OBSERVATIONS ON TEMPERATURE CHANGES IN PASTEURIZED MILK
DURING BOTTLING, STORAGE AND DISTRIBUTION

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Studies indicate that temperatures to which milk is cooled after pasteurization and before packaging are vitally important since storage room temperatures reduce the temperature of packaged milk very slowly. These studies also indicate that milk, when subjected to warm temperatures, increased in temperature to a point which might be considered harmful in a comparatively short time. A limited survey of open display cabinets indicated that temperatures varied at different points within the cabinets to a degree which could be harmful to the keeping quality of milk, especially if the cabinets are over-loaded.

Current trends in the market industry demand extremely efficient plant operation and proper distribution methods if dairy products are to be of high quality at the time of consumption. Factors which are important in the development and maintenance of high quality are; (a) good raw materials, (b) sanitation on the farms and in the plants, (c) efficiently operated modern production equipment, and (d) good transportation and merchandising facilities. A few years ago most of the bottled pasteurized milk was consumed within forty-eight hours after production. Today a considerable amount of milk is a week old, or older, when consumed. This greater age is due to such trends as every-other-day collection from bulk tanks on farms, five or six day plant operating schedules, paper cartoned milk which is transported over considerable distances, and the increasing amount of milk being handled through stores. This greater age of milk before consumption makes the factors effecting quality vitally important to the plant operator and producer as well as the consumer. One of these factors is the storage temperature to which milk may be subjected during the time it is in the plant after pasteurization, and during its transportation to retail and wholesale outlets and its storage at such locations.

The objective of the studies herein reported were to acquire information on temperature conditions of storage of pasteurized bottled milk which could be used in training in-plant personnel, as well as personnel involved in transportation and sales of dairy products.

These studies involved the recording of over 2,400 temperature readings and other operations.

Mr. Ratzlaff's early youth was spent on a farm in South Dakota. He was graduated from the University of Minnesota in 1935 with a major in Dairy Industry. Since that time he has had extensive experience in milk processing and quality control work. For several years he served as a member of the staff of the Minneapolis and St. Paul Quality Control Laboratory. On his return from military service during World War II he was employed by Marigold Dairies, Inc., Rochester, Minnesota, where he is now Director of Laboratories and Quality Control. Currently, Mr. Ratzlaff is President of the Minnesota Milk Sanitarians Association.

CHANGES IN TEMPERATURE OF (A) COLD MILK PLACED AT AN ELEVATED AMBIENT TEMPERATURE, AND (B) WARM MILK PLACED AT LOW AMBIENT TEMPERATURES

One set of samples of homogenized milk and butter-milk in glass and paper cartons at 40°F. was placed in a room maintained at a temperature of 82°F.±1°F. Another set was warmed to 64°F. and placed in a room maintained at 35°F.±1°F. and a third set was warmed to 64°F. and was placed in a domestic refrigerator at 40°F. A mercury thermometer was submerged two inches into the milk in each sample. The samples were placed four inches apart so that the surrounding air could contact freely all sides of each bottle. Temperature readings were taken each ten
minutes. Figure 1 illustrates the temperature changes which occurred in homogenized milk in glass bottles. Similar curves were obtained from samples of buttermilk in glass containers and homogenized milk and buttermilk in paper containers; although, the changes occurring in the products contained in paper containers were somewhat slower.

It may be observed that the temperature of the samples in the warm room increased 19°F, in the first thirty five minutes while the temperature of the samples in the cold room and the domestic refrigerator decreased only 4°F. Also, it was noted that whereas only thirty five minutes were required for the temperature to rise 19°F, nearly five hours were required for the temperature to drop 19°F under the good conditions of the cold storage room (air blast at 38° ± 1°F). This is about eight times longer than was required for the rise of 19°F in the warm room. An even greater length of time was required for the samples to decrease 19°F in the still air of a domestic refrigerator.

Numerous applications of this information can be made in the dairy industry. The receiving room operator or the technician taking raw milk samples, either in the receiving room or on the farm (as is the case of the bulk tank system), may not realize the rapidity with which the temperature of samples for bacterial analyses may rise. When one is busy, a “few minutes” delay in properly icing samples can stretch to a half hour or more very easily. If this occurs the sample is no longer reliable.

The information showing the rapid rise in temperature of milk when not properly protected has other applications such as: (a) in the plant processing room where the operator may, under certain conditions, allow milk to stand for varying periods of time in cans, in the filler bowl, in bottles in partially filled cases on the conveyor track, or on dollies before movement to the cold storage room; (b) to the route delivery man who must properly care for the milk while he is loading, hauling, or delivering the milk; and (c) to the housewife and restaurant operator who may allow the milk and cream to remain on the table or counter for extended periods of time and then feel dissatisfied with the keeping quality of the products. It is important that such individuals realize the slowness of cooling in the quiet air of refrigerators.

Effects of storage in wood and wire cases

Temperatures at the various points in the cases were determined by use of a potentiometer with 20 thermocouples. Figures 2, 3, 4, and 5 indicate temperatures which were found in one of the center quarts of milk contained in the case second from the floor in a stack of six milk cases. It was thought this particular quart would be the last to react to the effects of the ambient temperature.

