present article.

1. LIPIDS AND ESSENTIAL FATTY ACIDS

Lipids (fats or oils) are biological components soluble in organic solvents. They can be classified as fatty acids, triglycerides, phospholipids, glycolipids, sterols, fat-soluble vitamins, etc. The structures are very divergent and there are more than 1,000. Technically, fats and oils are triglycerides. Their properties are determined by the fatty acids they contain, which can be either saturated [$\text{H}_3\text{C}-(\text{CH}_2)_n-\text{COOH}$] or unsaturated [$\text{H}_3\text{C}-(\text{CH}_2)_n-\text{HC}=\text{CH}-(\text{CH}_2)_n-\text{COOH}$]. The common fatty acids in feeds and animal tissues generally contain 16, 18, or 20 carbon atoms.

Lipids fulfill many essential functions in the body including being an energy source and storage form, providing basic material for cellular membranes and lipoproteins, as a precursor for biological components (prostaglandins, steroid hormones, bile salts, essential fatty acids, etc.), and as vitamins A, D, K, and E. They also have a number of technological characteristics related to absorption of dust, palatability of the diet, and carcass fat consistency.

Rabbits, as do other mammals, need certain unsaturated fatty acids that must be supplied in the diet because they do not have an enzyme system capable of forming a double bond beyond carbon atom nine in the fatty acid chain. For example, linoleic and linolenic acids are essential fatty acids required as building blocks for a variety of other unsaturated fatty acids which are components of structural lipids. However, rabbit diets are mainly of vegetable origin. To ensure a sufficiently high level of indigestible cell-wall constituents, raw materials such as alfalfa, sunflower meal or grain by-products are the main ingredients of rabbit diets. Meanwhile, the naturally occurring concentration of 2-2.5% lipids provides sufficient polyunsaturated fatty acids (linoleic and linolenic acid) to cover the requirements (CHEEKE, 1987). Therefore, no constraints are needed in rabbit diet formulation regarding addition of essential fatty acid sources (LEBAS, 1989).

2. MILK LIPIDS

Young rabbits are able to ingest and to digest high amounts of fat. Rabbit milk is composed mainly of proteins ($\pm 12\%$) and lipids ($\pm 13\%$) while the lactose content is very low (LEBAS, 1971; FRAGA *et al.*, 1989). Consequently, rabbit milk has a high energy content (Table 1). Peak milk production is around 50-g/kg live weight (MCNITT and LUKEFAHR, 1990). This explains the favorable conversion ratio of milk to body weight

Table 1: Chemical composition of rabbit milk (FRAGA *et al.*, 1989)*

Nutrients	g/kg	Main fatty acids	g/kg of milk fat
Dry matter	290.6	C8:0	177.6
Protein	116.1	C10:0	150.3
Fat	134.2	C16:0	211.6
Energy (MJ/kg DM)	27.7	C18:0	40.3
		C18:1	135.1
		C18:2	122.4

* Average values of the different diets fed.

gain of young which is as high as 1.8 between birth and 21 d of lactation (LEBAS, 1969).

The main components of milk fat of does are the medium-chain fatty acids C8:0 and C10:0 that account for about 40% of total fatty acid. The long chain fatty acids C16 and C18 are also important (Table 1). Especially, the long chain fatty acids can be modified by the dietary manipulation as shown by FRAGA *et al.* (1989). The high content of C18:1 in pork lard, used at a dietary level of 3.5%, was reflected in the milk fat. Dietary sunflower oil or rapeseed oil increases the unsaturated fatty acid content of the milk and decreases medium chain fatty acids (C8 to C15) as shown by LEBAS *et al.* (1996) and CHRIST *et al.* (1996).

