

STUDIES ON METHODS FOR PREDICTING THE SHELF LIFE
OF PASTEURIZED MILK AND MILK PRODUCTS

By

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STUDIES ON METHODS FOR PREDICTING THE SHELF LIFE
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TABLE OF CONTENTS

	Page
I. INTRODUCTION	1
II. REVIEW OF LITERATURE	3
III. EXPERIMENTAL METHODS	9
Sample Procurement	9
Disposition of Samples	9
Determination of Shelf Life.	10
Bacteriological Plate Counts	10
Keeping Quality Tests.	11
Statistical Analysis of Data	11
IV. RESULTS AND DISCUSSION	13
Storage Temperatures	13
Keeping Quality Test	16
Initial Plate Counts	17
Plate Counts on Stored Samples	18
Standard Plate Counts.	18
CVT Counts	21
Summary of All Variables	21
Relationship of Psychrophilic to CVT Counts.	24
V. SUMMARY AND CONCLUSIONS.	28
VI. SELECTED BIBLIOGRAPHY.	30
APPENDIX	32

LIST OF TABLES

Table	Page
I. Shelf Life at Various Temperatures	14
II. Keeping Quality Test	16
III. Initial Plate Counts	18
IV. Standard Plate Counts After Storage for 24 Hours	19
V. Standard Plate Counts After Storage for 48 Hours	20
VI. CVT Counts After Storage for 24 Hours.	22
VII. CVT Counts After Storage for 48 Hours.	23
VIII. Summary of Comparisons of Various Tests with Shelf Life at 45°F.	25
IX. Relationship of Psychrophilic to CVT Counts.	26
 Appendix Tables	
A. Commercial Samples	33
B. University Samples	37
C. Comparison of Psychrophilic and CVT Counts on Commercial Samples.	43
D. Comparison of Psychrophilic and CVT Counts on University Samples.	45

INTRODUCTION

Good shelf life has been an important problem with milk plants for many years. The current trends toward fewer and larger plants, larger retail packages, every-other-day deliveries, increasing volume of sales of milk in stores and supermarkets and the transportation of the milk for long distances from the processing plants to sales outlets all enhance the chances for spoilage before the milk reaches the consumers' tables. Various tests have been applied to pasteurized milk in attempts to predict shelf life in order to insure high quality at the consumer level. Many plants use shelf life at refrigeration temperatures as a final test but the time required to obtain the results is so long that the milk has usually been consumed before the final results are obtained. There is a great need for a rapid and accurate test for predicting shelf life.

The investigations herein reported were undertaken in an attempt to find a reliable and rapid method for predicting the shelf life of pasteurized milk and milk products.

The objectives of these investigations were to determine the relationships of various tests with the shelf life at 45°F as follows:

- (1) Shelf life at 50°, 55°, 60° and 70°F.
- (2) Keeping quality test with a reagent.
- (3) Initial Standard Plate, psychrophilic and CVT counts.
- (4) Increase in Standard Plate Counts and in CVT counts during storage at 45°, 50°, 55°, 60° and 70°F.

- (5) Increase in CVT counts and in psychrophilic counts during storage at 45°, 50°, 55° and 60°F.

REVIEW OF LITERATURE

Numerous reports have been published on investigations concerned with tests for predicting the shelf life of pasteurized milk at refrigeration temperatures. The methods that have been tested include Standard Plate Counts, psychrophilic counts, coliform counts and dye reduction tests.

Several investigators have reported that Standard Plate Counts on freshly pasteurized milk are of little value in predicting the keeping quality of milk at refrigeration temperatures (3, 5, 8, 15, 20). Ashton (3) stated that the value of such counts is limited to an indication of the general conditions of production and handling of the milk prior to pasteurization.

Several investigators have attempted to correlate the rates of increase in bacterial counts during refrigerated storage with the shelf life at refrigeration temperatures. Nelson and Baker (18) found that plating the samples initially and again after storage at 10°C (50°F) for 2 days was possibly the best method for detecting psychrophilic bacteria as an indication of the potential shelf life. They recommended incubation of the plates at 25°C (77°F) for 3 days for maximum counts. Atherton et al. (4) reported that with milk pasteurized in test tubes, there was very little or no increase in plate counts in milk stored at 45°F for periods up to 15 days. At 50°F, however, growth of the organisms was

rather rapid. The counts were determined at incubation temperatures of 10°, 25°, and 35°C (50°, 77° and 95°F) for 10, 3 and 2 days, respectively. The multiplication patterns were similar but the plates incubated at 25°C (77°F) gave significantly higher numbers than the counts at the lower or higher temperatures. In bottled milk exposed to some contamination, increases in counts occurred even at a storage temperature of 40°F.

Dahlberg (10) noted that the counts of freshly pasteurized milk samples increased only slightly when held at room temperature for 6 hours and that decreases in counts occurred when the milk was held at 35° to 40°F for 4 days.

Johns (16) described a plating procedure for detecting post-pasteurization contamination which involved plating initially for SPC and coliforms and then replating after storage at 7°C (45°F) for 5 days. A great increase in count indicates contamination. He reported that the SPC was more sensitive than coliform counts in detecting contamination.

Coliform counts have been used extensively to detect post-pasteurization contamination, although some investigators have demonstrated that certain strains of E. coli are resistant to ordinary pasteurization. However, Buchbinder and Alff (7) concluded, after extensive investigations, that "so-called heat resistant coliform organisms are of absolutely no practical significance in the coliform test of pasteurized milk."

Johns (17) stated that it is generally accepted that the presence of coliforms in pasteurized milk products is an indication of contamination subsequent to pasteurization. Nelson and Baker (18) suggested that a negative or low coliform count is not necessarily an index of freedom

from contamination with psychrophilic bacteria. Olson et al. (20) reported that coliform counts, as routinely performed, are not a good indication of keeping quality.

Dahlberg (9) reported that the coliforms in pasteurized market milk held at refrigeration temperatures increased more rapidly in numbers than the total bacterial counts. Dahlberg (10) also noted that in milk stored for 4 days at 35-40°F, the coliform count remained constant, at 45-50°F the coliforms increased considerably and at 55-60°F the counts increased rapidly. Foster, et al. (14) stated that even small numbers of coliform bacteria present in freshly pasteurized milk are associated with poor keeping quality. A negative coliform count on a finished product does not always mean that such product will have long storage life.

Bacteria which grow rapidly at low temperatures in the range of 35° to 50°F are called psychrophilic (1). These psychrophilic bacteria which grow in refrigerated dairy products are of the genera *Pseudomonas*, *Achromobacter*, *Flavobacterium* and *Alcaligenes*. They are killed by proper pasteurization and their presence in pasteurized milk indicates post-pasteurization contamination (1, 25). Some of the common bacteriological defects developing in pasteurized milk held at refrigeration temperatures (35° to 40°F) are unclean, putrid, fruity, rancid, ropy, sweet curdling, bitter and greenish yellow coloration (14, 25).

