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Milk production and composition, milk fatty acid profile, and blood composition of dairy cows fed whole or ground flaxseed in the first half of lactation☆

H.V. Petit*, C. Côrtes

Dairy and Swine Research and Development Centre, Agriculture and Agri-Food Canada, P.O. Box 90, Stn Lennoxville, Sherbrooke, QC, Canada J1M 1Z3

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ABSTRACT

A total of 27 multiparous Holstein cows averaging 634 kg body weight (BW) were allotted at calving to six groups of four cows and one group of three cows blocked for similar calving dates to determine effects of feeding whole or ground flaxseed on dry matter (DM) intake, milk production, milk composition, milk fatty acid profile and concentration of some blood metabolites. Cows within each block were assigned to one of four iso-net energy for lactation total mixed rations containing either 21 g/kg DM calcium salts of palm oil (control diet), 72 g/kg DM whole flaxseed, 72 g/kg DM ground flaxseed or 36 g/kg DM whole flaxseed and 36 g/kg DM ground flaxseed. Diets were fed for *ad libitum* intake from calving to week 28 of lactation. Flaxseed grinding and supplementation had no effect on BW and milk production, but intake of DM was lower for cows fed 72 g/kg DM ground flaxseed. The main difference in milk fatty acid profile determined on week 8 of lactation due to flax grinding was for linolenic acid proportion, which was higher in milk fat of cows fed ground (36 or 72 g/kg DM) flaxseed compared to cows fed 72 g/kg DM whole flaxseed. Flaxseed supplementation enhanced the linolenic acid proportion in milk fat compared to the control diet. Cows fed the control diet had higher proportions of 16:0 and *cis*7-16:1, and lower proportions of 18:0 and *cis*9-18:1, in milk fat than those fed flaxseed. Cows fed ground flaxseed tended (P=0.07) to have higher plasma concentrations of β-hydroxybutyrate (BHBA) than those fed the other diets. Compared to diets containing 21 g/kg DM calcium salts of palm oil, 72 g/kg DM whole flaxseed or a mixture of 36 g/kg DM ground and 36 g/kg DM whole flaxseed, feeding 72 g/kg DM ground flaxseed may contribute to increased lipolysis of early lactation cows, as indicated by lower DM intake and higher BHBA concentrations in blood.

1. Introduction

Flaxseed (*Linum usitatissimum*) has attracted attention as a lipid supplement for dairy cattle due to its high concentration of α-linolenic acid (C18:3n3), an essential fatty acid (FA) that is not synthesized in humans. The oil fraction of flaxseed is approximately 0.55 omega 3 α-linolenic acid (Mustafa et al., 2002), and research has shown several health benefits of

Abbreviations: ADF, acid detergent fiber; BHBA, β-hydroxybutyrate; CON, control TMR with 21 g/kg calcium salts of palm oil; CP, crude protein; DM, dry matter; EE, ether extract; FA, fatty acid; GRO, TMR with 72 g/kg ground flaxseed; MIX, TMR with 36 g/kg whole flaxseed and 36 g/kg ground flaxseed; aNDF, neutral detergent fiber; NEFA, non-esterified fatty acids; NE_L, net energy for lactation; TMR, total mixed ration; WHO, TMR with 72 g/kg whole flaxseed.

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* Corresponding author. Tel.: +1 819 565 9171; fax: +1 819 564 5507.
E-mail address: helene.petit@agr.gc.ca (H.V. Petit).

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omega 3 FA in humans, including anticarcinogenic and potential cardioprotective roles as well as improvement of visual acuity (Parodi, 1997; Wright et al., 1998; Massaro et al., 1999). Feeding whole flaxseed (33 and 110 g/kg dry matter (DM) in prepartum and postpartum diets, respectively) compared to no fat or a source of saturated fatty acid (FA) from 6 weeks before calving, has been a useful strategy to increase liver concentrations of glycogen, and decrease those of triglycerides, in multiparous cows after calving (Petit et al., 2007a), which may contribute to decreased incidence of fatty liver syndrome. Moreover, flaxseed fed at 90–100 g/kg DM has been shown to reduce embryo mortality (Petit and Twagiramungu, 2006), thus improving general fertility of dairy cows (Ambrose et al., 2006). Feeding flaxseed generally results in the lowest omega 6 to omega 3 FA ratio in milk fat (Petit, 2002), which may improve milk FA profile and result in better human health. In general, untreated whole flaxseed is readily eaten by dairy cows, and feeding up to 150 g/kg DM as flaxseed had no effect on DM intake of early (Petit, 2002) and late lactation (Martin et al., 2008) dairy cows. However, feeding 142 g/kg *versus* 93 g/kg DM whole flaxseed decreased milk fat concentration and tended to decrease digestibility of the diet (Petit and Gagnon, 2009).

