THE INFLUENCE OF THE MAXIMUM TEMPERATURE RISE IN BULK TANKS ON MILK QUALITY

I. THE EFFECT ON RANCIDITY

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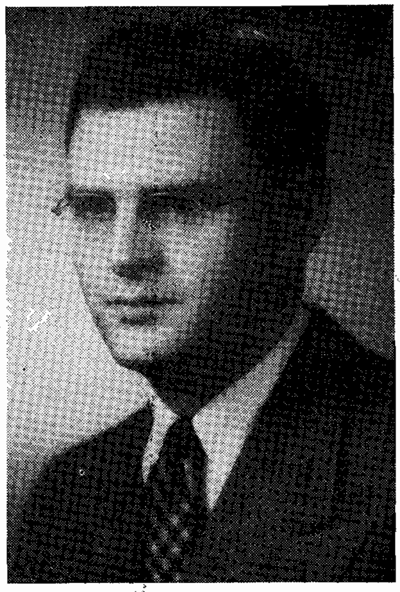
(Received for publication June 10, 1957)

On adding warm morning milk to cold evening milk no development of rancidity was detectable with blend temperatures of 40°F., 50°F., and 60°F., but was apparent at a maximum rise of 70°F. Under conditions simulating every-other-day pick-up no significant increase in rancidity occured on raising the blend temperature to 60°F., but a measureable increase did occur with a blend temperature of 70°F. The increment in acid degree values between 24 and 48 hours is much less with every-other-day pick-up than with samples picked up daily.



Dr. VanDemark received the Ph. D. degree in Bacteriology from Cornell University in 1950. Since that time he has served on the staff of the Laboratory of Bacteriology within the Department of Dairy Industry. During that period he has taught elementary microbiology and his research interests have been in bacterial physiology as well as dairy and food microbiology.

The United States Public Health Service milk ordinance (Item 23r, Section 7, 1953) requires that milk be cooled on farms to at least 50°F. and maintained at this temperature, or lower, until delivered to the milk receiving or processing plant *(1)*. This provision and regulations incorporating it were originated for can cooling operations and have now been applied to milk cooled in bulk tanks, thus requiring that blend temperatures in tanks never exceed 50°F. However, in actual practice there are cases where blend temperatures sometimes go above 50°F. for a short interval during the second milking when tanks are used to capacity or the loading rate is very rapid.

There has been no indication that temperatures 10 degrees or so above 50°F. for a short duration has had any detrimental effect on the milk, but in view of the above requirements it seemed advisable to study the effect of blend temperatures on milk quality and to determine whether or not 50°F. is a critical temperature, and, if not, where the upper limit might be.

Two areas for investigation seemed obvious; one, the effect on lipase activity or rancidity; the other, the effect on bacterial growth in the milk. The former study is presented in this first paper and the bacterial studies are presented in a second paper *(4)*.

Procedure

Twenty-one different farms were visited, several upon two occasions, making a total of 36 different investigations. The number of milking cows in these herds varied from 7 to 82 (see Table 1). The stage of lactation of the cows varied considerably with many cows in late stages of lactation. The quality of milk produced on these farms also varied considerably from top quality to poor quality. A number of these farms were equipped with pipeline milkers, as indicated in Table 1. The methods employed in this study were intended to simulate in the laboratory, as closely as possible, the actual farm procedure. Herd samples of evening and morning milk were taken at the farm at the time of milking and brought immediately into the laboratory. The temperature of the milk on arrival at the laboratory was usually about 90°F. To simulate bulk tanks, one-gallon milk containers were equipped with an agitator blade and motor at 33 1/3 rpm and placed in a 40°F. cooler. The cooling rates of these "simulated bulk tanks" are shown in Figure 1. It can be seen that these cooling rates are considerably slower than in the actual bulk tank performance. One-liter aliquots of evening milk were added to each of

