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FAT ADDITION TO FEEDS FOR GROWING RABBITS, DIFFERING IN FIBER LEVEL AND NATURE: EFFECTS ON GROWTH RATE, DIGESTIBILITY AND CAECAL FERMENTATION PATTERNS

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ABSTRACT

Fat addition to feeds for growing rabbits, differing in fibre level and nature, and its effects on growth rate, digestibility and caecal fermentation patterns, were evaluated. Eight experimental diets were formulated, in a factorial 2 x 2 x 2 arrangement: two levels of NDF (25% *vs*. 35%), two sources of fiber (lucerne, LC *vs*. wheat bran + citrus pulp, BC) and two levels of added fat (0% *vs*. 6% sunflower oil). Each experimental diet was fed to 11 four-week old rabbits during six weeks. In the fifth week, faeces were collected for digestibility measurement. At the end of the period rabbits were killed and their caecal contents collected. Level and source of fat were more influential on growth performance than fat, though added fat decreased daily intake, from 116.2 to 107.9 g. The increase in fibre level was detrimental to all except the ADF digestibilities: dry matter, organic matter and energy digestibilities were 12 points lower, approximately, in the high-fiber diets. All digestibilities, except for cellulose, were higher in BC diets than in LC diets: organic matter, 75 vs. 69%; CP, 76 vs. 75%, EE, 84 vs. 79%; and NDF, 40 vs. 27%. Fat addition improved all digestibilities except cellulose, in LC diets but not in BC diets, in which it only improved fat digestibility. There is, then, an interaction between fat addition and nature of fat. Fiber which is more fermentable, as in BC, and the addition of fat, lead to changes in caecal fermentation patterns, through an alteration in microbial activity, reflected in lower acetic and higher butyric acid proportions.

INTRODUCTION

Fat addition to rabbit diets allows to formulate feeds that, while high in energy, still have the levels of fiber that are necessary for a good functioning of their digestive systems (LAPLACE, 1978).

Rabbits are able to make good use of fat, and its addition to the diet seems to have synergistic effects on its digestibility. MAERTENS *et al.* (1986) and FERNANDEZ *et al.* (1994) did even detect a positive effect of fat addition on diet fat digestibility. An effect of fat addition on the digestibilities of the other fractions of the diet, in particular protein and fiber, while lower and less consistent, was detected by several researchers (FERNANDEZ *et al.*, 1994; FALCÃO E CUNHA *et al.*, 1996, 1998). FEKETE *et al.* (1990) did detect a positive effect of fat on fiber digestibility, but only in high-fiber levels, and FALCÃO E CUNHA *et al.* (1996) an interaction between fat and the nature of fiber in the diet. Although the amount of fat that reaches the caecum is usually small (MAERTENS *et al.*, 1986), the possibility of fat increasing the digestibility of fiber fractions, through somehow influencing caecal fermentative activity, cannot be ruled out.

The objective of this study was to evaluate the effects of fat addition to feeds for growing rabbits, differing in fibre level and nature, on growth rate, digestibility, and caecal fermentation patterns.

MATERIALS AND METHODS

Eight experimental isonitrogenous diets were formulated, in a factorial 2 x 2 x 2 arrangement: two levels of NDF (25% *vs*. 35%), two sources of fiber (lucerne, LC *vs*. wheat bran + citrus pulp, BC), two levels of added fat (0% *vs*. 6% sunflower oil) (Table 1)

Table 1. Centesimal composition and chemical composition of the experimental diets

	LUCERNE (25%NDF)		BRAN+CITRUS (25%NDF)		LUCERNE (35%NDF)		BRAN+CITRUS (35%NDF)	
FAT	0%	6%	0%	6%	0%	6%	0%	6%
Centesimal Composition (%)								
Amido	37.2	31.2	21.0	15.0	27.7	21.7	6.0	--
Soybean meal	19.0	19.0	10.0	10.0	19.0	19.0	10.4	10.4
Lucerne	42.0	42.0	67.2	67.2	10.5	10.5	16.2	16.2
Wheat bran	--	--	--	--	25.0	25.0	40.0	40.0
Citrus pulp	--	--	--	--	16.0	16.0	25.6	25.6
Sunflower oil	--	6.0	--	6.0	--	6.0	--	6.0
L-Lysine	--	--	--	--	--	--	0.1	0.1
DL-methionine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Calcium carbonate	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dicalcium phosphate	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sodium chloride	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Trace minerals/vitamins[1]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Chemical Composition (p.100DM)								
Dry matter	91.0	90.3	89.6	89.6	91.6	91.2	88.1	89.7
Ash	7.7	7.9	6.5	6.2	10.0	10.1	8.1	8.2
Crude protein	15.8	16.1	16.1	16.1	15.5	15.4	15.8	15.7
Ether extract	2.3	8.6	3.0	9.2	2.3	8.6	3.7	9.6
Neutral detergent fiber	24.8	23.4	22.9	23.64	35.3	35.6	33.8	33.5
Acid detergent fiber	17.9	16.5	10.6	9.9	25.5	25.5	16.2	16.5
Acid detergent lignin	3.9	4.8	3.0	3.1	2.3	9.2	6.3	6.6
Gross Energy (kcal/kg DM)	4219	4619	4315	4689	4216	4571	4410	4688