Young rabbits are well adapted to digest large amounts of milk lipids. Suckling rabbits have to possess a developed preduodenal lipolytic activity so that with the lipase present in milk, they can assimilate the milk fat globule. Due to this enzyme activity, the medium chain fatty acids of the milk can pass the stomach wall. On the other hand, the pancreatic lipase secretion is very limited before 24-25 days of age (CORRING *et al.*, 1972). From then off, a quick increase occurs and at the age of 42 days adult level is reached quite independently of the diet used (LEBAS *et al.*, 1971). In fact, the daily intake of saturated fatty acids from milk in the second and third week of age is much larger than when fed a fat-added diet after weaning (FERNANDEZ *et al.*, 1994). It has even been shown that they are able to consume the total milk production of two does (MCNITT and MOODY; 1988, SZENDRÖ *et al.*, 1998). The double-fed young gained about 40% more weight during the suckling period than single fed controls. However, a high mortality rate (31%) was observed after weaning in the double-fed young, indicating that their enzymatic system was not sufficiently developed at weaning (35 d) (SZENDRÖ *et al.*, 1998).

In contrast with other mammals, creep feeding is not utilized in rabbit production. Scientific evidence of the dietary requirements in the transition period are not

Table 2 : Fat digestibility and digestible energy content of a number of feedstuffs

Feedstuff	Ether extract (%/kg) ¹	DCF (%)	DE (MJ/kg) ¹	Reference for Digestibility Coef. of Fat
Wheat	2.2	87	13.1	Maertens <i>et al.</i> , 1990
Corn	3.8	80	13.1	Maertens <i>et al.</i> , 1988
Wheat bran	4.4	77	10.1	Maertens <i>et al.</i> , 1990
Rice bran	15.3	87	12.4	Raharjo <i>et al.</i> , 1986
Corn gluten feed	4.3	75	11.4	Maertens <i>et al.</i> , 1988
Brewer's grains	6.8	91	10.1	Maertens & Salifou, 1997
Alfalfa meal	3.2	51	7.4	Maertens <i>et al.</i> , 1990
Soybeans	19.3	97	18.0	Fernandez <i>et al.</i> , 1994
Soybean meal	1.8	83	13.3	Maertens <i>et al.</i> , 1990
Rapeseed	39.6	93	20.9	Maertens <i>et al.</i> , 1996
Soybean oil	99	98	35.6	Fernandez <i>et al.</i> , 1994
Tallow	99	66	27.3	Maertens <i>et al.</i> , 1986
Fat blends	99	81	33.5	Maertens <i>et al.</i> , 1986

¹ Composition and DE value are those proposed by PEREZ *et al.* (1998)

available. We can only remark that rabbit kits have to change within a few days from a lipid rich milk to a carbohydrate rich diet with a very low content of lipids. However, it has been shown that early weaning is possible at 14 d using artificial milk feeding till 21 d of age (FERGUSON *et al.*, 1997) or using a commercial rabbit diet to which milk powder and molasses is added (MCNITT and MOODY, 1992). In both cases live weight gain was lower but the survival rate was nearly the same as in litters weaned at 28 d postpartum. These works indicate that a dietary balance between fiber constituents and energy source is important during the third and fourth week of age.

3. DIGESTIBILITY OF FATS OR OILS

Fats and oils are digested in the small intestine. The digestive process involves splitting fatty acids off the triglyceride molecules, which is accomplished by the lipase enzymes secreted by the pancreas gland. Bile, produced in the liver and secreted into the duodenum, contains bile salts that emulsify fats and also function in fat absorption. Fatty acids, bile salts and other lipid-soluble materials aggregate into micelles that transport the fats to the villi membranes, where absorption occurs. Although little information is available on specific sites of fat digestion in rabbits, it is assumed that it occurs primarily in the small intestine in a manner comparable with other monogastric animals.

Published digestibility coefficients of fats (DCF) as shown in Table 2 have to be taken with caution, because many of the values are highly overestimated due to insufficient fat extraction from

the feces. In 1974, PARIGI-BINI *et al.* reported that saponified fat in the feces is not detected by a single ether extraction as in other monogastric animals. Acid hydrolysis of fecal samples prior to the ether extraction will avoid underestimation of fat because of calcium soap formation. In Table 3 the overestimation of the fat digestibility due to an incomplete extraction is clearly demonstrated (MAERTENS *et al.*, 1986).

Raw materials commonly used in rabbit diets contain low levels of lipids (<2.5%). Because the precision of estimation of nutrient

digestibility is directly related to the dietary level and the substitution rate in the basal diet (VILLAMIDE, 1996), a low accuracy is obtained for the DCF of such feedstuffs. However, the dietary energy contribution of this small lipid fraction is limited.