TABLE 1 — DATA CONCERNING THE FARMS

Farm number	Month visited	Number of milking cows	Per cent cows in late lactation	Type of pipeline milkers, if used.
1	Sept.	10	100	
2	Sept.	80	60	Transport
3	Sept.	60	60	
4	Sept.	33	30	
5	Sept.	40	30	
6	Sept.	20	100	Around the barn
7	Sept.	60	60	
8	Sept.	80	25	
9	Oct.	40	15	
10	Oct.	40	25	
11	Oct.	43	25	
12	Oct.	80	25	
13	Oct.	30	25	
14	Oct.	32	20	Parlor
15	Oct.	42	25	
16	Oct.	40	30	Around the barn
17	Oct.	50	2	Parlor
18	Nov.	33	25	
19	Nov.	60	100	
20	Nov.	10	100	
21	Nov.	35	6	Parlor
22	Nov.	30	0	Parlor
23	Nov.	42	25	
24	Dec.	34	6	
25	Dec.	7	40	
26	Dec.	26	30	
27	Dec.	21	50	
28	Dec.	50	2	Parlor
29	Dec.	38	16	
30	Dec.	82	25	
31	Dec.	40	5	
32	Dec.	60	60	
33	Dec.	80	25	
34	Jan.	34	25	
35	Jan.	36	10	Parlor
36	Jan.	40	30	Around the barn

the "simulated bulk tanks" and cooled and held at 40°F. overnight Twelve hours later equal aliquots of the morning milk samples from the same herd were added to this pre-cooled evening milk. To vary the maximum temperature rise, the morning samples were cooled to that temperature necessary to give the desired blend temperature when mixed with an equal volume of the evening milk sample at 40°F. For example, to obtain a final blend temperature of 60°F. an aliquot of morning milk was cooled to 80°F. and then added immediately to the equal volume of the evening milk at 40°F. This procedure was followed in the preliminary portion of this study where final blend temperatures of 40°, 50°, and 60°F. were desired. In the second phase of this investigation it was desired to study the relative effect of blend temperatures of 40°, 60° and 70° F. There it was necessary to raise the temperature of the warm morning milk slightly to 100°F. in a warm water bath, then add aliquots at the desired temperature to the pre-cooled evening samples. This alteration in technique was necessitated in order to obtain a blend temperature of 70°F.

In the final portion of this study, every-other-day pick-up was simulated. To do this, equal volumes of a second evening and morning milkings were added to the original samples employing the same blending technique as outlined above.

Lipase activity of the various temperature blends was determined after 0, 24 and 48-hour time periods. No test was run after 48 hours because previous studies *(2)* have shown that there is no significant increase in rancidity after this period. This rancidity level was measured as the acid degree value using Gander's modification *(2)* of the method of Herrington and Krukovsky *(3)*. This modification is a semi-micro method, using only one gram of milkfat. In this determination the fat is titrated in a non-aqueous solvent with sodium methoxide. As with Herrington and Krukovsky's original method, the rancidity is measured in acid degrees. The threshold value, where rancidity is detectable by taste, is approximately 1.5 acid degrees or above. The method has an experimental tolerance of approximately 0.2 acid degrees.

Flavor tests were also run on all samples after 72 hours to check for any rancidity detectable by taste.

RESULTS

Table 2 shows the results of taste tests and rancidity measurements on milk samples with blend tempera-

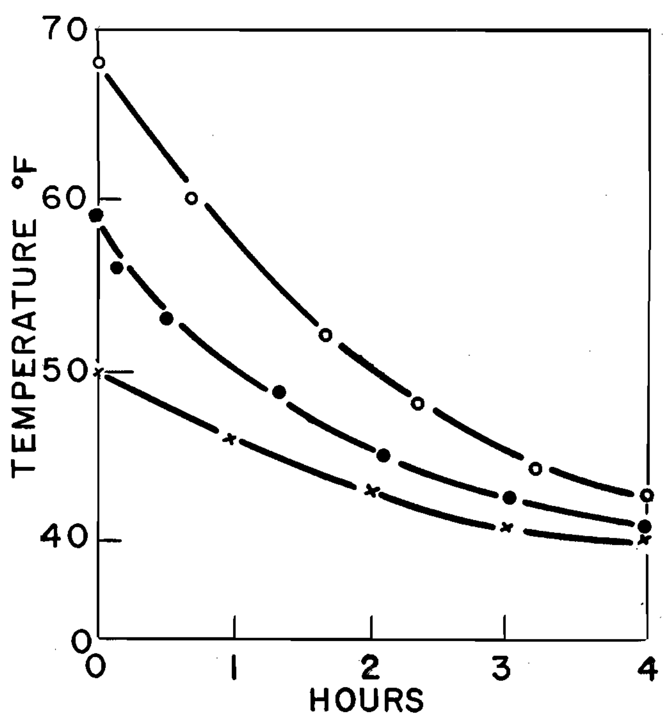


FIGURE 1. The cooling rates of the simulated bulk tanks with various blend temperatures.

