3871

GROWTH, PLASMA LIPIDS AND FATTY ACID COMPOSITION OF VEAL CALVES FED POLYUNSATURATED FATS

T. Randall Wrenn,[1] Joan R. Weyant,[1] Chester H. Gordon,[2]
H. Keith Goering,[3] Leslie P. Dryden,[1] Joel Bitman,[1]
Locke F. Edmondson [4] and Raymond L. King,[5 6]

United States Department of Agriculture,
Beltsville, Maryland 20705

Summary

Supplemental feeding of milk high in linoleic acid (14.1% $C_{18:2}$) to young bull calves for 10 weeks was followed by feeding safflower oil for an additional 7 weeks that was protected from microbial hydrogenation in the rumen. The protection from degradation was provided by a casein-formaldehyde coating. Plasma cholesterol was elevated by feeding the protected safflower oil. Higher concentrations of linoleic acid were found in blood and biopsied fat of experimental calves fed polyunsaturated milk and protected safflower oil than in calves fed normal milk and unprotected safflower oil. Growth and health of the calves were normal. At slaughter at 18 weeks of age, over four times control concentrations of linoleic acid were present in depot fat of the calves exposed to the greatest amount of polyunsaturate feeding. The linoleic acid of intramuscular veal fat was nearly doubled by feeding the polyunsaturated diets. Plasma triglycerides, non-esterified fatty acids, and blood vitamin E showed no changes correlated with the treatments.

[1] ARS., Animal Physiology and Genetics Institute, Agricultural Research Center East, Building 161, Beltsville, Maryland 20705.

[2] Present Address: European Regional Research Office, IPD, A.R.S. c/o American Embassy, Rome, Italy.

[3] A.R.S., Nutrition Institute, Agricultural Research Center East, Building 200, Beltsville, Maryland 20705.

[4] Dairy Products Laboratory, Agricultural Research Service, U.S.D.A., Washington, D.C. 20250.

[5] Dairy Science Department, University of Maryland, College Park, Maryland 20740.

[6] The authors wish to thank Drs. Tommy L. Pike and Gilbert Samuelson, Jr. for their generous and skillful veterinary aid in evaluating health and providing fat biopsies.

Introduction

The possibility exists that food products containing high levels of polyunsaturated fatty acids may be useful in dietary prevention and alleviation of atherosclerosis. If clinicians prove an associative effect of dietary fatty acid saturation with incidence of cardiovascular disease, it will become desirable for dairy and beef producers to develop methods of increasing the degree of polyunsaturation in milk and meat fat.

The effects of different levels and types of dietary fats on adult ruminant fat metabolism and milk fat secretion has been studied by various workers [for reviews, see Moore and Steele, 1968; Storry, 1970]. The efficacy of feeding growing ruminants various fats other than milk fat of normal composition has been studied less. Adams *et al.* (1959a,b) in papers describing biochemical and physiological effects of rearing calves on highly unsaturated vegetable fat, observed poor gains, ill health and high mortality. The recent development by Australian workers (Scott *et al.,* 1970; Scott, Cook and Mills, 1971; Pan, Cook and Scott, 1972; Cook, Scott and Pan, 1972) of a method whereby dietary unsaturated vegetable fats are protected from hydrogenation in the rumen makes it desirable to examine further the efficacy of plant lipids as a principal calf nutrient. Faichney *et al.,* 1972, have reported that 9-month-old steers showed no significant differences in growth when fed a formaldehyde protected safflower oil casein supplement, although their dry matter consumption and energy intake was less than for steers on a conventional diet. They noted (Cook *et al.,* 1972) increased incorporation of linoleic acid into plasma and tissue lipids of these steers.

The present experiment was initiated in order to determine patterns of growth, blood lipid, and tissue fatty acid compositions of calves raised on diets containing higher than usual amounts of polyunsaturated fatty acids. Calves were first fed milk containing high levels of linoleic acid produced by cows fed safflower oil casein protected with formaldehyde, and were later fed a concentrate containing the protected oil supplement. We have previously reported our success in the preparation and utilization of protected fats to produce milk containing increased amounts of polyunsaturated fatty acids (Plowman *et al.*, 1972; Bitman *et al.*, 1973).

