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Digestibility of rumen protected fat in cattle

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ABSTRACT

The nutrient digestibility of fat supplemented diets was studied in growing cattle. Hydrogenated triacylglyceride from palm oil (HPO), fractionated triacylglyceride from palm oil (FPO) and calcium soap from palm oil (Ca-PFA) were used as fat sources. On DM basis, about 6.6% of fat were added to the diets. The source of fat did not affect digestibility of carbohydrates and crude protein. Digestibility of organic matter was higher for diet with Ca-PFA than for diets with HPO and FPO, because of increased digestibility of ether extract (EE). The digestibility of EE, calculated by difference to the basal diet, amounted to 9.7, 40.6 and 78.3% for HPO, FPO, and, Ca-PFA respectively. The results show, that high saturated triglycerides with high proportion of stearic acid (> 50% of total FA) or palmitic acid (about 75% of total FA) are only little or insufficiently digested by ruminants. The calculated NEL concentration was 2.4, 10.1 and 16.4 MJ/kg DM for HPO, FPO, and, Ca-PFA respectively.

Keywords: cattle, rumen protected fat, digestibility, energy content

INTRODUCTION

Supplemental fat is increasingly included in the diets of high yielding dairy cows (Kellogg et al., 2001; Männer, 2002). This allows to modify the fatty acids (FA) pattern of the milk fat (Precht et al., 2001) and to improve the energy supply of the cow. Furthermore, supplemental fat act as nutritional modifier of physiology and metabolism (Voigt et al., 2005). However, unprotected, unsaturated FA can be toxic to the rumen microbes unless saturated by microbial hydrogenation (Harfoot, 1981). To avoid or decrease interferences with microbial fermentation hydrogenated triacylglycerides (or long-chain FA) or fractionated triacylglycerides with more than 80% of palmitic and stearic acid are used. A melting point of higher than 50°C is characteristic for these products. Another possibility is the use of calcium salts of long-chain FA. The calcium salts are insoluble at ruminal pH higher 6 and have thus little effect on microbial fermentation.

The protection of fat against rumen degradation is not difficult to achieve. However, the rumen-protected fats have to be highly digestible in the postruminal tract. In comparison with digestible carbohydrates the energy content of digestible fat per unit of mass is more than twice as high. The efficacy of triglycerides or FA added to ruminants' diets depends on their digestibility and their influence on the digestibility of other nutrients in the diet. Because energy intake results from dietary energy concentration and intake of dry matter (DM), the influence of the supplemental fat on food consumption also has to be taken into account.

This paper is focused on measurement of fat digestibility and calculation of the NEL content of different rumen stable fat supplements in cattle.

MATERIAL AND METHODS

Experimental design

The studies were carried out as period trial using the addition method. In basal periods, the diets contained no supplemental fat, in supplemental periods the diets contained 6.7 % as supplemental fat. The fat supplements differed in form (FA or triacylglycerides) and fatty acid pattern.

We used hydrogenated triacylglyceride from palm oil (**HPO,** Harles & Jentzsch GmbH, Uetersen, Germany), fractionated triacylglyceride from palm oil (**FPO**, Bergafet T-300, Berg & Schmidt GmbH, Hamburg, Germany), and calcium soap from palm oil

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(**Ca-PFA**, Hajenol Lipicafett, Harles & Jentzsch GmbH, Uetersen, Germany).

Animals and diets

Eight young, growing cross-breed bulls (German Holstein * Charolais) with a BW of 385.8 ± 10.5 kg were used in basal periods and supplemental periods. Bulls were housed individually in metabolic cages and had free access to water. The diets were mixed and fed daily at 7.00 a.m. and 4.00 p.m. The nutrition level was about 1.2 times maintenance.

