Enrichment and Fortification of Dairy Products and Margarine

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For more than two decades, virtually all homogenized and evaporated milk consumed in the U.S. has been fortified with vitamin D. The marked decline in the incidence of rickets has been credited in large part to this practice. Currently, much bottled fluid low fat milk and skim milk is enriched with vitamins A and D, and frequently is fortified with thiamine, riboflavin, niacin, iron, and iodine. Nonfat milk solids and lactose, or both, are often added to improve palatability. Standardization of the milk solids-not-fat content of fluid milk is a controversial issue. Recently, nonfat dry milk exported in connection with the Food for Peace Program has been enriched with vitamins A and D, but the definition by Act of Congress precludes similar enrichment of that produced for domestic sale. Margarine is enriched with vitamin A to render it nutritionally equivalent to butter. Technological problems associated with practices and proposed changes in standards of identity currently under consideration are discussed. Data are presented on the possible nutritional significance of the proliferation of substitutes for conventional dairy products.

The dairy products consumed in the United States make a significant nutritional contribution to our national diet. According to data compiled by the U.S. Department of Agriculture (Table I) of the total nutrients supplied by all food available for consumption during 1962, milk products, excluding butter, contributed, in per cent, approximately 77 of the calcium, 45 of the riboflavin, 38 of the phosphorus, 24 of the protein, 15 of the fat, 13 of the energy, 12 of the vitamin A, 10 of the thiamine, 8 of the carbohydrate, 5 of the ascorbic acid, 2 of the iron, and 2 of the niacin. Milk is of special significance in infant diets, and makes a major contribution to the nutrition of adults as well.

Enrichment and fortification of dairy products for nutritional reasons generally has been limited to those used primarily for beverage purposes. For this discussion, fortified milk products are defined as those containing added amounts of nutrients normally present in the product. Enriched dairy products may be considered as those to which nutrients not normally present, or that have been removed or lost during processing, are added. It is the intent of the subsequent discussion to review briefly the common types of fortification and enrichment, the justifications advanced for such practices, recent developments which may affect the future status of these practices, and some of the technological problems associated with the addition of certain nutrients.

Table I. Per Cent of Total Nutrients Contributed by Dairy Products in the United States, 1962[a]

	Dairy Products, Excluding Butter	Butter
Food energy	12.8	2.0
Protein	24.0	0.1
Fat	15.2	5.0
Carbohydrate	7.5	<0.05
Calcium	76.6	0.2
Phosphorus	38.4	0.1
Iron	2.3	0.0
Vitamin A value	12.3	3.8
Thiamine	10.2	0.0
Riboflavin	44.6	0.0
Niacin	1.9	0.0
Ascorbic acid	5.2	0.0

[a] U.S. Department of Agriculture, 1965.

VITAMIN AND MINERAL FORTIFICATION AND ENRICHMENT OF DAIRY PRODUCTS

Vitamin D Fluid Milk. The first fluid vitamin-fortified milk was promoted for commercial sale in 1931 (Teply *et al.*, 1956). The product was certified metabolized vitamin D milk produced by feeding irradiated standardized yeast to a herd of certified cattle. Later, other methods of increasing the vitamin D content of milk were introduced, notably, direct ultraviolet irradiation and direct addition of a concentrate of a highly purified form of vitamin D. The latter method is used exclusively today. As is well known, interest in fortification of foods with vitamin D arose from the discovery of its role in the prevention of rickets, along with the fact that its level in common natural foods, including milk, is low. Nutritional authorities have generally endorsed milk as the logical food for fortification with vitamin D. It provides both calcium and phosphorus that must be present with vitamin D for normal calcification of bones and teeth, is readily available in this country, and is a major food for infants and the developing child for whom the need for supplementation of the diet with this vitamin apparently is greatest. Since World War II, virtually all homogenized fluid whole milk and evaporated milk has been fortified with vitamin D. The recommended daily dietary allowance for vitamin D for growing children and pregnant women has been set at 400 I.U. (Food and Nutrition Board, 1964). Vitamin D milk and milk products are defined by the U.S. Public

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Health Service (U. S. Department of Health, Education, and Welfare, 1965) as "milk and milk products, the vitamin D content of which has been increased by an approved method to at least 400 U.S.P. units per quart." State standards generally conform to this definition. The Federal Standard of Identity for Evaporated Milk lists vitamin D as an optional ingredient, but when added, the product must contain not less than 25 U.S.P. units per fluid ounce. This is equivalent to 400 U.S.P. units per reconstituted quart.