Methods

Four 4-day-old Holstein bull calves were fed from a pail 6.35 kg milk per day containing highly polyunsaturated fat milk (PUM) from cows on a formaldehyde-protected safflower oil-casein dietary supplement and four control calves were fed the same quantity of normal milk (NM) until 10 weeks of age. The composition of the milks is shown in table 1. The milks were supplemented with 486 mg of alpha tocopherol acetate per calf per day. This was done to assure that adequate vitamin E was present, since it has been found that vitamin E requirements go up when unsaturated fats are fed (Horwitt *et al.*, 1961; Harmon, Witting and Horwitt, 1966; Green *et al.*, 1967; Hayes, Nielsen and Rousseau, 1969; Bieri and Poukka, 1970). Grain and alfalfa hay were fed *ad libitum*. From 11 to 18 weeks the calves were fed a ration providing 20% protein which included either formaldehyde protected safflower oil-casein (SOC-F) or unprotected safflower oil-casein (SOC) as 13% of the total concentrates fed. The oil to sodium caseinate ratio of the SOC supplements averaged 65:35. Both the SOC-F and the SOC fed groups contained two calves previously fed polyunsaturated milk and two calves previously fed normal milk. Hay was provided at the rate of 0.45 kg per calf per day. An adjustment period of a week elapsed between stopping milk and starting the oil supplements. The composition of the concentrate fed between 11 and 18 weeks is shown in table 2. The feeding regimen for the entire experiment is summarized in table 3.

TABLE 1. COMPOSITION OF MILKS FED VEAL CALVES. (MEANS OF WEEKLY ANALYSES)

Item	Normal milk	Polyunsaturated milk
Fat, %	3.58	3.58
Protein, %	3.47	3.53
SNF, %	8.89	9.15
Cholesterol mg/100 ml	15.2	14.2
Linoleic acid,%	2.5	14.1

In table 4, the fatty acid composition of the milk high in polyunsaturated fat is compared with that of normal milk. Feeding high linoleic milk provided over five times as much polyunsaturated fatty acid as normal milk.

The fatty acid composition of safflower oil fed in the second phase of the experiment is shown in table 5. Seventy-six percent of the fatty acids were linoleic acid ($C_{18:2}$).

Biopsy samples of tailhead fat and jugular vein blood were taken for analyses at 1- or 2-week intervals.

Veterinary evaluation of condition and health of the calves was conducted each week. Plasma cholesterol was determined by the method of Pearson, Stern, and McGavack (1953) and triglycerides by the micromethod of Van Handel and Zilversmit (1957) as modified by Van Handel (1961). Non-esterified fatty acids of plasma were determined by the method of Dole (1956) as modified by Annison (1960). Vitamin E was analysed by the method reported by Tikriti (1969). The calves were slaughtered at 18 weeks and samples of tailhead, omental and perirenal fat, and cuts of round and chuck were collected for determination of fatty acids. In addition, after evisceration digesta was sampled from the rumen,

TABLE 2. COMPOSITION OF CONCENTRATES FED CALVES FROM 11 TO 18 WEEKS.

Ingredient	Ration SOC[a]	Ration SOC-F[b]
	%	%
Corn, dent #2	30	30
Oats, grain	13	13
Alfalfa, dehy., 17% CP	4	4
Soybean meal	13	13
Linseed meal	9	9
Wheat bran	13	13
Molasses, cane	4	4
Vit. A., 10,000 IU/g	0.02	0.02
Salt, trace minerals added	0.8	0.8
Dicalcium phosphate	0.8	0.8
SOC[c]	13	—
SOC-F[c]	—	13

[a]Safflower Oil Casein.
[b]Formaldehyde protected Safflower Oil-Casein.
[c]SOC and SOC-F supplements were each 65% safflower oil and 35% sodium caseinate.

TABLE 3. CALF DIETS[a]

N	to 10 weeks[b]	11 to 18 weeks[c]
2	NM	SOC
2	NM	SOC–F
2	PUM	SOC
2	PUM	SOC–F

[a]Abbreviations: NM = Normal Milk, PUM = Polyunsaturated Milk, SOC = Safflower Oil-Casein, SOC-F = Formaldehyde protected Safflower Oil-Casein.
[b]Grain and alfalfa hay fed *ad libitum*.
[c]SOC and SOC-F comprised 13% of total concentrates. Hay was limited to .45 kg per calf per day.

abomasum, small intesting and large intestine, and analysed for fatty acid distribution. Volatile fatty acids (VFA) were determined on fluid collected from the rumen following slaughter and evisceration. This was between 16 and 19 hr. after the last feeding. The fluid was strained through several layers of cheesecloth prior to analysis.

Lipids of blood, depot fat, meat and digesta were extracted with chloroform-methanol (2:1). Methyl esters were prepared by the method of Christopherson and Glass (1969) and their fatty acid composition determined by programmed gas-liquid chromatography, using a column packed with 10% EGSS-X on Gas-Chrom P (100/120 mesh). Statistical comparisons are by analysis of variance.