Olson et al. (20) reported that psychrophilic bacteria are killed by proper pasteurization. However, the absence of psychrophiles in one or two milliliters of milk is not a guarantee of long storage life. Rogick and Burgwald (21) reported that no psychrophiles were found in

4.1 ml of pasteurized milk taken from the LT-LT vat or from HTST pasteurization systems. However, psychrophiles were found in samples of the first milk bottled but not in the milk bottled at the end of the operation.

Andrews and Kaufman (2) reported that 66 psychrophilic organisms isolated from milk and water did not survive heating at 143°F for 25 minutes. Thomas and Sekhar (24) reported that 206 representative strains of psychrophiles isolated from raw and from pasteurized milk were all destroyed by laboratory pasteurization.

Boyd et al. (5) reported that the average shelf life of commercially pasteurized milk held at 40°F was 13 to 18 days, and that the deterioration was related to the growth of psychrophilic bacteria at refrigeration temperatures. Organisms isolated from the milk having poorest keeping quality were gram negative rods. Psychrophilic counts on freshly pasteurized milk were of little value in predicting quality of milk when held at 35° or 40°F. The causative spoilage organisms were present in freshly pasteurized milk in so few numbers that psychrophilic counts do not detect them accurately.

Burgwald and Josephson (8) reported that the deterioration of pasteurized milk which occurs during refrigeration is due to psychrophilic bacteria which produce acid at 40°F. They observed that the initial psychrophilic count does not serve as an index of the potential keeping quality of milk stored at 40°F.

Day and Doan (11) reported that pasteurization destroyed the psychrophilic bacteria and that their presence is due to post-pasteurization contamination. They stated that even a very few psychrophiles will

shorten the shelf life of milk at refrigeration temperatures. Also, the numbers of psychrophiles were usually so small that counts made on freshly pasteurized milk were worthless as indicators of keeping quality. They stated that the types of psychrophiles rather than the numbers are important in determining rates of deterioration.

Elliker et al. (13) stated that the presence of psychrophilic organisms in pasteurized milk is due to post-pasteurization contamination and that the common sources are plant equipment, soil, water and dust. They grow well at refrigeration temperature and cause defects such as unclean, fruity, stale, rancid, bitter and cheesy flavors and odors. Johns (17) stated that pasteurization destroys psychrophilic organisms in milk and that their presence in the pasteurized product is due to recontamination. Also, psychrophilic counts on freshly pasteurized milk are of no great value because of the small numbers normally present. He suggested a test for psychrophiles which involved determination of the initial count, holding at 7.2°C (45°F) for 5 days and replating for psychrophiles. Nelson and Baker (18) recommended incubation of plates at 21°C (70°F) for 4 days or 25°C (77°F) for 3 days for determining increases in total counts during refrigerated storage.

Several investigators have suggested tests for predicting the shelf life of milk at refrigeration temperatures. Rowlands and Provan (22) applied the methylene blue and resazurin reduction tests to 160 samples of pasteurized milk immediately after processing. Neither the methylene blue nor the resazurin test at 37°C was a reliable measure either of recontamination or of the keeping quality on freshly pasteurized milk. However, results of the methylene blue test at 15.5°C (60°F) indicated

that some preliminary incubation is necessary before either of these tests is applied.

Day and Doan (11) developed a test to predict the keeping quality of pasteurized milk which involved adding 0.5 ml of 0.2 % aqueous solution of neo-tetrazolium to 5 ml of milk and incubating under vacuum for 4 hours at 37°C (99°F). A detectable pink color appearing in the sample indicates that the milk would undergo flavor spoilage within 4 days. The milk samples were pre-incubated for 3 days at refrigerated storage (40°F) before testing.

Broitman et al. (6) developed a keeping quality test for pasteurized milk which involved the addition of one ml of an indicator solution to 10 ml of pasteurized milk and incubating at 20°C (68°F). The indicator was a buffered aqueous solution containing an inhibitor for gram positive organisms and 2, 3, 5 triphenyltetrazolium chloride as an indicator of bacterial activity. They showed that there was a relationship between the period required for a positive test and the shelf life.

EXPERIMENTAL METHODS

Sample procurement. Samples of milk were obtained from a large commercial milk plant in Oklahoma City and from the Oklahoma State University dairy plant. Both these plants used welded milk lines, HTST pasteurization and automatic in-place cleaning. The samples from the commercial plant were taken immediately after processing and stored in ice during holding and transportation to the laboratory for analysis. The milk products were usually processed on Saturday and examined on Monday so that they were normally held for 2 days at 32°-40°F before plating.

The samples from the University dairy plant included line samples as follows: No. 1 - raw milk; No. 2 - pasteurized milk entering the surge tank; No. 3 - pasteurized milk from the surge tank; No. 4 - first carton filled and No. 5 - random carton taken after several cases had been filled. Samples Nos. 2 and 3 were taken with sterile one quart stainless steel graduates while samples 4 and 5 were sealed quart containers from the filling machine. Sample No. 1 (raw milk) was about 10 ml taken from the raw milk balance tank just before entering the heating unit of the HTST pasteurizer and was used for determination of Standard Plate Count only.

Disposition of Samples

The samples from the two plants were plated for the various counts and then about 100 ml portions were poured into sterile 6 oz milk dilution

bottles closed with double parchment paper secured with rubber bands. These portions were then stored at various temperatures for determination of shelf life and for changes in bacterial populations. The samples were stored in refrigerated rooms or incubators which were thermostatically controlled to $\pm 1^{\circ}\text{F}$ of the desired temperature.

Determination of Shelf Life

Samples stored at 55° , 60° or 70°F were examined organoleptically at daily intervals until definite defects occurred. The samples stored at 45° and at 50°F were examined at two day intervals, beginning with the 7th day unless the shelf life at a higher temperature indicated rapid spoilage. Two bottles of each sample were stored at these two temperatures. One bottle was examined repeatedly until a definite defect appeared and then the duplicate bottle was opened and examined until it, too, showed definite bacterial deterioration. This use of duplicate bottles minimized deterioration due to contamination during the examinations.

Bacteriological Plate Counts

Standard Plate Counts (SPC), coliform counts and psychrophilic counts were conducted according to Standard Methods, using Difco Laboratory products (1, 12). Plates for SPC were incubated at 32°C (90°F). Violet red bile agar and an incubation temperature of 32°C (90°F) were used for coliform counts. Plates for psychrophilic counts were incubated at 7°C (45°F) for 10 days.

CVT counts are selective for detection of Gram negative organisms. The procedure used was essentially the same as first published (19) but involved minor changes. Briefly, the procedure used in the trials herein

reported was as follows: To Standard Plate Count agar was added 1 or 2 ppm of crystal violet (as a 0.1% aqueous solution) before sterilization. To the melted and cooled (113°F) agar was added 50 ppm of 2, 3, 5 tri-phenyltetrazolium chloride (1 ml of a 0.5% alcoholic solution to 100 ml agar). With 0.5 ml of milk added directly to a plate, the plate was poured with agar containing 2 ppm of crystal violet, while with dilutions of 1-10 or higher, agar with 1 ppm of crystal violet was used. The plates were incubated at 90°F for 48 hours before counting. Only distinctly red colonies were counted. A disk of thin paper (onion skin) was placed under the plates on the Quebec colony counter to make the colonies easily distinguishable.