Table 1: Ingredient and nutrient composition (% DM basis) of basal diet and fat supplemented diets

	Basal	HPO	FPO	Ca-PFA
Ingredient				
Hay, chopped, kg/d	1.65	1.65	1.65	1.65
Concentrate, kg/d[1]	3.3	3.3	3.3	3.3
Fat supplement, kg/d	0.0	0.33	0.33	0.38
Nutrients				
Crude fiber	16.6	16.0	14.8	15.8
Starch	17.4	16.1	16.0	16.1
Sugar	12.8	12.0	12.7	11.9
Crude protein	15.4	13.3	15.4	13.1
Ether extract	2.0	8.8	8.6	8.6

[1]Composition: 35.8 % soy extracted meal, 23.0% triticale, 20.0% corn meal, 15.3% corn gluten feed, 2.0% rape extracted meal, 2.0% $NaHCO_3$, 1.4% CaO, 0.25% NaH_2PO_4, 0.15% vit. E mixture , 0.05% NaCl

Experimental procedures

Each experimental period lasted for 16 days, divided into an adaptation period of 10 days and a sampling period for faeces of 5 days.

During the sampling period, faeces were collected quantitatively. Each day, the collected faeces were homogenized, and aliquots (10% of weight) were stored at 4°C for analysis. The dietary components were sampled on d_8 through d_{15}. Orts were missing. For nutrient analyses, DM content of feed ingredients was estimated in pooled samples. Furthermore, samples were dried at 65°C, ground to pass a 1-mm screen, air equilibrated, and stored until analysis. Faecal samples were dried at 65°C, ground to pass a 1-mm screen, air equilibrated, and stored for analysis of DM, ash, CP and ether extract (**EE**). Fresh subsamples were used to estimate DM and Kjeldahl N.

Chemical analysis

DM of food and faecal samples were estimated using a 60°C forced-air oven for 24 h and a 105°C oven for 3 h. The content of crude ash, crude fiber and EE of these samples was estimated as described by Naumann and Bassler (1988). Ether extract was determined by petroleum ether extraction after treatment with hydrochloric acid (Kuhla et al; 1983). Starch was measured by amyloglucosidase-catalysed release of glucose. For glucose and sugar analysis standard methods were used (UV-test, R-BIOPHARM AG, Darmstadt, Germany).

The content of N was estimated in dried feed and fresh faeces by Kjeldahl method (Naumann and Bassler, 1988).

Statistical analysis

Data were analysed using the one-factorial ANOVA procedure of SPSS (Vers. 13.01). Values are expressed as means with SE. Differences between fat supplements were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

The chemical composition and melting points of the used fat supplements are listed in Table 2.

Table 2: Chemical composition and melting points of the fat supplements

	HPO	FPO	Ca-PFA
Dry matter, %	99.9	99.9	98.4
Ether extract, % of DM	99.4	99.4	85.2
Melting point, °C	55.5 – 65.5	54.5 – 61.2	-
FA pattern, % of total FA[1]			
C14:0	1.0	1.5	1.5
C16:0	44.6	≥75.0	44.0
C18:0	52.3	≥ 8.0	5.0
C18:1	1.7	10.0	40.0
C18:2		2.0	9.5

[1]FA pattern on basis of analysis by producer

The HPO was characterized by a high melting point and a high content of stearic acid. The FA of the FPO consisted of 75% palmitic acid. The Ca-PFA contained 50% unsaturated FA and only 85% EE in DM.

Source of fat supplement affected nutrient digestibility (Table 3). Differences between diets were greater for EE digestibility than for any other nutrient component. The higher EE digestibility for Ca-PFA diet in comparison to the other fat supplemented diets was the reason for the differences in digestibility of DM and organic matter. The poor EE digestibility for the HPO diet (19.2%) is most likely caused by the high content of saturated fatty acid, particularly with regard to the high melting stearic acid. According to literature data, Firkins and Eastridge (1994) demonstrated that saturated fats are less digestible than unsaturated fats and the digestibility increased, as the ratio of C_{16} to C_{18} FA also increased.

Recently, Harvatine and Allen (2006) confirmed this result in studies with dairy cows. Weiss and Watt (2004) found a significantly lower digestibility of FA in diets with HPO in comparison to diets with Ca-PFA (55% vs. 80%) in dairy cows. However, the digestibility of HPO was higher than in our study (55% vs. 19%). This might be a consequence of the higher C_{16}/C_{18} ratio in HPO used in the study of Weiss and Watt than in HPO used in our study (1.54 vs. 0.82). Weisbjerg et al. (1992) demonstrated the higher digestibility of $C_{16:0}$ compared with $C_{18:0}$ in cows.