TABLE 4. FATTY ACID COMPOSITION OF FAT IN MILK FED TO VEAL CALVES. (MEANS OF WEEKLY ANALYSES)

Fatty acid	Control milk	Polyunsaturated milk[a]
	%	%
$C_{4:0}$	2.3	1.9
$C_{6:0}$	1.8	1.3
$C_{8:0}$	1.1	0.8
$C_{10:0}$	2.7	1.7
$C_{12:0}$	3.4	2.0
$C_{14:0}$	12.3	7.4
$C_{14:1}$	1.5	0.8
$C_{15:0}$	1.0	0.6
$C_{16:0}$	31.0	18.5
$C_{16:1}$	2.4	1.4
$C_{17:0}$	0.6	0.4
$C_{18:0}$	10.6	14.9
$C_{18:1}$	24.4	31.6
$C_{18:2}$	2.5	14.1
$C_{18:3}$	1.1	1.5
Others	1.4	1.1

[a]Milk containing high amounts of polyunsaturated fats (PUM).

TABLE 5. FATTY ACID COMPOSITION OF SAFFLOWER OIL FED TO VEAL CALVES, 11 TO 18 WEEKS

Fatty acid		%
$C_{14:0}$		0.2
$C_{16:0}$		8.0
$C_{16:1}$		0.1
$C_{18:0}$		2.4
$C_{18:1}$		12.6
C18:2		76.0
C18:3		0.4
C20:0		0.3
	Saturated acids	10.9
	Unsaturated acids	89.1
	Total	100.0

Meat from these calves was made available to scientists of the Eastern Regional Research Laboratory, Philadelphia, Pennsylvania, for evaluation of quality and flavor characteristics. They found (R. Ellis *et al., unpublished data*) oxidative stability of fats was enhanced in meat from the calves fed tocopherol supplemented polyunsaturated fat diets.

Results and Discussion

Growth. Body weights taken at weekly intervals revealed that calves fed polyunsaturated milk grew at the same rate as those fed normal milk (Figure 1). The average daily gain for the 10-week milk feeding period was .86 kg for the four polyunsaturated milk fed calves, and .84 kg for those fed normal milk. Growth of these calves was superior to published growth standards for Beltsville Holstein bulls (Matthews and Fohrman, 1954) in which average daily gain to 10 weeks of age was .55 kilograms.

Figure 2 shows the growth of the calves while on the formaldehyde protected and unprotected safflower oil-casein rations. Intake and gain data for the calves from 11 to 18 weeks is in table 6.

An explanation of the lower intake of the protected ration is not readily apparent. It may have been less appetizing, or perhaps satiety occurred with less intake, due to differences in ruminal degradation of feed. To some extent differences in average daily gain may reflect the lower weight of the SOC calves following regrouping at the 10th week. Daily total protein intakes during this period (table 6) were less for all calves than the National Research Council suggested amount of 420 g for veal calves weighing about 120 kilograms. It seems

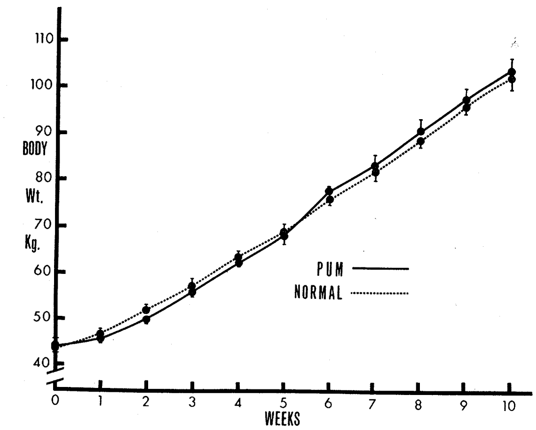

Figure 1. Growth of calves fed polyunsaturated and normal milk. Vertical bars indicate the standard error of the mean in one direction. N=4 for each mean.

that the calves did not consume adequate protein for optimal growth between 11 and 17 weeks. This effect was more pronounced with the protected than with the control ration. Even though marked differences in intakes and average daily gains were observed, there was no difference in slaughter weight of the calves fed protected or unprotected safflower oil-casein.

Health. Weekly veterinary evaluation of the appearance and health of the calves revealed no abnormalities associated with the dietary treatments. The calves were examined for condition of coat, abnormalities of stance or gait, stiffness and evidence of muscular dystrophy, excitability or nervousness, and respiratory infections or abnormality. This result contrasts with the reports of others (Adams *et al.*, 1959a,b; Gullickson, Fountaine and Fitch, 1942) who experienced poor weight gains, bad health, and considerable mortality of calves on rations high in unsaturated vegetable fat. All the calves in our study, whether fed milk containing high or normal amounts of polyunsaturated fatty acids, received supplemental vitamin E. The presence of this vitamin E during these early growth stages may be the explanation for the very satisfactory growth and weight gains during the milk feeding period, which contrasts with the growth deficiencies and health problems encountered by Adams *et al.* (1959a,b). Under the conditions of our experiment and feeding trials, the presence of high levels (14.1% linoleic acid) of polyunsaturated fats has not adversely affected the health of young calves.