Keeping Quality Tests

The keeping quality test used to predict shelf life was essentially that given by Broitman et al. (6). Briefly, the method was as follows: one ml of reagent was added to each of two 10 ml portions of milk contained in sterilized screw capped test tubes. One tube was incubated at 70°F and the other at 60°F. The tubes were examined at 12 hour intervals and the time required for a slight pink coloration recorded as the end point. The reagent contained 0.1% 2, 3, 5 triphenyltetrazolium chloride, 0.1% sodium alkylaryl sulfonate, 5.0% di-potassium phosphate and 0.1% mono-potassium phosphate in aqueous solution. The solution was sterilized in 10 ml quantities in vials and stored in the refrigerator.

Statistical analysis of data. Most of the calculations were made by an IBM 1410 electronic computer. The equation $Y = a + bx$ was fitted by the method of least squares (23) where Y = shelf life in days at 45°F

and X = one of the variables. The correlation coefficients were estimated by the equation:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}$$

RESULTS AND DISCUSSION

A total of 23 samples of milk and milk products from a commercial milk plant and 32 samples of milk from the Oklahoma State University dairy plant were submitted to various tests in an attempt to discover the best and most practical test for predicting shelf life. The detailed results are presented in Tables A, B, C and D of the Appendix. Incomplete data were obtained with some of the samples due to (1) insufficient sample for storage at all temperatures or (2) the malfunction of the thermostat on the refrigerator set at 55°F which resulted in spoilage of the samples. However, complete data were obtained on 15 commercial and on 16 University samples. With some of the tests, data on additional samples were available and were included in the statistical analysis. All tests were compared with the shelf life at 45°F.

The counts on the raw milk were not considered in the analysis of the data. All the raw milk qualified as grade A for pasteurization. During the period of the investigation the counts on the raw milk from the commercial plant ranged from 1,000 to 100,000 and averaged 15,337 while those on the University milk ranged from 1,000 to 9,000 and averaged 5,721.

Storage Temperatures

Fifteen commercial and 16 University samples were used in comparing the shelf life of milk stored at 45°F to that stored at higher temperatures.

The commercial samples included 4 of each of homogenized milk, multi-vitamin fortified milk and skim milk, 2 chocolate milk and one half and half. The University samples were all homogenized milk.

The data on the shelf life of the samples of milk stored at 50°, 55°, and 60°F compared to that on the samples stored at 45°F are summarized in Table I. The samples were also stored at 70°F but the data are not included because the samples all spoiled in two days. The data show that the length of shelf life decreased rapidly as the temperature of storage became higher and that there was only a general relationship between the shelf life at 50°, 55° or 60° and that at 45°F. With the commercial milk it appeared that storage at 55°F was best for predicting shelf life but was far from satisfactory as the standard error of estimate was 5.0 and the correlation coefficient only 0.58. With the University samples, storage at 50°F appeared best but the reliability appeared to be even less than that for the commercial samples ($s = 4.3$ and $r = 0.40$).

TABLE I
SHELF LIFE AT VARIOUS TEMPERATURES

Source	Samples No.	Shelf life at		Temperature of Storage							
		45°F		50°F		55°F		60°F			
		Mean Days	Mean Days	s	r	Mean Days	s	r	Mean Days	s	r
Comm.	15	18.3	9.5	5.4	0.48	6.0	5.0	0.58	3.5	5.8	0.33
Univ.	16	27.9	12.8	7.3	0.40	6.8	7.9	0.16	4.4	7.9	0.17

s = standard error of estimate

r = correlation coefficient

The data show that at each of the temperatures of storage the results obtained with the commercial samples were more reliable in predicting shelf life than were those obtained with the University samples. The poor correlations obtained with the University samples, which had a much longer mean shelf life at 45°F, were probably due to the growth of non-psychrophilic types during the long periods of storage.

The temperature of storage had an important influence on the types of spoilage occurring in the samples and there also appeared to be a difference in the types of spoilage occurring in the commercial and the University samples. The following shows the percentages of the samples having the most frequently occurring defects at the different temperatures:

45°F	Commercial - Sour, 53%; cowy, 27%, and putrid, 20%.
	University - Musty, 38%; sour, 29%, and rancid, 25%.
50°F	Commercial - Unclean, 53%; sour, 47%, and bitter, 20%.
	University - Sour, 33%; sweet curdling, 21%, and unclean, 21%.
55°F	Commercial - Unclean, 60%; sour, 33%, and bitter, 33%.
	University - Sweet curdling, 46%; bitter, 25%, and musty, 21%.
60°F	Commercial - Sour, 87% and unclean, 20%. (Only two defects)
	University - Sweet curdling, 58%; sour, 29%, and unclean, 25%.

Various other defects, such as feed, fishy, fruity, gassy, mousey, ropy and stale occurred in only a few samples and were largely confined to the samples stored at 45° and 50°F. Some of the percentages given above for the various temperatures total more than 100 due to the fact that many of the samples had more than one defect. Sweet curdling was usually associated with bitterness and sour and unclean commonly occurred

together. The predominance of sweet curdling in the University samples stored at 55° and 60°F was likely due to the growth of heat resistant types rather than to contaminants.

Keeping Quality Tests. Keeping quality tests with a reagent were conducted on 22 commercial and 16 University samples at incubation temperatures of 60° and 70°F. The two temperatures were used to determine which one would give the best results, although the test is normally conducted at 70°F only. The results obtained are shown in Table II. The general results indicate that the keeping quality test is not reliable for predicting the shelf life of pasteurized milk. With the commercial samples the best results were obtained at an incubation temperature of 70°F while with the University samples the best results were obtained at 60°F. However, the standard errors of estimates were rather high and the correlation coefficient values too low to be reliable. One observation of interest is that at 70°F incubation, the mean time required for a positive test was 38.6 hr for the commercial samples and only 35.3 hr for the University samples despite the fact that the latter samples had the longer shelf life at 45°F.

TABLE II

KEEPING QUALITY TEST

Samples Source	No.	Shelf life at 45°F	Keeping Quality Test Incubated at					
			60°F			70°F		
		Mean Days	Mean Hrs	s	r	Mean Hrs	s	r
Comm.	22	18.9	82.8	.6.0	0.22	38.6	5.5	0.43
Univ.	16	27.9	97.5	7.2	0.43	35.3	8.0	0.10

There appeared to be only a slight advantage in incubating the tests at 60°F rather than at 70°F and the longer period required for getting the results may nullify any advantages of using the lower temperature.