The decline in the incidence of rickets in recent decades has been credited in large part to the fortification of cow's milk with vitamin D (Food and Nutrition Board, 1964).

Multivitamin- and Mineral-Fortified Fluid Milk. For several years, vitamin D–fortified milk was the only fluid milk product that was vitamin-fortified. With the establishment of the fact that this was a sound public health practice, the fortification and enrichment of milk with other vitamins and later, certain minerals, were promoted. Thus, in the early 1940's, multivitamin/mineral-fortified milk and milk products were introduced in an attempt to supply in 1 quart the minimum daily adult requirement of the major vitamins and minerals. A typical rate of fortification with various nutrients as compared with typical amounts in average milk is shown in Table II.

Such fortification of whole fluid milk has apparently been limited. A survey of state standards (U.S. Department of Agriculture, 1962) showed that the sale of multivitamin- and mineral-fortified milk was illegal in 11 states.

Vitamin- and Mineral-Fortified Fluid Skim Milk Products. The addition of vitamins A and D to fluid skim milk used for beverage purposes has become widespread. The enrichment of skim milk with these fat-soluble vitamins has been justified on the basis that they are removed with the fat. In many markets, multivitamin and mineral fortification of fluid skim milk and low fat milk (typically 2%) is a common practice. A popular level of fortification is shown in Table II.

Enrichment of Nonfat Dry Milk. The export of large quantities of nonfat dry milk (NDM) to nutritionally deficient areas of the world where much of it is consumed as a beverage by children (Bauernfeind and Allen, 1963)

Table II. Vitamin and Mineral Content of Average Milk and Multivitamin- and Mineral-Fortified Milk

Nutrient	Average Milk,[a] per Quart	Multivitamin/ Mineral-Fortified Milk,[b] per Quart
Vitamin A	500–1000 I.U. (winter) 2000–3000 I.U. (pasture)	4000 I.U.
Vitamin D	5 to 15 I.U.	400 I.U.
Thiamine (B_1)	0.35 to 0.40 mg.	1 mg.
Riboflavin (B_2)	1.5 mg.	2 mg.
Niacin	0.2 to 1.2 mg.	10 mg.
Iron	2.26 mg.	10 mg.
Iodine	0.04 to 0.07 mg.	0.1 mg.

[a] Jenness and Patton, 1959.
[b] Carlson, 1960.

has stimulated interest in the enrichment of this product with vitamins. Nonfat dry milk is defined by Act of Congress (Public Law 244, March 2, 1944, as amended by Public Law 646, July 2, 1956), which does not provide for enrichment. Starting in 1965, NDM enriched with vitamins A and D has been purchased for export in connection with the Food for Peace Program. Current purchase specifications of the Commodity Credit Corp. for fortified NDM call for 5000 I.U. of vitamin A and 500 I.U. of vitamin D per 100 grams of NDM (U. S. Department of Agriculture, 1967). These purchases are for export only.

Since stability of the vitamin is a consideration, the products as well as the methods of addition are specified. The use of a "suitable food-grade antioxidant" is permitted.

There has not been a concerted effort on the part of the dry milk industry to legalize enrichment of nonfat dry milk for domestic sale.

Butter. The vitamin A activity of milk fat varies from season to season largely because of differences in the carotenoid content of the feed of the cow. Certain breeds of cattle (Hartman and Dryden, 1965) convert less of the carotenoids to vitamin A than others, and incorporate more of the highly colored but less active carotene and beta-carotene into the milk fat. Average butter has a vitamin A activity equivalent to about 15,000 I.U. per pound, although values below 10,000 I.U. per pound are common in winter butter and above 20,000 I.U. in that produced during the summer months.

Fortification of winter butter with vitamin A to standardize the vitamin A activity of butter to a minimum value approximating the mean does not seem unreasonable. We know of numerous discussions of this possibility. Butter is defined by Act of Congress, March 4, 1923. A change in the law would be necessary to legalize fortification. Interested groups at various times have discussed amendment of the law in this and other particulars, but no concerted effort by the industry to secure change has been mounted.

Other Dairy Products. Vitamin fortification of other normal dairy products such as cheese, cream products, and ice cream would be difficult to justify. There is no evidence of extensive interest in the addition of vitamins to these products. Infant milk formulas intended as a replacement for mother's milk are usually milk-based. These are extensively fortified and modified, but are not considered relevant to this discussion.

