PRESENT PROBLEMS IN HIGH-HEAT PASTEURIZATION PROCESSES[1]

Harold B. Robinson

Milk and Food Program, Public Health Service

U. S. Department of Health, Education, and Welfare

Washington, D. C.

Pasteurization of milk on a commercial scale originated in the early part of this century as a continuous flow process in which milk was brought to pasteurization temperature during passage through heating equipment and then promptly cooled. The process was introduced primarily as a means of enhancing the keeping quality of milk and, for the most part, was rejected as a public health measure because of insufficient information on the thermal destruction of pathogenic microorganisms in the temperature ranges of the process and because no controls were available which would assure a continuous and consistent process temperature. Consequently, as the public health benefits of pasteurization were recognized, early emphasis was placed on holding methods of pasteurization which could be based on the observed thermal death times of pathogens and which were readily controllable by manual means.

The desire of the dairy industry for faster, more efficient, and less space-consuming equipment for pasteurizing milk was met in part during the early 1930's with the development and acceptance of high-temperature short-time pasteurization at 160°F. for 15 seconds (now 161°F. for 15 seconds). Acceptance was predicated on an increased knowledge of thermal destruction characteristics of milkborne pathogens, on technological advances in the design of control instruments and processing equipment, and on plant level studies on destruction of *Mycobacterium tuberculosis*. Controls had been designed which would maintain product temperature within rather narrow limits and which could be interlocked with a pump which would stop operating if the temperature should drop below the point at which the control was set. In addition, pumps had been developed which were acceptable under contemporary standards of sanitary construction and which would deliver milk at a reasonably uniform rate so that a holding time could be provided under flow conditions. The HTST method of pasteurization has gained wide acceptance, has been subject to much improvement insofar as equipment and controls are concerned, and is the method employed for most of the milk now pasteurized in the United States.

The pasteurization processes which are now emerging employ higher temperatures than the 161°F. specified for the HTST method and employ holding times of the order of only one second. Advocates of these higher heat processes claim numerous advantages, including better kill of the natural milk flora, better product keeping quality, and improvement of flavor. They also state that these processes require less space within the plant.

Problems associated with the acceptance of these processes for pasteurization by health officials, for the most part, are the same as those which had to be resolved for both the 30-minute holding and high-temperature short-time methods. They vary substantially, however, in range and degree. In essence, the problems are: (*a*) establishment of an operating standard of time and temperature for effective pasteurization in the high heat range; (*b*) development of specifications for equipment and controls which will assure conformance with the standard during all phases of operation and under conditions of credible failure; and (*c*) assessment of the processes and equipment for side effects which might be deleterious to the product or to the public health.

The Operating Standard

The Public Health Service has not as yet included in its recommended sanitation ordinances and codes for milk, milk products, and frozen desserts, (*12*, *13*, *14*) temperature standards for pasteurization with holding times of the order of one second. Current standards for pasteurization are 145°F.[2] for 30 minutes or 161°F. for 15 seconds for milk, and 155°F. for 30 minutes and 175°F. for 25 seconds for frozen desserts. The higher temperatures prescribed for frozen desserts are in recognition of the protective action of higher solids in the destruction of bacteria by heat. Both definitions include a proviso that nothing contained in the definition shall be construed as barring

[1]Presented at the 46th Annual Meeting of the *International Association of Milk and Food Sanitarians, Inc.*, Glenwood Springs, Colorado, August 25-28, 1959.

[2]The cited temperature of 145°F. for 30-minute pasteruization by the vat method is in accordance with a memorandum to State and Territorial milk control authorities and others concerned, dated July 16, 1956, from Dr. Otis L. Anderson, Chief, Bureau of State Services, Public Health Service, U. S. Department of Health, Education, and Welfare, a copy of which appears in the third printing of the *Milk Ordinance and Code—1953 Recommendations of the Public Health Service.*

any other process which has been demonstrated to be equally efficient and which is approved by the State health authority.

Accordingly, the definitions do not preclude processes using higher temperatures and shorter holding times.

In the past the Public Health Service has, in response to requests from States, expressed opinions concerning the adequacy of specific pasteurization processes. One such process appeared to be satisfactory when operating with appropriate controls at 194°F. In this process the time during which the product remains at 194°F. is not affected significantly by operating variables; therefore, no time requirement was stated. In another case, an opinion was given that a process using 200°F. with a calculated hold of three seconds appeared to be adequate for the pasteurization of frozen desserts. These opinions were based on experimental data from studies with the equipment concerned and calculations therefrom.

