Food Values of Dairy Products as Affected by Methods of Handling in Production, Distribution, and Use*

Riboflavin, Thiamin, Vitamin A

Food and Nutrition Section

THE Committee on Milk and Dairy Products has surveyed recent research studies in an attempt to determine the effect of many factors operating between production and consumption, which may influence the ultimate nutritive values of dairy products.

Obviously, it was impossible to draw general conclusions regarding food values when several dairy products were considered and many possible affecting factors were analyzed. The only course for the committee to take was to limit the scope of the study to a consideration of a few nutrients. The following report, therefore, is based on recent literature (1940–1946) pertaining chiefly to the nutrients: riboflavin, thiamin, and vitamin A.

Each of the dairy products—milk, butter, cheese, and ice cream—is considered here from the standpoint of factors which may affect their riboflavin, thiamin, and vitamin A values. Milk as the basic product from which all dairy foods are made is considered first, from production on the farm to use in the home.

RIBOFLAVIN IN MILK

The fact that milk is an excellent source of riboflavin makes it important to know what factors in production and handling of milk affect its riboflavin content and which of these factors can be controlled to assure a maximum concentration of riboflavin in the milk. The feed of the cow is naturally a first consideration.

Ration of the Cow—The literature indicates that the riboflavin content of milk *can* be influenced by the feed of the cow. However, increasing the riboflavin intake of the cow by 30 to 50 per cent, as reported in one study, caused only a temporary increase in the concentration of the riboflavin in milk. In the same study, a good winter ration maintained milk riboflavin at pasture levels.[1] According to another report, cows transferred from winter rations to young green pasture gave *more* milk but with slightly lower concentration of riboflavin.[2] Other investigators have also shown the inverse relationship between milk yield and riboflavin content of milk. In addition, they have demonstrated that the concentration of riboflavin in milk can be increased when a dry ration is supplemented with a silage.[3]

In spite of these apparently conflicting observations, it appears likely that milk, as produced under standardized

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feeding and management conditions existing on modern dairy farms, is relatively uniform in riboflavin content the year around.[4] The fact that some synthesis of riboflavin in the bovine rumen has been demonstrated on specified experimental rations[5, 6] may help to explain the relatively stable riboflavin content of milk.

Light and Heat—The action of heat alone does not influence the riboflavin content of milk. However, heat and light acting together, may be responsible for considerable loss. The studies reporting such losses vary greatly in plan and procedure, a fact which makes it difficult to compare their results. In general, milk exposed either to direct sunlight out-of-doors or to relatively strong daylight indoors loses riboflavin, the amount of loss depending on the directness and strength of the light, the length of time of exposure, and the temperature and pH of the milk. Strong light, long exposure, warm temperature, and increase in alkalinity all contribute to losses of riboflavin. Typical studies are reviewed briefly.

In one study, milk in pint bottles, exposed to the direct sun (between midmorning and midafternoon) on an open porch, lost from 28 to 72 per cent of its original riboflavin content, the time of exposure ranging from 30 minutes to 3½ hours. The atmospheric temperature varied from 60 to 72° F. Control samples of milk, kept in a dark room for 24 hours or in a refrigerator for 7 days, suffered no loss of riboflavin.[7] Similar findings are reported by other investigators.[8–11]

Reports also describe research designed to answer questions covering the effect of sunlight on different types of milk, on milk in different kinds and sizes of containers, and under various other conditions of practical importance.

In general, it was found that there was less destruction of riboflavin when homogenized milk (27.6 per cent) was exposed to sunlight from 1 to 2 hours than when pasteurized (35.4 per cent) or raw milk (40.1 per cent) was subjected to the same treatment. Destruction of riboflavin in clear glass bottles ranged from 9 to 77.5 per cent (the amount related directly to time and temperature); in brown bottles from 0.6 to 5.6 per cent; in paper bottles from 0.6 to 16.9 per cent.[11]