tures of 40°, 50° and 60°F., respectively. In no case did any of these samples develop a rancid flavor. While milk samples from various farms showed differences in acid degree values with the variation in blend temperature, the overall average of these acid degree values is relatively constant with the variations in blend temperatures of 40°, 50° and 60°F. These data are perhaps better illustrated in Figure 2, where the increment in acid degrees at 24 and 48-hour periods is plotted against the maximum blend temperature. This plot would seem to indicate that there is little, if any, significant rise in acid degree values with blend temperatures as high as 60°F. Figure 3 is an attempt to show graphically the relative minimum average and maximum acid degree values obtained in this experiment. The threshold level in acid degrees where rancidity is detectable by taste is also shown in this figure. It can be seen that all values were below this threshold value.

TABLE 2 — THE COMARATIVE EFFECT OF BLEND TEMPERATURES OF 40°, 50° AND 60° F. ON THE ACID DEGREE OF MILK SAMPLES UNDER SIMULATED EVERY-DAY PICKUP

Trial	Flavor	Initial	After 24 hours Total	After 24 hours Increase[a]	After 48 hours Total	After 48 hours Increase[a]
Acid degree values using blend temperatures of 40°F.						
1	Good	0.209	0.284	0.075	0.334	0.125
2	Good	0.336	0.437	0.071	0.428	0.062
3	Good	0.395	0.515	0.020	0.545	0.050
4	Good	0.197	0.187	–0.010	0.203	0.006
Mean of 17 trials	None rancid	0.430	0.509	0.079	0.532	0.102
Acid degree values using blend temperatures of 50°F.						
1	Good	0.232	0.270	0.038	0.332	0.095
2	Good	0.406	0.460	0.054	0.463	0.057
3	Good	0.416	0.577	0.161	0.624	0.208
4	Good	0.175	0.189	0.014	0.190	0.015
Mean of 17 trials	None rancid	0.458	0.572	0.059	0.566	0.108
Acid degree values using blend temperatures of 60°F.						
1	Good	0.209	0.307	0.098	0.346	0.135
2	Good	0.379	0.415	0.036	0.428	0.049
3	Good	0.499	0.605	0.106	0.575	0.176
4	Good	0.179	0.189	0.010	0.211	0.032
Mean of 17 trials	None rancid	0.441	0.515	0.074	0.562	0.121

[a]Change in acid degrees from initial value.

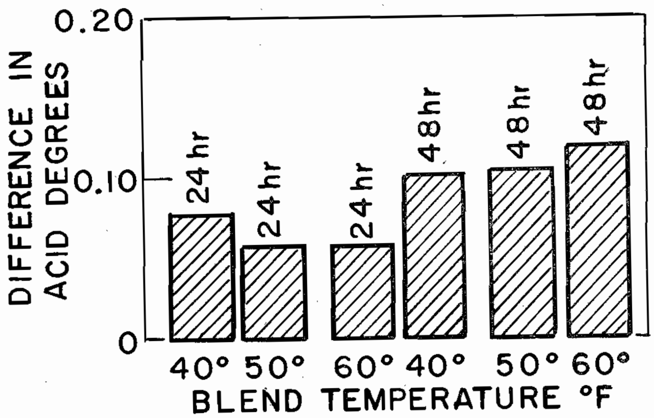


FIGURE 2. Influence of blend temperatures of 40°, 50° and 60°F. on the difference between the initial acid degree value and that obtained after 24 and 48 hours storage.

It was therefore thought desirable to experiment with a higher blend temperature of 70°F. The results of these latter experiments are summarized in Table 3 and Figure 4. Examination of these data shows an average rise in rancidity of 0.2 acid degrees occurring when the blend temperature is increased from 60° to 70°F. This rancidity increase at 70°F. was sufficient to be detected organoleptically in 4 of the 15 farms tested in this phase of the study. In one of these 4 cases (Run #29) the rancidity was caused by factors other than blend temperature. As in the previous study, the differences in acid degree values between the blend temperatures of 40° and 60°F. were small. One would expect the rancidity rise to be even more marked if one increases the blend temperature to approach the melting point of milk fat, this critical temperature being shown by Herrington and Krukovsky *(3)* to be approximately 85°F.