Proposed Standards of Identity for Vitamin- and Mineral-Fortified Foods. The Food and Drug Administration (1967) has recently published proposed standards of identity for vitamin- and mineral-fortified foods which, if adopted, will bring about significant modifications of many current practices. Principal motivation for the proposal was concern for the possibility of toxic levels of vitamin D in the diet of the public. Documentation of facts leading to issuance of the proposal was published in the *Federal Register* (Aug. 28, 1965).

Specific provisions which would affect the enrichment and fortification of dairy products appear to be: Fortification of fluid or powdered whole milk and fluid or powdered whole milk product intended for beverage purpose would be limited to vitamin D (400 U.S.P. units per quart, reconstituted basis). Fortification of fluid skimmed milk, fluid skimmed milk product, fluid or powdered low fat milk, and fluid or powdered low fat milk product intended for beverage purposes would be limited to vitamins A and D (2000 and 400 U.S.P. units per quart, respectively, reconstituted basis).

If the order should become effective, it would obviously result in the elimination of multivitamin/mineral-fortified milks. Notably missing from the list of milk products approved for fortification with vitamins A and D is nonfat dry milk. This product is defined by public law. Thus, appropriate Congressional action would be necessary before fortification for domestic consumption can be considered.

In a report submitted to the Food and Drug Administration (1965), the joint ad hoc committee of the Council on Drugs and the Council on Foods and Nutrition of the American Medical Association recommended that "the addition of vitamin D to fluid, evaporated, and dry whole milk, fluid skim milk, and nonfat dry milk should be permitted and encouraged but the quantity added should not exceed 400 U.S.P. units per quart of fluid or reconstituted milk." Recently, the American Academy of Pediatrics (1967) stated that "nonfat dry milk for infants and children is an 'invitation to rickets' without vitamin D supplementation."

Flavor Problems Due to Added Vitamins and Minerals. Under certain conditions, flavor defects may develop in milk or milk products containing added vitamins and minerals.

A flavor described by such terms as haylike, strawlike, and raspberry has been associated with the presence of added vitamin A in fluid skim milk, low fat milk, and vitamin A-enriched nonfat dry milk. The flavor is attributed by Weckel and Chicoye (1954) to oxidative deterioration of vitamin A. This vitamin has been shown by Cox *et al.* (1957) to be more stable in whole milk products than in low fat or skimmilk products, presumably because of natural antioxidants present in milk fat.

The stability of vitamin A in fluid milk products is not a major deterrent to fortification under present commercial conditions. The availability of vitamin preparations having improved stability, increasing the milk fat content of skim milk to some level above that common in efficient separation, and the almost universal use of containers which materially reduce ultraviolet transmission all favor increased stability.

Rather extensive work has been directed toward improvement of the stability of vitamin A in nonfat dry milk. Research in this area has been summarized by Bauernfeind and Allen (1963). Present commercial practice, as specified by the U.S. Department of Agriculture (1967), is a result of these findings. Both a wet and a dry process may be used. In the wet process, vitamin A palmitate is emulsified in the condensed skim milk before drying. A small amount of a suitable bland edible oil may be used as a diluent and solvent for the purpose of adjusting the potency to give not less than 1,000,000 I.U. per gram. Hydrogenated coconut oil is used to dilute the vitamin preparation further before emulsifying in the skim milk. In the dry process, either vitamin A palmitate or acetate is blended in a bland dry edible carrier capable of being dispersed readily when the nonfat dry milk is reconstituted. The addition of a suitable food grade antioxidant is permitted with either process. Vitamin D as D_2 or D_3 is included in the dispersions in the ratio of 1 unit of D to 10 of A. The stability of vitamin A in nonfat dry milk prepared to meet these specifications is adequate for nutritional purposes. There seems to be no question that some vitamin flavor may develop (Bauernfeind and Allen, 1963; Thomas *et al.*, 1965). The latter suggest that the typical stale flavor which occurs in nonfat dry milk in storage may overshadow the vitamin flavor.

The dry milk industry has not made a concerted effort to legalize the domestic sale of vitamin A- and D-enriched nonfat dry milk.

Increases in free fatty acid content, sometimes sufficient to result in a rancid flavor defect, may occur in milk containing added minerals. This is a direct result of fat splitting by the milk enzyme lipase. Investigations by Harper and Gould (1959) of the components of the fortifying mixtures show that iron appears to protect the milk lipase from heat inactivation when added prior to pasteurization and homogenization, but has no effect when it is added after pasteurization. A recent instance of rancid flavor in the 2% (low fat) milk produced by a dairy in Minnesota was definitely attributed to the addition of the vitamin-mineral mixture to the raw milk in the storage tank. In this case, the remedy selected was limiting fortification to the addition of vitamins A and D.