[1] for the composition see Falcão e Cunha and Freire (1993)

During six weeks, feeds were distributed *ad libitum* to eight groups of 11 four-week old rabbits, all housed in individual cages. Every week, daily intake was registered three times, and body weight registered once. In the fifth week of the trial, faeces were daily collected and stored at -20º C for further analyses and digestibility measurements. All digestibilities quoted are apparent. In the end of the trial rabbits were killed and their caecal contents collected for DM, pH and VFA measurements.

Feeds and faeces, the latter after unfreezing and drying during 48 h at 70º C, were milled through a 1 mm screen. Analyses were repeated three times on two samples of each feed, and two times on faeces. DM was measured by oven-drying during 24 hours at 103º C, ash by burning overnight at 550º C, CP by the Kjeldahl method, and NDF, ADF and ADL according to VAN SOEST *et al.* (1991). Hemicellulose and cellulose were calculated as the differences NDF-ADF and ADF-ADL, respectively. Fat was measured in a Soxlet extractor (Tecator Soxtec System - extraction unit) after acid hydrolysis pre-treatment (Tecator Soxtec System - hydrolysing unit). The energies of feeds and faeces were measured in a bomb calorimeter (Parr model 1261). VFA of caecal contents were measured by gas chromatography, according to JOUANY *et al.* (1982).
Results were compared by variance analysis in a 2 x 2 x 2 arrangement, with fiber level, fiber nature and fat addition as variation factors, with the SAS statistical package (SAS, 1989). Whenever the value F of the variance analysis was significant, averages were subjected to the Duncan multiple range test.

RESULTS

Table 2 shows the growth performances of the rabbits during the six weeks of the trial. Average final bodyweight was 2,450 g, and was not significantly affected by any of the variables under study. Daily DM intake was mainly affected by the nature of fiber (P<0.001), being in average 124.2 g in LC diets and 100.0 g in BC diets. Fat addition decreased daily DM intake, but only in the higher fiber diets, from 123 to 107.4 g. Daily weight gain was significantly affected by both the level (41.4 in lower vs. 38.8 g/d in higher fiber diets, P<0.05) and the nature of fiber (41.4 g/d in LC diets *vs*. 38.8 g/d in BC diets). Again, feed conversion ratio was also significantly affected (P<0.001) by both the level (2.63 in lower vs. 2.98 in higher fiber diets) and the nature of fiber (2.58 in BC diets *vs*. 3.03 in LC diets). Although fat addition did not in itself affect the feed conversion ratio, an interaction between fat and the nature of fiber was detected: the FCR of BC diets, but not of LC diets, was improved by fat addition.

Table 2 Effect of fat addition and level and nature of fiber on growth performances

	LUCERNE				BRAN+CITRUS				Statistical significance (1)						
	25% NDF		35%NDF		25% NDF		35%NDF								
Fat	0%	6%	0%	6%	0%	6%	0%	6%	L	N	F	LxN	LxF	NxF	RSD
Initial weight (g)	799	767	730	766	788	788	770	787	NS	NS	NS	NS	NS	NS	89
Final weight (g)	2596	2557	2496	2337	2409	2505	2413	2320	*	NS	NS	NS	NS	NS	263
Daily food intake (g/d)	120.8	119.3	135.1	121.6	98.2	97.5	110.9	93.2	NS	***	*	NS	*	NS	15.2
Weight daily gain (g/d)	43.4	42.6	42.0	37.4	38.6	40.9	39.1	36.5	*	*	NS	NS	NS	NS	5.7
Feed/gain (g/g)	2.78	2.83	3.24	3.29	2.55	2.38	2.84	2.56	***	***	NS	NS	NS	*	0.27

(1) Effects: L fibre level; N fibre nature; F fat; NS: not significant; *P<0.05; *** P< 0.001, RSD residual standard deviation

Table 3 shows all the digestibility results. Only simple effects are shown, because no significant interactions were detected; the only exception, that of the interaction between fat and nature of fiber, is detailed in table 4.

