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Alteration of the Fatty Acid Content of Milk Fat

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ABSTRACT

Milk fatty acid composition can be influenced by several factors, many of which are interactive. These include stage of lactation, seasonal variation, low milk fat syndrome, feeding, genetic variation, and changes in the energy status of the cow due to administration of bovine somatotropin. Utilization of feeding, genetic variation, and bovine somatotropin should produce a milk fat lower in saturated and higher in unsaturated fatty acids. This may be beneficial to consumers, as many health professionals are recommending diets lower in saturated fatty acids. Giving consumers the option of purchasing low saturated fatty acid dairy products may also assist in alleviating the current milk fat surplus in the dairy industry.

Milk from dairy cows, being a biological fluid, varies considerably in many of its constituents. Fat content of milk is the constituent exhibiting the most variation in its percentage. Milk fat is one of the most complex of all common fats, composed of about 98% triglycerides (*38*). It contains numerous fatty acids (*39*), mainly saturated (66%), but also monosaturated (30%) and polyunsaturated (4%) (*75*). All short-chain (4:0 to 10:0) and half of the medium-chain (12:0 to 17:0) fatty acids in milk fat are synthesized from acetate and B-hydroxybutyrate in the mammary gland epithelial cells. The other half of medium-chain and almost all long-chain (18:0 and longer) fatty acids are derived from blood plasma fatty acids of dietary origin or from mobilization of body fat stores (*28,44*).

FACTORS AFFECTING MILK FATTY ACID COMPOSITION

Several factors, many of which are interactive, are known to cause variation in milk fatty acid composition (*21,44*). These include stage of lactation, seasonal variation, low milk fat syndrome, feeding (*37*), genetic variation (*27*), and changes in the energy status of the cow due to administration of bovine somatotropin (*7,13,28*).

Stage of lactation

Stage of lactation is known to affect milk fat percentages. Milk fat percentages are highest in colostrum, then decline during the next 8 weeks of lactation, followed by a slow increase until the end of lactation (*44*). It has been reported that colostral milk fat secreted during the first day of lactation contained lower levels of short-chain fatty acids, while over the next 15 d palmitic acid (16:0) levels increased (*66*). There is some disagreement as to the nature of changes that may occur after the first week of lactation (*21*). In a stage of lactation study (*55*), butyric acid (4:0) was highest during the first month of lactation, while caproic (6:0) to myristic (14:0) acids all increased during the first 4 to 8 weeks of lactation, remained constant to the fifth or sixth month, then decreased toward the end of lactation. The longer chain fatty acids, stearic (18:0) and linoleic (18:1), were highest in early lactation, decreased until mid-lactation, then increased toward the end of lactation. To summarize, most studies agree that short-chain fatty acids, with the possible exception of butyric (4:0), increase for the first 8 to 10 weeks of lactation, while palmitic acid (16:0) remains unchanged and stearic (18:0) and oleic (18:1) acids decrease. Changes occurring after the tenth week of lactation tend to be relatively minor (*21*).

Season

The effect of seasonal variation on fatty acid composition of milk fat has been extensively evaluated (*14,34, 40,57*). Milk fat in winter contained more palmitic acid (16:0) and lower levels of stearic (18:0) and oleic (18:1) acids than milk fat of summer months. Many other factors interact with seasonal variation, and it has been proposed that seasonal changes in milk fatty acid composition are ultimately due to dietary effects (*39*). Dietary changes from hay-concentrate mixtures to fresh pasture grasses containing higher proportions of linoleic acid (18:2) probably have the greatest influence on seasonal differences in milk fatty acid composition (*21*) .

Low milk fat syndrome

Cows fed diets low in roughage produced milk which was below the normal range in percentage of fat (*20,64*). Levels of fat may be as low as 1 to 2% fat; this is known as low milk fat syndrome (*21*). Milk fatty acid composition was also altered in that short-chain fatty acids decreased and unsaturated fatty acids, particularly oleic acid (18:1), increased (*21,38*). Cows fed diets deficient in hay produced milk fat with increased levels of trans-monounsaturated fatty acids (*71*).