ENRICHMENT OF MARGARINE

McCollum (1957) recounts the dramatic story of the pioneer studies on vitamin A. He describes the work by Block with numerous cases of xeropthalmia among the children of Copenhagen during World War I. Block's discovery of the curative effects of milk fat and cod liver oil, but not of margarine, gave impetus to studies which eventually led to the enrichment of margarine with vitamin A. For many years, essentially all margarine has been enriched to contain not less than 15,000 I.U. of vitamin A per pound. The possible exception is margarine prepared for use in industrial cooking or baking. The current standard of identity, Code of Federal Regulations, Title 21, Part 45, Chapter 1, lists vitamin A as an optional ingredient and provides considerable latitude in the type of concentrate which may be used. The recent proposal of the Food and Drug Administration (1965) would preclude the addition of vitamin D.

FORTIFICATION OF FLUID MILK PRODUCTS WITH MILK SOLIDS-NOT-FAT

The concept that the composition of milk as produced by the cow was as nature intended and should not be manipulated by man became strongly rooted in the dairy industry, and to some degree still remains. Deviations have largely been a result of economic pressure. Thus, the fat content of fluid milk is standardized typically to approximate closely the legal minimum in the particular market. Data derived from the U.S. Department of Agriculture Report of fluid milk and cream sales in the federal order and state marketing areas suggest that there has been a gradual reduction in the fat of the fluid milk sold.

Data on the solids-not-fat content of milk sold are not available. The general situation, however, is as follows. The solids-not-fat content of skim milk or low fat fluid milk products is normally, but not universally, increased to above that present in the natural fluid milk products used by the addition of solids-not-fat in the form of nonfat dry milk or condensed skim milk. The solids-not-fat content of bulk skim milk characteristically varies within the range of 8.15 to 9.0%. Commercial practice varies, but products such as skim milk, cultured buttermilk, chocolate drink, and yogurt may be fortified to contain as much as 11% milk solids-not-fat, and the 2% low fat milk, 9.5 to 10.5% solids-not-fat.

The increase in milk solids-not-fat content of these products improves their flavor and physical characteristics. Such fortification is doubtless of nutritional significance, since the protein and mineral content is increased in direct proportion to the increase in milk solids-not-fat, but is not the direct reason for the practice. Some processors add lactose rather than nonfat milk solids. From a nutritional standpoint, the results would not be equivalent.

Similar fortification or at least standardization of the solids-not-fat content of fluid whole milk has been advocated by many investigators, including Custer *et al.* (1958), Wahid-Ul-Hamid (1960), Hillman *et al.* (1962), and Day (1963). There seems to be no question that the flavor and general acceptability of fluid milk having a fat content of 3.0 to 3.5%, the legal minimum in most states, to most people are optimum at a milk solids-not-fat content somewhere around the 9.5% level. This is substantially higher than the solids-not-fat content of the normal bulk supplies, although milk from Jersey and Guernsey herds may approach this figure. Hartman and Dryden (1967) report that at least one manufacturer of filled milk (a skim milk and vegetable fat product) is taking advantage of this information, and standardizing the solids-not-fat content of the product at about 9.5%.

Actually, under existing laws and regulations, the legality of standardizing the solids-not-fat content of fluid milk could be questioned in most if not all states or jurisdictional areas. As of 1962 (U.S. Department of Agriculture, 1962), 20 states had no requirements for solids-not-fat content, five required not less than 8%, two not less than 8.15%, 20 not less than 8.25%, one not less than 8.3%, 11 not less than 8.5%, and Puerto Rico not less than 9%. There is no mention of standardization or fortification of the solids-not-fat content. The solids-not-fat content of milk can be influenced by man prior to milking by breeding, feeding, and management. There seems to be no rational basis, therefore, for objecting to altering the composition by abstraction of water after milking, or, what is equivalent, the addition of condensed skim milk or nonfat dry milk. The commercial dairyman faced by an immediate increase in ingredient cost without certainty of the recovery of that cost is reluctant to accept the risk. Inclusion of the solids-not-fat content in the pricing scheme for milk would seem to be a necessary precursor to standardization of the solids-not-fat content of the product sold.

