

Milk Fat with Increased Polyunsaturated Fatty Acids

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Abstract

Milk fat with increased polyunsaturated fatty acids was produced by feeding cows a diet containing a formaldehyde-treated safflower oil-casein particle. This treatment protected the linoleic acid of the safflower oil from hydrogenation in the rumen, and the linoleic acid content of the milk increased from 3% to 35% of the total fatty acids. Total milk production was not altered, but fat content of the milk increased 1.0 to 1.5 percentage units.

Introduction

Milk containing fats having large percentages of polyunsaturated acids has recently been produced in Australia (7). Scott and his co-workers (2, 7) have developed a technique to increase polyunsaturation in milk fats by feeding polyunsaturated oils encased in a formaldehyde-protein coat. This protects dietary fats from hydrogenation to saturated fats in the rumen. In the study reported here we have utilized the Scott fat protection concept and confirmed the increase in polyunsaturation of fat in the milk. In addition we have studied the time course of changes in polyunsaturated fat and have observed an increase of greater than 1% in total milk fat test.

Experimental Procedures

Preparation of formaldehyde-treated and untreated casein-safflower oil particles. Safflower oil (23.6 kg) was metered into a continuous flow line of 12.5% sodium caseinate solution (11.8 kg of acid-precipitated casein, pH 6.8) at 65 C, followed immediately by two-stage homogenization (140 and 35 kg/cm²). The safflower oil-caseinate product was collected in a 189-liter tank. A 37% formaldehyde solution (1.2 kg = 10% by weight of protein) was slowly added to the homogenized oil-caseinate mixture with thorough stirring. Immediately following a 20 min stirring, the mixture was

spray dried by 140 kg/cm² pump pressure through a 1.0 mm nozzle with an inlet temperature of 143 C. Casein-safflower oil particles were also prepared essentially as described without formaldehyde treatment. Composition of the treated particles was 58% oil, 40% casein, 2% formaldehyde; untreated particles contained 60% safflower oil and 40% casein.

Formaldehyde-treated and untreated safflower oil-casein particles were incubated with rumen fluid to determine whether protection from saturation by rumen microorganisms was achieved by formaldehyde treatment. The *in vitro* system consisted of 125 ml flasks in which .5 g of treated or untreated particles were incubated at 39 C in 40 ml of nutrient medium and 10 ml of strained rumen fluid under CO₂ (3). Flasks were removed at 0, 24, and 48 hr and the contents extracted with chloroform-methanol (2:1, v/v). The lipid extract was purified by chromatography on silicic acid (4) to obtain the triglyceride fraction. After methylation with methanolic-HCl-dimethoxypropane (6), fatty acids were determined by programmed gas liquid chromatography on 15% EGS (ethylene glycol succinate) on Anakrom AB (100/110 mesh) in a .63 cm × 182 cm glass column with a Model 801 Perkin-Elmer gas chromatograph.

Animals and treatment. Two 600 kg Holstein cows, in the 7th month of lactation and producing 15 to 20 kg of milk per day, were used in a 5-period switch-back experiment lasting 40 days. After standard hay-concentrate feeding 10 days one cow was fed protected oil-casein while the other was fed unprotected oil-casein for 5 days. This was followed immediately by another standard 10 days, after which experimental treatments were switched so that the cow previously fed protected particles received unprotected particles while the cow previously fed untreated particles received formaldehyde-treated safflower oil-casein. Finally, both cows were fed the standard hay-concentrate ration for 10 days.

The standard ration consisted of medium quality orchardgrass hay fed *ad libitum* and

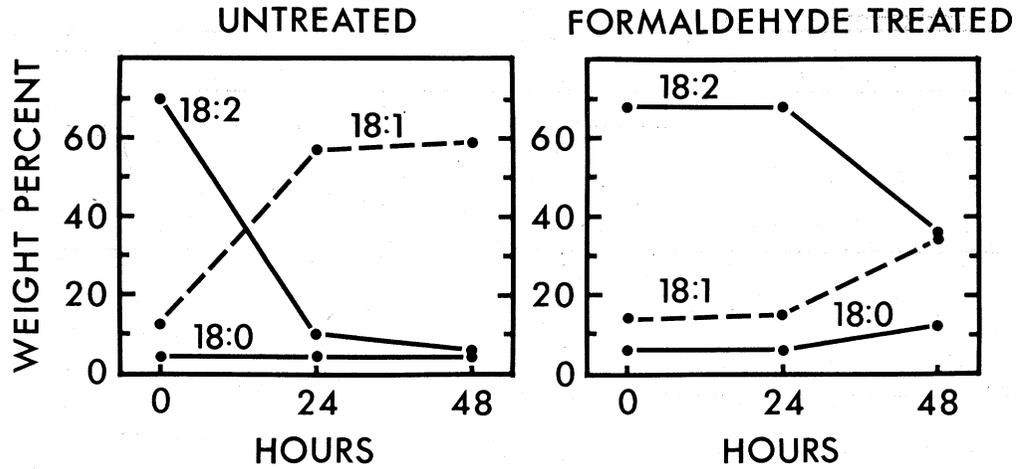


FIG. 1. Changes in C₁₈ fatty acids during in vitro rumen incubation of safflower oil-casein particles.