Based on a literature review, DCF of grains are in the range of 80-90% while grain by-products as well as oil meals seem to have a somewhat lower DCF (MAERTENS *et al.*, 1990). Nevertheless, by-products with a significant amount of fat, if not too lignified, show a high fat digestibility as was recently shown for brewer's grains (MAERTENS and SALIFOU, 1997). The fat linked to plant structures in conventional raw materials has a lower availability to digestive enzymes and consequently a lower digestibility. Alfalfa meal and

Table 3 : Digestibility of fats according to extraction technique and dietary inclusion level (MAERTENS *et al.*, 1986).

Fat source	Inclusion level	Digestibility of the added fat	
		Ether extraction	3N-HCl + ether extraction
Tallow	6	98.7	66.1
	12	95.2	52.6
Lard	6	96.5	79.2
	12	95.8	73.3
Fat blends	6	98.5	81.3
	12	94.4	75.8
Soybean oil	6	99.5	93.3

grass meal are such raw materials and their DCF is around 50% (MAERTENS *et al.*, 1990). We may assume that the lipids of tropical forages and woody legumes also show a moderate digestibility. The overall low digestibilities of protein and energy, determined by RAHARJO *et al.* (1986), provide some indirect evidence.

Feedstuffs containing larger amounts of lipids, especially oilseeds, show a high DCF (Table 2). Full-fat soybeans or rapeseed have a DCF of 90-95% (FERNANDEZ *et al.*, 1994; MAERTENS *et al.*, 1996). The digestible energy contents proposed for soybeans (20% EE) and rapeseed (40% EE) are 18 and 20.9 MJ/kg, respectively (Perez *et al.*, 1998).

Several researchers have studied the digestibility of added fats and its influence on dietary nutrient digestibility. Vegetable oils (e.g. soybean oil or sunflower oil) are highly digestible and the DCF improves with the degree of unsaturation (SANTOMA *et al.*, 1987; FERNANDEZ *et al.*, 1994). Animal fats contain a higher level of saturated fatty acids (C16 and C18) and a lower level of the easily digested unsaturated fatty acids. Because of the positive relationship between the degree of unsaturation of fats and their digestibility, animal fats are less digestible (MAERTENS *et al.*, 1986; SANTOMA *et al.*, 1987; FERNANDEZ *et al.*, 1994). MAERTENS *et al.* (1986) found also a negative relationship between dietary fat level and fat digestibility for saturated fats (Table 3). Therefore it may be assumed that under field conditions (0-3% of added fat in the diet), the digestibility is higher than shown in Table 3. The effects on digestibility of the inclusion level and the dietary unsaturated/saturated ratio, have been demonstrated in numerous trials with poultry and pigs. Because of the parallelism with these species, the knowledge related to the addition of fats or high fat containing feedstuffs may probably be extrapolated to rabbits.

An exception to this parallelism is the lack of an age dependent effect on fat digestibility in rabbits (FERNANDEZ *et al.*, 1994). On the other hand, indications of an extracaloric effect of fats have been demonstrated (MAERTENS *et al.*, 1986; SANTOMA *et al.*, 1987; FERNANDEZ *et al.*, 1994). Added fat has a synergistic effect on the digestibility of the dietary fat fraction (FEKETE *et al.*, 1990; FERNANDEZ *et al.*, 1994). This interaction is less pronounced with the dietary protein and fiber fraction (FERNANDEZ *et al.*, 1994; FALCAO E CUNHA *et al.*, 1998).

As a result of both the gross energy content and the high digestibility of fats or high fat containing feedstuffs, the DE content of diets increases with the level of addition. For each 1% increase in dietary EE content, an increase of approximately 250 joule may be assumed (SANTOMA *et al.*, 1987, FERNANDEZ *et al.*, 1994). However, this assumption may be valid only at low inclusion levels.