Feeding

Considerable resesearch has been reported on the feeding of fats, oils, and oilseeds to dairy cows (*54*). There is ample evidence that feeding cows various fat sources can affect milk fatty acid composition (*21*). Fat sources fed to dairy cows included whole sunflower seeds (*50,60*), rolled sunflower seeds (*29,52*), soybean oil (*8,43,47,69,70*), soybean oil meal (*45*), safflower oil (*56*), tallow (*53,68*), cottonseed oil (*25,68*), marine oils (*3*), coconut oil (*1*), menhaden oil (*33*), and oleic acid (*63*). In virtually all experiments where cows were fed fats high in long-chain unsaturated fatty acids, the milk fat contained increased amounts of stearic (18:0) and oleic (18:1) acids, whereas amounts of medium-chain fatty acids decreased (*21*).

In the early 1970's, reseachers in Australia developed a method for protecting polyunsaturated lipids from hydrogenation in the rumen (*23,61,62*). Polyunsaturated oils were coated with a protein and treated with formaldehyde for protection from hydrogenation by rumen microorganisms. Feeding of protected lipids elevated the amount of polyunsaturated fatty acids, particularly linoleic acid (18:2), in milk fat. Some formaldehyde was also transferred into the milk (*82*); therefore, formaldehyde protected lipid supplements have not been approved by FDA for commercial use in the U.S. Protected fats, oils, and oilseeds evaluated as fat supplements in dairy cow rations included coconut, safflower, cottonseed, and/or soybean oils (*1,4,5,11,12,30,49,59,72,81,82*), rapeseed oil (*2*), cod-liver oil (*73*), tallow (*12,26,42,48,65,80*), and canola (*18*). In summary, feeding protected lipids had a greater influence on fatty acid composition of milk fat than feeding unprotected lipids. Milk fat containing lower amounts of polyunsaturated fatty acids was produced from cows fed diets of unprotected lipids. Increased amounts of monounsaturated fatty acids, particularly oleic acid (18:1), were reported in milk fat from cows fed unprotected lipids (*8,50,56,60,68*).

Genetic variation

Genetic factors can cause variation in milk fatty acid composition. In a study involving Ayrshire twin cows, comparisons between the variation within pairs of one- and two-egg twins showed that proportions of different fatty acids were subject to a high degree of genetic control. It was concluded that due to the small size of genetic variances for individual fatty acids, manipulation would be a long-term undertaking (*27*).

Bovine somatotropin

Administration of bovine somatotropin (bST) to lactating dairy cows increased milk production (*19,28,51,58*). Bovine somatotropin (51.5 mg/day) treated cows, in a short-term 14-d trial, produced milk fat with 6% less short- (caproic, 6:0; caprylic, 8:0; capric, 10:0) and medium- (lauric, 12:0; myristic, 14:0; myristoleic, 14:1; pentadecylic, 15:0; palmitic, 16:0) chain fatty acids and 6% more long-chain (oleic, 18:1) fatty acids (*13*). In another short-term 10-d trial, milk fat from cows treated with bST (50 and 100 IU/d) contained more palmitoleic (16:1) and oleic (18:1) acids (*28*).

In a complete lactation study where cows were given biweekly treatments of bST (500 mg), the fatty acid composition of milk fat was not significantly altered (*46*). In another complete lactation study (*7*) in which mid-lactation cows were treated with bST (30.9 mg/day), reductions in short- and medium-chain fatty acids and increases in long-chain fatty acids were reported for bST milk fat. Milk fat from cows treated with bST was more unsaturated, mainly due to higher amounts of oleic acid (18:1). Long-chain and unsaturated fatty acids increased the most during the first 8 weeks of bST treatment, when cows were in a negative energy balance. Unsaturated fatty acid levels remained slightly higher in the bST milk fat throughout the treatment period (*7*). This may indicate that high producing cows produce milk fat with a higher percentage of unsaturated fatty acids, or it may indicate an effect of bST. Additional research needs to be done to establish possible interaction between bST and high producing cows.

