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Effects of extruded linseed or alfalfa protein concentrate in interaction with two levels of concentrates on milk production and composition in dairy cows

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ABSTRACT

Improving ω3 fatty acid (**FA**) transfer from feed to milk and decreasing milk saturated FA (**SFA**) without increasing trans mono-unsaturated FA are desirable goals. Our objective was to study the effects of supplying two α-linolenic acid (**ALA**)-rich feedstuffs in interaction with proportion of concentrate in the diet on milk FA composition. The two ALA sources were extruded linseed (**LIN**, 700 g/d) and alfalfa protein concentrate (**APC**, 2 kg/d), supplying 115 and 49 g/d ALA, respectively, per cow per day. Two groups of 12 cows paired according to milk yield, milk fat and milk protein contents, lactation rank (primiparous or multiparous), lactation stage, DMI, milk proportions of saturated and polyunsaturated FA were fed a corn silage-based diet with 30% (**C30**) or 65% (**C65**) cereal-based concentrate and received the 2 ALA sources in a reversal design during 5-wk periods. The cows averaged 117 ± 14 DIM at the beginning of the experiment. Data were analyzed according to a split-plot design using the Proc mixed procedure. There was no significant interaction between the concentrate level and ALA source for most measured parameters. Treatment C65 decreased milk fat content (−1.15%), milk fat yield (−301 g/d), and proportion of SFA, especially C16:0, C18:0, C4:0, C6:0 and C8:0, and increased *trans*-C18:1, especially t9, t10 and t12. Treatment C65 significantly increased milk yield (+3.7 kg), milk protein content (+0.16%) and milk protein yield (+141 g/d), decreased casein-to-protein ratio (−2.6 percentage units). Compared to LIN, APC increased milk fat content (0.33%), milk fat yield (76 g/d), proportion of SFA, especially C4 to C12, C14:0 and C16:0, and decreased *cis* and all *trans* C18:1 isomers. APC tended to decrease milk yield (0.9 kg/d, $P=0.061$) although DMI was not affected, and did not affect protein yield. APC increased both total protein and total casein contents without impact on casein-to-protein ratio and milk protein yield. The transfer rate of C18:3 from feed to milk was much higher in APC treatment than in LIN treatment (15.3% vs 4.7%). This trial shows that adding ALA-rich feedstuffs to the diet to enrich milk can have very marked effects on milk FA composition but also on milk protein composition. These effects are stronger with high concentrate diets, resulting in acidogenic risk. The rate of transfer of ALA from feed to milk

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also varies according to lipid source. Higher transfer rates lead to lower modifications of milk composition.

1. Introduction

PUFA-rich feedstuffs are added to dairy cow diets to modify milk FA profiles, by increasing α-linolenic acid (**ALA**), and c9t11 conjugated linoleic acid (**CLA**) (rumenic acid) contents. In most cases, these feedstuffs are oilseeds such as linseed or rapeseed in various forms (raw, ground, extruded), but new alternative feed sources of ALA are emerging, such as alfalfa protein concentrate (**APC**) which comes from pressed alfalfa juice heat-treated to concentrate its nutrient content (proteins, lipids, iron and vitamins). Fatty acids from all of these feedstuffs undergo a strong rumen biohydrogenation which results in a low transfer of dietary ALA (often under 5%) into the milk (Bauman and Griinari, 2003). Moreover, the rate of ALA transfer from linseed varies according to the supplied form and level, from 0.5% with linseed oil (Chilliard et al., 2000) to 0.9–2.2% with extruded or micronized linseed (Gonthier et al., 2005) and 5.6% with ground linseed (Sterk et al., 2011). It also varies according to the amount of ALA in feedstuffs (Chilliard and Ferlay, 2004). The amount of ALA in APC is relatively low compared to linseed and the rate of transfer of ALA from APC is around 17% (Peyraud, personal communication). PUFA are also isomerized in the rumen with the appearance of *trans* forms, whereas all the PUFA from fodder and concentrates are in *cis* form. Metabolism of ALA results in the production of a series of intermediates (mainly c9t11c15 C18:3, t9t12t15 C18:3, t11c15 C18:2, t11t13 CLA, t11c13 CLA, t11 C18:1 and t13 C18:1) whereas linoleic acid (**LA**) rumen metabolism results in the production of 8,10-CLA, 9,11-CLA, t10c12 CLA and t10 C18:1 (Chilliard et al., 2007). The preferential pathway is *trans* 11 which ultimately leads to the transfer of rumenic and vaccenic acid to the milk.