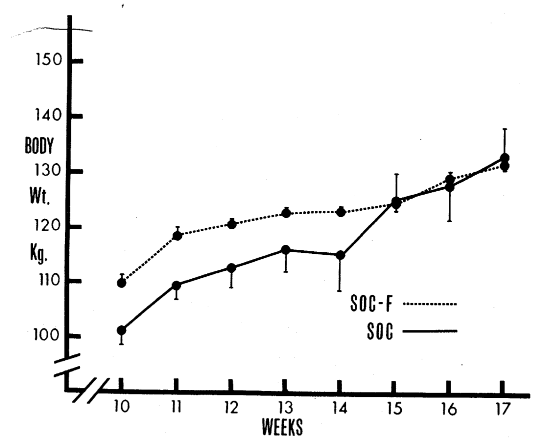

Figure 2. Growth of calves during feeding of formaldehyde protected and unprotected safflower oil-casein. Vertical bars indicate the standard error of the mean in one direction. N=4 for each mean.

Blood Constituents. Figure 3 shows blood plasma cholesterol values during the experiment. These were not different from controls during the unsaturated milk feeding period, but marked elevation of cholesterol occurred later when the safflower oil-casein was protected from degradation in the rumen. Toward the end of the experiment the cholesterol of calves on the protected diet declined. We do not know why this occurred.

We also followed non-esterified fatty acids and triglycerides in calf plasma. Neither of these showed trends that could be associated with treatment.

Blood levels of vitamin E are in figure 4. The high levels of both groups during the milk feeding period result from the tocopherol supplementation of the milk.

Evidence that the dietary alterations in this experiment changed blood levels of linoleic acid is provided in figure 5. Both the feeding of milk high in polyunsaturated fat and the protection from rumen hydrogenation afforded by the formaldehyde protection of the safflower oil-casein resulted in higher levels of plasma linoleic acid. The higher plasma linoleic acid of the PUM-fed calves, during the milk feeding period, suggests that the esophageal groove reflex was functional during most of this time. Thus, the hydrogenation by rumen microflora was probably avoided and the unsaturated fat was available for absorption in the lower tract. Ørskov and Benzie (1969) have recently reinvestigated the esophageal groove reflex in sheep and suggest that control of the reflex would be a useful technique for nutrient by-pass of the

TABLE 6. MEAN FEED INTAKE AND WEIGHT GAINS OF CALVES, 11 TO 18 WEEKS.

Item	NM[a] SOC[c]	NM[a] SOC-F[d]	PUM[b] SOC[c]	PUM[b] SOC-F[d]	SE[e]
	g/calf/day				
Concentrates	1608	1423	1800	1323	±73
Safflower oil-casein	209	185	234	172	±10
Total protein	338	303	378	283	±15
Daily gain	543	473	756	439	±69

[a]Normal milk.
[b]Polyunsaturated milk.
[c]Safflower Oil-Casein (65% safflower oil, 35% sodium caseinate).
[d]Formaldehyde protected Safflower Oil-Casein (65% safflower oil, 35% sodium caseinate).
[e]Standard error of the means.

rumen. The reflex seems to be better conditioned and maintained, however, when milk is sucked from a nipple than when given from a pail as in our experiment.

Tissue Fatty Acid Composition. In table 7 the relative concentrations of major fatty acids of the tailhead fat biopsies are shown for the various treatments after 10 weeks of milk feeding, and later at 17 weeks for the combined treatments. As the exposure to dietary polyunsaturates increased, whether from polyunsaturated milk during the first 10 weeks, or formaldehyde protected safflower oil-casein fed later, the concentration of $C_{18:2}$ in the depot fat also increased. The amount of linoleic in the two calves that received both PUM and SOC-F was about 13% of total lipid fatty acid, which was about 3 1/2 times the level of those fed normal milk and unprotected SOC. The early feeding of PUM caused a higher 17-week linoleic acid level than did the 10- to 17-week feeding of SOC-F (11.0 *vs.* 9.4%, respectively). Compensatory decreases occurred in myristic ($C_{14:0}$) and palmitic ($C_{16:0}$) acids of tailhead fat as linoleic ($C_{18:2}$) increased.

The production of higher unsaturated fat in various depots was verified by analysis of tissues collected at slaughter. In table 8 these data are shown for linoleic acid. As exposure to polyunsaturate feeding increased, the concentration of $C_{18:2}$ increased and showed a quadrupling in relative content.