5.8 kg of 16% crude protein mixed concentrate per day. The untreated and treated safflower oil-casein was fed at 1,500 g per day in two portions as a partial replacement of grain on a w/w basis. Calculated energy intake varied less than 10% between treatment and standard periods. Both cows were fed an ex-

cess of protein and energy based on National Research Council requirements. Daily composite milk samples were analyzed for fat, protein, solids-not-fat and for milk fat composition (4, 6). Two blood samples were taken during each standard or treatment period and cholesterol (8) and triglycerides (9) deter-

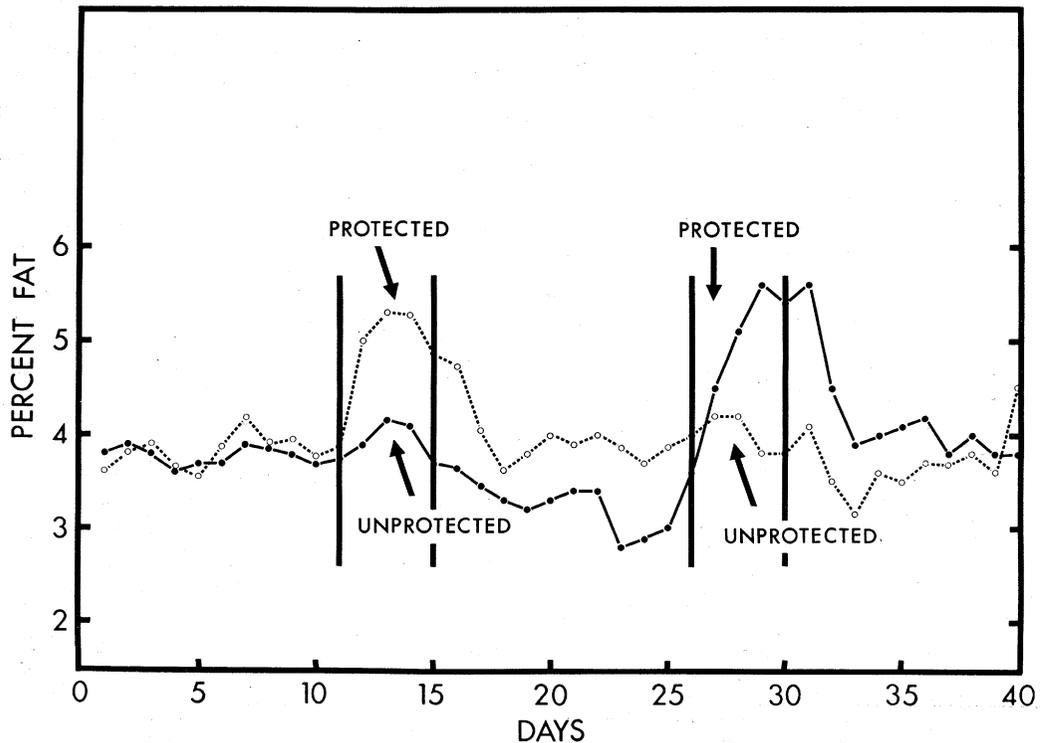


FIG. 2. Changes in per cent milk fat during feeding of formaldehyde-treated and untreated safflower-oil casein.

mined. Milk cholesterol, triglycerides, and lactose (1) were also measured.

Results and Discussion

Formaldehyde-treated safflower oil-casein particles were completely protected in vitro for 24 hr from hydrogenation by rumen microorganisms (Fig. 1). At 48 hr, however, about 50% of the linoleic acid (18:2) was converted to either C18:1 or stearic acid (18:0), and these fractions show a corresponding increase. Untreated particles underwent extensive hydrogenation (Fig. 1). Linoleic acid declined and C18:1 exhibited a corresponding increase. There were little or no changes in shorter or longer chain fatty acids. These results suggest that the formaldehyde treatment affords protection to the linoleic acid of the safflower oil for a major part of the expected transit time in the rumen (5).

There were no significant changes in the total amount of milk produced during the treatment as compared to standard feeding periods. There was, however, a large increase (1.0 to 1.5 percentage units) in fat content of milk when cows were fed the protected material (Fig. 2). The increase was within 24 hr after feeding was initiated and persisted for 24 to 48 hr after withdrawal of the protected particles.

When the composition of the C₁₈ fatty acids in milk fat is examined (Fig. 3), milk from cows fed the protected fat shows a rapid increase in linoleic acid (18:2) concentration to 30 to 35% of the total fatty acids. The decline to the standard 3 to 4% linoleic acid was slow and was not achieved until Day 9, four days

TABLE 1. Changes in amount and composition of milk during protected and unprotected safflower oil-casein feeding to Cows A and B.

