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Effect of dietary flax seed and oil on milk yield, gross composition, and fatty acid profile in dairy cows: A meta-analysis and meta-regression

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ABSTRACT

Several experiments were conducted over the past few years to evaluate the feeding value of flax seed and oil in dairy cow diets. The current meta-analysis and meta-regression was undertaken to assess the overall effect of different forms of flax, as a source of trienoic (*cis*-9, *cis*-12, *cis*-15 18:3) fatty acids (FA), on lactation performance and on transfer efficiency of its constituent n-3 FA from diet to milk fat. Comparisons were first conducted with nonsupplemented controls or with diets containing either saturated (mainly 16:0 or 18:0 or both), monoenoic (mainly *cis*-9 18:1), or dienoic (mainly *cis*-9, *cis*-12 18:2) FA. Results indicate that supplementing flax seed and oil decreased dry matter intake, as well as actual and energy-corrected milk yield without affecting the efficiency of utilization of dietary dry matter or energy as compared with nonsupplemented iso-energetic controls. When compared with the other 3 types of dietary fat evaluated, flax rich in trienoic FA supported a yield of energy-corrected milk similar to supplements rich in saturated, monoenoic, or dienoic FA. Greater milk fat concentration and feed efficiency were observed with saturated supplements. However, milk fat concentration and yield were lower with dienoic FA than with flax supplements. Further analyses were conducted to compare the effect of different forms of flax oil, seed, or fractions of seed. Among the 6 categories evaluated, mechanically processed whole seed (rolled or ground) allowed the greatest yield of energy-corrected milk and the best feed efficiency when compared with free oil, intact or extruded whole seed, protected flax, and flax hulls. Feeding protected flax and flax hulls allowed the greatest milk fat concentration of *cis*-9, *cis*-12, *cis*-15 18:3. Moreover, the greatest transfer efficiencies of this fatty acid from diet to milk were recorded with the same 2 treatments, plus the mechanically processed whole seed. These results make this last category the most suitable treatment, among the 6 flax forms evaluated, to combine optimum lactation performance and protection of flax constituent *cis*-9, *cis*-12, *cis*-15 18:3.
Key words: linseed, dietary fat, milk composition, fatty acid, α-linolenic acid

INTRODUCTION

Consumption of food products from animals fed flax seed (also called linseed; *Linum usitatissimum*) as a source of n-3 fatty acids (**FA**), including milk, has been associated with positive effects on blood lipid profile in humans (Weill et al., 2002; Malpuech-Brugère et al., 2010). Flax oil contains 54 to 55% α-linolenic acid (*cis*-9, *cis*-12, *cis*-15 18:3, INRA-AFZ, 2002; Glasser et al., 2008a) and is therefore a rich source of n-3 PUFA. Intake of flax seed or oil by dairy ruminants has also been shown to mitigate their methane production (Chilliard et al., 2009), improve reproductive performance (Santos et al., 2008; Zachut et al., 2010b), and modulate immune functions (Caroprese et al., 2009, 2016). For these reasons, several experiments were conducted in dairy cows to study the effect of different forms of flax seed and oil, and also to compare their effects with other lipid sources on milk yield and composition. Among several factors evaluated, a specific objective of these experiments was to study the effects on milk FA profile, with a special emphasis on the transfer efficiency of *cis*-9, *cis*-12, *cis*-15 18:3 from diet to milk secretion.

In a meta-analysis, Glasser et al. (2008a) individually compared different oilseeds (flax seed, rapeseed, soybean, and sunflower seed) with nonsupplemented control treatments. However, no direct comparison between these different types of oilseeds was conducted. Similarly, Brunschwig et al. (2010) in a literature review and Sterk et al. (2012) in a meta-analysis compared different forms of technologically processed flax seed and oil to control treatments, but the difference between these varying flax forms was not determined. More recently, Meignan et al. (2017) conducted a meta-analysis to study the effect of extruded flax seed on milk yield

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and composition. Finally, Petit (2010) published a literature review on the effects of flax seed on feed intake, milk production, and milk composition of dairy cows, but differences between processing technics were not assessed statistically.