The similarity of values (table 8) for depot fat from various locations -- tailhead, omental and perirenal, suggests that frequent biopsy of the tailhead fat is a valid and useful indicator of

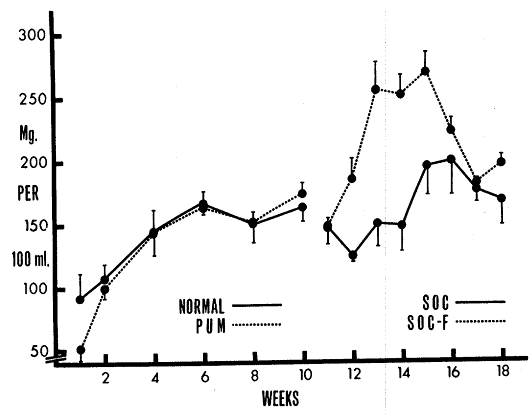

Figure 3. Plasma cholesterol of veal calves fed normal and polyunsaturated milk, and formaldehyde protected and unprotected safflower oil-casein. Vertical bars indicate the standard error of the mean in one direction. N=4 for each mean.

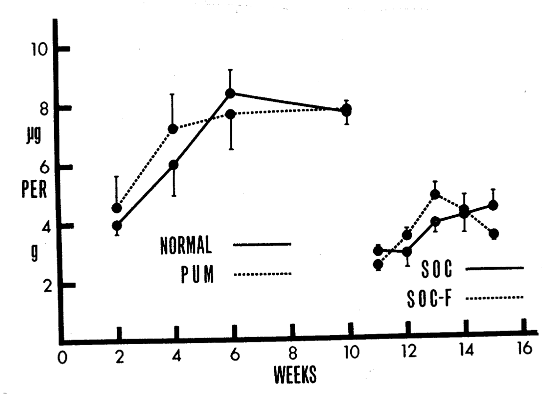

Figure 4. Vitamin E in plasma of calves fed normal and polyunsaturated milk, and formaldehyde protected and unprotected safflower oil-casein. Vertical bars indicate the standard error of the mean in one direction, N=4 for each mean.

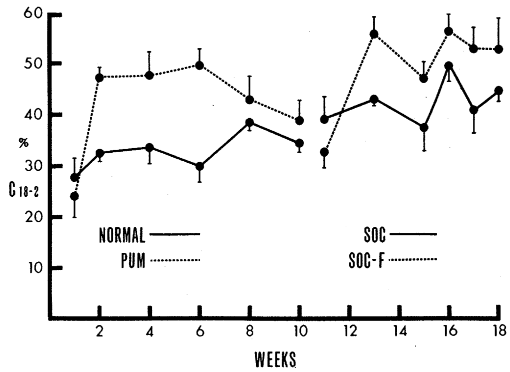

Figure 5. Linoleic acid in lipid of blood plasma of veal calves fed normal milk and milk high in polyunsaturated fats, and protected and unprotected safflower oil-casein.

fatty acid composition of body fat in general. Increases observed in linoleic acid concentration of body fat deposits were balanced by compensatory decreases in saturated fatty acids, primarily palmitic ($C_{16:0}$) and to a lesser extent myristic ($C_{14:0}$).

We also analyzed solvent-extracted intramuscular fat from cuts of round and chuck. The samples chosen were from lean areas and averaged 0.4% fat on a wet-weight basis. This level of fat is much less than that occurring in similar cuts of mature beef (range from about 6 to 10% as reported by Marchello, Dryden and Ray, 1968; Terrell, Suess and Bray, 1969; Dryden and Marchello, 1970; Garrett and Hinman, 1971), but this is not surprising in the light of Callow's (1962) conclusion that early developing areas contain much less intra-

TABLE 7. FATTY ACIDS COMPOSITION OF CALF TAILHEAD FAT BIOPSIES AFTER FEEDING NORMAL MILK AND MILK HIGH IN POLYUNSATURATED FATS FOR 10 WEEKS, AND AT 17 WEEKS FOLLOWING FEEDING OF FORMALDEHYDE PROTECTED OR UNPROTECTED SAFFLOWER OIL CASEIN

	–% at 10 weeks –		% at 17 weeks			
Fatty acid	NM[a]	PUM[b]	NM SOC[c]	NM SOC-F[d]	PUM SOC	PUM SOC-F
N	4	4	2	2	2	2
12:0	0.4[e] ±.04	0.2 ±.02	0.4 ±.04	0.2 ±.07	0.2 ±0	0.2 ±0
14:0	8.8 ±.27	5.6 ±.34	7.9 ±.21	4.9 ±.21	4.5 ±.42	4.7 ±0
14:1	1.6 ±.10	1.4 ±.08	1.4 ±.04	0.8 ±.18	0.8 ±.07	1.0 ±0
16:0	31.0 ±1.91	21.4 ±.34	30.1 ±.42	23.4 ±.11	20.2 ±1.13	22.4 ±1.59
16:1	4.6 ±.16	3.5 ±.10	4.4 ±.04	3.3 ±.35	3.2 ±0	3.2 ±0
18:0	13.3 ±.93	11.2 ±.22	15.0 ±.35	18.2 ±.35	18.0 ±.50	15.6 ±.32
18:1	33.9 ±.97	41.4 ±.48	33.2 ±.21	35.2 ±.81	38.2 ±1.70	36.8 ±2.72
18:2	3.2 ±.20	11.6 ±.36	3.6 ±.04	9.4 ±.57	11.0 ±.57	12.8 ±.99
18:3	0.8 ±.05	1.3 ±.06	1.0 ±0	0.8 ±.07	1.6 ±.11	1.0 ±.04
Others	2.6 ±.21	2.6 ±.14	3.0 ±.14	3.8 ±.35	2.3 ±0	2.2 ±.04

