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Effects of feeding extruded linseed on production performance and milk fatty acid profile in dairy cows: A meta-analysis

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ABSTRACT

The objectives of this study were to quantify the effects on production performance and milk fatty acid (FA) profile of feeding dairy cows extruded linseed (EL), a feed rich in α-linolenic acid, and to assess the variability of the responses related to the dose of EL and the basal diet composition. This meta-analysis was carried out using only data from trials including a control diet without fat supplementation. The dependent variables were defined by the mean differences between values from EL-supplemented groups and values from control groups. The data were processed by regression testing the dose effect, multivariable regression testing the effect of each potential interfering factor associated with the dose effect, and then stepwise regression with backward elimination procedure with all potential interfering factors retained in previous steps. This entire strategy was also applied to a restricted data set, including only trials conducted inside a practical range of fat feeding (only supplemented diets with <60 g of fat/kg of dry matter and supplemented with <600 g of fat from EL). The whole data set consisted of 17 publications, representing 21 control diets and 29 EL-supplemented diets. The daily intake of fat from EL supplementation ranged from 87 to 1,194 g/cow per day. The dry matter intake was numerically reduced in high-fat diets. Extruded linseed supplementation increased milk yield (0.72 kg/d in the restricted data set) and decreased milk protein content by a dilutive effect (−0.58 g/kg in the restricted data set). No effect of dose or diet was identified on dry matter intake, milk yield, or milk protein content. Milk fat content decreased when EL was supplemented to diets with high proportion of corn silage in the forage (−2.8 g/kg between low and high corn silage-based diets in the restricted data set) but did not decrease when the diet contained alfalfa hay. Milk *trans*-10 18:1 proportion increased when EL was supplemented to high corn silage-based diets. A shift in ruminal biohydrogenation pathways, from *trans*-11 18:1 to *trans*-10 18:1, probably occurred when supplementing EL with high corn silage-based diets related to a change in the activity or composition of the microbial equilibrium in the rumen. The sum of pairs 4:0 to 14:0 (FA synthesized de novo by the udder), palmitic acid, and the sum of saturated FA decreased linearly, whereas oleic acid, vaccenic acid, rumenic acid, α-linolenic acid, and the sums of mono- and polyunsaturated FA increased linearly when the daily intake of fat from EL was increased. In experimental conditions, EL supplementation increased linearly proportions of potentially human health-beneficial FA in milk (i.e., oleic acid, vaccenic acid, rumenic acid, α-linolenic acid, total polyunsaturated FA), but should be used cautiously in corn silage-based diets.
Key words: dairy cow, extruded linseed, milk yield, milk fatty acid, meta-analysis

INTRODUCTION

The onset of lactation leads to profound physiological changes marked by a negative energy balance. Increasing the energy content of the diet should help limit the length and severity of the negative energy balance status while maintaining milk yield in high-producing dairy cows. Indeed, feeding fat to dairy cows could increase energy density of diets without increasing high-starch concentrate intake and reducing fiber intake, which are both negatively related to rumen function (Palmquist and Jenkins, 1980). However, the effects of fat addition to the diet on milk yield (**MY**; Rabiee et al., 2012), DMI (Allen, 2000), and milk fat content (**MFC**; Palmquist et al., 1993) are heterogeneous. These effects seem dependent on the nature of the fat supplement and its processing, the amount of fat supplemented (Jenkins, 1997), and the nature of the forage in the diet (Onetti and Grummer, 2004). Palmquist and Jenkins (1980) stated that the total fat in the diet should not exceed

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6 to 8% of DM to avoid the negative effects of lipids on rumen function associated with a high-fat diet.

Increasing knowledge about the potential benefits of α-linolenic acid (**ALA**; *cis*-9,*cis*-12,*cis*-15 18:3), long chain n-3 fatty acids (**FA**), and low n-6-to-n-3 ratio on human health (Simopoulos, 2008; Barceló-Coblijn and Murphy, 2009; Rajaram, 2014) has raised consumer demand for better nutritional quality of fat in dairy products. Considerable evidence exists that milk FA composition can be rapidly and widely modulated by adding oilseeds to the diets of dairy cows (Chilliard et al., 2007).