Table 4 shows the values of experiments intended to simulate every-other-day pick-up. In these every-other-day pick-up experiments 0 time was on the first addition of morning's milk to the precooled evening milk, and the next two additions of milk were made at the 12 and 24-hour periods. Examination of these acid degree values shows little significant increase in the total acid degrees of every-other-day pick-up over that of every-day pick-up. However, close examination of the data shows a marked difference in the rate of increase in acid degrees between the 24 and 48-hour periods. With every-other-day pick-up (Table 4) the increase between the 24 and 48-hour period is much less than that found in every-day pick-up (Table 3). This observation is perhaps better illustrated in Figure 4. It would appear that the initial increase in acid degrees in both cases is about the same, but

TABLE 3 — THE COMPARATIVE EFFECT OF BLEND TEMPERATURES OF 40°, 60° AND 70° F. ON THE ACID DEGREE OF MILK SAMPLES UNDER SIMULATED EVERY-DAY PICKUP

Trial	Flavor	Initial	After 24 hours Total	After 24 hours Increase[a]	After 48 hours Total	After 48 hours Increase[a]
Acid degree values using blend temperatures of 40°F.						
1	Good	0.415	0.417	0.002	0.469	0.056
2	Sl. Oxid.	0.347	0.442	0.095	0.640	0.293
3	Sl. Feedy	0.299	0.362	0.074	0.330	0.042
4	Good	0.6?8	0.708	0.100	0.704	0.096
Mean of 15 trials	One slight rancid sample	0.569	0.812	0.243	0.973	0.404
Acid degree values using blend temperatures of 60°F.						
1	Good	0.396	0.449	0.053	0.462	0.066
2	Sl. Oxid.	0.353	0.422	0.069	0.803	0.450
3	Sl. Feedy	0.273	0.320	0.032	0.336	0.048
4	Good	0.568	0.676	0.108	0.741	0.173
Mean of 15 trials	None rancid	0.542	0.772	0.230	0.948	0.406
Acid degree values using blend temperatures of 70°F.						
1	Good	0.361	0.512	0.151	0.623	0.262
2	Sl. Oxid	0.377	0.519	0.142	0.820	0.443
3	Sl. Feedy	0.293	0.414	0.126	0.445	0.157
4	Good	0.566	0.772	0.206	0.865	0.299
Mean of 15 trials	Four rancid samples	0.555	0.877	0.322	1.145	0.590

[a]Change in acid degrees from initial value.

that on the third and fourth additions of milk in every-other-day pickup there is, of course, a dilution effect with fresh milk which causes a slower rate of rancidity increase during this time period.

DISCUSSION

When cold raw milk is warmed to 85°F. and recooled it will quickly develop a rancid flavor. This phenomenon, which is known as temperature activation, was demonstrated by Herrington and Krukovsky in 1939. This temperature of 85°F. is a critical one, in that on

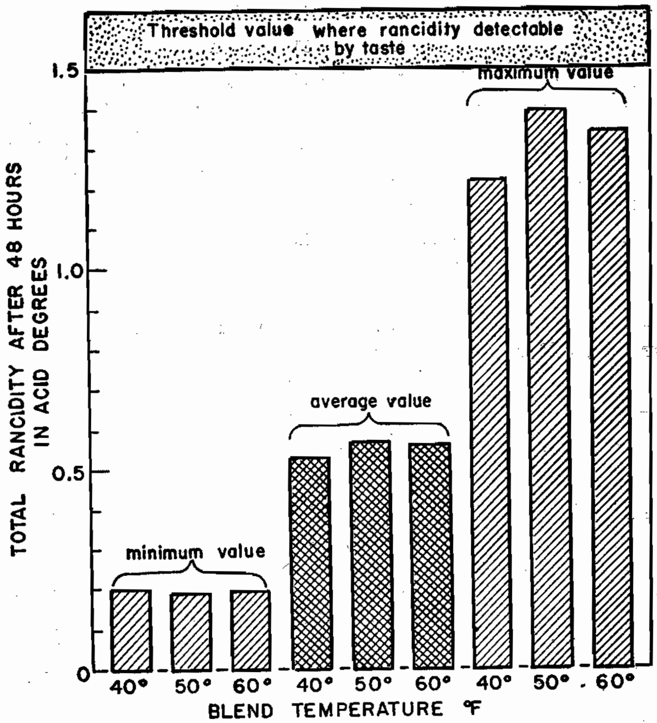


FIGURE 3. Illustration of the minimum, mean, and maximum acid degree values obtained with relation to the threshold acid degree level detectable by taste.

