Transfer Efficiency of Unsaturated Fatty Acids into Milk of Cows Fed Supplements of Cottonseed Protected from Rumen Degradation

G. C. Simos1, J. J. Della-Vedova1, S. K. Gulati2, K. H. Myung2, E. Fleck3, J. M. Gooden1 and P. C. Wynn1

1 Department of Animal Science, University of Sydney, Camden, NSW, 2570.
2 Department of Animal Science, Chonnam National University, Kwangju, 500-757, Korea
3 Division of Animal Production, CSIRO, Locked Bag 1, Delivery Centre, Blacktown, NSW, 2148

ABSTRACT: The strong link between saturated fat intake and increasing rates of coronary heart disease have provided the impetus for the dairy industry to provide milk with an increased proportion of polyunsaturated fatty acids. This can be achieved with the inclusion of protected lipid supplements in the diet of dairy cows. The protection from ruminal degradation is achieved by encapsulation of the lipid in a matrix of treated protein. In this study, feeding supplements of protected cottonseed (0, 1 and 2 kg/d) to lactating dairy cows significantly increased the amount of linoleic acid (C18:2) and stearic acid (C18:0) and decreased the proportion of oleic acid (C18:1 cis) in the milk. In addition, C18:2 increased and C18:1cis decreased proportionately in the plasma fatty acid profile, however C18:0 remained unchanged. There was no significant difference in the production parameters of milk yield, fat yield and protein yield between the treated and control groups. The transfer efficiency of C18:2 into milk was 45.2% and 36.5% for the 1 and 2 kg supplemented groups respectively. This high efficiency of transfer has resulted in the development of milk containing high levels of polyunsaturated fatty acids.

Key Words: Milk Fat, Fatty Acid, Rumen Protected Lipids

INTRODUCTION

Differences in dietary saturated fat intake are thought to be the principal source of varying concentrations of atherogenic lipoproteins among the world’s populations, strongly linked to incidence of coronary heart disease (Havel, 1997). Thus the recommendation from health authorities for the inclusion of higher proportions of unsaturated fatty acids in human diets, has challenged the dairy industry to develop novel products to meet this demand. The challenge stems from the extensive hydrogenation of unsaturated fatty acids in the rumen prior to their passing into the small intestine adsorbed onto solid remnants in the digesta (Garton, 1961, Knight et al, 1994). Thus up to 60% of the long chain fatty acids in milk are saturated and only 2% are polyunsaturated (Havel, 1997).

The innovative development of methods for treating feed supplements to protect them from ruminal degradation has provided two major benefits to ruminant production, the first obviously being the increased unsaturation of lipid in ruminant products. The second stems from the altered fatty acid composition of the structural lipids (the phospholipids) of the cellular lipid bilayer, which are now recognised as essential components of the transduction system for endocrine-directed signals controlling gene transcription in target tissues (Ashes et al, 1995). Thus commercially important tissues, such as the mammary epithelium, may become more sensitive to the biosynthetic signals conveyed by metabolic hormones and cytokines.

Having established these principles, the next challenge has been to refine the technology for the protection of nutrients from ruminal degradation to allow the level of transfer of unsaturated fatty acids into both tissues and into milk to be predicted. Since the extent of ruminal degradation is dependent on the composition of the ruminal microflora, logically, the nature of the diet to which the protected supplement is added will play an important role in determining the efficiency of transfer of the protected nutrient into the intestinal environment. In addition poorly protected fat supplements will depress fibre digestion, dry matter intake and produce more trans fatty acids. This will result in depressed milk protein content and will not achieve desirable changes in the nutritional characteristics of milk fat, thus it is important that lipid supplements are highly protected (>75%) (Gulati et al., 1999), .

The inability of ruminants to either assimilate sufficient C18 polyenoic fatty acids from their diet or synthesise their own makes this class of fatty acids a logical candidate for protection. This is facilitated by the number of oil seeds particularly rich in linoleic acid which may be protected from ruminal hydrogenation by encapsulation in a matrix of formaldehyde-crosslinked protein (Scott et al., 1970). This study investigates the efficiency of transfer of unsaturated fatty acids into milk and plasma in Holstein-Friesian cows fed a formaldehyde-treated cottonseed supplement, which has a high (56%) C18:2 content.

MATERIALS AND METHODS

Animals and diets

Multiparous Holstein-Friesian cows (n=30), lactating for 60-140 days, were allocated at random (but matched for stage of lactation) to 3 groups (n=10), which were supplemented with 0, 1 and 2 kg of protected cottonseed supplement (34% fat) (Rumentek Industries), for a period of 5 weeks. All cows were offered a mixed ration at 10kg DM/d (ME 12 MJ/kg, 20% protein), in addition to a ryegrass/kikuyu pasture ad libitum.
Milk and plasma samples
Cows were milked twice daily and integrated milk samples (1% of production) were collected daily from the a.m. and pm milking commencing 5 days prior to the provision of the supplement, for the subsequent 14 days and weekly thereafter. Blood samples were collected 1 day prior to the provision of the supplement, and at 6 and 27 days after the introduction of the supplement. Milk was analysed for fat and protein content (Mid infra red reflectance; milko-scan 130 series, Foss Electric, Denmark). Fatty acid composition (>C10) in milk and blood plasma were analysed by gas-liquid chromatography (Gulati et al., 1997).