Table III. Comparison of Certain Dairy Products and Their Simulated Counterparts

Constituents Per 100 G. of Dry Matter

		Gross Composition, G.				Minerals, Mg.			Vitamins		
		Carbohydrates[a]	Fat	Protein[b]	Ash	Calcium	Phosphorus	Sodium[c]	A,[d] I.U.	Riboflavin,[e] μg.	Total Solids, G.
Coffee (light) cream		14.6	72.7	10.5	2.2	353	280	182	3020	509	27.5
Coffee whiteners											
Dry	A	48.5	39.9	4.9	2.8	12	718	293	110	0	98.9
	B	49.1	36.5	5.0	2.7	16	625	258	110	0	98.9
	C	46.1	37.2	5.0	2.7	46	561	290	440	108	98.9
	D	48.7	35.8	4.9	3.0	12	62	146	200	219	98.5
Liquid	A	50.2	47.9	3.0	1.5	23	30	543	2170	0	26.7
	B	42.0	48.0	5.0	2.0	70	155	245	250	0	20.0
	C	49.1	40.5	8.6	2.7	72	212	496	0	0	22.2
Whipped (heavy) cream		7.8	85.3	5.6	1.2	190	149	98	3510	268	41.0
Whipping toppings											
Dry	A	40.8	43.2	4.6	1.0	17	32	100	800	0	99.9
	B	40.6	45.4	5.7	0.6	12	46	97	1370	0	98.9
Liquid	A	25.7	58.5	0	0.5	15	3	198	1040	0	39.3
	B	31.6	55.3	2.0	0.2	14	20	20	2220	0	49.1
Aerosol											
Dairy base	A	22.0	58.0	10.7	2.3	310	276	255	2540	145	35.5
	B	20.4	63.3	8.5	2.3	274	267	413	2650	189	41.2
Simulated	A	29.2	58.7	0	0.5	10	3	243	1130	0	39.1
	B	23.9	67.7	7.6	0.5	23	71	173	1370	0	39.3

[a] Modification of phenolsulfuric acid method for total carbohydrates of Dubois *et al.* (1956).
[b] Protein calculated from Kjeldahl nitrogen data (TPN × 6.38).
[c] Atomic absorption method of Murthy and Rhea (1967).
[d] Modification of Carr-Price method for total vitamin A activity of Boyer (1944).
[e] Scott *et al.* (1946).

NUTRITIONAL STATUS OF SIMULATED DAIRY PRODUCTS

The rapid proliferation of products made and sold in semblance of normal dairy products and doubtless consumed by the public in the belief that since they look like dairy products they must be nutritionally equivalent may justify consideration of whether indeed they are nutritionally equivalent, and, if nutritionally inferior, if this should be a matter of regulatory concern. We intend merely to record some analytical data which confirm information deducible from the ingredient listing and to suggest that at some point, if products of this kind increase in number and in use, their nutrition properties may become important. Pertinent analytical data for certain dairy products and their counterparts are shown in Table III.

The simulated products on a dry matter basis all contain substantially more carbohydrate (corn sirup solids and cellulose) and less fat.

The protein content of the coffee whiteners is variable but typically about one half that of coffee cream. Two of the six whipped toppings contained no protein. Protein, where it is present, is usually alkali caseinate. The calcium content is only a small fraction of that of the dairy product, and in most, the sodium and phosphorus salts are high because of the use of alkali caseinate and buffering salts. Vitamin A activity of the simulated products is highly variable.

An assay was made for vitamin B_2 as indicative of the relative content of the water-soluble vitamins normally present in skim milk. Only two of the 13 simulated products contain significant amounts of vitamin B_2. The ingredient list of these shows that vitamin B_2 is added.

Perhaps whipped toppings and coffee whiteners represent such a minor part of the calorie intake of the most avid user that the substitution of the simulated for the original is nutritionally of no consequence. Add the deficiencies of one to those of another and yet another as these proliferate, and at some point the substitutions must become nutritionally significant. Similar substitution for homogenized fluid milk obviously could be significant.

DISCUSSION

Fortification of pasteurized homogenized fluid milk with vitamin D is not controversial. In fact, vitamin D fortification of homogenized milk is such a common practice that it is taken for granted by many, if not the majority, of consumers.

