THE KEEPING QUALITY OF PASTEURIZED MILK AS INFLUENCED BY THE GROWTH OF PSYCHROPHILIC BACTERIA AND THE ADDITION OF AUREOMYCIN*

J. C. Olson, Jr., D. S. Willoughby, E. L. Thomas, and H. A. Morris

Department of Dairy Husbandry
University of Minnesota
St. Paul, Minn.

In studies of the keeping quality of pasteurized milk, it was found that past records from milk plants showing good bacterial counts of finished products, afforded a rather reliable indication that milk from such plants may show better keeping quality than milk from plants with poor past records. Proper pasteurization resulted in extensive if not complete destruction of psychrophiles. Negative coliform counts of freshly pasteurized milk were not reliable as indicators of good keeping quality during storage at the temperature used in these studies. The mere absence of psychrophiles in one or two milliliters of milk was not found to be a guarantee of long storage life. The presence of aureomycin in the concentration used in these studies had no effect in extending the keeping quality of pasteurized milk.

At least three trends within the market milk industry have accentuated the importance of factors influencing the storage life or keeping quality of unfrozen fresh pasteurized milk. These trends are, (1) the lengthening of the time between processing and wholesale or retail delivery of milk, (2) the increase in volume of milk distributed over wide areas from centralized processing plants, and (3) the extensive interstate traffic in fresh pasteurized milk which often involves several days of transport.

Organoleptic Defects

One of the major factors which influences the keeping quality of pasteurized milk is the metabolic activity of bacterial species which are capable of relatively rapid growth in milk at low temperatures, generally within the range of 35° to 45° F. The descriptive noun "psychrophile" is commonly used to designate such a bacterial group. The influence of this group of bacteria on the flavor of milk kept under refrigeration does not manifest itself usually until after three or four days of storage and often not until a considerably longer period has elapsed. In fact, it is not uncommon to find commercially pasteurized milk which has excellent keeping quality for seven to ten days of storage. Sooner or later, however, all commercially processed milk held at temperatures within a few degrees above freezing will show a flavor defect due to the metabolic products produced as a result of bacterial proliferation. The period of storage required for this will vary depending upon the species present and their level of population in the milk at the time the finished product emerged from the bottle-capping machine. A large variety of flavor defects may be attributed to the growth of psychrophiles in milk. Some of the more common of these are unclean, putrid, fruity, and an unclean sour flavor. Changes in the body or appearance of milk often may be observed as a result of the growth of these bacteria. At times a thickening may occur which is often associated with a ropy or stringy condition. Quite often a slight green or yellow coloration may be observed usually near the surface edge. These body and color defects occur almost invariably after the flavor defects have become pronounced; so much so that there is little likelihood of the product being acceptable. At this point it might be well to mention that fluid milk products are not the only milk products subject to deterioration by psychrophilic bacteria. Flavor defects in butter, cheese, and other concentrated products often are caused by members of this group.

A number of questions arise relative to the flavor deterioration of fluid milk through the activity of psychrophilic bacteria. Some may be answered with dispatch; the answers to others must await gathering of more knowledge.

Dr. Olson's early youth was spent on the farm in Iowa and Minnesota. He received the B.S. degree in dairy products, the M.S. degree in dairy bacteriology, and the Ph.D. degree in bacteriology, all from the University of Minnesota. During World War II his principal assignment was in the production of typhoid vaccine at the U.S. Army Medical Department Laboratory in Lansing, Michigan, where he was in charge of production. Since 1948 he has been in charge of the Bacteriology Section, Department of Dairy Husbandry, University of Minnesota.

Occurrence in Raw Milk

The first question which logically might be asked is: to what extent are psychrophiles found in fresh raw milk supplies? In answer to this the literature reveals that all who have sought to find these bacteria in raw milk have succeeded, particularly if their analytical procedure included incubation of poured plates for a sufficient period of time within a temperature range of 5°-10° C. The numbers which have been reported by various investigators have varied greatly, some being in excess of 100,000 per milliliter. Such being the case, one immediately may ask whether exposure to the minimum time-temperature relationships for pasteurization of milk will destroy

*Presented at the Thirty-ninth Annual Meeting of the International Association of Milk and Food Sanitarians, Inc., Minneapolis, Minnesota, October 20, 1952.