Table 3. Effect of fat addition and level and nature of fiber on apparent digestibility

	Fiber level		Fiber nature		Fat		Statistical significance (1)			
	25% NDF	35% NDF	LC	BC	0%	6%	L	N	F	RSD
Digestibility coefficient (%)										
Dry matter	78.1	66.1	69.7	74.6	71.4	72.8	***	***	*	2.64
Organic matter	78.2	65.4	68.6	75.1	71.1	72.6	***	***	*	2.66
Crude protein	80.2	73.2	74.6	78.8	75.6	77.9	***	***	***	3.14
Extract ether	83.3	76.7	76.0	84.0	71.4	88.6	***	***	***	6.51
Neutral detergent fiber	35.8	31.0	27.0	39.9	31.3	35.6	**	***	**	6.50
Acid detergent fiber	27.0	23.9	21.8	29.1	23.6	27.3	TS	***	*	7.93
Hemicellulose (NDF-ADF)	46.2	42.9	40.3	48.9	43.1	46.0	*	***	*	6.96
Cellulose (ADF-ADL)	25.8	13.8	19.0	20.6	20.3	19.3	***	NS	NS	8.84
CCnN (2)	96.6	91.8	93.7	94.7	94.6	93.9	***	***	**	1.16
Energy	78.1	66.1	68.6	75.6	70.5	73.6	***	***	***	2.69

(1) Effects: L fibre level; N fibre nature; F fat; NS: not significant; TS P<0,10; *P<0.05; ** P<0.01; *** P< 0.001, RSD residual standard deviation (2) NNCC = organic matter - NDF – CP

When NDF was increased from 25 to 35%, all digestibilities were significantly reduced (P<0.001), except ADF (non significant reduction). The reductions in the digestibilities of dry matter, organic matter, and energy, amounted to about 12 percentage points (from about 78% to about 66%). Other digestibilities were also reduced, but in a lesser scale: CP and EE about 7 percentage points (from 80 to 73% and from 83 to 77%, respectively), NDF about 5 percentage points (from 36 to 31%).

All fractions had significantly higher digestibilities (P<0.001) in BC than in LC diets; the one exception was cellulose, which digestibility was not significantly different between sources of fiber. Digestibilities of dry matter, organic matter and energy were, respectively, 75, 75 and 76 in BC diets and 70, 69 and 69% in LC diets. CP and EE digestibilities were 75 and 79 in BC diets, 76 and 84% in LC diets, respectively. Also, a significant effect of fiber on the digestibility of fiber fractions could be detected: while NDF digestibility was 40% in BC diets, it was only 27% in LC diets, a fact that can be related to an higher (about 9% higher) hemicellulose digestibility in the former diets.

Fat addition increased the digestibilities of all fractions except cellulose. It namely increased (P<0.001) the digestibilities of energy, protein and fat. The digestibilities of NDF and hemicellulose were 31.3 and 35.6% without added fat, 43.1 and 46% with added fat, respectively.

Non nitrogenous cell contents all had digestibilities above 90%, which were significantly affected by all the three variables under study.
The significant interaction, concerning digestibility, between fiber nature and fat addition, results from a positive effect of fat addition to LC diets; in BC diets, fat addition only affects its own digestibility (table 4).

Table 4. Interaction between fat added and nature of fiber in digestibility

	LUCERNE		BRAN + CIT		Statistical significance(1)	
FAT	0%	6%	0%	6%	N x F	RSD
Digestibility coefficient (%)						
Dry matter	67.8[a]	71.6[b]	75.1[c]	74.0[c]	***	2.64
Organic matter	66.6[a]	70.6[b]	75.7[c]	74.5[c]	***	2.66
Crude protein	72.0[a]	77.2[b]	79.1[b]	78.7[b]	***	3.14
Extract ether	61.5[a]	90.4[b]	81.3[c]	86.7[b]	***	6.51
Neutral detergent fiber	22.9[a]	31.1[b]	39.7[c]	40.1[c]	**	6.50
Acid detergent fiber	17.1[a]	26.4[b]	30.1[b]	28.2[b]	**	7.93
Hemicellulose (NDF-ADF)	38.0[a]	42.6[b]	48.2[c]	49.5[c]	*	6.96
Cellulose (ADF-ADL)	18.3	19.7	22.4	18.9	NS	8.84
CCnN	93.6[a]	93.7[a]	95.5[b]	94.0[a]	**	1.16
Energy	65.6[a]	71.6[b]	75.4[c]	75.6[c]	***	2.69

(1) Effects: N fibre nature; F fat; NS: not significant; *P<0.05; ** P<0.01; *** P< 0.001, RSD residual standard deviation; different letters on the same line indicate that means differ significantly (P<0.05)

The caecal fermentation parameters that were measured (table 5) show significant effects on molar proportions of acetic and butyric acids, which vary in opposite directions. Acetic acid proportion increases with the increase in NDF, is higher in LC than in BC diets, and decreases with fat addition. Caecal contents pH seems to be affected only by the fat addition. On the other hand, their DM content is higher in BC than in LC diets, and also higher when fat is added than when it is not.