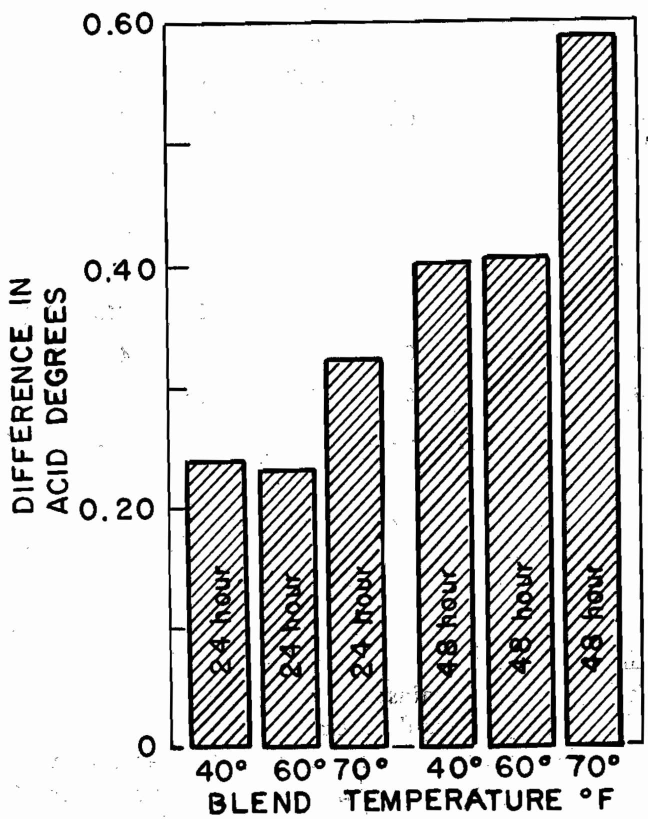


FIGURE 4. Influence of blend temperatures of 40°, 60° and 70°F. on the difference between the initial acid degree value and that obtained after 24 and 48 hours storage.

TABLE 4 — THE INFLUENCE OF BLEND TEMPERATURES ON RANCIDITY WITH SIMULATED EVERY-OTHER-DAY PICKUP.

Trial	Flavor	Initial	After 24 hours Total	After 24 hours Increase[a]	After 48 hours Total	After 48 hours Increase[a]
Acid degree values using blend temperatures of 40°F.						
1	Good	0.121	0.445	0.324	0.478	0.357
2	Sl. rancid	1.081	1.381	0.300	1.461	0.380
3	Good	1.148	1.462	0.314	1.570	0.422
Mean	—	0.783	1.096	0.313	1.170	0.387
Acid degree values using blend temperatures of 50°F.						
1	Good	0.153	0.527	0.374	0.535	0.382
2	Sl. rancid	1.107	1.427	0.320	1.492	0.385
3	Good	1.170	1.491	0.321	1.578	0.408
Mean	—	0.810	1.148	0.338	1.202	0.392
Acid degree values using blend temperatures of 60°F.						
1	Good	0.137	0.485	0.348	0.578	0.441
2	Sl. rancid	1.064	1.394	0.330	1.809	0.415
3	Good	1.132	1.495	0.343	1.630	0.498
Mean	—	0.778	1.125	0.347	1.339	0.561
Acid degree values using blend temperatures of 70°F.						
1	Good	0.144	0.505	0.361	0.535	0.391
2	Sl. rancid	1.078	1.498	0.420	1.748	0.670
3	Good	1.172	1.727	0.555	2.120	0.948
Mean	—	0.798	1.243	0.445	1.468	0.670

[a]Change in acid degrees from initial value.

heating to either lower or higher temperatures the increase in rancidity will not be as great.

This relationship between temperature rise and the degree of rancidity increase has not been well-studied or elucidated. Regulations concerning maximum temperature rise in raw milk apparently have been established so as to be on the ultraconservative or safe side. However, the data in the present paper indicates that the increase in rancidity with respect to the rise in blend temperature is not a linear relationship; instead, the increase in rancidity is apparently an exponential function of the blend temperature.