In 1943 Ball (*1*) described a method for calculating equivalence of different time and temperature combinations for the destruction of microorganisms. To use the method one needs to know the slope of the thermal death curves of the organisms concerned and their position with reference to time and temperature required for the desired degree of bacterial destruction. The problem in the use of this method for computing pasteurization temperatures above 190°F. is the lack of information on the thermal destruction of pathogens in this range. Extensive extrapolation of low temperature range data does not appear to be justifiable.

Another approach to the problem has been the use of test organisms which are not completely destroyed by conventional pasteurization. By measuring the degree of destruction at various temperatures it is possible to compute the equivalence of a proposed time-temperature combination with accepted pasteurization standards. Studies by this method (*2, 6, 9, 10, 11*) have, by and large, indicated that temperatures of 192°F.-194°F. for one second provide the same degree of kill of the test organism (MS102, an unidentified micrococcus was used in most of the studies) in ice cream mix as does pasteurization at 155°F. for 30 minutes. This method is subject to the limitation that the test organism may have a different slope from milkborne pathogens. However, a study by Read, Hankinson, and Litsky (*5*) of the thermal destruction characteristics of *Escherichia coli* and several pathogens of significance showed that these organisms were destroyed in milk at temperatures below 175°F. with a holding time of 0.05 second and a heating time above 135°F. of 0.25 second. In addition, some investigators have used the slope of the thermal destruction curve for *M. tuberculosis*, as determined from studies in lower temperature ranges, to compute pasteurization equivalents in the 190°F. range (*5, 9*).

In presenting their data, some investigators have calculated the lethality of the heat-up period in terms of holding time at the terminal temperature. Others have not done so, limiting their reporting to observations at various temperatures with a given piece of equipment. This is a very significant point in interpreting results and in establishing an operating standard for pasteurization. Lethality during heat-up in 30-minute holding pasteurization is insignificant in relation to that provided during the holding period. At temperatures around 190°F., however, lethality during heating may exceed considerably that provided during the short ensuing holding period. Obviously, the amount of lethality during heating will vary inversely with the time required to bring the product to pasteurizing temperature, and it would follow that for equivalent results, slower heating processes would require lower terminal temperatures. Conceivably, each type and size of pasteurization equipment may have its own precise point of equivalence with pasteurization by accepted methods.

Traditionally, pasteurization standards have been expressed in terms of a single temperature for a specified time interval. The data referenced above would support such a standard for pasteurization of frozen dessert mixes. A temperature of 192-194°F. for holding times of the order of one second would appear to provide an adequate basic standard for pasteurization of frozen dessert mixes with present types of equipment. More information is needed, however, to define a similar standard for milk if a lower temperature is needed and to establish the extent of the safety factor inherent in such a standard.

INSTRUMENTATION AND CONTROLS

A basic standard of the type mentioned above would be valid as an operating standard only if it incorporated a sufficient margin of safety to compensate for the limitations of commercial controls and equipment. In 1927, Frank *et al.* (*4*) pointed out the need to consider every particle of product in standards for pasteurization and to include the term "every particle" in definitions of the process. Therefore, unless equipment and controls are available which will prevent the forward flow of any subtemperature milk, the standard must be adjusted to compensate for the limitations of equipment and controls that are available. It then becomes necessary to determine whether available controls and equipment will prevent milk from going forward at a temperature below that needed for effective pasteurization, and to prescribe the adjustments in the standard if such are necessary.

The type of control instrumentation for the new high-heat treatments is substantially the same as that required for HTST pasteurization. The essential differences in instrumentation requirements from those described in the *Milk Ordinance and Code* recommended by the Public Health Service and in the 3-A Accepted Practices covering HTST equipment (*8*) are with respect to speed of response of the control instrument and the temperature range in which it must operate and maintain accuracy. The temperature controls consist of a thermostatic device to control product temperature and a flow-stop to stop or divert the forward flow of product if minimum temperature is not maintained. The instrument lag and speed of valve response specifications of the *Milk Ordinance and Code* are predicated on needs associated with conventional HTST pasteurization. Weber (*15*) analyzed the limitations of the temperature control on such systems and estimated that, under extreme conditions of equipment failure, milk as much as 1.75°F. less than the set point of the controller might pass the flow diversion valve before the valve diverted. He felt, however, that this drop was well within the safety factor of the HTST standard. The potential temperature drop of milk that can pass the flow diversion valve under adverse conditions in these new processes is readily computable if the following are known: (*a*) the thermometric lag of the control instrument; (*b*) the response time of the flow diversion valve; (*c*) the distance between the sensing bulb and the flow diversion valve; (*d*) the rate of product flow in feet per second; and (*e*) the maximum rate of product temperature drop in the pasteurization equipment. With this information one can compute the length of time that milk will continue to flow past the flow diversion valve after milk below required temperature has contacted the sensing bulb. This time multiplied by the rate of temperature drop permits calculation of the lowest temperature of milk that will pass the flow diversion valve.