The rapid increase in the use of fluid skim milk or partially skimmed (low fat) milk products in place of fluid whole milk supports the optional fortification of these products with vitamin D to the same level as fluid whole milk and with vitamin A to a level approximately that contained in average fluid whole milk: about 2000 I.U. per quart. Action should be taken to permit optional fortification of nonfat dry milk intended for domestic household use with the same vitamins to a similar level on a reconstituted basis. Vitamin-fortified nonfat dry milk purchased by the U.S. Department of Agriculture is required to contain 5000 I.U. of vitamin A and 500 I.U. of vitamin D per 100 grams, which on a reconstituted basis is equivalent to about 1 quart. The higher level of vitamin A fortification in this export product may be justified because it is largely intended for vitamin-deficient areas.

Fortification of skim milk and fluid low fat milk products with added milk solids has become a common and accepted practice.

The dairy industry has been and probably will continue to be reluctant to press for legislation permitting the sale of fluid whole milk which has been fortified by the addition of non-fat milk solids. Nevertheless, such a practice is reasonable and desirable.

There is no immediate reason for concern because of the nutritional properties or deficiencies of the various products now being sold in simulation of dairy products. We suggest that there be awareness of the potentialities of this situation.

ACKNOWLEDGMENT

The assistance of P. B. Manning in the analyses reported in Table III is gratefully acknowledged.

LITERATURE CITED

American Academy of Pediatrics, cited in *J. Am. Med. Assoc.* **201** (4), 36 (1967).
Bauernfeind, J. C., Allen, L. E., *J. Dairy Sci.* **46**, 245 (1963).
Boyer, P., *Ind. Eng. Chem., Anal. Ed.* **15**, 101 (1944).
Carlson, W. A., *Am. Milk Rev.* **22** (1), 60 (1960).
Cox, D. H., Coulter, S. T., Lundberg, W. O., *J. Dairy Sci.* **40**, 564 (1957).
Custer, E. W., Herzer, F. H., Cardwell, J. T., *Mississippi State Coll. Agr. Expt. Sta. Bull.* **561** (1958).
Day, R. R., M. S. thesis, University of Minnesota (1963).
Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A., Smith, F., *Anal. Chem.* **28**, 350 (1956).
Food and Drug Administration, *Federal Register* **30**, 1140 (Aug. 28, 1965).
Food and Drug Administration, *Federal Register* **32**, 5736 (April 8, 1967).
Food and Nutrition Board, "Recommended Dietary Allowances," 6th revised ed., National Academy of Sciences–National Research Council Pub. **1146** (1964).
Harper, W. J., Gould, I. A., *Proc. XV Intern. Dairy Congr.* **1**, 455 (1959).
Hartman, A. M., Dryden, L. P., "Vitamins in Milk and Milk Products," American Dairy Science Association, Champaign, Ill., 1965.
Hillman, J. S., Stull, J. W., Angus, R. C., *Univ. of Arizona Agr. Expt. Sta. Tech. Bull.* **153** (1962).
Jenness, R., Patton, S., "Principles of Dairy Chemistry," p. 404, Wiley, New York, 1959.
McCollum, E. V., "A History of Nutrition," Houghton Mifflin, Boston, 1957.
Murthy, G., Rhea, U., *J. Dairy Sci.* **50**, 313 (1967).
Scott, M. L., Hill, F. W., Norris, L. C., Heuser, G. F., *J. Biol. Chem.* **165**, 65 (1946).
Teply, L. J., Prier, R. F., Scott, H. T., *Food Res.* **21**, 671 (1956).
Thomas, E. L., Coulter, S. T., Kudale, J. M., *J. Dairy Sci.* **48**, 1561 (1965).
U.S. Department of Agriculture, *AMS*, "Federal and State Standards for the Composition of Milk Products," Agricultural Handbook No. **51**, Revised June 1962.
U.S. Department of Agriculture, ASCS Commodity Office, Minneapolis, Minn., Announcement No. **MP-M-18** (Feb. 15, 1967).
U.S. Department of Agriculture, *ERS*, "U.S. Food Consumption, 1909–63," Statistical Bull. **364**, 63 (1965).
U.S. Department of Health, Education, and Welfare, "Pasteurized Milk Ordnance, 1965 Recommendations of the United States Public Health Service," Pub. **229** (1965).
Wahid-Ul-Hamid, S. S., Manus, L. J., *J. Dairy Sci.* **43**, 1430 (1960).
Weckel, K. G., Chicoye, E., *J. Dairy Sci.* **37**, 1346 (1954).

Received for review October 20, 1967. Accepted December 11, 1967. Paper No. 6428, Scientific Journal Series, Minnesota Agricultural Experiment Station.