Initial Plate Counts

The initial Standard Plate, psychrophilic and CVT counts on 17 commercial and 16 University samples are shown in Table III. The logarithmic means were calculated for the SPC and CVT counts, while the arithmetic mean was calculated for the psychrophilic counts. The initial coliform counts were also determined but these are not included in the results because none were detected in any of the samples of University milk and only 3 of the samples of commercial milk were positive with counts of 1, 1, and 3 for sample numbers G, I and J, respectively.

The data show that the best results were obtained with the psychrophilic counts. With the commercial samples the standard error of estimate was 4.3 and the correlation coefficient 0.73, while with the University samples these values were 7.0 and 0.49, respectively. Generally poorer results were obtained with the SPC and CVT counts. Most of the samples had at least a few psychrophiles, while many of them, especially among the University samples, had CVT counts of 0 in 1 ml. This accounts, in part, for the poor results obtained with the CVT counts. Every sample had a count of at least a few hundred on the SPC plates but the results indicate a very poor correlation between the initial SPC and the shelf life at 45°F.

Although the psychrophilic counts appeared to be the most reliable of the initial counts for predicting the shelf life at 45°F, the time required for completion of the counts is too long to be of practical value.

TABLE III
INITIAL PLATE COUNTS

Source	Samples No.	Mean Shelf Life at 45°F	Standard Plate Counts			Psychrophilic Counts			CVT Counts		
			Mean ¹	s	r	Mean ²	s	r	Mean ¹	s	r
Comm.	17	18.4	1,232	6.1	.23	2	4.3	.73	2 ³	4.3	.23
Univ.	16	27.9	933	7.6	.30	4	7.0	.49	3	8.0	.08

1 = Log average

2 = Arithmetic average

3 = 22 samples only

Plate Counts on Stored Samples

Standard Plate Counts and CVT counts were run on the samples initially (Table III) and again after holding for 24 hours at 55°, 60° and 70°F and for 48 hours at 45°, 50°, and 55°F.

Standard Plate Counts. The Standard Plate Counts on 17 commercial and 16 University samples after 24 hours holding at various temperatures are shown in Table IV. The standard error of estimates and the correlation coefficients indicate that these counts would be unreliable in predicting the shelf life of milk stored at 45°F. The best correlation (0.53) was obtained with the commercial samples held at 70°F.

The Standard Plate Counts on the samples held for 48 hours at 45°, 50° and 55°F also showed poor correlations with the shelf life at 45°F (Table V). The best correlation (0.44) was obtained with the University samples stored at 45°F but the standard error of estimate was rather high (7.2). It may be noted that the SPC on the samples held at 45°F for 48

TABLE IV

STANDARD PLATE COUNTS AFTER STORAGE FOR 24 HOURS

<u>Samples</u>		Shelf life at 45°F	Temperature of Storage								
Source	No.		55°F			60°F			70°F		
		Mean Days	Mean SPC	s	r	Mean SPC	s	r	Mean SPC	s	r
Comm.	17	18.4	1,320	6.2	.15	14,320	6.3	.03	13,580,000	5.3	.53
Univ.	16	27.9	972	7.9	.21	5,914	8.0	.03	12,140,000	7.9	.12

TABLE V

STANDARD PLATE COUNTS AFTER STORAGE FOR 48 HOURS

<u>Samples</u>		Shelf life at 45°F	Temperature of Storage								
Source	No.		45°F			50°F			55°F		
		Mean Days	Mean SPC	s	r	Mean SPC	s	r	Mean SPC	s	r
Comm.	17	18.4	1,014	6.2	.15	1,825	6.3	.05	9,460	6.1	.25
Univ.	16	27.9	933	7.2	.44	1,153	7.6	.32	5,363	8.0	.08

hours were always lower than they were initially. This indicated that some of the organisms in the milk died because of the unfavorable conditions. These decreases may have off-set some of the increases due to the growth of psychrophiles at other temperatures.

CVT Counts. Since the CVT counts exclude most of the organisms that survive pasteurization, it was thought that these counts might be used to measure the growth of organisms at low temperatures and thereby predict the shelf life. The CVT counts obtained after 24 hours holding at 55°, 60° and 70°F are summarized in Table VI. The results with the commercial samples indicate a fairly good correlation between the counts and the shelf life at 45°F. The best correlation (0.69) was obtained with the samples held at 55°, with lower values (0.62 and 0.50) for the samples held 60° and 70°F, respectively. Very poor correlations between CVT counts and shelf life were obtained with the University samples. This was probably largely due to the fact that most of the counts were 1 or less than 1 and in the calculations for log averages these were recorded as 0.

The results of the CVT counts on the samples held for 48 hours at 45°, 50° and 55°F are summarized in Table VII. The best correlation (0.56) was obtained with the samples held at 55°F, with lower values for those held at 45° and 50°F (0.39 and 0.44, respectively). Very poor correlations were obtained with the University samples because of the predominance of very low or negative counts.

Summary of All Variables

A total of 20 variables was used in comparison with the shelf life at 45°F to evaluate each as a method for predicting the shelf life. The

TABLE VI

CVT COUNTS AFTER STORAGE FOR 24 HOURS

Source	Samples No.	Shelf life at										
		Temperature of Storage										
		45°F	55°F			60°F			70°F			
		Mean Days	Mean CVT Count	s	r	Mean CVT Count	s	r	Mean CVT Count	s	r	
Comm.	17	18.4	3	4.6	.69	134	4.9	.62	43,120	5.5	.50	
Univ.	16	27.9	4	8.0	.10	9	8.0	.07	816	7.7	.27	

TABLE VII

CVT COUNTS AFTER STORAGE FOR 48 HOURS

Samples Source	No.	Shelf life		Temperature of Storage								
		at 45°F	Mean CVT Days	45°F			50°F			55°F		
			Count	s	r	Count	s	r	Count	s	r	
Comm.	17	18.4	2	5.8	.39	9	5.6	.44	110	5.2	.56	
Univ.	16	27.9	2	8.0	.05	7	8.0	.08	14	8.0	.04	

mean values, the standard errors of estimates for the linear regressions and the correlation coefficients for each variable are summarized in Table VIII.

The data show that, for the commercial samples, the most reliable test appeared to be the initial psychrophilic count, followed in order by the initial CVT count and the CVT counts after holding for 24 hours at 55° and at 60°F. The correlation coefficients for these tests were 0.73, 0.71, 0.69 and 0.62, respectively. Other tests in the order of their efficiencies were: shelf life at 55°F, CVT count after holding 48 hours at 55°F, SPC after 24 hours at 70°F and CVT counts after 24 hours at 70°F. These variables had correlation coefficients of 0.58, 0.56, 0.53 and 0.50, respectively.

With the University samples it appeared that the best tests were, in order of reliability, initial psychrophilic count, SPC after 48 hours at 45°F, keeping quality test at 60°F and shelf life at 50°F. These results appeared to be much less satisfactory than those obtained with the commercial samples because the correlation coefficients of these tests were only 0.49, 0.44, 0.43 and 0.40, respectively.

Although the initial psychrophilic counts appeared to be the best for predicting shelf life, their use is impractical because of the long period required to obtain the results. For practical application, it appeared that the best measure of potential shelf life would be the CVT counts on samples held for 24 hours at either 55° or 60°F.