Dairy cows in early lactation (about the first 2 months) are normally in a negative energy balance (*10*). Increased energy needs are met by mobilization of body fat stores (*13,76*). Therefore, changes in fatty acid composition of milk fat from cows treated with bST are related to the energy status of the cow (*7,10,13,28*) and not likely a direct effect of bST.

EFFECT OF MILK FATTY ACID COMPOSITION ON DAIRY PRODUCTS

The type of fatty acids present in milk fat can influence the flavor and physical properties of dairy products, as well as results of analytical tests for determination of milk fat (*9*). Milk fat contains substantial amounts of short-chain fatty acids, making it unique compared to other fats. These short-chain fatty acids, particularly butyric acid (4:0), are important for flavor development in some cheeses and fermented dairy products (*9*).

It is well documented that spring and summer milk fat from cows on pasture contains more unsaturated fatty acids; hence, butter manufactured from this milk fat will be softer (*77*). The ratio of saturated to unsaturated fatty acids and the ratio of short- to long-chain fatty acids can affect the melting and spreadability of butter (*9,16,22,35,52,74,78,79*). As indicated in Table 1, medium-chain saturated fatty acids such as myristic (14:0), palmitic (16:0), and long-chain saturated fatty acids such as stearic (18:0) acid have the greatest influence on butter hardness, since they have the highest melting points.

TABLE 1. *Melting points of the major fatty acids in milk fat[1].*

Fatty acid[2]	Melting point (°C)
4:0	-8
6:0	10
8:0	16
10:0	31.5
12:0	44
14:0	58
16:0	64
18:0	69
18:1	13
18:2	-5

[1]Refs. (*6,24,38*).
[2]Expressed as number of carbons: number of double bonds.

It is possible that increased amounts of unsaturated fatty acids in milk fat may increase susceptibility to oxidation (*41*). Feeding protected unsaturated fat sources to cows gave no oxidative instability or off-flavors to milk or butter (*17*); similar results were reported for butter when cows were fed unprotected unsaturated fat sources (*29,52*). Milk flavor and susceptibility of milk to oxidized or rancid off-flavors were not affected by treating cows with bST, even though the milk was more unsaturated (*7*).

POSSIBLE HUMAN HEALTH IMPLICATIONS

Although little research has been reported on effects of monounsaturated fatty acids on human blood cholesterol levels, two recent studies have shown possible beneficial effects (*31,67*). In one of these studies, the consumption of raw almonds and almond oil as the only free fat source resulted in reductions of serum cholesterol (*67*). In the other study, safflower oil high in oleic acid (18:1) was consumed and resulted in lower plasma cholesterol levels (*31*).

Research has also shown that myristic (14:0) and palmitic (16:0) acids raise human serum cholesterol levels (*36*), while caprylic (8:0), capric (10:0), and stearic (18:0) acids have no effect (*15*). It is therefore incorrect to designate all saturated fatty acids as human blood cholesterol-raising substances (*32*).

CONCLUSION

Changes in fatty acid composition of milk from cows fed protected or unprotected polyunsaturated lipids or treated with bST seem to be advantageous, as many health professionals are recommending diets lower in saturated fatty acids. It may be possible to utilize the influence that feeding, genetic variation, and bST (or a combination of these factors) has on milk fatty acid composition in a beneficial manner. Therefore, the dairy industry should be able to produce milk and dairy products with increased amounts of unsaturated fatty acids, which may be more desirable to the consumer.