A recently reported study combines an investigation of theoretical losses of riboflavin with observations of ordinary practices in handling milk, which may influence such losses.[12] The authors agree that losses *can* be severe but that the consumer takes greater precautions in the care of milk than is ordinarily assumed. They found, for example, that 70 per cent of all milk delivered on retail routes was removed from the doorstep or was protected from light in some manner (often by a covered receptacle) within 5 minutes after delivery. As a result, the milk lost almost no riboflavin. Only 3.3 per cent of the customers left milk exposed on doorsteps for more than 2½ hours. The authors indicate that a calculated loss of 3.25 per cent of riboflavin, after milk is delivered to the customer's doorstep, is a high estimate.[12]

Other interesting observations: The smaller the container of milk, the greater the destruction of riboflavin in a given time. Also, as would be expected, wooden cases for holding bottles protect milk from riboflavin losses more effectively than do wire cases; milk stored at the back of the delivery truck, away from light and warmth, has the advantage over milk placed near the door.

Losses enroute are negligible in general, except where milk is on a route for 5 hours or more.[12]

Another group of investigators found that chocolate milks lost riboflavin very slowly when exposed to sunlight. The average loss of riboflavin after 4 hours, for five different brands of chocolate milk, was about 12 per cent as compared to a loss of 80 per cent for white milk.[13]

Proper care of milk in the home is important if the riboflavin content of milk is to be protected. In one study, conducted in a well lighted room, milk placed 5 feet from a window lost from 16 to 99 per cent of its riboflavin when held at 100° C. (boiling) for varying periods from 5 minutes to 1 hour and as the pH increased from 3 to 6.5.[14] When milk was allowed to simmer for 30 minutes in a covered glass pan, in a covered aluminum pan, and in an uncovered aluminum pan, the losses of riboflavin were 8 to 11 per cent; 1.1 per cent; and 10 to 12 per cent, respectively.[11] When quart bottles of milk were allowed to stand for 2 forenoon hours on a table in a light kitchen with east exposure, but not in direct sunlight, 3.2 per cent of the riboflavin was lost during the first trial and 4 per cent during the second trial.[12]

The practical application of these findings is obvious. For the most part, the properly informed consumer can protect his supply of riboflavin in milk. The need for removing milk from the doorstep *promptly* cannot be overemphasized.

A receptacle which is *dark* and *cool* is the alternative if the riboflavin is to be retained. When the milk is taken into the kitchen it should be refrigerated immediately and continuously in the interest of protecting it from light and from warm temperature. Cooking in covered, opaque containers is a further precaution.

The question of the effect of ultraviolet light on the riboflavin content of milk is often raised in connection with irradiation of milk to increase vitamin D content. Losses, if they occur, appear to be negligible.[15, 16]

Pasteurization—Reports, for the most part agree that there is no significant loss of riboflavin in milk as a result of pasteurization by the high-temperature-short-time method or by the holding method.[3, 17–19]

Evaporation—No loss of riboflavin was found when milk was condensed in a batch evaporator for 3 hours at 115 to 120° F. Similarly, there was no loss when milk was evaporated at 120° F. for 35 minutes and then sterilized in cans at 235° F. for 15 minutes.[20]

Drying—An extensive study of recent date on spray dried whole milk shows its riboflavin content to be equivalent to that of market milk. Samples were obtained from various areas of the world, as well as approximately one hundred samples from various parts of the United States. In addition, a much larger number of samples was obtained from a few plants. The samples of milk were studied while fresh and after various periods of storage.[21]

Storage—No loss of riboflavin is indicated in fresh milk stored for 24 hours at 40° F. in a dark refrigerator.[3] Likewise, there appears to be general agreement that no loss of riboflavin occurs in dry and condensed milks under normal storage conditions. Dried whole milk stored for 6 months at 100° F. (in air and also inert gas) showed no loss of riboflavin.[21] Condensed milk stored for different periods up to a year at 15° C. showed no riboflavin destruction. However, there were losses up to 35 per cent after 6 months' storage at 37° C.[20]

RIBOFLAVIN IN CHEESE

Processing—The content of water soluble vitamins in cheese will vary with: (1) the amount of whey retained in the curd, (2) the extent to which heat is used, (3) the methods of salting—*i.e.*, whether or not a brine bath is used, which tends to dissolve out the water soluble vitamins, and (4) the amount of exposure of ingredients to air and light, especially during heating.