Linseed oil contains about 55% of ALA (Petit, 2010), the n-3 FA precursor of long chain n-3 FA. However, in ruminants, PUFA are largely biohydrogenated in the rumen before their absorption in the small intestine. Glasser et al. (2008c) estimated by meta-analysis that 87% of the ALA ingested was biohydrogenated in the rumen. Indeed, adding PUFA to the diet leads to the formation of many intermediates of biohydrogenation in the rumen, in interaction with the ruminal microorganisms ecosystem (Jenkins et al., 2008), including *trans* FA and precursors of CLA that may induce milk fat depression (Shingfield et al., 2010). The efficacy of ALA transfer into the duodenum thus depends on the degree to which ALA is protected against ruminal biohydrogenation.

The extrusion of oilseeds is a heat treatment that may protect UFA against ruminal biohydrogenation and the rumen environment against the adverse effects of UFA (Sterk et al., 2012). Indeed, Kennelly (1996) stated that heat treatment denatures the protein matrix surrounding the fat droplets, thus reducing the UFA availability for rumen microorganisms. However, the effects of extrusion on ruminal degradability of oilseeds are inconsistent in the literature (Dang Van et al., 2011; Troegeler-Meynadier et al., 2014). The analysis of the protective effect of extrusion on UFA obviously depends on the oilseed form taken for comparison (i.e., free oil, raw, technologically or chemically treated), and on the method of evaluation of UFA biohydrogenation (i.e., duodenal flows or milk FA profiles; Doreau et al., 2009). Another hypothesis on the mechanism of the potential protective effect of extrusion on UFA is that extrusion increases the rate of oil release in the rumen fluid, resulting in a higher bypass of PUFA from the rumen to the duodenum compared with whole and rolled seeds (Chilliard et al., 2009; Doreau et al., 2009). Indeed, Reddy et al. (1994) stated that extrusion ruptures fat micelles, thus increasing fat release and postruminal absorption compared with whole seeds (Sterk et al., 2010).

The use of extruded linseed (**EL**) in diet of dairy cows could both increase the energy density of the diet and improve the milk FA profile while limiting the putative negative effects of PUFA on the rumen function. Glasser et al. (2008a) summarized the effects of various oilseed supplements (i.e., various sources and forms), including linseed supplements on MFC and milk FA using a meta-analysis approach. However, they pooled several linseed forms to obtain a sufficient amount of data. Extruded linseed was associated with micronized, ground, and whole linseeds in the analysis (Glasser et al., 2008a). The evaluation of the specific effects of EL supplementation was therefore limited. The study of factors describing basal diet composition as potential modulating factors to responses was also limited due to the scant available data in their subdata sets (Glasser et al., 2008a). Since the publication of the meta-analysis by Glasser et al. (2008a), the effects of EL supplementation in lactating dairy cow diets have been tested under multiple experimental conditions (Chilliard et al., 2009; Ferlay et al., 2010, 2013; Hurtaud et al., 2010; Lerch et al., 2012; Neveu et al., 2013, 2014; Oeffner et al., 2013); however, MY and milk composition responses to EL seem inconsistent (Petit, 2010). We hypothesized that the dose of EL and the composition of the basal diet could explain this variability. The objectives of our study were to quantify, using a meta-analysis approach, the effects of feeding dairy cows with EL on milk yield and milk components, including FA profile, and to assess whether the size of the dose supplemented and the composition of the basal diet could influence responses.

MATERIALS AND METHODS

Literature Search and Selection of Publications

Our literature search was conducted in the Web Of Science, Google Scholar, and CABI databases using the key words “extruded linseed,” “linseed,” “dairy,” “cow,” and “cattle,” as well as French terms in the database of peer-reviewed *Rencontres Autour des Recherches sur les Ruminants* conference proceedings. References cited in papers of interest were also included.

Inclusion criteria of studies defined a priori by authors were (1) study with lactating dairy cows, (2) control diet without fat supplementation, (3) treatment diet supplemented with EL only (i.e., no other form of linseed and no other lipid supplement), (4) absence of alfalfa protein concentrate in control and EL-supplemented diets because it is an alternative ALA source (Hurtaud et al., 2013); and (5) DMI measured. Furthermore, exclusion criteria were applied to obtain an adequate number of similar and sufficiently detailed milk FA profiles: (1) unknown measure methodology, and (2) inadequate quality of measure and inadequate FA profile (insufficient length of the capillary column