Table 5: Effect of fat addition and level and nature of fiber on caecal fermentation patterns

	Fiber level		Fiber nature		Fat		Statistical significance (1)			
	25% NDF	35% NDF	LC	BC	0%	6%	L	N	F	RSD
Caecal dry matter (%)	22.5	22.4	22.0	22.8	21.9	22.9	NS	**	***	0.01
PH caecal	5.8	5.7	5.7	5.7	5.8	5.7	NS	NS	*	0.2
VFA (mol/100mol)										
C2	70.8	73.3	73.4	70.7	73.1	71.0	***	***	**	3.2
C3	8.9	9.0	8.8	9.2	8.8	9.2	NS	NS	NS	1.9
C4	20.3	17.7	17.9	20.1	18.1	19.8	***	**	*	3.1

(1) Effects: L fibre level; N fibre nature; F fat; NS: not significant; *P<0.05; ** P<0.01; *** P< 0.001, RSD residual standard deviation.

DISCUSSION

Level and nature of fat had a much stronger effect on growth performances than fat addition. Fat addition, by increasing the energy concentration of the diets, led to a decrease of intake, particularly in high-fiber ones; yet, total digestible energy intake was higher with added fat. This fact, also reported by other researchers (PARTRIDGE *et al*., 1986), did not, however, lead to an higher growth rate. MAERTENS (1998) states that growth rates only increase when DE intakes are much increased.

Contrary to MAERTENS 1998 review, our results do not show an unquestionable positive effect of fat addition on FCR, though we could detect this effect on BC diets, which had an higher energy concentration. On the other hand, the negative effect of fiber, and the effect of the nature of fiber, on FCR, are in agreement with the rabbit being able to regulate its energy intake (LEBAS, 1975).

The reduction of digestibility, by about 1.3 percentage points for each extra percentage point of NDF reflects the classical negative effect of fiber on digestibility, which can be explained by an acceleration of digestive transit (LEBAS & LAPLACE, 1977; GIDENNE, 1994), or by high-fiber feeds having higher cell wall contents. As a matter of fact, the digestibility of non-nitrogenous cell contents is also negatively affected by the level of fiber in the diet.
It should be noted, however, that although an increase in fiber leads to a reduction of its own digestibility, the rabbit digests a 30% higher amount of fiber in the high-fiber diets. This fact leads to an alteration of caecal fermentation patterns, and particularly to changes in the proportions of acetic and butyric acids. BELLIER & GIDENNE (1996) found similar effects on VFA proportions of caecal contents with the increase of fiber in the diet.

The fact that LC diets have lower digestibilities than BC diets, although both have the same level of NDF, results from their NDFs having different compositions. The fiber of BC diets is lower in lignin, and higher in hemicelluloses, and the latter are better digested than cellulose by the rabbit (FALCÃO E CUNHA, 1988; GIDENNE, 1996).

The general increase of digestibility when fat is substituted for starch may have been a consequence of a synergistic effect of added fat, which has been reported by several workers (MAERTENS *et al*., 1986; FERNÁNDEZ *et al*., 1994; FALCÃO E CUNHA *et al*., 1998). There was, however, an interaction between fat addition and the nature of fiber, with the positive effect of fat on digestibility only occurring (except for fat) in LC diets. This is in agreement with FEKETE *et al.* (1990), who showed that fat addition improves the digestibility of low digestible energy diets.

Fiber which is more fermentable, as in BC, and the addition of fat, lead to changes in caecal fermentation patterns, through an alteration in microbial activity, reflected in lower acetic and higher butyric acid proportions. Also BELLIER & GIDENNE (1996) found that the origin of fibre could affect the caecal fermentation pattern.

Our results show that fiber level and/or nature have a stronger influence than fat addition on growth performances; that the occurrence of a positive effect of added fat on digestibility depends on the nature of fiber; and that the molar proportions of VFA in caecal contents are influenced by all three variables under study, fiber level, fiber nature, and fat addition.

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