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The effects of adding fat to diets of lactating dairy cows on total-tract neutral detergent fiber digestibility: A meta-analysis

K. A. Weld and L. E. Armentano[1]
Department of Dairy Science, University of Wisconsin-Madison, Madison 53706

ABSTRACT

The objective of this meta-analysis was to determine the effects of supplemental fat on fiber digestibility in lactating dairy cattle. Published papers that evaluated the effects of adding fat to the diets of lactating dairy cattle on total-tract neutral detergent fiber digestibility (ttNDFd) and dry matter intake (DMI) were compiled. The final data set included 108 fat-supplemented treatment means, not including low-fat controls, from 38 publications. The fat-supplemented treatment means exhibited a wide range of ttNDFd (49.4% ± 9.3, mean ± standard deviation) and DMI (21.3 kg/d ± 3.5). Observations were summarized as the difference between the treatment means for fat-supplemented diets minus their respective low-fat control means. Additionally, those differences were divided by the difference in diet fatty acid (FA) concentration between the treatment and control diets. Treatment means were categorized by the type of fat supplement. Supplementing 3% FA in the diet as medium-chain fats (containing predominately 12- and 14-carbon saturated FA) or unsaturated vegetable oil decreased ttNDFd by 8.0 and 1.2 percentage units, respectively. Adding 3% calcium salts of long-chain FA or saturated fats increased ttNDFd by 3.2 and 1.3 percentage units, respectively. No other fat supplement type affected ttNDFd. Except for saturated fats and animal-vegetable fats, supplementing dietary fat decreased DMI. When the values for changes in ttNDFd are regressed on changes in DMI there was a positive relationship, though the coefficient of determination is only 0.20. When changes in ttNDFd were regressed on changes in DMI, within individual fat supplement types, there was no relationship within calcium salt supplements. There was a positive relationship between changes in ttNDFd and changes in DMI for saturated fats. Neither relationship suggested that the increased ttNDFd with calcium salts or saturated FA was due to decreased DMI for these fat sources. A subset of the means included measured ruminal neutral detergent fiber digestion. Analysis of this smaller data set did not suggest that ruminal neutral detergent fiber digestibility is depressed by fat supplementation more than ttNDFd. Adding fats, other than those with medium-chain FA, consistently increased digestible energy density of the diet. However, due to reduced DMI, this increased energy density may not result in increased digestible nutrient intake.

Key words: NDF digestibility, dietary fat, DMI, dairy cow

INTRODUCTION

The NRC (2001) and literature reviews (Palmquist and Jenkins, 1980; Jenkins, 1993) cite dietary fat as having a negative effect on fiber digestibility in lactating dairy cattle. This conclusion is primarily based on evidence showing that fat decreases NDF digestibility in steers and sheep (Ward et al., 1957; Devendra and Lewis, 1974; Jenkins and Palmquist, 1984). Overall, evidence is lacking that the same decrease in fiber digestibility occurs in lactating dairy cattle when fat is supplemented (Palmquist, 1991; Brask et al., 2013). Some studies have found that fat significantly decreased total-tract NDF digestibility (**ttNDFd**) in lactating dairy cattle, but the magnitude of the decrease was minimal (Ueda et al., 2003; Martin et al., 2008; Reveneau et al., 2012). A published summary of the effect of fat addition on fiber digestion in lactating dairy cows is not available.

The NRC (2001) cites unsaturated fats as having a more negative effect on rumen fermentation compared with calcium salts and hydrogenated fats. This is attributed to possible differences in the effects on microbial populations as it is known that UFA can affect microbial growth rates in vitro (Maia et al., 2007). Additionally, increasing the particle size of the fats or oilseeds is recognized as a possible mechanism for decreasing negative effects of UFA (Weld and Armentano, 2016). The presence of additional dietary calcium or fat in the form of calcium salts, rather than fatty acids (**FA**), has been shown to reverse negative effects of fat

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[1]Corresponding author: learment@wisc.edu

on fiber digestibility (Ward et al., 1957; White et al., 1958; Jenkins and Palmquist, 1984).