The temperatures to which most cheeses are subjected are not high enough to cause much destruction of vitamins. However, the exposure of heated ingredients in large vats and the stirring, cutting, and handling to which cheese is subjected may cause vitamin losses.

The limited data available indicate that about one-fourth to one-third of the riboflavin originally found in the milk from which cheese is made is retained in the cheese. In one study 23 per cent of the riboflavin of the milk was retained in day-old Cheddar cheese made from raw milk.[22] The percentage retention of riboflavin in day-old brick cheese was reported by the same authors to be 27.4 per cent; in blue cheese 30.1 per cent.

Pasteurization of milk, either by the holder process or by the high-temperature-short-time method had no deleterious effect on the riboflavin content of fresh Cheddar cheese, nor on the cheese during a 6 months' ripening period. Likewise, homogenization of milk, prior to making blue cheese, had no detrimental effect on the riboflavin content of that type of cheese.[22]

Storage—Sacrifice of certain of the vitamins in cheese making is possibly offset to some extent by the fact that they may be synthesized in the outer layers of some kinds of cheese during the ripening process. In one study microörganisms isolated from the surface of four kinds of cheese, synthesized considerable quantities of B-vitamins when introduced into synthetic media. Riboflavin and other B-vitamins, as determined microbiologically, appeared to increase in the surface layers of these cheeses through progressive stages of ripening.[25]

Other workers found the riboflavin content of Cheddar cheese relatively stable during the ripening process. There was a slight decline in riboflavin during the first 2 months of ripening but an equal rise during the final months to the values found in the fresh cheese.[22] Still other investigators, after analyzing different types of cheese for riboflavin and other B-vitamins, concluded that, whereas certain other B-vitamins appear to vary with the age of the cheese and the ripening process employed, the riboflavin content of cheese is relatively stable to such variations.

RIBOFLAVIN IN ICE CREAM

Storage—One report is available on the stability of riboflavin in ice cream manufactured under commercial ice cream plant conditions from fresh, whole milk, cream (40 per cent fat), cane sugar, and gelatin. Three flavors —coffee, maple, and vanilla—were used. The "over run" was 85 per cent. Samples of each of the three flavors were assayed before and after 7 months' storage at 10° F. The loss of riboflavin was 5.4 per cent.[26]

THIAMIN IN MILK

Ration of the Cow—The limited number of recent studies on this subject indicate little if any change in thiamin content of milk with fluctuation in the ration of the cow. One study reports that when cows were changed from good winter rations to early spring pasture of rapidly growing grass, there was no change in the thiamin content of the milk.[2] Investigations indicate synthesis of thiamin in the rumen.[5, 6]

Light—No evidence was found in the literature that thiamin of milk is affected by sunlight as is the riboflavin in milk. The thiamin content of experimental and market milks irradiated to produce 400 U.S.P. units of vitamin D per quart was not reduced.[15]

Pasteurization—A few studies published between 1940 and 1943 agree to a thiamin loss of about 10 to 25 per cent (with the first figure most common), in milk pasteurized by the holding process compared with that found in the original raw milk.[17, 27, 28, 29] A 1945 study in which milk was assayed immediately before and immediately after pasteurization by the high-temperature-short-time process reports the small loss of 3 per cent.[19]

Boiling—A study on the effect of boiling pasteurized milk in preparing babies' formulae shows a loss of 8 per cent in thiamin.[30]

Evaporation—Milk evaporated in a batch evaporator at 120° F. for 35 minutes and then sterilized for 15 minutes in 4 and 6 ounce cans showed a loss of 27 per cent of its thiamin.[20] Earlier findings are in general agreement with these figures and indicate a loss of approximately one-third of the thiamin content as a result of evaporation procedures.[28-30] Milk condensed at 115 to 120° F. for 3 hours suffered a loss of 3.5 per cent of thiamin.[20]

