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Influence of the diet structure on ruminal biohydrogenation and milk fatty acid composition of cows fed extruded linseed

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ABSTRACT

This experiment studied the influence of the diet structure value (SV) on ruminal biohydrogenation and milk fatty acid (FA) responses in cows fed heterogeneous basal diets equally supplemented with FA. Eight lactating Holstein cows were used in a replicated 4 × 4 Latin square design with four dietary treatments and four 21-day periods. The iso-fat, iso-18:2 *n* – 6 and iso-18:3 *n* – 3 diets were formulated to display three different SV, using different sources and proportions of forages, energy and nitrogen concentrates. The four diets contained maize silage as the main forage (SV1.2 diet), grass hay as the main forage (SV2.0 diet), maize silage and grass hay in a 4:1 ratio (SV1.6 M diet) or maize silage and grass hay in a 1:1 ratio (SV1.6H diet). The diets also contained soya bean meal and/or urea as additional sources of nitrogen, sugar beet pulp and barley in a 1:1 ratio as additional source of energy, extruded linseed as supplemental 18:3 *n* – 3, a mineral and vitamin mix and a vitamin E preparation. Wheat straw was added to the diets as additional structure source, except for the SV2.0 diet. Soya bean oil was added to the diets as supplemental 18:2 *n* – 6 to adjust the diets for this FA, except for the SV1.2 diet. The diets were distributed as a restricted total mixed ration. The various C18 FA expressed as 100 g of total C18 FA in milk fat are relevant indicators of ruminal biohydrogenation since duodenal concentrations of C18 FA follow similar changes as those in milk fat, and since these ratios only take into account FA involved in ruminal biohydrogenation. All the various C18 FA to total C18 FA in milk fat differed among diets ($P < 0.05$). Milk 18:2 *n* – 6 + 18:3 *n* – 3/total C18 FA and total trans-C18 FA/total C18 FA decreased from SV1.2 to SV2.0 diets, whereas 18:0/total C18 FA increased from SV1.2 to SV2.0 diets. Subsequently, transfer efficiencies of 18:2 *n* – 6 and 18:3 *n* – 3 from diet to milk were higher for the SV1.2 diet than for the other diets ($P < 0.05$). These results confirm the hypothesis that ruminal biohydrogenation is more complete with higher diet SV, which is consistent with results from other published experiments where high forage diets or grass silage compared to maize silage-based diets were used. This experiment showed that the concept of diet SV is a valid tool characterizing heterogeneous basal diets differing in sources and proportions of forages and concentrates.

Abbreviations: ADFom, acid detergent fibre expressed exclusive of residual ash; aNDFom, neutral detergent fibre assayed with a heat stable amylase and expressed exclusive of residual ash; BW, body weight; CLA, conjugated linoleic acid; CP, crude protein; DM, dry matter; FA, fatty acid; FAME, fatty acid methyl ester; F:C, forage-to-concentrate; GLC, gas–liquid chromatography; OM, organic matter; SMCFA, short and medium-chain fatty acid; SV, structure value; UFA, unsaturated fatty acid; MilkFU, Milk Forage Unit.

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1. Introduction

There has been growing interest in modulating the bovine milk fatty acid (FA) composition because some milk FA have well-known or potential positive effects on human health (mainly 18:3 $n-3$, c9-18:1 and c9,t11-conjugated linoleic acid (CLA)), whereas others have negative effects when consumed in excess (mainly 12:0, 14:0, 16:0 and some trans FA) (Mensink et al., 2003; Parodi, 2005).

Extensive research has examined the impact of unsaturated FA (UFA) supplements on bovine milk FA composition. In addition to the amount and type of UFA supplements, it is well established that the composition of the basal diet also influences the ruminal lipid metabolism and the milk FA response to lipid supplements (Chilliard and Ferlay, 2004; Dewhurst et al., 2006). Numerous studies have indeed examined the impact of characteristics of the basal diet, such as the forage-to-concentrate (F:C) ratio, types of forages and concentrates, dietary fibre level and forage particle length, on the milk FA response to FA supplements. In these studies however, the characteristics of the basal diet have hardly been considered as a whole, which makes comparisons difficult.