To illustrate the above point, a unit is assumed having the following characteristics: (*a*) the lag of the controller is five seconds; (*b*) the response time of the flow diversion valve is one second; (*c*) the sensing bulb is located 18 inches upstream from the flow diversion valve; (*d*) the flow rate through the tube between the sensing bulb and the flow diversion valve is 1½ feet or 18 inches per second; and (*e*) the maximum rate of product temperature drop has been determined as one degree per second. Under these conditions milk would flow for five seconds past the sensing bulb before the temperature change was registered, and for an additional second before the flow diversion valve could pass from the forward flow to the diverted flow position. The sensing bulb is, however, one second flow time upstream from the valve, which would leave a net of five seconds flow of subtemperature milk past the flow diversion valve. The rate of temperature drop has been assumed as 1° per second, and, assuming linearity of temperature drop, milk entering the valve at the time of diversion would be 5 times 1.0, or 5.0° below the set point.

This, of course, is a hypothetical example and there are measures that can and are being taken to reduce the differential between the set point and the temperature of milk or milk product that may go forward. In practice, instruments and valves are being provided with shorter lags than those currently specified in the *Milk Ordinance and Code*. Also, the flow time between the sensing bulb and the valve can be varied to more nearly approximate the lag of the controller and valve. The purpose of this example has been to illustrate that a significant differential can exist and the reason why it is necessary to consider the time of instrument and valve response in the derivation of time and temperature requirements for these new pasteurization processes. It is significant that process deviations of time and temperature which might be considered inconsequential where a 15-second hold is concerned become highly significant when rapid heating and only a one-second hold is provided.

As mentioned above, faster instruments are now being provided for use with the high-heat process (studies on one unit (*3*) showed a drop of only 0.35° F. below set point at the time of diversion) and supplemental controls are available which provide further safeguards against forward flow of subtemperature milk. Some installations employ a pressure switch on the steam supply which renders the unit inoperative whenever the steam pressure falls below that required for proper operation. Thus, the technical know-how is available to provide adequate controls for pasteurization in the higher temperature ranges. The problem is to reduce the variables to simple terms that are easily understood and applied, and to agree upon standard specifications for instruments and equipment which may be incorporated into an operating standard.

ASSESSMENT OF SIDE EFFECTS OF NEW PASTEURIZATION PROCESSES

Shift in pasteurization temperatures to higher ranges may well be attended by differences in the degree of change in other characteristics of the product. Also, the means of heating may introduce new variables requiring public health control. It is proposed to discuss here one such change, namely, the use of direct steam introduction for product heating.

During the past few years, there has been a marked increase in the use of equipment which employs direct steam for product heating. By and large, this use of steam has been in connection with vacuum flavor control devices which bring about a removal of volatile flavor components. However, some pasteurizers depend on direct steam introduction to bring the product to pasteurization temperature. Whether the intended use is flavor control or pasteurization is not significant insofar as the problem to be discussed is concerned.

When introduced into the product, some steam will be condensed and unless removed in equal volume by vacuum, a diluted and, in the case of milk, adulterated product will result. If there were no heat loss from the system and only pure steam was introduced, removal by vacuum of the same amount of heat as was added by the steam would provide an undiluted product. However, heat loss from the equipment and, perhaps, entrained water droplets in steam require a temperature drop in the final vacuum chamber somewhat greater than the temperature rise resulting from introduction of steam, if dilution is to be avoided. In most cases, the temperature differential between incoming and outgoing milk is around 8 or 10°F., but will vary with the size of the units and other factors. Therefore, the differential needed to maintain an undiluted product should be established for each installation by comparison of the solids content of incoming and outgoing product. Automatic controls are available which will maintain a preset temperature differential.

Steam in contact with milk and milk products also poses another problem. Theoretically, steam is H_2O in the vapor phase. Practically, steam may be this vapor plus water droplets and other substances. The other substances may include scale and rust particles, obviously undesirable, and chemicals used in boiler water treatment. None of these "other substances" should be present in steam which is introduced into milk and milk products. Keeping them out breaks down to proper installation, operation, and maintenance of steam equipment and proper selection of boiler water and chemicals used for its treatment.