In an attempt to determine the cooling effect of the ambient temperature on all of the milk in the entire stack, one of the corner bottles, one of the side bottles, and one of the center bottles in the top case, as well as bottles in the same location in the case second from the bottom, were wired with thermocouples. While the information derived as to the temperatures of each of these six bottles is not presented, it was noted that none of the temperatures varied appreciably from the temperatures which were charted. The maximum difference between these temperatures was 5°F.

The wooden cases in which the paper cartoned milk was stored were solid on all sides except for the small hand opening on each end. The wooden cases used for the glass bottled milk contained the same hand openings on the ends and also contained an opening on each side 2½x12 inches. The wire cases were of the usual wire construction which permitted air movement around and over the top and bottom of the cartons or bottles.

Temperature readings were taken at fifteen minute intervals for the first few hours of each of these studies and then less frequently as the changes in temperature became less rapid.

Milk in glass bottles—warm milk placed at low ambient temperatures. Figure 2 shows the comparison of the cooling effects on glass bottled milk in wood and wire cases. The samples of milk used in this test were first warmed to 60°F. and then placed in the milk storage room at a temperature of 41.3°±3°F. During cooling, the temperatures of these samples of
milk were above 40° to 45°F for a considerable number of hours.

Psychrophilic organisms have come to be very important to the dairy industry today because the modern trends promote greater age of the milk at the time of consumption than was the case some years ago. For this reason a number of factors involved in the handling of milk are very important. Temperature at which the milk is held is one of these important factors. Psychrophilic organisms can grow well at 45°F and can grow much more rapidly at temperatures of 50° and 55°F. During the hours above 40° to 45°F, as illustrated in Figure 2, the spoilage bacteria which can produce fruity or other undesirable flavors and odors may develop rapidly.

From Figure 2 it may be observed that nearly eleven hours were required to bring milk at 60°F in glass bottles packed in wooden cases down to 45°F. In slightly more than eighteen hours the temperature in this milk reached 40°F. The same milk in wire cases required five hours to reach 45°F and ten hours to reach 40°F.

Although, milk may be stored later at a somewhat lower temperature, psychrophilic bacteria which may have increased during holding at the elevated temperatures may produce spoilage in a much shorter time than would have been the case if the milk had been initially placed in the cold milk storage room at the proper temperature. It should be emphasized that the cold milk storage room should be considered only as "storage" room, and should never be considered as a cooling room in which improperly cooled products are placed to cool. The cooling effect is so slow that deterioration of the product is apt to result before the product has cooled to good storage temperature.

The temperature of 60°F at which these cooling tests were begun may seem high. However, in processing and transporting dairy products numerous factors may contribute to high temperatures. In the case of glass bottled milk a rise of seven degrees was found between the time the milk came from the cooling section of the pasteurizer and the time the bottles of milk reached the milk storage room. This temperature rise occurred due to the heat picked up while passing through the surge tank, the sanitary lines, the filler bowl, and perhaps most of all from the heat contained in the glass bottles. At the time these tests were made the milk was coming from the cooling section at 37°F. By the time the milk reached the cold storage room the temperature was 44°F. This constitutes a rise of seven degrees. During these tests the bottle washer was considered to be in normal operating condition. The bottles were being cooled before being discharged from the washer by the cold water rinse. This is standard operation in most washers. In case the bottles are not cooled by this cold water rinse they will cause an even greater increase in the temperature of the milk being bottled. Instances have been noted, after a shut down, in which operators neglected to turn on the cold water rinse. In these cases a considerable amount of heat is added to the milk as the bottle is being filled.

Poor refrigeration in the final section of the plate or other cooler may allow the milk to reach the filler at too high a temperature. If this milk is bottled, cased, and placed in the milk storage room, many hours are required to bring this milk down to the desired temperature. Poor handling while loading trucks can easily allow an appreciable rise in the temperature of the milk being handled on a warm day. Poor refrigeration and insulation in the trucks while the milk is being delivered or transported over the road may contribute greatly to excessive temperatures. Milk in paper cartons—warm milk placed at low ambient temperatures. As might be expected, milk in paper cartons cooled more slowly than milk in glass bottles. This is illustrated by the curves shown in Figure 3.
Glass bottles do not pack as solidly in the cases as do paper cartons. This allows space for a small amount of air movement around the bottles while no chance exists for such air movement around the paper cartons which pack solidly in the cases. When wire cases are used a chance exists for air to move across the tops of the bottles or cartons even though the day's production may be stacked closely together in the cold milk storage room. The wooden cases which were used in these tests did not allow for this air passage, therefore, cooling was very slow in these cases. A drop of 10°F was noted after eighteen hours which brought the temperature of the milk down to 50°F. On the other hand, paper cartoned milk in wire cases dropped to 50°F in about three and one-half hours.