The concept of diet structure value (SV) takes into account several characteristics of the basal diet and allows to characterize and compare diets in terms of rumen buffering through saliva, acidotic effect (pH decrease), particle size and physical form of the feeds (De Brabander et al., 1999). In a previous paper, we demonstrated that even a modest increase in SV in a diet supplemented with extruded linseed decreased milk concentrations of c9,t11-CLA and t11-18:1 and increased that of 18:0 (Dang Van et al., 2008). We hypothesized that ruminal biohydrogenation may have been more complete for the diet with higher SV, going all the way to 18:0, thus allowing fewer intermediates to escape (Dang Van et al., 2008). However, in the previous experiment, the increase in diet SV was made by adding only wheat straw to the same basal diet, thus essentially increasing the intake of fibre. Therefore, the objective of the present experiment was to verify the influence of the diet SV on ruminal biohydrogenation and milk FA responses in cows fed heterogeneous basal diets equally supplemented with FA. To achieve this, different sources and proportions of forages (maize silage, grass hay and wheat straw), energy (sugar beet pulp and barley) and nitrogen (soya bean meal and urea) concentrates were used.

2. Materials and methods

2.1. Experimental design, animals and management

Eight lactating Holstein cows were blocked according to their milk yield and assigned to four dietary treatments in a replicated 4×4 Latin square design. Each experimental period lasted 21 days. At the onset of the experiment, cows averaged 3 ± 0.8 lactations, 91 ± 34.5 days in milk, 651 ± 48.8 kg of body weight (BW) and yielded 29.9 ± 4.87 kg of milk/day (mean $\pm$ standard deviation). Cows were housed in individual stalls. The floor of the stalls was bedded with mats and sawdust and cleaned twice daily. Cows were fed individually twice daily at 0830 and 1730 h and had free access to water and mineral blocks. Cows were milked twice daily at 0730 and 1630 h. The experiment was carried out at the Centre wallon de Recherches agronomiques (Gembloux, Belgium) from February to April 2008 and was in accordance with the recommendations on care and use of laboratory animals of the Université catholique de Louvain.

2.2. Experimental diets

Four heterogeneous diets were formulated to display three different SV, using different sources and proportions of forages, energy and nitrogen concentrates. The diets were formulated to be iso-fat, iso-18:2 $n-6$ and iso-18:3 $n-3$, to remove the effect of the FA composition of the forages. The four diets contained maize silage as the main forage (SV1.2 diet), grass hay as the main forage (SV2.0 diet), maize silage and grass hay in a 4:1 ratio (SV1.6 M diet) or maize silage and grass hay in a 1:1 ratio (SV1.6H diet). The diets also contained soya bean meal and/or urea as additional sources of nitrogen, sugar beet pulp and barley in a 1:1 ratio as additional source of energy, extruded linseed as supplemental 18:3 $n-3$ to favour UFA production in milk, a mineral and vitamin mix and a vitamin E preparation to avoid milk oxidation (Focant et al., 1998). Wheat straw was added to the diets as additional structure source, except for the SV2.0 diet. Soya bean oil was added to the diets as supplemental 18:2 $n-6$ to adjust the diets for this FA, except for the SV1.2 diet. Extruded linseed, supplied as Nutex Compact® (Dumoulin, Seilles, Belgium), consisted of an extruded mixture of linseed, wheat, sunflower cake, field beans, peas, BHT and salt (584, 150, 140, 51, 50, 20 and 5 g/kg total raw materials, respectively). The ingredient composition of the experimental diets as fed is given in Table 1. The dry matter (DM) content and chemical composition of individual feedstuffs are given in Table 2. The diets formulated in this way displayed two different ranges of F:C ratio (63:37 and 64:36 *versus* 48:52 and 50:50). The SV1.6M and SV1.6H diets had a similar SV but different F:C ratios. 18:3 $n-3$ was the predominant FA in the extruded linseed mixture and accounted for 52 g/100 g identified FA, whereas 18:2 $n-6$ was the predominant FA in soya bean oil and accounted for 55 g/100 g identified FA. The diets were formulated to meet energy and protein requirements of cows according to the French Milk Forage Unit (MilkFU) and Digestible Proteins Entering the Small Intestine systems using the INRAtion software (version 3.21; Institut National de la Recherche Agronomique, Paris, France) for a cow of 650 kg yielding 30 kg of milk/day. The amounts of the diets were distributed as a restricted total mixed ration in order to control the intakes and were adapted to the individual milk production of cows.