4. EFFECT OF FAT ON THE PERFORMANCE OF GROWING RABBITS

An increase of the dietary DE content resulting from fat inclusion leads to a decreased feed intake. However, in experiments in which oil, fat or fat containing raw materials were used to increase the dietary energy content, the daily DE intake tended to be higher (PARTRIDGE *et al.*, 1986; SANTOMA *et al.*, 1987; MAERTENS *et al.*, 1988 ; CERVERA *et al.*, 1997). Liveweight gain of fryers is commonly not significantly influenced when fast-growing rabbits are used (FERNANDEZ and FRAGA, 1996). Only if the daily DE intake was clearly higher on fat-added diets, a slight improvement in growth rate was observed.

Under hot environmental conditions, a tendency to improved growth performance was observed due to the higher energy intake on fat added diets (CERVERA *et al.*, 1997). Nevertheless, this gain was limited to 5% (30°C) or to 10% (33°C) while the corresponding depressing effect of the hot temperature was 32 and 43%, respectively. When a fat and protein concentrate was fed together with a standard diet (30:70 ratio), a slightly positive response was observed during summer conditions (BORGIDA and DUPERRAY, 1992). The effect was most pronounced shortly after weaning and could partly be ascribed to higher dietary protein quality. These authors also reported a visually noticeable improvement in skin quality with the fat-rich complementary feed. The same phenomenon was mentioned by CHEEKE (1987). The addition of vegetable oil (a teaspoon of corn oil to a rabbit's feed every few days) helps to promote a shiny, lustrous hair coat, desirable in show rabbits.

Numerous studies have clearly demonstrated that the dietary energy content is the most significant factor controlling feed intake in rabbits (LEBAS, 1989). Rabbits try to adjust their voluntary feed intake in response to changes in dietary energy concentration. This regulation of intake, to achieve constant daily energy intake, is only possible at a DE concentration above 9.3 MJ/kg (MAERTENS, 1992) and under neutral environmental temperatures (CERVERA *et al.*, 1997). The most favorable effect of fat addition is thereby an energetic one. Because of the increased dietary DE content, rabbits improve their feed efficiency. For nutritionally well balanced diets, the relationship between the dietary DE content and the feed efficiency of fryers can be expressed as follows:

Feed (kg):gain (kg) = 6.60 - 0.33 DE content (MJ/kg) (MAERTENS and DE GROOTE, 1987).

This relationship is only applicable above a dietary DE level of 9.3 MJ/kg and during the 6 weeks fattening period (4/5 to 10/11 weeks of age).

Table 4: Effect of fat-enriched diets on rabbit meat fatty acid composition (%) (Cobos *et al.*, 1993).

	Diets			
	Control	+ 3% beef tallow	+ 3% soya and sunflower oleins	+ 3% soya bean oil
C14:0	3.9 ^a	3.8 ^a	2.9 ^b	2.7 ^b
C16:0	32.3 ^a	30.1 ^b	26.0 ^c	24.8 ^c
C16:1	5.5 ^a	4.9 ^a	2.5 ^b	2.9 ^b
C18:0	7.0 ^a	7.9 ^b	7.8 ^b	7.1 ^{ab}
C18:1	29.0 ^a	32.7 ^b	26.5 ^c	26.7 ^c
C18:2	20.0 ^a	18.4 ^a	32.1 ^b	32.8 ^b
C18:3	1.8 ^a	1.5 ^b	1.2 ^b	2.4 ^c
C20:4	0.7 ^a	0.8 ^a	0.9 ^a	0.7 ^a

Means in the same row with different superscripts differ ($P < 0.05$)

There is no evidence that rabbits tolerate or accept vegetable oils more than animal fats (SANTOMA *et al.*, 1987; FERNANDEZ and FRAGA, 1996; CERVERA *et al.*, 1997). However, certain by-products of the oil-refining industry such as oleins have shown to depress the voluntary feed intake (SANTOMA *et al.*, 1987, FERNANDEZ and FRAGA, 1996). Attention also has to be paid to storage conditions of fats and fat-added diets in order to avoid rancidity (CHEEKE, 1987). Antioxidants protect against the process of oxidation.