Scientific Journal Series Paper No. 2959, Minnesota Agricultural Experiment Station.

The authors acknowledge funds for research contributed by the Twin City Quality Control Committee.

TABLE 1—BACTERIAL COUNTS OF MIXED HERD MILK BEFORE AND AFTER LABORATORY PASTEURIZATION (143°F—30 MINUTES) BY SEALED-TUBE, TOTAL-IMMERSION TECHNIQUE.

Trial	SPC (32°C.)*	SPC(35°C.)	Coliform count	Psychrophile count (7°C.)
1. Raw	730,000	630,000	18,000	200,000
1. Pasteurized	.....	.....	.....	0
2. Raw	710,000	830,000	22,000	130,000
2. Pasteurized	9,100	.....	.....	0
3. Raw	>3,000,000	370,000	8,000	152,000
3. Pasteurized	>30,000	>30,000	0	0
4. Raw	1,600,000	1,600,000	890,000	680,000
4. Pasteurized	8,400	4,400	.....	0
5. Raw	360,000	480,000	5,400	62,000
5. Pasteurized	330,000	110,000	0	0

*SPC = Standard plate count.

psychrophilic bacteria.

EFFECT OF PASTEURIZATION

The heat resistance of this group of bacteria or even representative species of the group has not been studied precisely. However, a number of investigators have subjected milk inoculated with pure cultures of psychrophiles to laboratory pasteurization and have sought to detect their presence in the pasteurized. product. The results reveal some difference of opinion. For example, Kennedy and Weiser[3] reported that all but one of fifteen pure cultures survived 145°F. for 30 minutes and did so in considerable numbers. On the other hand, only six of 41 cultures of psychrophilic bacteria isolated from fresh butter and studied by Jezeski and Macy[2] survived laboratory pasteurization at 150° F. for 30 minutes. In a more extensive study, Erdman and Thornton[1] observed that only four of 722 psychrophilic cultures survived laboratory pasteurization, presumably at 145° F. for 30 minutes. Watrous, Doan, and Josephson[5] subjected 35 psychrophilic cultures to laboratory pasteurization at 62.8° C. for 30 minutes and none were found to survive.

Recent studies reported by Rogick and Burgwald[4] on the effect of commercially applied low-temperature-holding and high-temperature-short-time pasteurization processes on the destruction of psychrophiles showed quite conclusively that when samples drawn aseptically from the units were analyzed, both processes resulted in destruction of this group at least to the extent that they were not detected in 4.1 milliliter quantities of the freshly pasteurized product. Psychrophiles were found after storage of these same samples for seven days at 4°-7°C., but judging from the counts reported, had not reached sufficient populations to result in flavor deterioration during that period of storage. When samples drawn as finished products were analyzed, psychrophiles were found in 21 of the 30 samples. Similar results were obtained by Watrous, Doan, and Josephson[5]. These investigators studied the effect of both laboratory pasteurization and the commercial low-temperature-holding process on the destruction of psychrophiles. Their results were even more conclusive. All psychrophile counts obtained from a series of 75 samples immediately after laboratory pasteurization and again after 10 and 20 days of storage at 5° C were less than one per milliliter. No evidence of psychrophilic bacteria was found in any sample of pasteurized milk drawn aseptically from the holding vat either when analyzed immediately or after 15 days of storage at 5° C. These same investigators as well as others observed extensive growth of psychrophiles in samples obtained as finished products. In such products, when fresh, the extent of their presence has been shown to vary among samples of the same lot and among samples from different plants.