The objective of this meta-analysis is to provide a quantitative summary of the effects of fat supplementation on ttNDFd in lactating dairy cattle reported in the literature. Despite the presence of reviews on the effects of fat on ruminal fermentation, they do not offer a quantitative summary or analysis of the effects of fat on fiber digestibility. As the complexity of nutrient requirement models intensifies, a quantitative understanding of the effects of fat supplementation to the diets of high-producing dairy cattle will be necessary.

MATERIALS AND METHODS

Study Selection

Papers published in English between 1980 and 2015 that reported ttNDFd in lactating dairy cattle fed fat-supplemented diets and a corresponding lower-fat control diet were compiled using Google Scholar, Web of Knowledge, and the Journal of Dairy Science as search engines. Combinations of the following search terms were used: fat, fatty acid, fiber digest, dairy, cow, oil, tallow, Ca salts, hydrogenated, saturated, canola, flaxseed, linseed, sunflower, soybean, and rapeseed. Relevant citations from these papers were included as well.

Treatments included in the final analysis reported ttNDFd and dietary FA or ether extract (**EE**); had a corresponding low-fat control diet with a similar forage-to-concentrate ratio as the treatment diet(s) (within 5 percentage points); used lactating dairy cows; and supplemented fat orally. We excluded studies supplementing fat in the form of full-fat oilseeds of any particle size due to the possible confounding effect of altering the source of NDF in the diet and oil availability.

We formed supplemental fat categories based on the descriptions and FA compositions of fat supplements reported in the studies, which resulted in some variation of FA composition within categories (Table 1). Calcium salts of palm oil were categorized separate from calcium salts of long-chain FA (**LCFA**) because of the differing FA profile. Oils and calcium salts of LCFA include all seed oils, but not palm oil. Oleamide treatments were included in the analysis for the purpose of study effects, but the results are not reported because there were only 2 treatments. One publication did not report the standard error (**SE**) of ttNDFd, so SE was calculated using the mean square error reported (Smith et al., 1993).

Statistics

Many studies fed more than 1 fat type at similar dietary concentrations with a shared lower-fat control diet, whereas relatively few studies examined multiple levels of the same fat type (Figure 1). For all studies, each fat treatment mean and its corresponding control mean within a study were summarized into 1 observa-

Table 1. Description of the fat treatment means included in the data set

Variable	Mean	SD	Minimum	Maximum	n[2]
ttNDFd[1] (%)	49.4	9.3	28.8	66.8	98
DMI (kg/d)	21.3	3.5	13.4	27.8	93
Acetate:propionate ratio	2.73	0.45	1.46	3.61	63
Diet characteristics					
Fatty acids (% DM)	6.2	1.3	3.8	10.0	98
ΔFA[3] (% DM)	3.3	1.3	1.1	6.6	98
NDF (% DM)	32.4	4.3	22.5	43.3	98
CP (% DM)	17.1	1.3	14.1	20.8	98
NFC (% DM)	36.2	4.9	22.6	48.9	98
Calcium (% DM)	1.0	0.2	0.5	1.3	47
Forage level (% DM)	49.6	7.7	35.0	67.0	98
Production parameters					
Milk (kg/d)	32.3	7.5	14.1	57.7	89
Fat (%)	3.36	0.47	2.37	4.67	89
Protein (%)	3.07	0.19	2.71	3.54	87
DIM	101	52	31	213	82
Total-tract apparent digestibility					
Fatty acids (%)	67.3	11.3	36.7	92.7	56
Ether extract (%)	77.6	9.8	59.6	93.0	32
OM (%)	67.4	4.7	54.1	77.1	75

[1]ttNDFd = total-tract NDF digestibility.

[2]n = number of fat treatments.

[3]ΔFA = change in dietary fatty acid concentration from the lower fat control.