Physical breakdown of the flaxseeds in the diet could contribute to increased milk production by dairy cows. Indeed, in a short-term experiment (*i.e.*, 3 week periods), dairy cows fed 100 g/kg DM ground flaxseed had a 6.5% increase (1.2 kg/d) in milk production compared to those fed 100 g/kg DM whole flaxseed (da Silva et al., 2007). Similarly, feeding rolled, compared to whole, untreated flaxseed at 100 g/kg DM increased milk production of early lactation cows by 10% (Kennelly, 1996). Processing flaxseed may also improve milk FA profile from a human health perspective due to increased proportions of conjugated linoleic acid and omega 3 FA and decreased proportions of medium-chain and saturated FA in milk fat of cows fed ground compared to those fed whole flaxseed (da Silva et al., 2007). However, most comparisons of effects of flaxseed processing on productivity of dairy cows have used short-term experiments of less than 2 months. There is no information on effects of feeding ground or whole flaxseed from calving through the first half of lactation. Moreover, no comparison has been made of effects of grinding or mixing ground and whole flaxseed on dairy cow productivity, although processing may increase availability of oil in the rumen.

The objective of this experiment was to determine effects of flaxseed processing (*i.e.*, grinding *versus* whole *versus* a mixture of both) on performance (*i.e.*, feed intake, milk production and milk composition), milk FA profile and blood parameters related to fatty liver syndrome in early lactation dairy cows.

2. Materials and methods

2.1. Cows, experimental design and diets

The experiment was conducted at the Atlantic Dairy and Forage Institute (ADFI) near Fredericton Junction, NB, Canada, from January 2008 to March 2009 using 27 multiparous (initial body weight (BW): 634 ± 74.2 kg) Holstein cows. Cows were blocked for similar expected calving dates. The experiment was from calving to week 28 of lactation. Cows were housed in tie stalls and fed individually. Cows within groups were assigned randomly to one of four total mixed rations (TMR; Table 1). There were six groups of four cows and one group of three cows. The four TMR consisted of a control TMR with 21 g/kg DM calcium salts of palm oil (CON), a TMR with 72 g/kg DM (DM basis) whole flaxseed (WHO), a TMR with 72 g/kg DM ground flaxseed (GRO) and a TMR with 36 g/kg DM whole flaxseed and 36 g/kg DM ground flaxseed (MIX). All diets were designed to have similar concentrations of crude protein (CP), ether extract (EE) and net energy for lactation (NE_L). The commercial calcium salts of palm oil (Megalac; Church and Dwight Co. Inc., Princeton, NJ, USA) were used in the control diet to make all diets iso-NE_L. Feed consumption was recorded daily. Diets were fed twice daily at 07:00 and 15:00 h at *ad libitum* rates to allow 100 g/kg refusals. Cows were milked twice daily at 05:45 and 16:45 h and cared for in accordance with guidelines of the Canadian Council on Animal Care (CCAC, 1993). Milk production was recorded at every milking. The BW of each cow was determined weekly for the first 8 weeks of lactation and every 4 week afterwards.

2.2. Sample collection and analyzes

Samples of TMR were collected weekly, frozen and composited on a 4-week basis. Composited samples were mixed thoroughly and subsampled for chemical analyzes. Silage DM was analyzed weekly for DM adjustment of the TMR. Milk samples were obtained once every 4 weeks from each cow for two consecutive milkings and analyzed separately to determine milk composition. Milk samples were stored at +4 °C with a preservative (bronopol-B2) until analyzed 2 days later for fat, CP, lactose and somatic cell count. On week 8 of lactation, milk samples were collected without preservative for two consecutive milkings from the first 6 blocks of cows to calve. Milk samples were pooled within cow relative to production to obtain one composite milk sample per cow and frozen at −20 °C until analyzed for milk FA profile.

Blood was collected from all cows within 24 h of calving and on week 1, 2, 3, 4, 5 and 6 postpartum 3 h after the 05:45 h feeding to determine non-esterified FA (NEFA), BHBA and glucose concentrations. Blood was withdrawn from the jugular vein into vacutainer tubes (Becton Dickinson and Cie, Rutherford, NJ, USA) containing EDTA. Tubes were immediately placed on ice and centrifuged within 1 h at 4 °C for 30 min at 3000 × g. Plasma were separated and frozen at −20 °C for subsequent analysis.

Dry matter of TMR was determined by drying at 105 °C for 48 h (AOAC, 1990; Method 930.15). The TMR were dried at 55 °C and ground to pass a 1 mm screen in a Wiley mill before analyzes of N, EE, acid detergent fiber (ADF) and neutral detergent