Drying—The most recent study available on this subject reports the thiamin content of spray dried whole milk. The authors conclude that "whole milk powder ranks with market milk" in thiamin content.[21] Earlier studies reported from England on spray and roller dried skim milk indicate a loss of thiamin up to 10 per cent in the spray dried product and up to one-third in the roller dried product.[28, 29]

Storage—It is reported that "under good operating conditions" no appreciable loss of thiamin occurs in the storage of spray dried whole milk, packed either in air or inert gas, even when held at 100° F. for 6 months.[21] Condensed milk is reported to lose up to 29 per cent of its thiamin activity when stored for one year at 15° C., and up to 84 per cent when it is stored 4 months at 37° C.[20] In a study of several kinds of evaporated milk the amount of thiamin destruction varied with the different milks—two samples reached 50 per cent destruction after one year's storage. Loss was presumably more rapid during the first few months and eventually reached equilibrium.[30]

THIAMIN IN CHEESE

Processing—Statements made in the section on riboflavin in cheese (regarding the transfer of riboflavin from the curd to the whey in making cheese), largely hold true for thiamin. The relatively low thiamin content of cheese is predominantly due to its high solubility. In a recent study on Cheddar cheese, no actual destruction of thiamin was found to take place in the process of manufacturing the cheese. However, the retention, in the cheese, of the thiamin present in the original milk was only 8.8 per cent.[23] A study conducted in England and reported in 1945 revealed that approximately 15 per cent of the thiamin present in the milk was retained in Cheddar, Cheshire, and Stilton cheeses.[24]

Storage — Apparently, the nutrient content of cheese with respect to certain vitamins can be augmented during storage by the synthetic action of microörganisms.[25] However, in the study of Cheddar cheese cited above,[23] there was a progressive decrease in the thiamin content of the cheese with increasing ripening period. The losses in 12 months ranged from 43 to 73 per cent. Ripening at 58° F. caused greater decreases than ripening at 40° F.[23] In contrast, the 1945 English study revealed that no significant losses of thiamin occurred during ripening for periods up to 42 weeks.[24]

VITAMIN A IN BUTTER AND MILK

The differences in the vitamin A potency of summer and winter butter and milk are due largely to variations in the carotene content of summer and winter feeds. This fact is clearly evident from a nation-wide coöperative study conducted by the U. S. Department of Agriculture, the Association of Land-Grant Colleges and Universities, twenty-one state agricultural experiment stations, and one federal laboratory. Over 4,000 samples of butter were analyzed. These extensive studies of differences in vitamin A potencies, as well as possible factors relating to the retention of such values, have been fully summarized so recently[31, 32] that no effort is made here to refer to individual reports. High points of these studies as they pertain to the subject of this report are indicated briefly.

Ration of the Cow—Of the creamery butter analyzed, 35.7 per cent was considered " winter " butter with an average vitamin A potency of about 11,000 I.U. per lb.; 64.3 per cent was butter produced in summer months when the cows were on pasture, and it had an average potency of about 18,000 I.U. per lb. No significant difference was found, in areas where tested, between the average vitamin A potency of butter on retail markets and the average of the creamery butter produced in this country.[31, 32]

The average vitamin A potency of the fat in winter butter produced in the United States was about 30 I.U. per gm. and that of summer butter was 49 I.U. per gm. On this basis, the average vitamin A potency of milk containing 4 per cent of fat may be calculated to be 1,140 I.U. per qt. for winter milk and 1,800 for summer milk.[31] " There is ample experimental evidence that vitamin A potency of milk, and also of butter made from milk, can be readily changed by increasing or decreasing the quantity of carotene in the cow's ration—any condition which tends to increase the lushness of pasture or carotene content of winter fed forages—either silages or hays—will increase the vitamin A potency of milk and butter very much." [31]