5. EFFECT OF DIETARY FAT ON CARCASS COMPOSITION

Fats have an indirect effect on the carcass fat content. When the fat addition results in a decreased protein/energy ratio, an increased carcass fat level is

Table 5: Effect of fat addition on the performance of does and litters (Xiccato *et al.*, 1995)

	Diets	
	Control (0% added fat)	2.5% included animal fat
Diet's DE content (MJ/kg)	10.14	10.72
DE intake (kJ/d during lactation)	3107 ^a	3368 ^b
Milk production (g/d)		
0-10 d	137 ^a	151 ^b
10-20 d	233 ^a	255 ^b
20-30 d	141 ^a	165 ^b
Litter weight (g) at parturition	456	434
10 th d	1317	1372
20 th d	2409 ^a	2629 ^b
30 th d	4661	4838

Means in the same row bearing different superscripts vary ($P < 0.05$).

observed (PARTRIDGE *et al.*, 1986; OUHAYOUN, *et al.* 1987a, FERNANDEZ and FRAGA, 1996; MAERTENS *et al.*, 1997). The dietary energy source also has a significant effect on the carcass lipid content. When starch was replaced on an iso-energetic basis by fat or oil, fatter carcasses were obtained (MAERTENS *et al.*, 1998). The increased body fat content due to fat addition is significant both in fat deposits and in muscular fat (FERNANDEZ and FRAGA, 1996).

As in other non-ruminant species, the body fatty acid (FA) pattern may be manipulated to a large extent by the dietary fat inclusion (OUHAYOUN *et al.*, 1987a). It appears that the greater part of dietary FA are unmodified during digestion and they are incorporated into the fat depots almost unchanged. Consequently, an enrichment of the diet with soybean, sunflower or rapeseed oil allows the production of rabbit meat with a higher degree of unsaturation (Table 4), especially C18:2 and C18:3 (COBOS *et al.*, 1993; KESSLER and PALLAUF, 1994; CAVANI *et al.*, 1996). However, the cholesterol level seems to be independent of the fat level and source (KESSLER and PALLAUF, 1994).

The dietary incorporation of soybean oil affects not only the linoleic acid, polyunsaturated FA (PUFA) and PUFA : saturated FA ratio in fat deposits and in muscular fat, but the peroxidation of muscle fat (TBARS) tended to increase with increasing inclusion level (CAVANI *et al.*, 1996). Furthermore, drip losses were higher at a dietary inclusion of 10% full-fat soybeans (MAERTENS *et al.*, 1998). On the contrary, the dietary incorporation of copra oil results in a lower PUFA : saturated FA ratio and causes a bad flavor due to the presence of lauric acid that causes a soap taste (OUHAYOUN *et al.*, 1987b). These observations emphasize that the selection of the dietary fat source is important in view of meat processing, storage and consumer acceptability.

6. EFFECT OF THE DIETARY FAT ON DOES PERFORMANCE

The effects of dietary fat on the reproductive performance of does were recently briefly reviewed (FORTUN-LAMOTHE, 1997). Based on the results of 14 experiments carried out during the last ten

years, conclusions concerning the dietary fat addition could be drawn. The results of this excellent review will therefore be summarized.

In 1983, PARTRIDGE *et al.* demonstrated in their balance trials that does are in a negative energy balance during the lactation. The limited voluntary food intake on conventional diets during lactation was insufficient to supply the large nutrient requirements, especially at peak lactation. This situation is emphasized in primiparous does because body growth still occurs and the ingestion capacity is not fully developed (for a review see XICCATO, 1996) or under hot temperature due to the reduced feed intake. Poor body condition and negative energy balance are considered to be associated with lower reproductive performance and reduced longevity.

An increase of the dietary energy content should theoretically decrease the nutritional deficit of the doe. Because a relatively high minimum level of dietary fiber has to be maintained to prevent digestive disorders, the inclusion of fat in the diet of lactating does seems an interesting possibility to increase their daily energy intake.

FORTUN-LAMOTHE (1997) calculated from bibliographic data (12 experiments) the relationship between daily DE intake of lactating does and dietary fat content. The increase accounted 231 kJ per 1% increase of the dietary ether extract. However, after a critical evaluation of the experiments used, we found a more moderate increase of the DE intake on fat added diets (about +5% higher DE intake/1% ether extract). An increase of the palatability of the diet and a better nutrient equilibrium are suggested as responsible for the increased DE intake (CHEEKE, 1987; XICCATO, 1996). There are no indications that this intake is dependent on the fat source used (vegetable oil, full-fat seeds or good quality animal fats).