Results and Discussion

Production parameters
The production parameters of milk yield, fat yield and protein yield did not differ between the control and supplemented groups (Table 1).

Table 1: Milk production parameters.

<table>
<thead>
<tr>
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<th>Control (mean ± SEM)</th>
<th>1 kg (mean ± SEM)</th>
<th>2 kg (mean ± SEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk Yield (kg/d)</td>
<td>24.3±1.5</td>
<td>23.9±1.2</td>
<td>23.9±1.9</td>
</tr>
<tr>
<td>Fat Yield (g/d)</td>
<td>780.4±77.2</td>
<td>785.3±57.5</td>
<td>823.8±77.2</td>
</tr>
<tr>
<td>Protein Yield (g/d)</td>
<td>760.2±42.8</td>
<td>744.8±35.6</td>
<td>765.1±59.1</td>
</tr>
</tbody>
</table>

Fatty Acids:
The fatty acid profile in milk collected from cows receiving the protected cottonseed supplement differs markedly from the fatty acid profile of the control cows. Of particular interest are the C18 fatty acids that are predominant in cottonseed.

The milk fatty acid profile of cows receiving the supplement showed a dose-dependent decrease in myristic acid (C14:0), palmitic acid (C16:0) and C18:1cis, which were associated with a 3-5-fold increase in C18:2, and a 50% increase in C18:0 (Figure 1). The changes to the fatty acid profile occurred rapidly. C18:2 peaked in the milk after 6-7 days after supplement, and this persisted for the duration of the treatment period (Figure 2).

Figure 1. Fatty acid profile in milk in response to dietary supplementation with protected cottonseed (0, 1 or 2kg per day) after 28 days of supplementation.
Figure 2: The effect of dietary supplementation with protected cottonseed (0, 1 or 2 kg per day) on the relative concentration of C18:2 in milk.

Similar changes in relative concentration of the C18 fatty acids in the circulating plasma were observed on lipid supplementation, however these changes were of a lower magnitude (Figure 3). The mammary epithelium appears capable of selective uptake of linoleic acid since the changes in circulating concentrations and those in milk vary considerably.

Absorption of dietary fatty acids occurs in the small intestine, and the composition of absorbed fatty acids is close to the composition of fatty acids leaving the rumen (Doreau et al., 1997). The transfer of lipids from blood to milk is high, and as such the uptake of long-chain fatty acids by the udder is increased when lipids are added to the diet (Pennington and Davis, 1975). Upon addition of lipid to the diet, the uptake of the precursors of de novo synthesis (acetate and 3-hydroxybutyrate) is generally reduced, due to the increase in propionate in the VFA mixture (Doreau et al., 1997).

Although there was an increase in C18:0 in the milk profile of protected cottonseed supplemented cows, no change in C18:0 was evident in the plasma fatty acid profile of these animals. Once it is absorbed, C18:0 is usually subjected to desaturation by stearoyl coenzyme A (CoA) desaturase (Δ9 desaturase) to produce C18:1cis (German et al., 1997). This enzyme is inhibited by cyclopropene fatty acids that are found in cottonseed (Gunstone et al., 1994) and may also be inhibited by an increase in dietary linoleic acid (Gulati et al., 1997). Gulati et al. (1997) also noted an increase in C18:0 in milk fatty acids of lactating goats fed a protected cottonseed supplement, and this was attributed to an inhibition of Δ9 desaturase activity.

These changes in fatty acid profiles are consistent with results obtained by Gulati et al. (1997).
They reported that feeding rumen protected cottonseed to lactating goats increased the proportion of C18:2 and C18:0 and decreased the C18:1 while the C16:0 was unchanged. The transfer of C18:2 from the diet into milk was 43%. Gulati et al. (1997) also noted that when supplements are very well protected from ruminal hydrogenation, as with the protected cottonseed meal used here, the constituent C18 fatty acids are transferred into milk fat more efficiently.

C18:2 is an appropriate marker for estimating transfer efficiency into milk due to the lack of de novo synthesis. The protected supplement contained 315 g of lipid per kg, of which 56% is C18:2. As such, the supplemented cows received 176 and 353 g/d C18:2 in the 1 and 2 kg supplemented groups respectively. The transfer of C18:2 from the supplement to milk fat was calculated to be 27.1% and 21.9% (1 and 2 kg groups respectively) which was corrected for basal C18:2 content in the other dietary components. The supplement has been shown to be 75% protected in vitro, which was equivalent to a 60% protection in vivo (Ashes, 1979). Thus the efficiency of transfer of C18:2 from the supplement delivered to the small intestine is 45.2% and 36.5% for the 1 and 2 kg treatment groups respectively. This is consistent with the 45% transfer of C18:2 from a protected canola-soybean supplement reported by Gulati et al. (2000).

The high relative efficiency of transfer of these important fatty acids into milk provides further evidence for the strategic use of protected dietary supplements for the production of value added milks for the dairy industry.

REFERENCES