[a]Normal milk.
[b]Milk containing high levels of polyunsaturated fats.
[c]Safflower Oil Casein.
[d]Safflower Oil Casein, formaldehyde protected.
[e]Values are means ± standard error.

TABLE 8. LINOLEIC ACID CONTENT OF DEPOT FAT AND FAT EXTRACTED FROM MUSCLE OBTAINED AT SLAUGHTER

Diet		% $C_{18:2}$[e]				
To 10 weeks	10 to 18 weeks	Tailhead fat	Omental fat	Perirenal fat	Extracted fat from round	Extracted fat from chuck
NM[a]	SOC[c]	3.0 ±0	3.2 ±.18	3.2 ±.07	19.0 ±2.5	16.4 ±2.7
PUM[b]	SOC	10.2 ±.04	9.7 ±.21	7.7 ±.28	20.2 ±5.1	25.4 ±4.8
NM	SOC-F[d]	10.9 ±.14	12.6 ±.57	16.0 ±.07	23.2 ±7.0	29.0 ±3.2
PUM	SOC-F	12.4 ±.14	14.0 ±.53	13.7 ±.99	24.3 ±1.5	30.8 ±0.4

[a]Normal milk.
[b]Milk containing high levels of polyunsaturated fats.
[c]Safflower Oil-Casein.
[d]Safflower Oil-Casein, formaldehyde protected.
[e]Values are means ± standard errors, two calves per group.

muscular fat than later developing areas of beef muscle.

Reports by Link *et al.* (1967) and Prost, Pelczynska and Pikielna (1972) provide evidence that total intramuscular lipid increases as beef cattle grow older and heavier. The data of Prost *et al.* (1972) show that the fat content of muscles ranged from 0.67% for 6- to 8-week-old calves to 4.77% in mature cattle.

The experiments of Callow (1962) also showed that developing areas contained more unsaturated than saturated fats as determined by higher iodine numbers. Our data (table 8) show that the linoleic acid concentration varied between 19 and 24% in fat extracted from round, and from 16 to 31% in fat from chuck. The higher concentrations in both cuts were from calves that received both the milk containing highly polyunsaturated fat and the protected safflower oil-casein. Our levels of linoleic in muscle were much higher than those reported by others in mature beef (Waldman, Suess and Brungardt, 1968; Marchello, Dryden and Ray, 1968; Dryden and Marchello, 1970;–range 1.8 to 2.8%).

Digesta. At slaughter in order to gain insight into the effect of encapsulation and the different dietary regimens on fatty acid metabolism, we determined the fatty acid composition of the contents of various parts of the digestive tract. In table 9 is shown the percent $C_{18:2}$ in fat of the digesta in the rumen, abomasum, and

TABLE 9. LINOLEIC ACID CONCENTRATION IN FAT OF DIGESTA

		% in fat[e]				
To 10 weeks	11 to 18 weeks	Rumen	Abomasum	Upper small intestine	Lower small intestine	Large intestine
NM[a]	SOC[c]	20.4 ±0.1	36.4 ±1.8	20.0 ±0.4	26.6 ±3.6	20.0 ±1.6
PUM[b]	SOC	10.8 ±4.2	39.3 ±5.2	26.0 ±2.7	21.6 ±0.1	14.0 ±3.9
NM	SOC-F[d]	50.7 ±3.7	73.3 ±1.0	33.6 ±6.7	36.8 ±5.8	14.8 ±9.3
PUM	SOC-F	59.9 ±2.8	63.0 ±0.3	37.1 ±0.8	27.4 ±4.7	28.1 ±2.9

[a]Normal milk.
[b]Milk containing high levels of polyunsaturated fats.
[c]Safflower Oil-Casein.
[d]Safflower Oil-Casein, formaldehyde protected.
[e]Values are means ± standard errors, two calves per group.