Storage—Seven state experiment stations studied the effect of storage on the vitamin A potency of butter. Samples of butter were handlde and stored under various practical conditions. The results indicate that both carotene and vitamin A are very stable in butter under the conditions tested; that little if any loss of vitamin A potency occurs during the periods that commercial butter is ordinarily stored; and that, in so far as the effect of storage is concerned, one would not expect the average vitamin A potency of the butter sold on the retail markets in this country to be significantly different from the average of the creamery butter produced in the country as a whole.[32] " This must mean that the antioxidants which occur naturally in butter are exceedingly effective in preserving its vitamin A potency." [32]

Other Conditions—Vitamin A appears relatively stable when subjected to the usual processes in the handling of milk. There is no loss of vitamin A potency due either to exposure to sunlight or to ultra-violet light in producing vitamin D milk of 400 U.S.P. units potency.[15] No evidence was found in the literature of losses in vitamin A due either to the short-time-high-temperature pasteurization process or to the holding method. Likewise, there is no evidence of loss of vitamin A as a result of evaporating milk. One extensive study on spray dried whole milk indicated that if any loss occurred during manufacture it was less than 10 per cent.[21] The vitamin A content was maintained satisfactorily during storage. After 6 months' storage at room temperature, no detectable loss of vitamin A was found in inert-gas-packed powder and only about 6 per cent in air-packed powder. Powder held at 100° F. for 6 months was found to lose 10 to 15 per cent of its vitamin A value in inert-gas-packed powder and perhaps 30 per cent of its value in the powder packed in air.[21]

VITAMIN A IN CHEESE

Processing—Since most of the fat of the original milk is retained in cheese making, much of the fat soluble vitamin A should also be present in the finished product. One study reports the distribution of vitamin A potency in Cheddar cheese making as follows: 85 per cent retained in the cheese, 7 per cent in the whey, 8 per cent unaccounted for. These figures apply to both carotene and vitamin A. The authors suggest that losses probably occurred in the adherence of milk fat to containers and equipment during processing.[33]

Storage—No losses were noted in vitamin A potency when Cheddar cheese was stored for nearly one year. The carotene content showed a slight increase while the vitamin A content was quite constant.[33]

In certain mold ripened cheeses, it appears possible that some synthesis of vitamin A takes place since food tables show vitamin A values higher than can be accounted for by the vitamin A found in the milk from which the cheeses originated. One experimental study on blue cheese indicates no change in its vitamin A value during aging.[34]

CAROTENE AND ICE CREAM

Storage—According to one study (quoted above under the discussion of riboflavin), ice cream showed a loss of carotene during storage which amounted to 15.7 per cent.[26]

SUMMARY

From the foregoing discussion it is evident that it is impossible to generalize on the all-round stability of the nutrients contained in dairy products as they are subjected to the varied conditions which prevail in the handling of the products from production to consumption. However, it is possible to indicate in broad terms the relative stability of specific nutrients. It may be stated, for example, that riboflavin is remarkably stable except when acted on by light; this photo-chemical reaction is accelerated by heat. Thiamin is somewhat less stable to heat than riboflavin but is not influenced by the light-heat combination. Neither the riboflavin nor the thiamin content of milk is strongly affected by the feed of the cow. The vitamin A value of dairy products, on the other hand, depends to a great extent on the carotene content of the cow's ration; in general, however, it remains stable during ordinary processing and handling of the products.

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Walter Reed Bust in the Hall of Fame

The American Society of Tropical Medicine is sponsoring a campaign for funds in order to have a bust of the late Dr. Walter Reed placed in the Hall of Fame. This niche has heretofore remained empty for lack of funds, although Dr. Reed was elected to the Hall of Fame in 1945. It is hoped to have the funds collected and the sculpture completed so that the dedication ceremonies may be part of the International Congress for Tropical Medicine and Malaria to be held in Washington in the spring. The evening of May 12, 1948 has been set aside for the ceremony.

It is estimated that about $6,000 will be needed. Contributions should be sent to Norman H. Topping, M.D., Secretary-Treasurer of the American Society of Tropical Medicine, National Institute of Health, Bethesda 14, Md.