Relationship of Psychrophilic to CVT Counts

Although the CVT count was developed primarily for the purpose of detecting contamination subsequent to pasteurization, some laboratories

TABLE VIII

SUMMARY OF COMPARISONS OF VARIOUS TESTS WITH SHELF LIFE AT 45°F*

Variable	Mean observed value (\bar{Y})		Standard error of estimate (s)		Correlation coefficient(r)	
	C	U	C	U	C	U
Shelf life at 50°F, days	9.5	12.8	5.4	7.3	0.48	0.40
Shelf life at 55°F, days	6.0	6.8	5.0	7.9	0.58	0.16
Shelf life at 60°F, days	3.5	4.4	5.8	7.9	0.33	0.16
KQ test at 60°F, hrs	82.8	97.5	6.0	7.2	0.22	0.43
KQ test at 70°F, hrs	38.6	35.3	5.5	8.0	0.43	0.10
Initial SPC	1,232	933	6.1	7.6	0.24	0.30
Initial Psy. count	2	4	4.3	7.0	0.73	0.49
Initial CVT count	2	3	4.3	8.0	0.71	0.08
SPC 24 hr at 55°F	1,320	972	6.2	7.9	0.15	0.21
SPC 24 hr at 60°F	14,320	5,914	6.3	8.0	0.03	0.03
SPC 24 hr at 70°F	13,580,000	12,140,000	5.3	7.9	0.53	0.12
SPC 48 hr at 45°F	1,014	933	6.2	7.2	0.15	0.44
SPC 48 hr at 50°F	1,825	1,153	6.3	7.6	0.05	0.32
SPC 48 hr at 55°F	9,460	5,363	6.1	8.0	0.25	0.08
CVT 24 hr at 55°F	3	4	4.6	8.0	0.69	0.10
CVT 24 hr at 60°F	134	9	4.9	8.0	0.62	0.07
CVT 24 hr at 70°F	43,120	816	5.5	7.7	0.50	0.27
CVT 48 hr at 45°F	2	2	5.8	8.0	0.39	0.05
CVT 48 hr at 50°F	9	7	5.6	8.0	0.44	0.08
CVT 48 hr at 55°F	110	14	5.2	8.0	0.56	0.04

*Mean shelf life at 45°F = 18.9 days for C (Commercial samples) and 27.9 days for U (University samples).

attempt to use it as a measure of the psychrophilic contamination. Trials were conducted in which psychrophilic and CVT counts were run on samples of milk initially and on these same samples after holding at 60°F for 1 day, 55°F for 2 days, 50°F for 4 days and 45°F for 6 days. It was presumed that considerable psychrophilic growth would occur with some of the treatments. These trials involved 6 commercial and 8 University samples. Chlorine treatment of the equipment was deliberately omitted prior to processing one series (4 samples) of the University milk (Trial VIII). The data are presented in Tables C and D of the Appendix and are summarized in Table IX.

TABLE IX
RELATIONSHIP OF PSYCHROPHILIC TO CVT COUNTS

Treatment	Commercial Samples			University Samples		
	Log Average Counts Psychro.	CVT	r	Log Average Counts Psychro.	CVT	r
Initial Counts	1	4	-0.49	1	2	0.23
60°F - 1 day	133	14	0.53	1	3	0
55°F - 2 days	42	88	0.64	2	3	0.20
50°F - 4 days	1,771	66	0.62	1	1	0
45°F - 6 days	1,827	19	0.81	1	1	0

The data show that there is only a general relationship between the two counts and suggest that the CVT counts cannot be used as a measure of the numbers of psychrophiles present in milk or milk products. With the commercial samples, the initial counts had a correlation coefficient (r value) of -0.49, while the remainder of the comparisons had correlation

coefficients ranging from 0.53 to 0.81. It appeared that the correlations increased as the counts increased. It may be observed that the CVT counts were generally much lower than the psychophilic counts.

Very poor correlations were obtained between the two counts applied to the University samples. The data show that the average counts were very low and the detailed data show that the majority of the counts were 1 or less than 1 which caused the very low correlation coefficients.

SUMMARY AND CONCLUSIONS

Trials were conducted to evaluate the effectiveness of each of several tests for predicting the shelf life of milk and milk products. Shelf life at 45°F was used as the standard for comparison. The tests used included shelf life at temperatures of 50°, 55°, 60° and 70°F, a keeping quality test with a reagent, initial Standard Plate, psychrophilic and CVT counts, and Standard Plate and CVT counts after holding for various periods at temperatures of 45° to 70°F. A total of 23 samples of milk and milk products from a commercial milk plant and 32 samples of milk from the University dairy plant were studied. Complete data were obtained on 10 commercial and on 16 University samples. The data were analyzed statistically for standard error of estimate for the linear regression and for correlation coefficients.

The periods of time required for milk to spoil at 50°, 55°, or at 60°F are rather poor measures for predicting the shelf life at 45°F. With the commercial samples, the best results were obtained at 55°F while with the University samples the best results were obtained at 50°F. The types of defects which occurred in the spoiled milk indicated that growth of non-psychrophilic organisms occurred in the samples held at 50°F or higher.

A keeping quality test with a reagent was not accurate in predicting the shelf life of milk. Incubation of the test at 60°F resulted in only a slight improvement in accuracy over incubation at 70°F.

With commercial samples the initial psychrophilic counts and the initial CVT counts proved to be the best measures of shelf life. With the University samples the initial psychrophilic count also appeared to be best, while the initial CVT counts appeared to be of little value. The initial SPC was of little value for predicting the shelf life of either the commercial or the University samples. From the practical standpoint, the initial psychrophilic counts are of little value because of the long period required for obtaining the results.

There was very little relationship between the shelf life at 45°F and the Standard Plate Counts after holding the samples for 24 hours at temperatures of 55°, 60°, or 70°F or for 48 hours at 45°, 50° or 55°F.

With the commercial samples it appeared that the CVT counts on the samples held at 55° or at 60°F for 24 hours were the most rapid and accurate tests for predicting the shelf life. These tests, however, gave rather poor results with the University samples.

In 14 of the 20 tests tried the commercial samples gave better correlations with the shelf life than did the University samples. These generally poorer results with the University samples were probably due to less contamination and, consequently, much longer shelf life than those for the commercial samples.

CVT counts are not a good measure of the psychrophilic counts. With very small numbers of psychrophiles present very poor correlations were obtained between the CVT and psychrophilic counts while with considerable numbers present, the correlations were much closer. It appeared that the CVT counts should be used primarily for detecting contamination subsequent to pasteurization.