Strategies to design nonsupplemented control diets may differ in feeding trials conducted to study the effect of different lipid sources, such as flax seed or oil, on animal performance. In several experiments, supplemental fats are added to dairy cow diets at the expense of forage, concentrate, or both on a kilogram-for-kilogram basis, without adjustment for the extra energy provided by the lipid source. Another strategy is to modify the ingredient composition of the control diet, in particular the forage-to-concentrate ratio, with the objective to adjust its energy concentration as compared with the fat-supplemented ration. These different approaches, related to dietary energy supply, may affect the outcomes of the experiment.

Consequently, the current meta-analysis and meta-regression was undertaken to assess the effect of flax seed and oil when comparison is made with low-fat control treatments or with diets containing different lipid sources presenting varying levels of unsaturation. A second objective was to compare the effects of different forms of flax seed and oil on milk yield, milk composition, milk FA profile, and on the transfer efficiency of *cis*-9, *cis*-12, *cis*-15 18:3 from diet to milk secretion.

MATERIALS AND METHODS

Data Collection

The research of articles was conducted using Google Scholar (Google, Mountain View, CA) for which literature coverage has been assessed by Gehanno et al. (2013). The following key words were used: dairy cows, flaxseed, linseed, FA profile, milk yield, and milk composition. The research was conducted from September 2015 to January 2016, included articles published until December 31, 2015, and was restricted to French and English languages. With each positive result, the "cited by" function was used to find articles that did not contain our key words, but which could possibly be included in the database. One hundred thirteen articles were recorded. Among them, a total of 78 research papers reporting 84 experiments published between 1998 and 2015 (Table 1) met the predetermined selection criteria. These criteria included evidence that (1) paper was peer-reviewed; (2) at least one treatment was supplemented with flax oil, seed, or fractions of seed; (3) the study was conducted on dairy cattle breeds; and (4) milk yield, milk fat percentage, and concentration of *cis*-9, *cis*-12, *cis*-15 18:3 in milk fat were reported. The database contained 294 treatments among which 160 included flax oil, seed, or fractions of seed.

Number of observations, diet composition, as well as production performance and milk composition for 5 different comparisons evaluated in experiments 1 and 2 are reported in Supplemental Tables S1 and S2 (https://doi.org/10.3168/jds.2017-12637). The composition of experimental rations containing 6 different categories of flax forms is presented along with their respective number of observations in Supplemental Table S3 (https://doi.org/10.3168/jds.2017-12637).

When ether extract (**EE**) concentration of the ration was the only value available to establish lipid intake, the FA intake was estimated by multiplying the EE concentration by the average FA to EE ratio (0.760 ± 0.095; mean ± SD), calculated from research articles included in the original database where both values were reported (n = 33).

The feed library of the Cornell Net Carbohydrate and Protein System (version 6.6.5, Cornell University, Ithaca, NY) and the INRA-AFZ (2002) tables of feed composition were used to complete the missing FA profile of experimental feed ingredients, as suggested by Mannai et al. (2016). The yield of ECM was calculated as described by Madsen et al. (2008). Metabolizable energy was converted to NE_L according to NRC (2001).

Total odd-chain FA (**ΣOCFA**), *trans* octadecenoic acids (**Σ*t* 18:1**), *cis* octadecenoic acids (**Σ*c* 18:1**), and CLA (**ΣCLA**) were calculated based on the FA in these categories reported within each article. Total de novo synthesized FA (**ΣDNFA**) included 4:0, 6:0, 8:0, 10:0, 12:0, 14:0, and 14:1. Articles for which major FA of the respective categories were not reported or out of biologically valid ranges were excluded from the analysis.

Data Investigation and Statistical Analysis

Four different series of statistical analyses were conducted using sub-data sets from the original database. In a first experiment, rations containing dietary supplements of flax oil, seed, or fractions of seed rich in *cis*-9, *cis*-12, *cis*-15 18:3, a trienoic FA (**flax-TRI**), were compared with nonsupplemented control treatments. In a second experiment, flax-TRI supplements were compared with lipid sources varying in FA composition. In a third experiment, comparisons were established between different forms of flax-TRI supplementations. The fourth experiment was a factorial analysis with the objective to compare the interrelationships within a set of variables of our original database with established theoretical meaningfulness with regards to lipid