Results shown in tables 1 and 2 which are representative of those obtained in our laboratories concurrently with those referred to above, can only add to the literature which shows quite conclusively that proper pasteurization as commonly practiced destroys the psychrophilic bacteria present in raw milk, at least to the extent that they would not be a factor in flavor deterioration over an extended storage period. The data presented in table 1 are representative of those obtained before and after laboratory pasteurization (143° F.—30 minutes) of samples of mixed herd milk. Psy-

chrophile counts were obtained by incubating plates at 7°C. for ten days. At no time have we recovered psychrophiles after laboratory pasteurization of milk by the sealed-tube, total-immersion technique. Similar results obtained from samples drawn aseptically from a point between the flow division valve and the regeneration section of the high-temperature, short-time pasteurizer are shown in table 2. The pasteurizer was operating at 162°F. with a holding time of 16 seconds. Data obtained from fresh samples, and after 3, 4, 5, and 7 days of storage, are presented. Also, a series of results obtained from the analysis of the bottled product is shown.

From the experimental work which has been done in our laboratories and elsewhere on the psychrophile problem as it relates to the keeping quality of milk, one may conclude that proper pasteurization is effective in the destruction of this group.

OCCURRENCE IN PASTEURIZED MILK

The answer to the next logical question, "What then is the source of these bacteria in pasteurized milk and how may they be controlled?", becomes obvious. The fact that psychrophiles are commonly found in freshly pasteurized milk indicates almost unquestionably that they have been introduced at one or more points during post-pasteurization handling of the product. This points directly to the lack of effective cleaning and/or bactericidal treatment of all equipment surfaces involved from the pasteurizer on through the bottling and capping operations.

The effectiveness with which the cleaning and sanitizing procedures are carried out in milk plants varies greatly. This is evident from the results of physical inspections, as well as the results of coliform counts, swab counts, and other laboratory tests on "line run" samples and finished products. The coliform count has occupied an important place among the procedures which are valuable in detecting post-pasteurization contamination.

At this point the question may arise as to the value of standard plate counts, coliform counts, and psychrophile counts on fresh products as indicators of keeping quality. This is of practical importance, for the plant superintendent is ever alert to information on probable storage life at low temperature of products being turned out under his supervision.

In our studies we have concerned ourselves to some extent with this aspect of the problem. To begin with we wished to learn what relationship existed between the past records of bacterial counts of finished products from a milk plant and the keeping quality of products from the same plant when stored at low temperature. Fortunately in the Minneapolis and St. Paul milk shed, a rather extensive quality control program is in operation. Past records of laboratory results from all products distributed by each plant were available. Through an examination of these records, plants could be placed in various categories. Having done this, an attempt was made to determine the current situation with re-

TABLE 2—BACTERIAL COUNTS OF PASTEURIZED MILK, (1) DRAWN ASEPTICALLY FROM HTST PASTEURIZER, AND (2) OBTAINED AS FINISHED BOTTLED PRODUCT.

Bacterial counts after storage at 45° F for time indicated.	From HTST pasteurizer		Bottle of finished product		
	Sample 1	Sample 2	Bottle 1	Bottle 2	Bottle 3
0 days—fresh sample					
SPC* (32°C.)	11,000	12,000	10,000	11,000	.....
Coliform count	0	0	2	8	.....
Psychrophile count.	0	0	26	40	.....
3 days					
SPC* (32°C.)	11,000	11,000	9,200	13,000	.....
Coliform count	0	0	2	3	.....
Psychrophile count.	1	1	45	90	.....
4 days					
SPC* (32°C.)	8,900	11,000	9,400	12,000	.....
Coliform count	0	0	0	2	.....
Psychrophile count.	0	0	49	300	.....
5 days					
SPC* (32°C.)	9,200	12,000	140,000	6,100,000	.....
Coliform count	0	0	0	2	.....
Psychrophile count.	2	1	2,800	2,400	.....
7 days					
SPC* (32°C.)	9,700	10,000	6,700,000	4,700,000	2,100,000
Coliform count	0	0	5	6	0
Psychrophile count.	3	0	9,600,000	2,100,000	2,000,000

* SPC = Standard plate count.

TABLE 3—BACTERIAL AND FLAVOR CHANGES DURING STORAGE* OF HOMOGENIZED PASTEURIZED MILK, WITH AND

TABLE 5—BACTERIAL AND FLAVOR CHANGES DURING STORAGE* OF HOMOGENIZED PASTEURIZED MILK FROM PLANTS C, D, E, F, AND G.