As the blend temperature approaches the critical temperature of 85°F., the increase in rancidity is rapid, but at temperatures further from this critical temperature the increase is much less. Thus, as shown in the data presented, the increase in acid degrees on raising the blend temperature from 40° to 60°F. is negligible, and cretainly far below that level detectable by taste. However, on increasing the blend temperature to 70° F., the acid degree begin to increase at a more rapid rate and one would expect that as blend temperature approached 85° F. rate of increase would be even more marked.

While the data concerning the relationship of every-other-day pick-up to rancidity increase presented here is somewhat incomplete, it would seem to indicate that there is no marked rancidity problem over and above that normally encountered in every-day pick-up The data would seem to indicate that the third and fourth additions of milk on the second day actually dilute the rancidity level and delay the overall increase. Furthermore, on each subsequent milking the blend temperature rise becomes less, and one would expect the increase in acid degrees with each addition to be less than that resulting from the initial blending of morning and evening milk.

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the effect of various blend temperatures upon the lipase activity in milk.

It is known that warming cold raw milk to 85°F. and recooling will greatly stimulate lipase activity and cause rancidity.

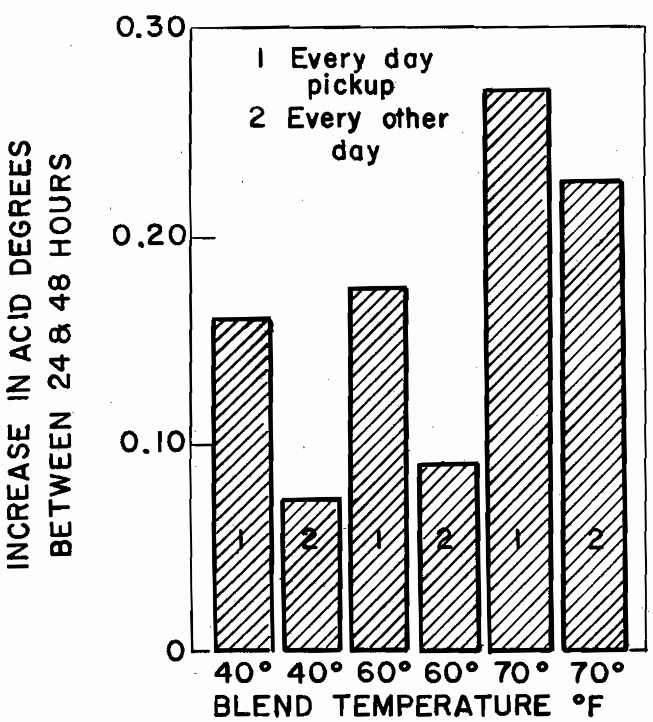


FIGURE 5. A comparison of the increase in acid degree value between every day and every-other-day pickup within the 24 to 48 hour storage period.

When the second milking is added to the cold milk in a bulk tank, the blend temperature may sometimes rise above 50°F.

In this study herd samples were collected from a wide cross section of farms and cooled to 40°F. with constant agitation. Twelve hours later equal portions of herd samples at various temperatures were added to the cold milk to give blend temperatures of 40°, 50° and 60°F. The milk was then cooled to 40° with agitation. Lipase activity was measured in terms of acid degrees (Gander's modification of Herrington and Krukovsky) after 0, 24 and 48 hours. There was no significant increase in acid degrees in this series of tests. Therefore, blend temperatures of 40°, 60° and 70°F. were investigated.

The blend temperature of 70°F. in this series caused an increase of acid degrees up to 0.2, and the development of slightly rancid flavors in 3 out of 15 samples.

Every-other-day pick-up of milk was studied on three farms. The data show no significant increase in acid degree values between 40° and 60° F. blend temperatures, but there was a significant increase at 70°F. The increase in acid degree values between 24 and 48 hours is much less with every-other-day pick-up than with samples picked up daily.

REFERENCES

1. Milk Ordinance and Code. 1953 Recommendations of the Public Health Service. Item 23r, Section 7, Part III, 1953.

2. Gander, G. W. A study of lipolysis in milk. M. S. Thesis, Cornell University, Ithaca, N. Y., 1955.

3. Herrington, B. L. and Krukovsky, V. N. Studies of lipase action. II. The activation of milk lipase by temperature changes. J. Dairy Sci., **22**: 137, 1939.

4. VanDemark, P. J. and March, R. P. The Influence of Maximum Temperature Rise in Bulk Tanks on Milk Quality. II. The Effect on Bacterial Counts. J. Milk and Food Technol., In Press, 1957.