Increased energy intake always leads to a higher milk production and consequently to heavier young during the lactation period. However, the higher energy intake does not appear to have a positive effect on energy deficit of the doe because fat-added diets primarily stimulate milk production (Table 5).

Results concerning fertility and prolificacy are controversial. A tendency to positive effects was found when does were submitted to an intensive reproduction rhythm (MAERTENS and DE GROOTE, 1988). High energy diets (fat-added diets) have to be used with care. When does are not lactating, the increased energy intake would cause excessive fattening with negative consequences on their reproductive capacities. Therefore fat-added diets have to be limited to lactating does or fed on a restricted basis outside the lactation period.

Under hot temperature conditions (30°C), FERNANDEZ-CARMONA *et al.* (1996) obtained a positive response to fat-added diets. Litter size was increased,

Table 6: Effect of dietary fat addition on pellet quality (MAERTENS & DE GROOTE, 1987)

% added fat	0	2	4
Durability test (% of fines)	1.4	2.3	6.7
Pellet sieving test (% of meal)	0.6	1.0	3.3

kits were heavier at 21 d and at weaning, and young survival rate increased (+30%). However, overall performance levels under the thermal stress were low (e.g. mortality rate of kits was 46%).

7. EFFECT OF FAT ADDITION ON PELLET QUALITY

Given the same diet, rabbits show a strong preference for pellets over meal. Significantly lower amounts are consumed on meal diets, resulting in lower gains, deteriorated feed efficiency and worsened slaughter yield (CHEEKE, 1987). When pellets are used, the durability or hardness is a major concern because rabbits do not eat the fines that result from broken pellets.

Fat addition has a negative effect on pellet quality. At 4% of added fat or oil, the percentage of fines was five times higher compared to the non fat-added diet (Table 6). Such diets will cause problems in the feeders and can not be used in semi-automatic or automatic feeding systems. Therefore 2-3% of added fat is considered a maximum level to obtain a quality pellet. However, several other factors affect pellet quality including the dietary composition, pellet mill equipment, and technology. An increase of the dietary fat content partly from oilseeds and partly from added fat has a less negative effect on pellet quality. Extrusion or coating pellets with fat are other techniques to avoid the adverse effects on pellet quality. On the other hand, fat addition tends to reduce the dustiness of diets which may increase the acceptability of diets containing large amounts of alfalfa meal and/or cassava meal.

CONCLUSIONS

In general, no special problems associated with feeding fat added diets are reported in rabbits. Rabbits digest fats in a way comparable to other monogastric animals. Therefore fats are a real alternative to increase the dietary energy content and to favor feed conversion. With the exception of some by-products of the oil-refining industry, fats or heat treated full-fat seeds are well accepted and do not provoke dietary palatability problems at reasonable levels of inclusion.

When using balanced diets, liveweight gain is not improved by adding fats in fryer diets. Fat-added diets do lead to higher carcass lipid content than iso-energetic starch based diets. The dietary fatty acid composition is also largely reflected in the body fatty acid pattern.

In does, fat addition leads to higher daily energy intake which is primarily used for the increased milk production. However, body condition is not significantly improved during the lactation while effects on overall long-term reproductive performance are unclear.

The use of fat-added diets only seems economically useful in intensive rabbit meat production systems to optimize feed efficiency. Under the current European price situation for feed ingredients, fats only become economically acceptable above a dietary DE concentration of 10.25 MJ/kg. But even when fat is an economical alternative for starch-rich feedstuffs, technological constraints limit its use. Above 2% addition, fats strongly affect pellet quality and provoke practical feeding problems. An increase of the dietary fat content to 5% and the production of quality pellets is also possible using fat-rich feedstuffs or with coating of the pellets.

Finally, fats show some potential to improve performance at high environmental temperatures, although special attention should be given to protein level and quality of fat enriched diets.

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