SELECTED BIBLIOGRAPHY

- (1) American Public Health Association, Inc. Standard Methods for the Examination of Dairy Products. Eleventh Edition. New York, N. Y. 1960.
- (2) Andrews, R. H. and O. W. Kaufman. The Destruction of Psychrophilic Bacteria in Milk by HTST Pasteurization Based on Thermal Death Time Studies. J. Dairy Sci., 36:570. 1953.
- (3) Ashton, T. R. Some Bacteriological Aspects of the Deterioration of the Pasteurized Milk. J. Dairy Res., 17:261. 1950.
- (4) Atherton, H. V., F. J. Doan, and G. W. Watrous, Jr. Observations on Bacterial Population and Characteristics of Bottled Milk Under Refrigerated Holding. J. Dairy Sci., 36:570. 1953.
- (5) Boyd, J. C., C. K. Smith, and G. M. Trout. The Role of Psychrophilic Bacteria in the Keeping Quality of Commercially Pasteurized and Homogenized Milk. J. Dairy Sci., 36:571. 1953.
- (6) Broitman, Selwyn, W. L. Mallmann, and G. M. Trout. A Simple Test for Detecting Keeping Quality for Milk. J. Milk and Food Tech., 21:280. 1958.
- (7) Buchbinder, L., and E. C. Alff. Studies on Coliform Organisms in Dairy Products. J. Milk and Food Technol., 10:137. 1947.
- (8) Burgwald, L. H., and D. V. Josephson. The Effect of Refrigerator Storage on the Keeping Qualities of Pasteurized Milk. J. Dairy Sci., 30:371. 1947.
- (9) Dahlberg, A. C. The Relationship of the Growth of All Bacteria and Coliform Bacteria in Pasteurized Milk Held at Refrigeration Temperatures. J. Dairy Sci., 29:651. 1946.
- (10) Dahlberg, A. C. The Keeping Quality of Pasteurized Milk in the New York Metropolitan Area During Cool Weather as Determined by Bacterial Counts, Presence of Coliform Bacteria, and Flavor Scores. J. Dairy Sci., 28:779. 1945.
- (11) Day, E. A., and F. J. Doan. A Test for the Keeping Quality of Pasteurized Milk. J. Milk and Food Technol., 19:63. 1956.

- (12) Difco Laboratories Inc., Detroit, Michigan. Difco Manual, Ninth Edition. 1962.
- (13) Elliker, P. R., E. L. Sing, L. J. Christensen and W. E. Sandine. Psychrophilic Bacteria and Keeping Quality of Pasteurized Dairy Products. J. Milk and Food Technol., 27:69. 1964.
- (14) Foster, E. M., F. E. Nelson, M. L. Speck, R. N. Doetsch, and J. C. Olson, Jr., Dairy Microbiology. Prentice-Hall, Inc., Englewood Cliffs, N. J. 1957.
- (15) Harmon, L. G., G. M. Trout, and T. I. Hedrick. Relationship Between Storage Temperatures and the Rate of Development of Various Organisms on the Shelf-life of Homogenized Milk. Milk Dealer, 48:40. 1959.
- (16) Johns, C. K. Detecting Recontamination of Pasteurized Products. Canad. Dairy Ice Cr. J., 38:34. 1959.
- (17) Johns, C. K. Applications and Limitations of Quality Tests for Milk and Milk Products. J. Dairy Sci., 42:1626. 1959.
- (18) Nelson, F. E., and M. P. Baker. The Influence of Time and Temperature of Plate Incubation Upon Bacterial Counts of Market Milk and Related Products, Particularly After Holding Under Refrigeration. J. Milk and Food Technol., 17:95. 1954.
- (19) Olson, H. C. Selective Plating Technique for Detecting Contamination in Pasteurized Milk. J. Dairy Sci., 46:362. 1963.
- (20) Olson, J. C., Jr., D. S. Willoughby, E. L. Thomas, and H. A. Morris. The Keeping Quality of Pasteurized Milk as Influenced by the Growth of Psychrophilic Bacteria and the Addition of Aureomycin. J. Milk and Food Technol., 16:213. 1953.
- (21) Rogick, F. A., and L. H. Burgwald. Some Factors Which Contribute to the Psychrophilic Bacterial Count in Market Milk. J. Milk and Food Technol., 15:181. 1952.
- (22) Rowlands, A., and A. L. Provan. The Methylene Blue and Resazurin Test for Pasteurized Milk. J. Dairy Sci., 25:A264. 1942.
- (23) Snedecor, G. W. Statistical Methods. The Iowa State University Press, Ames, Iowa, Fifth Edition. 1956.
- (24) Thomas, S. B., and C. V. Sekhar. Psychrophilic Bacteria in Raw and Commercially Pasteurized Milk. Proc. Soc. Appl. Bacteriol.
- (25) Witter, Lloyd D. Psychrophilic Bacteria-A Review. J. Dairy Sci., 44:983. 1961.

A P P E N D I X

TABLE A
COMMERCIAL SAMPLES

Samples No.	Product	Shelf Life and Defects at								Keeping Qual- ity test at		Psychro- philic Count
		45°F		50°F		55°F		60°F		60°F	70°F	
		Days	Defects	Days	Defects	Days	Defects	Days	Defects			
D	H	25	Feedy	11	Unclean, Sour	6	Bitter	4	Sour	60	44	<1
E	MV	23	Cow	7	Bitter	6	Unclean Sour	3	Sour	72	36	<1
F	S	25	Sour Cow	14	Unclean Bitter	7	Sw. curd.*	4	Sour	96	48	<1
G	H & H	21	Sour	-	-	-	-	-	-	48	36	<1
H	WC	25	Unclean	-	-	-	-	-	-	108	36	<1
I	H	7	Fruity	5	Fruity	4	Fruity Unclean	3	Sour	48	24	12
J	MV	10	Sour Unclean	8	Sour Unclean	4	Unclean	3	Sour	48	24	3
K	S	15	Sour Unclean	8	Sour Unclean	5	Sour Unclean	3	Sour	60	24	<1
L	H & H	19	Unclean Sour	-	-	-	-	-	-	60	24	2
M	WC	28	Ropy	-	-	-	-	-	-	108	48	<1
N	Choc	9	Sw. curd. Bitter	8	Putrid	-	-	-	-	84	24	3
O	H	20	Sour	7	Unclean	5	Unclean Bitter	3	Unclean Sour	72	36	<1
P	MV	16	Cow	8	Unclean	5	Unclean	3	Sour	84	24	8

TABLE A (Continued)

No.	Samples Product	Shelf Life and Defects at								Keeping Qual- ity test at		Psychro- philic Count
		45°F		50°F		55°F		60°F		60°F	70°F	
		Days	Defects	Days	Defects	Days	Defects	Days	Defects			
Q	S	14	Putrid Bitter	9	Bitter	5	Bitter Unclean	3	Unclean	72	48	< 1
R	H & H	21	Feedy Unclean	-	-	-	-	-	-	72	24	< 1
S	WC	19	Sour	-	-	-	-	-	-	108	60	< 1
T	Choc	16	Bitter Putrid	8	Sour	5	Sour	3	Sour	132	48	< 1
U	H	20	Sour	15	Sour	9	Unclean Fruity	5	Unclean	113	48	< 1
V	MV	22	Musty Sour	14	Unclean	8	Sw. curd Bitter	5	Sour	96	48	2
W	S	25	Cowy	9	Sour Unclean	7	Unclean Sour	4	Sour	96	48	1
X	H & H	25	Cowy	9	Sour Unclean	7	Unclean Sour	4	Sour	96	48	1
Y	WC	29	Feedy Sour	-	-	-	-	-	-	144	70	< 1
Z	Choc	11	Putrid	10	Putrid	7	Putrid Bitter	4	Sour	113	48	2