These biohydrogenation processes are strongly affected by rumen conditions, especially rumen pH. Low ruminal pH reduces rates of biohydrogenation (Kalscheur et al., 1997). Feeding high concentrate diets modify the isomerization pathways and lead to the formation of *trans* FA other than *trans*-11, particularly *trans*-10 FA (Chilliard et al., 2007; Loor et al., 2005). As the nutritional properties of some of these *trans* FA are not yet fully understood, their concentrations should be kept to a minimum.

Consequently, it becomes important to better define the conditions governing the use of ALA sources in dairy cows, which are particularly vulnerable to episodes of subclinical rumen acidosis due to their very high intake levels and very concentrate-rich diets. It is equally important to test whether PUFA metabolism in the rumen differs according to ALA source type.

This trial was designed to measure milk FA composition and quantify the rate of transfer to milk of two natural ALA sources (extruded linseed and APC providing the same amount of fat in diets) in dairy cows receiving a low-concentrate and thus relatively non-acidogenic diet compared to a much more concentrate-rich diet expected to lead to much lower rumen pH levels, and to identify the impact of these diets on milk protein and mineral contents that are important for cheese-making.

2. Material and methods

2.1. Animals

This study was conducted at the Méjusseaume experimental farm (UMR 1348 PEGASE, Le Rheu, France), and used 24 mid-lactation dairy cows (4 groups of 6 cows, 3 primiparous and 3 multiparous). Cows were allocated to groups based on parity (primiparous or multiparous), lactation stage (117 ± 14 d), milk yield (35.4 ± 5.1 kg/d), milk fat content (3.93 ± 0.43%), milk protein content (2.89 ± 0.23%), BW (617 ± 56 kg), total DMI, and milk SFA and PUFA (measured in mid-infrared). These parameters were measured 3 wk before the beginning of the experiment.

2.2. Treatments

Four experimental treatments were applied: a corn silage-based diet with 30% concentrate (energy concentrate and formaldehyde-treated soybean meal) (**C30**) and 1 kg VALOMEGA 160 (Valorex, Combourtillé, France) (**LIN**): C30-LIN; a corn silage-based diet with 30% concentrate (energy concentrate and soybean meal) (C30) and 2 kg EXTRALUZ (Désialis, Châlons-en-Champagne, France) (alfalfa protein concentrate, APC): C30-APC; a corn silage-based diet with 65% concentrate (energy concentrate and formaldehyde-treated soybean meal) (**C65**) and 1 kg VALOMEGA 160: C65-LIN; a corn silage-based diet with 65% concentrate (energy concentrate and soybean meal) and 2 kg EXTRALUZ: C65-APC.

Feed compositions are given in Table 1. VALOMEGA 160 is composed of 30% wheat meal and 70% extruded TRADI-LIN grain (extruded linseed). TRADI-LIN uses a patented process characterized by a preliminary maturing step of specific duration (between 10 and 30 min) and temperature ($< 100\ ^{\circ}C$), level of steam incorporation, and the mounting of the extruders (Patent no. EP 1 021 960 B1; Weill, 2000). EXTRALUZ is produced from cold-pressed alfalfa that is then heated to form a protein–lipid coagulate, dried, and granulated (Dang Van et al., 2011).

The composition of the experimental diets is given in Table 2. Diets were formulated to meet energy and protein requirements of cows according to the French Unité Fourragère Lait and PDI (protein digested in the small intestine) (INRA, 2007). Energy and protein balances were calculated as the differences between energy and protein supplies and energy and protein needs (INRA, 2007). All diets were iso-energetic (6.11 ± 0.02 MJ NE_L/kg DM) and iso-nitrogenous (109 ± 4.8 g of PDIE [protein digested in the small intestine supplied by rumen-undegraded dietary protein and by microbial protein from rumen-fermented organic matter]/kg DM;