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REFERENCES

1. Anderson, M. 1974. Milk fat globule membrane composition and dietary change: Supplements of coconut oil fed in two physical forms. J. Dairy Sci. 57:399-404.
2. Astrup, H. N., L. Baevre, L. Vik-Mo, and A. Ekern. 1980. Effect on milk lipolysis of restricted feeding with and without supplementation with protected rapeseed oil. J. Dairy Res. 47:287-294.
3. Astrup, H. N., 0. Fauske, and L. Baevre. 1981. Feeding of various hydrogenated marine oil products to the dairy cow. Acta Agric. Scand. 31:75-80.
4. Astrup, H. N., L. Vik-Mo, A. Ekern, and F. Bakke. 1976. Feeding protected and unprotected oils to dairy cows. J. Dairy Sci. 59:426-430.
5. Astrup, H. N., L. Vik-Mo, P. Lindstad, and A. Ekern. 1979. Casein protected oil supplement fed at a low level to milk cows. Milchwissenschaft 34:290-291.
6. Atherton, H. V., and J. A. Newlander. 1977. Composition of milk. pp. 1-35, *In* Chemistry and testing of dairy products, 4th ed. AVI Publ. Co., Inc., Westport, CT.
7. Baer, R. J., K. M. Tieszen, D. J. Schingoethe, D. P. Casper, W. A. Eisenbeisz, R. D. Shaver, and R. M. Cleale. 1989. Composition and flavor of milk produced by cows injected with recombinant bovine somatotropin. J. Dairy Sci. 72:1424-1434.
8. Banks, W., J. L. Clapperton, and M. E. Kelly. 1980. Effect of oil-enriched diets on the milk yield and composition, and on the composition and physical properties of the milk fat, of dairy cows receiving a basal ration of grass silage. J. Dairy Res. 47:277-285.
9. Barbano, D. M., and J. Lynch. 1987. Milk from BST-treated cows- its composition and manufacturing properties. pp. 66-73. *In* National Invitational Workshop on Bovine Somatotropin, St. Louis, MO.
10. Barbano, D. M., and J. M. Lynch. 1989. Milk from bst-treated cows: Composition and manufacturing properties. pp. 9-18. *In* Advanced technologies facing the dairy industry :bst. Anim. Sci. Mimeo. Series Proc. No. 133, Rochester, NY.
11. Barbano, D. M., and J. W. Sherbon. 1980. Polyunsaturated protected lipid: Effect of triglyceride molecular weight distribution. J. Dairy Sci. 63:731-740.
12. Barbano, D. M., and J. W. Sherbon. 1981. Polyunsaturated protected lipid: Effect on milk phospholipids. J. Dairy Sci. 64:2170-2174.
13. Bitman, J., D. L. Wood, H. F. Tyrrell, D. E. Bauman, C. J. Peel, A. C. G. Brown, and P. J. Reynolds. 1984. Blood and milk lipid responses induced by growth hormone administration in lactating cows. J. Dairy Sci. 67:2873-2880.
14. Boatman, C., D. K. Hotchkiss, and E. G. Hammond. 1965. Effect of season and stage of lactation on certain polyunsaturated fatty acids of milk fat. J. Dairy Sci. 48:34-37.
15. Bonanome, A., and S. M. Grundy. 1988. Effect of dietary stearic acid on plasma cholesterol and lipoprotein levels. N. Eng. J. Med. 318:1244-1248.
16. Buchanan, R. A., and W. P. Rogers. 1973. Manufacture of butter high in linoleic acid. Aust. J. Dairy Technol. 28:175-178
17. Cadden, A.-M., A. Urquhart, and P. Jelen. 1984. Storage stability of canola-based protected lipid feed supplement and its effect on characteristics of milk and butter. J. Dairy Sci. 67:1414-1420.
18. Cadden, A.-M., A. Urquhart, and P. Jelen. 1984. Evaluation of milk and butter from commercial dairy herds fed canola-based protected lipid feed supplement. J. Dairy Sci. 67:2041-2044.
19. Chilliard, Y. 1989. Long-term effects of recombinant bovine somatotropin (rBST) on dairy cow performances: A review. pp. 61-87. *In* K. Sejrsen, M. Vestergaard, and A. Neiman-Sorensen, (eds), Use of somatotropin in livestock production. Elsevier Applied Sci. Publ., New York.