A reduction in the quality of this milk might be expected since it would be held for an extended period of time at a temperature which may allow rapid reproduction of psychrophilic organisms. This very slow reduction in temperature is further evidence that the milk storage room should be considered only as cold storage space and not as a space for cooling a product which was improperly handled in the processing room or on the trucks.

Milk in glass bottles—cold milk placed at an elevated ambient temperature. In determining the rate of warm up occurring in cold milk, thermocouples were placed in the cold samples while still in the cold storage room. The stacks then were moved out into the processing room which was maintained at a temperature of 77°F±3°F and were placed so that the warm air could contact each side of the case. This was done in an attempt to simulate conditions under which milk may be handled after it is removed from the cold room, i.e. moving milk by conveyor over loading docks to trucks, movement of cases of milk into wholesale stops, transportation in small loads carried by uninsulated delivery trucks, unloading trucks, etc. The results are illustrated in Figure 4.

It was found that glass bottled milk warmed 10°F in one hour. Previous observations (see Figure 2) showed that about seven and one-half hours were required to reduce the temperature of glass bottled milk from 50°F to 40°F when stored in wire cases and longer when stored in wooden cases.

It was noted that whereas a considerable difference existed in the rate of cooling glass bottled milk in wood and wire cases there was very little difference in temperatures of the milk being warmed in the two types of cases. At no time during the tests made in warming glass bottled milk was there more than a 3°F difference in the two types of cases.

Milk in paper cartons—cold milk placed at elevated ambient temperatures. Milk in paper cartons warmed more slowly than milk in glass bottles. This may be observed from a comparison of the curves presented in Figures 4 and 5. Furthermore, the difference in temperature of the milk in paper cartons packaged in the two types of cases was greater than was the temperature difference in glass bottled milk packaged in the same types of cases.
**TEMPERATURE DIFFERENCES IN DISPLAY CASES**

A limited study of open display cases was carried out. Seven display cases were included in the study. Six of these cases were located in supermarkets and one in a dairy store. The ages of these cases ranged from six months to over ten years. One case was checked twice; once in summer with a room temperature of 86°F and again in winter when the room temperature was 75°F. Temperature readings were taken at three or more levels in the cabinets. The room temperatures were taken each time the cabinet temperatures were taken. Thermometers were placed on cards at various levels in the cases and were read three or more times at hourly intervals.

From each display case one set of readings was obtained at a point four inches above the bottom of the case, which is about the height of the center of a quart of milk resting on the bottom of the case. Another set of readings was taken at a point eight inches from the bottom and still another set was taken one and one-half inches below the top of the cabinet.

The temperatures of the air at various points in the cabinets which were surveyed are given in Table 1.

<table>
<thead>
<tr>
<th>Display case</th>
<th>Ht. of front</th>
<th>Temperatures recorded at locations indicated</th>
<th>Temp. of room</th>
<th>Avg. temperature</th>
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<td></td>
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<td>locations indicted</td>
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<td>1/2''</td>
<td>12''</td>
<td>18''</td>
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<tr>
<td>A</td>
<td>15</td>
<td>54</td>
<td>44</td>
<td>41</td>
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<td>B</td>
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<td>18.5</td>
<td>78</td>
<td>56</td>
<td>42</td>
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It was found that as long as the cartoned or bottled dairy products were stored in these cabinets in only one tier the temperatures usually were satisfactory.

At a point four inches above the floor of the cabinets an average temperature of 40.2°F was found, while at a point eight inches above the floor an average temperature of 42.1°F existed. At a point one and one-half inches below the top of the front side an average temperature of 55.5°F occurred. Cabinets G-1 and G-2 with apparently normal air movement and refrigeration showed temperatures which were satisfactory at four and eight inches above the floor, while the temperatures one and one-half inches below the top were very poor. For example, when the room temperature was 75°F the cabinet temperature at that point was 63°F; when the room temperature was 86°F the temperature at that point was 78°F. One can well understand the unsatisfactory condition of dairy products likely to be encountered in such cabinets, or other cabinets when they are overloaded.

In certain supermarkets where the sale of dairy products is large in proportion to the cabinet facilities available, a great tendency exists to overload the display cabinets. In such instances some of the products are subjected to unsatisfactory refrigeration.

**SUMMARY**

A knowledge of the rates at which bottled milk rises or drops in temperature under various conditions is important to plant personnel as well as to all others who are concerned with handling milk. It is essential that milk be properly cooled before being packaged and placed in the cold milk storage room since the temperature of the cold milk storage room may require several hours to affect the temperature of the packaged milk to any great extent. It was found that glass bottled milk reacts more rapidly to the cooling effects of the storage room temperatures than does paper cartoned milk. On the other hand the type of case, wood or wire, made little difference in the warming effects on glass bottled milk. In this series of tests the temperatures of the milk in the two types of cases was never over 3°F apart during a seven hour warming period. There was, however, a slightly greater difference between the temperatures of paper cartoned milk when tested in these same types of cases.

A limited survey of open display cabinets showed that in some instances the milk was subjected to excessively high temperatures while being merchandised. This was especially true if the cases were overloaded.

**ACKNOWLEDGEMENT**

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