The higher C_{16}/C_{18} ratio in FPO than in HPO might in addition be responsible for greater EE digestion in FPO (43.6% vs. 19.3%, Table 3). The significantly highest EE digestibility (73.2%) was found in the Ca-PFA diet. This fat supplement contained the highest proportion of unsaturated FA (Table 2).

The digestibilities of fiber, starch, and, sugar were not influenced by the fat supplements, suggesting that the used fat sources were ruminal inert. Recently, Manso et al. (2006) found that the NDF digestibility in growing lambs was significantly greater, when fat was included in the diet in the form of Ca-PFA rather than modified palm oil (mixture of free FA and triglyceride) with 50-55% palmitic acid.

Table 3: Effect of supplemental fat on nutrient digestibility [%]

Item	No fat	HPO	FPO	Ca-PFA	SE
DM	74.1[a]	69.5[b]	71.4[a]	73.8[a]	2.2
Organic matter	76.3[a,c]	71.1[b]	74.6[a]	77.6[c]	1.8
CP	67.2	67.4	69.6	68.8	3.3
Crude fiber	66.3	68.1	68.2	69.4	3.9
Ether extract	55.7[c]	19.2[a]	43.6[b]	73.2[d]	4.7
Starch	98.0	98.2	98.3	98.5	0.4
Sugar	99.2	99.2	99.5	99.3	0.4

[a, b, c, d] Means with different superscript differ significantly ($P < 0.05$)

The EE digestibility of the three fat supplements, calculated by difference, was significantly different (Table 4). The digestibility of EE from HPO was only 10%, the EE of FPO was 41% whereas the EE of Ca-PFA was 78%. The last value corresponds with the value of 86% (SD 11) given by NRC (2001) for FA digestibility. It is difficult to compare the value for HPO with data from the literature, because few data are available and differences in degree of hydrogenation and also esterification can not be excluded. Weiss and Wyatt (2004) found a value of 38% for FA digestibility, however the proportion of $C_{18:0}$ was only 31%. For FPO, no data could be found in the literature. When compared to Ca-PFA, the poor EE digestibility of HPO and low EE digestibility of FPO suggest, that lipolysis could limit the EE digestibility of saturated high melting fats in ruminants. This was confirmed in our study by direct extraction of triglyceride from faeces, that means the extraction was done also without prior hydrochloric treatment. In diets with HPO and FPO, about 60% of faecal EE were present as triglyceride.

The calculated ME and NEL value (Table 4) point out that only Ca-PFA double the energy concentration of grain.

In conclusion, the EE digestibility of Ca-PFA by ruminants is high and the energy concentration amounts to approximately the double of grain. Hydrogenated palm oil (HPO) with more than 50% stearic acid is barely digestible. Due to the reduced chain length of FA fractionated palm oil (FPO) with a palmitic acid proportion of 75% and higher is more digestible, but digestion is still insufficient. The results show, that the intestinal lipolysis of high melting saturated fat limits the EE digestibility.

Table 4: Calculated digestibility of ether extract (EE) and energy concentrations of the studied rumen stable fat supplements

	HPO	FPO	Ca-PFA	SE
EE, g/kg	994	994	838	
Digestibility[1], %	9.7[a]	40.6[c]	78.3[b]	6.4
Digestible EE, g/kg[2]	96.4	403.6	656.2	
ME, MJ/kg[3]	3.36	14.04	22.83	
NEL, MJ/kg[4]	2.42	10.11	16.44	

[1]Calculated as [EE from supplement – (total faecal EE – indigestible EE from basal diet)/EE intake from supplement] x 100. Indigestible EE from basal diet was related to the same animal.
[2]EE x digestibility/100.
[3]0.0348 x g digestible EE (Hoffmann, 1996)
[4]ME x 0.72 (Hoffmann, 1996)
[2, 3, 4] No SE could be given because treatment means were used in the calculations
[a, b, c] Means with different superscript differ significantly ($P < 0.05$)

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