Plant	No. days storage	S.P.C.** 32°C	S.P.C.** 35°C	Coliform count	Psychropile*** count	Flavor score and comments****
C	0	2,900	4,400	0	0	38 sl,fe
	3	2,000	3,400	0	23	38 sl,fe
	4	2,700	6,300	0	1,200	38 sl,fe
	5	4,500	6,500	11	3,300	38 sl,fe
	7	24,000	32,000	74	680,000	36 sl,uc
D	0	7,600	5,900	0	4	38 sl,uc
	3	790	660	0	530	38 sl,uc
	4	59,000	61,000	1	19,000	36 sl,uc
	5	470,000	320,000	8	390,000	36 sl,uc
	7	580,000	420,000	1,400	78,000,000	0 uc
E	0	8,200	6,800	30	9,000	36 sl,uc
	3	160,000	160,000	200	900,000	36 sl,uc
	4	1,200,00	1,400,000	460	1,100,000	32 sl,uc;ox
	5	2,500,000	2,800,000	2,900	37,000,000	0 uc
	7	44,000,000	26,000,000	4,600,000	130,000,000	0 uc
F	0	3,500	3,600	0	1	38h;sl,fe
	3	3,300	3,500	0	.....	38h;sl,fe
	4	60,000	44,000	0	5,200	38h;sl,fe
	5	87,000	89,000	0	280,000	38h;sl,fe
	7	240,000	430,000	0	26,000,000	38h;sl,fe
G	0	24,000	21,000	0	0	38 sl,fe;sl, ast
	3	17,000	17,000	0	.....	38 sl,fe;sl, ast
	4	18,000	16,000	1	6	35 sl,uc
	5	31,000	22,000	0	2,800	35 sl,uc
	7	480,000	390,000	0	7,100,000	0 ox;uc

*Storage was at 45° F.
**Standard Plate Count
***Incubation of plates at 45° F. for 10 days.
****See Table 3

sized that pasteurized milk must be extremely low in psychrophile population in order to assure good keeping quality. Such population levels must be considerably less than mere absence in one or two milliliters of fresh product.

EFFECT OF ANTIBIOTICS

Antibiotics must be considered in relation to the keeping quality problem. The use of antibiotics in the treatment of mastitis has had, of course, its impact upon the manufacture of cheese and cultured milks. In addition it has been said that in certain areas of the country, milk contains antibiotics in sufficient concentration to prolong abnormally the keeping quality of pas-

Data presented in table 3 were obtained during the course of a study to determine the effect of aureomycin on the keeping quality of pasteurized milk. Each sample from plant A was divided. To one lot, crystalline aureomycin was added to give a concentration of 0.2 microgram per milliliter of milk. Opinions and calculations of other investigators would lead one to believe that such a concentration might occur in pasteurized milk. Actually this concentration is slightly below that reported for complete inhibition of *Streptococcus lactis*.

The data presented in table 3 indicate generally lower counts for

ever. The flavor criticisms after four days of storage show that marked deterioration had taken place even when aureomycin had been added. The "malty" flavor observed in samples not containing antibiotic and the absence of this flavor in milk to which aureomycin had been added, provides evidence which indicates that suppression of the bacterial species responsible for this defect had occurred. The inhibition of this species, presumably *Streptococcus lactis* var. *maltigenes*, was nullified by the growth of other types which resulted in deterioration of flavor to the same extent as that which oc-

bacterial counts showed further increases accompanied by flavor deterioration to the point of zero score.

SUMMARY

In summary the evidence to date would indicate the following:

1. One may expect to find psychrophilic bacteria in raw milk supplies, and extensive proliferation of these bacteria will inevitably occur if such milk is held at low temperature.

2. Proper pasteurization as commonly carried out will result in extensive if not complete destruction of psychrophiles.

3. Proper cleaning and bactericidal treatment of all post-pasteurization equipment, including bottles, is essential to prevent the contamination of pasteurized milk with psychrophilic bacteria.

4. Standard plate counts, and coliform counts of freshly pasteurized milk as routinely performed are not good indicators of keeping quality.

5. A psychrophile count on fresh milk is not a good indicator of keeping quality unless a considerably larger quantity of milk than normally used is examined. The mere absence of psychrophiles in one or two milliliters of milk is not a guarantee of long storage life.