TABLE 10. RUMEN FLUID VOLATILE FATTY ACIDS AT SLAUGHTER

	SOC[a] Fed	SOC–F[a] Fed	SE [b]	Significance of difference between means[c]
	---------- meq/1 ----------			
Total VFA	127.7	97.0	8.4	P<.050
	----------Molar %----------			
Acetic	55.0	64.5	2.1	P<.025
Propionic	20.5	17.3	1.1	N.S.
Isobutyric	1.5	1.2	0.1	P<.025
Butyric	17.1	12.8	1.1	P<.050
Isovaleric	2.7	2.2	0.1	P<.025
Valeric	3.1	2.0	0.3	P<.010

[a]Values are group means of observations on four animals grouped without regard to type of milk fed during the first 10 weeks.
[b]Standard error of the treatment means.
[c]By analysis of variance.

intestine. The linoleic concentration was much higher in the rumen of SOC-F than SOC fed animals thus reflecting the protection from hydrogenation afforded by the formaldehyde coating. A marked gradient indicative of intestinal absorption occurred in the $C_{18:2}$ lipid content from the abomasum to the large intestine. Differences correlated with the formaldehyde protection were less apparent in the lower small gut and in the large intestine. The marked increases in $C_{18:2}$ in the digesta of animals that received SOC-F were accompanied by decreases in saturated acids, notably ruminal and abomasal $C_{16:0}$ and $C_{18:0}$.

Rumen fluid volatile fatty acid analyses were performed on samples obtained at slaughter. These data, table 10, show significantly higher total VFA for calves receiving unprotected than protected fat ($p < .05$). Even though the molar % of acetic acid was lower for the SOC than the SOC-F fed group, the meq/1 of acetic acid (127.7 x 55.0) was higher for the SOC calves than for those on the SOC-F diet (97.0 x 64.5). Thus, all of the VFA's were higher on the SOC diet than on the formaldehyde protected diet.

Conclusion

This experiment demonstrates that the feeding of highly polyunsaturated milk, and grain containing formaldehyde-protected safflower oil casein, had significant effects on the lipid metabolism of veal calves. Higher than normal levels of linoleic acid were found in the depot fat and cuts of meat of the calves fed the experimental diets. In general, our results confirm the reports of Faichney *et al.* (1972) and Cook *et al.* (1972) who fed a similarly protected safflower oil supplement for varying periods to 9-month-old steers. Their dietary 18:2 was rapidly incorporated into perirenal, subcutaneous, and omental fats as well as into intramuscular triglycerides and phospholipids. The rate of incorporation diminished from a maximum during the first 2 weeks to minimal at the end of their 8-week experimental trial. They experienced an increase in linoleic acid concentration from about 5% to about 30% of the lipid of the tissues studied. The higher levels of linoleic attained in the Australian work were undoubtedly due to their higher feeding level (over twice the levels of our experiment).

Literature Cited

Adams, R. S., T. W. Gullickson, J. E. Gander and J. H. Sautter. 1959a. Some effects of feeding various filled milks to dairy calves. I. Physical condition and weight gains, with special reference to low-fat rations. J. Dairy Sci. 42:1552.

Adams, R. S., J. E. Gander, T. W. Gullickson and J. H. Sautter. 1959b. Some effects of feeding various filled milks to dairy calves. III. Blood plasma tocopherol and vitamin A levels, diet storage effects, and evidence of toxicity. J. Dairy Sci. 42:1569.

Annison, E. F. 1960. Plasma non-esterified fatty acids in sheep. Australian J. Agr. Res. 11:58.

Bieri, J. G. and R. K. H. Poukka. 1970. In vitro hemolysis as related to rat erythrocyte content of a-tocopherol and poly-unsaturated fatty acids J. Nutr. 100:557.

Bitman, J., L. P. Dryden, H. K. Goering, T. R. Wrenn, R. A. Yoncoskie and L. F. Edmondson. 1973. Efficiency of transfer of polyunsaturated fat into milk. J.A.O.C.S. 50:93.

Callow, E. H. 1962. Comparative studies of meat. The percentage of fat in the fatty and muscular tissues of steers and the iodine number of the extracted fat, as affected by breed and level of nutrition. J. Agr. Sci. 58:295.

Christopherson, S. W. and R. L. Glass. 1969. Preparation of milk fat methyl esters by alcoholysis in an essentially nonalcoholic solution. J. Dairy Sci. 52:1289.

Cook, L. J., T. W. Scott, G. J. Faichney and H. Lloyd Davies. 1972. Fatty acid interrelationships in plasma, liver, muscle and adipose tissues of cattle fed safflower oil protected from ruminal hydrogenation. Lipids 7:83.

Cook, L. J., T. W. Scott and Y. S. Pan. 1972. Formaldehyde-treated casein-safflower oil supplement for dairy cows. II. Effect on fatty acid composition of plasma and milk lipids. J. Dairy Res. 39:211.

Dole, V. P. 1956. A relation between non-esterified fatty acids in plasma and the metabolism of glucose. J. Clin. Invest. 35:150.

Dryden, F. D. and J. A. Marchello. 1970. Influence of total lipid fatty acid composition upon the palatability of three bovine muscles. J. Anim. Sci. 31:36.