20. Chilson, W. H., and H. H. Sommer. 1953. A study of milk fat from cows on special roughage diets. J. Dairy Sci. 36:561 (Abstr.).
21. Christie, W. W. 1980. The effects of diet and other factors on the lipid composition of ruminant tissues and milk. Prog. Lipid Res. 17:245-277.
22. Clark, A. K., T. M. Gilmore, S. A. Slocum, and D. L. Wheelborg. 1983. Evaluation of butter processed from milk of cows fed whole-rolled sunflower seeds without additional limestone. J. Dairy Sci. 66(Suppl. 1):89 (Abstr.).
23. Cook, L. J., T. W. Scott, K. A. Ferguson, and I. W. McDonald. 1970. Production of polyunsaturated ruminant body fats. Nature 228:178-179.
24. DeMan, J. M. 1980. Lipids. p.78. *In* Principles of food chemistry. AVI Publ. Co., Westport, CT.
25. DePeters, E. J., S. J. Taylor, A. A. Franke, and A. Aquirra. 1985. Effects of feeding whole cottonseed on composition of milk. J. Dairy Sci. 68:897-902.
26. Dunkley, W. L., N. E. Smith, and A. A. Franke. 1977. Effects of feeding protected tallow on composition of milk and milk fat. J. Dairy Sci. 60:1863-1869.
27. Edwards, R. A., J. W. B. King, and I. M. Yousef. 1973. A note on the genetic variation in the fatty acid composition of cow milk. Anim. Prod. 16:307-310.
28. Eppard, P. J., D. E. Bauman, J. Bitman, D. L. Wood, R. M. Akers, and W. A. House. 1985. Effect of dose of bovine growth hormone on milk composition: alpha-lactalbumin, fatty acids, and mineral elements. J. Dairy Sci. 68:3047-3054.
29. Finn, A. M., A. K. Clark, J. K. Drackley, D. J. Schingoethe, and T. Sahlu. 1985. Whole rolled sunflower seeds with or without additional limestone in lactating dairy cattle rations. J. Dairy Sci. 68:903-913.
30. Goering, H. K., T. R. Wrenn, L. F. Edmondson, J. R. Weyant, D. L. Wood, and J. Bitman. 1977. Feeding polyunsaturated vegetable oils to lactating cows. J. Dairy Sci. 60:739-747.
31. Grundy, S. M. 1986. Comparison of monounsaturated fatty acids and carbohydrates for lowering plasma cholesterol. N. Eng. J. Med. 314:745-748.
32. Grundy, S. M. 1990. Trans monounsaturated fatty acids and serum cholesterol levels. N. Eng. J. Med. 323:480-481.
33. Hagemeister, H., D. Precht, and C. A. Barth. 1988. Studies on transfer of omega-3 fatty acids into bovine milk fat. Milchwissenschaft 43:153-158.
34. Hall, A. J. 1970. Seasonal and regional variations in the fatty acid composition of milk fat. Dairy Ind. 35:20-24.
35. Harrap, B. S. 1973. Recent developments in the production of dairy products with increased levels of polyunsaturation. Aust. J. Dairy Technol. 28:101-104.
36. Hegsted, D. M., R. B. McGandy, M. L. Myers, and F. J. Stare. 1965. Quantitative effects of dietary fat on serum cholesterol in man. Am. J. Clin. Nutr. 17:281-295.
37. Jack, E. L., and L. M. Smith. 1956. Chemistry of milk fat: A review. J. Dairy Sci. 39:1-25.
38. Jenness, R., and S. Patton. 1959. Milk lipides. pp. 30-72. *In* Principles of dairy chemistry. John Wiley and Sons, New York
39. Jensen, R. G., and R. W. Clark. 1988. Lipid composition and properties. pp. 171-213. *In* N.P. Wong (ed). Fundamentals of dairy chemistry, 3rd ed. Van Nostrand Reinhold Co., New York.
40. Jensen, R. G., G. W. Gander, and J. Sampugna. 1962. Fatty acid composition of the lipids from pooled, raw milk. J. Dairy Sci. 45:329-331.
41. King, R. L., R. Gaither, R. Singh, J. Bitman, H. K. Goering, and T. R. Wrenn. 1972. Oxidized flavor in milk from cows supplemented with