*Sw. curd = Sweet Curdling

TABLE A (Continued)

Samples No.	Product	Initial Count	Stand Plate Counts					
			After 48 hours at			After 24 hours at		
			45°F	50°F	55°F	55°F	60°F	70°F
D	H	3,300	2,300	4,100	24,000	2,400	60,000	110,000
E	MV	4,200	3,600	4,200	4,000	4,600	3,000	4,000,000
F	S	2,700	2,800	1,700	5,000	1,900	7,000	7,000,000
G	H & H	620	410	3,700	47,000	500	85,000	16,000,000
H	WC	630	670	1,800	26,000	1,400	3,000	6,000,000
I	H	940	620	740	25,000	1,100	34,000	100,000,000
J	MV	400	310	660	5,800	400	12,000	100,000,000
K	S	510	470	2,200	16,000	960	63,000	21,000,000
L	H & H	700	320	220	700	220	2,900	19,000,000
M	WC	430	230	290	1,000	520	6,800	24,000,000
N	Choc	1,000	1,400	3,100	100,000	1,400	87,000	13,000,000
O	H	8,000	8,900	6,800	10,000	7,300	61,000	28,000,000
P	MV	3,700	2,200	21,000	1,100	6,700	320,000	77,000,000
Q	S	840	900	920	4,700	780	1,300	21,000,000
R	H & H	810	640	1,700	55,000	1,000	66,000	22,000,000
S	WC	3,300	1,900	3,000	3,900	3,600	12,000	15,000,000
T	Choc	630	970	1,000	37,000	820	1,500	3,300,000

TABLE A (Continued)

Samples No.	Product	Initial Count	CVT Counts					
			After 48 hours at			After 24 hours at		
			45°F	50°F	55°F	55°F	60°F	70°F
D	H	< 1	< 1	130	10,000	< 1	< 1	50
E	MV	< 1	< 1	< 1	4	< 1	< 1	50
F	S	1	< 1	2	< 1	< 1	10	270,000
G	H & H	< 1	4	4	320	18	24,000	2,000,000
H	WC	< 1	< 1	< 1	< 1	< 1	2	100
I	H	3	3	30	28,000	34	14,000	2,400,000
J	MV	3	1	5	2,300	8	3,700	1,600,000
K	S	6	4	800	12,000	3	9,800	1,800,000
L	H & H	2	5	24	300	13	2,000	2,000,000
M	WC	< 1	< 1	< 1	4	1	< 1	33,000
N	Choc	6	12	330	2,900	150	4,600	620,000
O	H	< 1	8	8	600	1	40,000	1,700,000
P	MV	2	< 1	2	110	1	6	500
Q	S	9	< 1	6	110	5	280	96,000
R	H & H	2	1	8	200	3	210	290,000
S	WC	2	< 1	2	< 1	< 1	< 1	690,000
T	Choc	3	1	2	< 1	1	32	1,000

Legend: H = pasteurized homogenized milk; MV = multi-vitamin fortified homogenized milk;
 S = skim milk; H & H = half and half; WC = whipping cream; Choc = chocolate milk
 drink; - = data not available.

TABLE B
UNIVERSITY SAMPLES

Trial No.	Shelf Life and Defects at								Keeping Quality Test		Psychrophilic Count
	45°F		50°F		55°F		60°F		at 60°F	70°F	
	Days	Defects	Days	Defects	Days	Defects	Days	Defects	Hours	Hours	
Sample No. 2 - From Pasteurizer											
I	44	Unclean	12	Feedy	6	Bitter Musty	3	Sw. curd.	108	48	2
II	27	Feedy Rancid	8	Stale	5	Unclean Bitter	4	Rancid Unclean	72	48	13
III	40	Rancid	15	Rancid	7	Feedy Musty	6	Sw. curd.	108	36	2
IV	37	Musty Rancid	25	Unclean	10	Rancid	5	Sw. curd.	132	24	<1
V	38	Unclean	19	Sour Rancid	*		4	Sour	96	36	<1
VI	34	Sour Unclean	21	Sour	*		5	Rancid Bitter	98	24	2
VII	30	Feedy Unclean	24	Sour	9	Sw. curd.	5	Feedy Rancid	130	41	<1
VIII	31	Ropy	25	Sour	8	Sw. curd.	5	Sw. curd.	120	36	<1

TABLE B (Continued)

Trial No.	Shelf Life and Defects at								Keeping Quality Test		Psychro-philic Count
	45°F Days	Defects	50°F Days	Defects	55°F Days	Defects	60°F Days	Defects	at 60°F Hours	70°F Hours	
Sample No. 3 - From Pasteurized Milk Surge-Vat											
I	28	Feedy Unclean	12	Feedy	6	Rancid	3	Sour Unclean	72	36	3
II	21	Feedy Unclean	8	Feedy	6	Unclean Bitter	4	Sw. curd.	72	48	9
III	36	Fishy	14	Unclean Rancid	7	Musty	6	Sw. curd.	84	24	2
IV	24	Musty Sour	23	Unclean	7	Sw. curd.	4	Sw. curd.	108	24	<1
V	31	Rancid	13	Sour	*		4	Unclean Sour	96	36	1
VI	32	Sour Rancid	17	Ropy Unclean	*		4	Sw. curd.	98	36	<1
VII	40	Feedy	17	Sour	9	Sw. curd.	5	Sour	89	41	<1
VIII	36	Rancid Musty	21	Cowy	6	Sw. curd. Bitter	5	Sw. curd.	92	25	<1

TABLE B (Continued)

Trial No.	Shelf Life and Defects at								Keeping Quality Test		Psychro-philic Count
	45°F		50°F		55°F		60°F		at 60°F	70°F	
	Days	Defects	Days	Defects	Days	Defects	Days	Defects	Hours	Hours	
Sample No. 4 - First Carton Filled											
I	22	Musty	7	Unclean	5	Sour	3	Sour Unclean	72	36	4
II	18	Sour Rancid	4	Rancid	6	Unclean	4	Sw. curd.	72	48	6
III	21	Bitter Mousey	13	Sour Ropy	7	Sw. curd. Musty	6	Sw. curd	84	24	7
IV	32	Putrid	15	Sw. curd Bitter	6	Sw. curd.	4	Sw. curd	204	36	<1
V	24	Sour Unclean	10	Sour	*		5	Sour	48	36	<1
VI	21	Sour Musty	15	Sour Unclean	*		3	Unclean Sour	96	24	1
VII	23	Musty	19	Sour	8	Sw. curd. Bitter	5	Sour	130	41	<1
VIII	21	Sour Musty	14	Sour	7	Sour	3	Sour Unclean	96	25	<1