6. Individual plants vary greatly with respect to the presence of psychrophiles in their products and the keeping quality of their products.

7. Good past bacterial count records afford a rather reliable indication that products from such plants may show better keeping quality than products from plants with poor past records.

8. The concentration of aureomycin used in this study had no effect in extending the keeping quality of pasteurized milk.

9. The psychrophile problem as it relates to the keeping quality of pasteurized milk is a plant problem, and more specifically it appears to be a post-pasteurization sanitation problem.

REFERENCES

1. Erdman, I. E. and Thornton, H. R.: Psychrophilic Bacteria in Edmonton Milk and Cream, I. Numbers. *Can. J. Technol.*, 29, 232-237, (1951).

2. Jezeski, J. J. and Macy, H.: Cryophilic Orga nisms in Water and Butter. *J. Dairy Sci.*, 29, 439-452, (1946).

3. Kennedy, Lura, and Weiser, Harry: Some Observations on Bacteria Isolated from Milk That Grow within a Psychrophilic Temperature Range. *J. Milk and Food Technol.*, 13, 353-357, (1950).

4. Rogick, F. A. and Burgwald, L. H.: Some Factors Which Contribute to the Psychrophilic Bacterial Count in Market Milk. *I bid.*, 15, 181-185, (1952).

5. Watrous, G. H., Doan, F. J., and Josephson, D. V.: Some Bacteriological Studies on Refrigerated Milk and Cream. *Penn. Agr. Exp. Sta. Bull.* 551, (April, 1952).

Changes in Oakite Management Organization

Following a recent meeting of the board of directors of Oakite Products, Inc., manufactures of industrial cleaning and allied materials, three changes in the management organization were announced. J. J. Basch, former Philadelphia division manager and veteran of 28 years service with the company, was appointed manager of research and product development. He will be in charge of the company's expanding technical research program, and will supervise the field testing of new and experimental materials. A member of the company's boar dof directors since 1948, he has also been elected a member of its executive committee. At the same meeting, E. H. Steif, general attorney of the company and member of the Oakite organization since 1948, was appointed assistant secretary and elected to the board of directors. Another appointment announced was that of W. A. Baltzell, former southern division manager and with the company since 1941, as assistant sales manager. He will assist the general sales manager of the company's industrial division in connection with sales management functions.

The new appointments, a company spokesman states, are designed to add to the managing and operating strength of the company, and to assist it in meeting with maximum effectiveness the increasing demands made upon its facilities by all branches of industry.

Canco's Dr. Clark Named to NRC Food, Nutrition Board

Dr. Berton S. Clark, scientific director of the American Can Company, has been appointed a member of the Food and Nutrition Board of the National Research Council.

Members of the board, which is responsible for the "translation of nutritional science to the public welfare," are selected primarily for their leadership in an dknowledge of the food industry. Dr. Clark, a leader in research on food processing and preservation, als ois chairman of the research council's committee on packing, packaging and preservation and a member of the council's advisory boar don quartermaster research and development.

The Canco scientific directory recently became president of the Institute of Food Technologists.

ANDREW J. KROG RETIRES FROM LILY-TULIP CUP CORP.

Andrew J. Krog, who last year celebrated his twenty-fifth anniversary in the field of public health, is retiring from Lily-Tulip Cup Corporation it was announced by Fen K. Doscher, Vice President in charge of sales.

Mr. Krog became head of Lily's public health department in 1947 after spending twenty years as a health officer.

After doing some extensive traveling both here and abroad, Mr. Krog plans to settle in Daytona Beach, Florida, where he will seriously take up his favorite hobby of fishing.

COLORADO DAIRY PRODUCTS ASSOCIATION ANNOUNCES APPOINTMENT

Kenneth W. Bowman has been appointed Executive Secretary of the Colorado Dairy Products Association, according to True Adams, President of the Association. Mr. Bowman makes his home in Boulder, is married, and has two children. He received his education at the State University of Iowa, having fifteen years association with the dairy industry in the supply field, giving his an understanding of all phases of dairy operations. Mr. Bowman will assume the duties of executive secretary on July 1st.