formaldehyde-treated casein in safflower oil particles. J. Dairy Sci. 55:678 (Abstr.).

42. Kronfeld, D. S., S. Donoghue, J. M. Naylor, K. Johnson, and C. A. Bradley. 1980. Metabolic effects of feeding protected tallow to dairy cows. J. Dairy Sci. 63:545-552.
43. Larson, S. A., and L. H. Schultz. 1970. Effects of soybeans compared to soybean oil and meal in the ration of dairy cows. J. Dairy Sci. 53:1233-1240.
44. Linn, J. G. 1988. Factors affecting the composition of milk from dairy cows. pp. 224-241. *In* Designing foods: Animal product options in the market place. National Academy Press, Washington, DC.
45. Loosli, J. K., R. G. Warner, and H. F. Hintz. 1961. Value of corn distillers dried grains, soybean oil meal, heated soybeans and soybean oil meal plus starch for milk production. J. Dairy Sci. 44:1910-1914.
46. Lynch, J. M., D. M. Barbano, D. E. Bauman, and G. F. Hartnell. 1988. Influence of somatribove (recombinant methionyl bovine somatotropin) on the protein and fatty acid composition of milk. J. Dairy Sci. 71(Suppl. 1):100 (Abstr.).
47. Macleod, G. K., and A. S. Wood. 1972. Influence of amount and degree of saturation of dietary fat on yield and quality of milk. J. Dairy Sci. 55:439-445.
48. Macleod, G. K., Y. Yu, and L. R. Schaeffer. 1977. Feeding value of protected animal tallow for high yielding dairy cows. J. Dairy Sci. 60:726-738.
49. Mattos, W., and D. L. Palmquist. 1974. Increased polyunsaturated fatty acid yields in milk of cows fed protected fat. J. Dairy Sci. 57:1050-1054.
50. McGuffey, R. K., and D. J. Schingoethe. 1982. Whole sunflower seeds for high producing dairy cows. J. Dairy Sci. 65:1479-1483.
51. McGuffey, R. K., and J. I. D. Wilkinson. 1991. Nutritional implications of bovine somatotropin for the lactating dairy cow. J. Dairy Sci. 74:In Press.
52. Middaugh, R. P., R. J. Baer, D. P. Casper, D. J. Schingoethe, and S. W. Seas. 1988. Characteristics of milk and butter from cows fed sunflower seeds. J. Dairy Sci. 71:3179-3187.
53. Palmquist, D. L., and H. R. Conrad. 1980. High fat rations for dairy cows. Tallow and hydrolyzed blended fat at two intakes. J. Dairy Sci. 63:391-395.
54. Palmquist, D. L., and T. C. Jenkins. 1980. Fat in lactation rations: Review. J. Dairy Sci. 63:1-14.
55. Parodi, P. W. 1974. Variation in the fatty acid composition of milk fat: Effect of stage of lactation. Aust. J. Dairy Technol. 29:145-148.
56. Parry, R. M., Jr., J. Sampugna, and R. G. Jensen. 1964. Effect of feeding safflower oil on the fatty acid composition of milk. J. Dairy Sci. 47:37-40.
57. Patton, S., R. D. McCarthy, L. Evans, and T. R. Lynn. 1960. Structure and synthesis of milk fat. I. Gas chromatographic analysis. J. Dairy Sci. 43:1187-1195.
58. Peel, C. J., D. E. Bauman, R. C. Gorewit, and C. J. Sniffen. 1981. Effect of exogenous growth hormone on lactational performance in high yielding dairy cows. J. Nutr. 111:1662-1671.
59. 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. 55:204-207.
60. Rafalowski, W., and C. S. Park. 1982. Whole sunflower seed as a fat supplement for lactating cows. J. Dairy Sci. 65:1484-1492.
61. Scott, T. W., L. J. Cook, K. A. Ferguson, I. W. McDonald, R. A. Buchanan, and G. Loftus Hills. 1970. Production of polyunsaturated milk fat in domestic ruminants. Aust. J. Sci. 32:291-293.
62. Scott, T. W., L. J. Cook, and S. C. Mills. 1971. Protection of dietary polyunsaturated fatty acids against microbiol hydrogenation in ruminants. J. Am. Oil Chem. Soc. 48:358-364.
63. Selner, D. R., and L. H. Schultz. 1980. Effects of feeding oleic acid or hydrogenated vegetable oils to lactating cows. J. Dairy Sci. 63:1235-1241.