TABLE B (Continued)

Trial No.	Shelf Life and Defects at								Keeping Quality Test		Psychrophilic Count
	45°F Days	Defects	50°F Days	Defects	55°F Days	Defects	60°F Days	Defects	at 60°F Hours	70°F Hours	
Sample No. 5 - Random Carton											
I	22	Musty Rancid	7	Bitter Sw. curd.	5	Bitter	4	Sour Unclean	72	36	7
II	22	Sour	4	Sw. curd.	10	Unclean	4	Rancid Unclean	72	48	5
III	27	Sour	13	Rancid Sour	7	Musty	6	Sw. curd.	96	24	1
IV	25	Musty Sour	25	Unclean	8	Sw. curd.	5	Sw. curd.	132	24	<1
V	35	Unclean	12	Bitter Unclean	*		4	Sour	96	36	<1
VI	21	Sour Musty	17	Sour	*		4	Unclean Feedy	96	36	<1
VII	23	Sour	13	Sour	9	Sw. curd.	4	Sour	96	36	<1
VIII	20	Musty	10	Sw. curd.	9	Sour	5	Sw. curd.	108	25	3

TABLE B (Continued)

Trial No.	Initial Count	Standard Plate Counts					
		After 48 hours at			After 24 hours at		
		45°F	50°F	55°F	55°F	60°F	70°F
Sample No. 2 - From Pasteurizer							
I	1,700	1,400	1,500	20,000	1,700	190,000	11,000,000
II	1,300	1,200	1,400	3,200	1,300	4,000	9,600,000
III	550	360	450	2,500	500	2,500	31,000,000
IV	690	970	1,100	1,100	760	630	5,400,000
V	1,300	720	1,100	1,900	1,200	2,200	17,000,000
VI	900	160	180	*	160	2,000	9,200,000
Sample No. 3 - From Pasteurized Surge Vat							
I	1,800	1,500	2,300	22,000	2,000	110,000	23,000,000
II	1,500	1,400	900	2,900	1,200	2,000	11,000,000
III	580	370	610	8,800	580	2,100	22,000,000
IV	680	820	610	1,300	520	690	5,200,000
V	1,400	890	950	4,900	1,200	4,200	17,000,000
VI	310	310	390	*	340	2,400	9,500,000
Sample No. 4 - First Carton Filled							
I	1,800	1,200	3,500	32,000	2,400	630,000	13,000,000
II	1,400	1,400	1,700	1,900	1,200	3,000	12,000,000
III	660	680	530	73,000	530	5,200	18,000,000
IV	310	510	540	1,400	720	390	7,200,000
V	570	990	860	11,000	620	7,300	19,000,000
VI	320	250	270	*	400	2,300	9,600,000

TABLE B (Continued)

Trial No.	Initial Count	Standard Plate Counts					
		After 48 hours at			After 24 hours at		
		45°F	50°F	55°F	55°F	60°F	70°F
Sample No. 5 - Random Carton							
I	1,700	1,700	7,700	26,000	2,100	65,000	11,000,000
II	1,300	1,700	2,700	2,800	1,200	7,000	13,000,000
III	530	570	360	7,300	540	5,000	20,000,000
IV	610	890	950	1,100	710	660	7,800,000
V	980	960	840	1,600	600	2,000	19,000,000
VI	210	320	340	*	270	700	6,700,000
CVT Counts							
Sample No. 2 - From Pasteurizer							
I	2	<2	2	10	4	32	1,100
II	2	1	6	<2	<1	8	200
III	23	2	50	180	18	20	7,700
IV	<1	1	1	<2	2	<2	<10
V	9	<1	6	4	8	10	60
VI	10	4	1	*	1	13	3,100

TABLE B (Continued)

Trial No.	Initial Count	CVT Counts					
		After 48 hours at			After 24 hours at		
		45°F	50°F	55°F	55°F	60°F	70°F
Sample No. 3 - From Surge Vat							
I	<1	2	4	12	18	20	50
II	<1	1	4	14	3	<2	100
III	18	2	28	180	4	8	1,500
IV	<1	<1	<1	<2	2	2	200
V	7	2	20	4	10	8	220
VI	20	13	5	*	1	8	2,100
Sample No. 4 - First Carton Filled							
I	4	4	1,400	4,400	10	760	630,000
II	1	1	2	2	2	12	50
III	87	3	80	650	10	48	19,000
IV	<1	<1	<1	<2	<1	<2	<1
V	10	4	18	6,400	6	4,200	200,000
VI	9	12	4	*	6	1,000	100,000
Sample No. 5 - Random Carton							
I	7	<2	4	44	6	32	640,000
II	3	1	2	6	2	2	150,000
III	20	8	34	40	16	12	2,900
IV	<1	1	<1	<2	<1	2	90
V	4	1	8	6	11	2	50
VI	2	3	2	*	26	2	45,000

*Thermostat off

TABLE C
 COMPARISON OF PSYCHROPHILIC AND CVT COUNTS
 ON COMMERCIAL SAMPLES

Sample No.	Initial Counts	Counts After Holding at			
		60°F 1 day	55°F 2 days	50°F 4 days	45°F 6 days
Psychrophilic Counts					
U	<1	<1	<1	110	1,300
V	2	1	<1	6,400	400
W	1	350	36	2,000	4,200
X	<1	31,000	18,000	120,000	51,000
Y	<1	220	<1	<1	<1
Z	2	2,400	82,000	180,000	340,000
Log. Avg.	1	133	42	1,771	1,827
CVT Counts					
U	1	<1	<1	1	<1
V	1	1	200	200	5
W	64	1,900	4,800	5,400	130
X	33	4,100	1,800	6,200	350
Y	<1	<1	<1	<1	<1
Z	<1	<1	270	13	200
Log. Avg.	4	14	88	66	19

TABLE D
COMPARISON OF PSYCHROPHILIC AND CVT COUNTS
ON UNIVERSITY SAMPLES

Trial No.	Sample No.	Initial Counts	Counts After Holding at			
			60°F 1 day	55°F 2 days	50°F 4 days	45°F 6 days
Psychrophilic Counts						
VII	2	<1	1	<1	<1	<1
	3	<1	1	<1	<1	<1
	4	<1	<1	14	3	<1
	5	<1	<1	4	<1	<1
VIII	2	<1	<1	1	<1	<1
	3	<1	<1	<1	1	<1
	4	<1	<1	2	<1	<1
	5	3	<1	<1	1	<1
Log. Avg.		<1	<1	2	<1	<1
CVT Counts						
VII	2	1	<1	<1	<1	<1
	3	4	1	1	<1	1
	4	2	<1	3	<1	<1
	5	<1	1	2	<1	<1
VIII	2	<1	<1	<1	2	<1
	3	<1	5	<1	1	<1
	4	5	440	2,200	1	1
	5	3	1	<1	<1	<1
Log. Avg.		2	3	3	<1	<1

VITA

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