Faichney, G. J., H. Lloyd Davies, T. W. Scott and L. J. Cook. 1972. The incorporation of linoleic acid into the tissues of growing steers offered a dietary supplement of formaldehyde–treated casein-safflower oil. Australian J. Biol. Sci. 25:205.

Garrett, W. N. and N. Hinman. 1971. Fat content of trimmed beef muscles as influenced by quality grade, yield grade, marbling score and sex. J. Anim. Sci. 33:948.

Green, J., A. T. Diplock, J. Bunyan, D. McHale and I. R. Muthy. 1967. Vitamin E and stress. I. Dietary unsaturated fatty acid stress and the metabolism of a-tocopherol in the rat. Brit. J. Nutr. 21:69.

Gullickson, T. W., F. C. Fountaine and J. B. Fitch. 1942. Various oils and fats as substitutes for butterfat in the ration of young calves. J. Dairy Sci. 25:117.

Harmon, E. M., L. A. Witting and M. K. Horwitt. 1966. Relative rates of depletion of a-tocopherol and linoleic acid after feeding polyunsaturated fats. Amer. J. Clin. Nutr. 18:243.

Hayes, K. C., S. W. Nielsen and J. E. Rousseau, Jr. 1969. Vitamin E deficiency and fat stress in the dog. J. Nutr. 99:196.

Horwitt, M. K., C. C. Harvey, B. Century and L. A. Witting. 1961. Polyunsaturated lipids and tocopherol requirements. J. Amer. Dietetic Ass. 38:231.

Link, B. A., R. W. Gray, R. G. Cassens and R. G. Kauffman. 1967. Influence of age on lipids in skeletal muscle. J. Anim. Sci. 26:898.

Marchello, J. A., F. D. Dryden and D. E. Ray. 1968. Variation in the lipid content and fatty acid composition of three bovine muscles as affected by different methods of extraction. J. Anim. Sci. 27:1233.

Matthews, C. A. and M. H. Fohrman. 1954. Beltsville growth standards for Holstein cattle. Technical Bull. No. 1099, U. S. Department of Agriculture, Washington, D. C.

Moore, J. H. and W. Steele. 1968. Dietary fat and milk fat secretion in the cow. Proc. Nutr. Soc. 27:66.

Ørskov, E. R. and D. Benzie. 1969. Studies on the oesophageal groove reflex in sheep and on the potential use of the groove to prevent the fermentation of food in the rumen. Brit. J. Nutr. 23:415.

Pan, Y. S., L. J. Cook and T. W. Scott. 1972. Formaldehyde-treated casein-safflower oil supplement for dairy cows. I. Effect on milk composition. J. Dairy Res. 39:203.

Pearson, S., S. Stern and T. H. McGavack. 1953. Rapid accurate method for the determination of total cholesterol in serum. Anal. Chem. 25:813.

Plowman, R. D., J. Bitman, C. H. Gordon, L. P. Dryden, H. K. Goering, T. R. Wrenn, L. F. Edmondson, R. A. Yoncoskie and F. W. Douglas, Jr. 1972. Milk fat with increased polyunsaturated fatty acids. J. Dairy Sci. 55:204.

Prost, E., E. Pelczynska and N. Pikielna. 1972. Variability of basic composition of bovine meat (veal and beef) and its relation to individual muscles, age, sex and quality grade of carcass. Lebensm. – Wiss. u. 5:64.

Scott, T. W., L. J. Cook, K. A. Ferguston, I. W. McDonald, R. A. Buchanan and G. Loftus Hills. 1970. Production of poly-unsaturated milk fat in domestic ruminants. Australian J. Sci. 32:291.

Scott, T. W., L. J. Cook and S. C. Mills. 1971. Protection of dietary polyunsaturated fatty acids against microbial hydrogenation in ruminants. J. Amer. Oil Chem. 48:358.

Storry, J. E. 1970. Ruminant metabolism in relation to the synthesis and secretion of milk fat. J. Dairy Res. 37:139.

Terrell, R. N., G. G. Suess and R. W. Bray. 1969. Influence of sex, liveweight and anatomical location on bovine lipids II. Lipid components and subjective scores of six muscles. J. Anim. Sci. 28:454.

Tikriti, H. H. 1969. Metabolism of vitamin E by the lactating dairy cow in relation to oxidized flavor in milk. Ph.D. Thesis, University of Maryland, College Park.

Van Handel, E. 1961. Suggested modifications of the micro determination of triglycerides, Clin. Chem. 7:249.

Van Handel, E. and D. B. Zilversmit. 1957. Micromethod for the direct determination of serum triglycerides. J. Lab. Clin. Med. 50:152.

Waldman, R. C., G. G. Suess and V. H. Brungardt. 1968. Fatty acids of certain bovine tissue and their association with growth, carcass and palatability traits. J. Anim. Sci. 27:632.