Component	Base values	Per cent change from standard period mean	
		Protected	Unprotected
Milk	A 14.9 kg/day	+ 2.8	-9.0
	B 16.6 kg/day	- .2	+8.6
Milk fat	A 3.8%	+23.8	+4.4
	B 3.6%	+33.0	+7.7
Solids-not-fat	A 8.9%	+ 1.9	+1.6
	B 9.2%	+ 4.5	+ .2

after removal of the protected fat. As percentage of linoleic acid increased, shorter fatty acids (C₈-C₁₆) showed a relative decline. There were only minor changes in the other C₁₈ acids.

When cows were being fed the unprotected safflower oil-casein, linoleic acid (18:2) of the safflower oil was rapidly hydrogenated to C_{18:1}, and this was reflected in a large increase in the monoenoic acid content of the milk. This effect also persisted for several days after the cows were placed back on the standard diet.

Table 1 shows the changes in per cent fat, solids-not-fat, and total milk. Per cent changes were based on average values obtained during the three standard feeding periods. Possible carryover effects from the treatment were minimized by excluding values during the first three days after the cows were switched back to the standard ration. The most striking change in composition was the increase in fat content of milk for both cows when protected safflower oil-casein was included in their rations. Since the amount of milk produced was not affected, a large increase in fat production is implicit.

Changes in solid-not-fat per cent were relatively small, and no significance is attached to them. Values for per cent protein were variable due either to analytical techniques or true fluctuations in composition. Presentation and interpretation of these values, therefore, seem unwarranted.

No significant changes were observed in milk

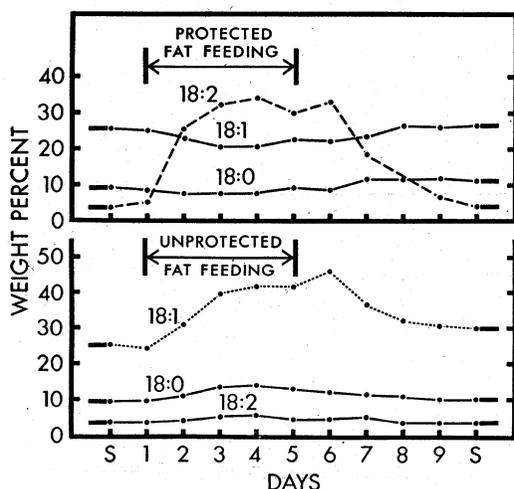


Fig. 3. Changes in C₁₈ fatty acid composition of milk from cows fed protected and unprotected fat. S represents standard period mean values.

TABLE 2. C₁₈ Fatty acid composition of rumen fluid.

Fatty acid	Weight per cent	
	Unprotected	Protected
C _{18:0}	47.6	42.1
C _{18:1}	38.3	13.8
C _{18:2}	1.2	22.4

cholesterol, lactose, or in blood cholesterol and triglycerides during treatment periods. Analysis of fecal samples did not reveal any increase in per cent fat or any change in the fatty acid composition of the fecal fat.

Samples of rumen fluid were obtained on the fourth day of the second treatment period (29th day of the 40-day experiment) when the cows were being fed protected and unprotected safflower oil-casein particles (Table 2). These limited observations also reflect the protection achieved, linoleic acid being high in the cow fed the protected particles (22.4%) and low (1.2%) in the fluid from the cow fed unprotected oil-casein. Similarly, the conversion to C_{18:1} in the milk and in the *in vitro* rumen fermentation (Fig. 1) is seen in the rumen fluid from the cow fed the unprotected fat (38.3%). The major fatty acid of bovine ruminal fluid is stearic acid (5), and this was observed in these *in vivo* samples. Our *in vitro* samples (Fig. 1) did not show an increase in stearic acid (18:0) during incubation, and no increases were noted in milk stearic acid (Fig. 3) during this experiment.

The results of this experiment demonstrate the effectiveness of formaldehyde treatment to protect a protein encapsulated oil from hydrogenation in the rumen. We have confirmed and extended the work of Scott (2, 7) and shown that cows fed protected unsaturated oil will produce milk fat with higher polyunsaturated fatty acids. In addition, fat content of the milk increased 1.0 to 1.5%. We have also studied the time course of the changes in polyunsaturation of the milk fat and found that increase was rapid and decline relatively slow.

Our results show that very large increases in polyunsaturated fat content of milk can be

produced by feeding cows protected oils having a high degree of polyunsaturation although longer feeding tests will be needed to determine feasibility of this procedure. Such extended experiments will need to establish conditions for practical preparation of protected oils and production of milk without significantly diminishing the consumer quality of milk and milk products.

Increasing polyunsaturated fat content of milk by feeding dairy cows may be advantageous when compared to direct additions of polyunsaturated fats to milk or other foods in that legal problems of labeling can be avoided. Milk enriched by this means might provide increased dietary intake of polyunsaturated fat for the general population.

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