64. Smith, J. A. B., and N. N. Dastur. 1938. II. The effect of inanition on the yield and composition of milk fat. Biochem. J. 32:1868-1876.
65. Smith, N. E., W. L. Dunkley, and A. A. Franke. 1978. Effects of feeding protected tallow to dairy cows in early lactation. J. Dairy Sci. 61:747-756.
66. Sneft, B., and F. Klobasa. 1970. Studies on the fatty acid composition of cow's colostrum. Milchwissenshaft 25:391-394.
67. Spiller, G. A., D. J. A. Jenkins, L. Cragen, O. Bosello, K. Berra, C. Rudd, and R. Superko. 1989. Sustained reduction of serum cholesterol over nine weeks on a diet with a high ratio of monounsaturated fats to other fats. *In* X International Symposium on Drugs Affecting Lipid Metabolism, Houston, TX.
68. Steele, W., and J. H. Moore. 1968. The effects of dietary tallow and cottonseed oil on milk fat secretion in the cow. J. Dairy Res. 35:223-235.
69. Steele, W., R. C. Noble, and J. H. Moore. 1971. The effects of two methods of incorporating soybean oil into the diet on milk yield and composition in the cow. J. Dairy Res. 38:43-48.
70. Steele, W., R. C. Noble, and J. H. Moore. 1971. The effects of dietary soybean oil on milk fat composition in the cow. J. Dairy Res. 38:49-56.
71. Storry, J. E., and J. A. F. Rook. 1965. The effects of a diet low in hay and high in flaked maize on milk fat secretion and on the concentrations of certain constituents in the blood plasma of the cow. Br. J. Nutr. 19:101-109.
72. Storry, J. E., P. E. Brumby, A. J. Hall, and V. W. Jonson. 1974. Response of the lactating cow to different methods of incorporating casein and coconut oil in the diet. J. Dairy Sci. 57:61-67.
73. Storry, J. E., P. E. Brumby, A. J. Hall, and B. Tuckley. 1974. Effects of free and protected forms of codliver oil on milk fat secretion in the dairy cow. J. Dairy Sci. 57:1046-1049.
74. Urquhart, A., A.-M. Cadden, and P. Jelen. 1984. Quality of milk and butter related to canola based protected lipid feed supplement. Milchwissenschaft 39:1-6.
75. US Department of Agriculture. 1976. Composition of foods: Dairy and egg products raw processed prepared. Agric. Handbook No. 8-1. U.S. Govt. Publ., Washington, DC.
76. Van den Berg, G. 1989. Milk from BST-treated cows; its quality and suitability for processing. pp.178-191. *In* K. Sejrsen, M. Vestergaard, and A. Neimann-Sorensen, (eds.), Use of somatotropin in livestock production. Elsevier Applied Sci. Publ., New York.
77. Wilster, G. H. 1948. Chemical and physical characteristics of milk fat. p. 216. *In* Practical butter manufacture. 6th ed. OSC Coop. Assn., Corvallis, OR.
78. Wong, W., P. Jelen, and J. M. DeMan. 1982. Softening of butter related to feeding low doses of protected-tallow supplement. J. Dairy Sci. 65:1632-1638.
79. Wood, F. W., M. F. Murphy, and W. L. Dunkley. 1975. Influence of elevated polyunsaturated fatty acids on processing and physical properties of butter. J. Dairy Sci. 58:839-845.
80. Wrenn, T. R., J. Bitman, R. A. Waterman, J. R. Weyant, D. L. Wood, L. L. Strozinski, and N. W. Hooven, Jr. 1978. Feeding protected and unprotected tallow to lactating cows. J. Dairy Sci. 61:49-58.
81. Wrenn, T. R., J. Bitman, J. R., Weyant, D. L. Wood, K. D. Wiggers, and L. F. Edmondson. 1977. Milk and tissue lipid composition after feeding cows protected polyunsaturated fat for two years. J. Dairy Sci. 60:521-532.
82. Wrenn, T. R., J. R. Weyant, D. L. Wood, J. Bitman, R. M. Rawlings, and K. E. Lyon. 1976. Increasing polyunsaturation of milk fats by feeding formaldehyde protected sunflower-soybean supplement. J. Dairy Sci. 59:627-635.