Requirements for process steam have been discussed by Thomsen (*7*), and there is in preparation a report by a committee of the National Association of Dairy Equipment Manufacturers which will set forth guidelines for production of culinary steam. Essential points insofar as installation and operation are concerned are: (*a*) observance of boiler manufacturer's directions with respect to water level and blowdown; (*b*) provision of sufficient radiation line to remove superheat from steam; (*c*) provision of sufficient strainers, purifiers and traps to remove detritus and condensed moisture prior to introduction of steam into processing equipment; and (*d*) selection of suitable feed water which is, or is so treated as to be, free of organic materials which may cause foaming and priming in the boiler with resultant carryover into the steam distribution system.

There are a number of different chemicals that are commonly employed in boiler water treatment. These include sodium triphosphate, sodium hexametaphosphate, sodium hydroxide, sodium sulfite, sodium silicate, sodium aluminate, and sodium alginate, all of which are nonvolatile. Accordingly, there would be no objection to these compounds when they are properly used and the boiler is properly operated. Tannin is also frequently added to boiler water to facilitate sludge removal during boiler blowdown. This product, while essentially nonvolatile, has been reported to give rise to odor problems, and for this reason should be used with caution.

The above compounds are used to prevent corrosion and scale in boilers or to facilitate removal of sludge. There are other compounds, namely, cyclohexylamine, morpholine, and octadecylamine, which are volatile and which are used to prevent corrosion in condensate return lines. Cyclohexylamine and morpholine are not regarded as hazardous in concentrations of less than 10 p.p.m. in steam used in direct contact with foods other than milk. However, because of the importance of milk in the diets of infants and children, these compounds should not be added to boiler feed waters when the steam is introduced into milk. The use of octadecylamine in steam contacting food of any type has not been sanctioned by the Food and Drug Administration, and any approval in the future depends upon the presentation of proper application and information under the new food additives amendment of the Federal Food, Drug, and Cosmetic Act.

Introduction of steam into milk and milk products for heating and for flavor control poses a new problem in the sanitary control of these products. The problem is not insurmountable, but requires recognition and attention by both plant personnel and sanitarians. Careful selection of boiler water treatment compounds and periodic analysis of condensate samples is recommended.

SUMMARY

In summary, the present problems in pasteurization of milk and milk products at temperatures above 190°F. with holding times of the order of one second are: (*a*) a need for further research on the thermal

destruction of significant microorganisms in this temperature range to define the limits of safety inherent in the process; (*b*) a need for development of specifications for equipment and controls which will assure proper pasteurization under all conditions of operation, including those resulting from abrupt failure of primary heat and power; and (*c*) recognition and control of related problems such as those presented by use of direct steam heating.

The greatest need appears to be one of bringing together available information and deriving therefrom standards for the design, construction and operation of these pasteurizers and procedures for sanitary control by official agencies.

REFERENCES

1. Ball, Olin C. Short-time Pasteurization of Milk. Industrial and Engineering Chemistry, **35**: 71-84. 1943.

2. Barber, F. W. and Hodes, H. P. Bacterial Studies of the High-Temperature Short-Time Pasteurization of Ice Cream Mix. (Abstract) J. Dairy Science, **33**: 402. 1950.

3. Barber, F. W. Personal Communication.

4. Frank, L. C., Moss, F. J., and LeFevre, P. E. Definitions of Pasteurization and Their Enforcement. Public Health Reports, **42**: 1152-1162. 1927.

5. Read, R. B., Norcross, N. L., Hankinson, D. J., and Litsky, Warren. Come-up Time Method of Milk Pasteurization. III Bacteriological Studies. J. Dairy Science, **40**: 28-36. 1957.

6. Speck, M. I., Grosche, C. A., Lucas, H. L., Jr., and Hankin, L. Bacteriological Studies on High-Temperature Short-Time Pasteurization of Ice Cream Mix. J. Dairy Science, **37**: 37-44. 1954.

7. Thomsen, L. C. Production of Quality Process Steam. J. Dairy Science, **42**: 1241-1245. 1959.

8. 3-A Accepted Practices for the Sanitary Construction, Installation, Testing and Operation of High-Temperature Short-Time Pasteurizers. International Association of Milk and Food Sanitarians, Shelbyville, Indiana.

9. Tobias, Jos., Kaufmann, O. W., and Tracy, P. H. Pasteurization Equivalents of High-Temperature Short-Time Heating with Ice Cream Mix. J. Dairy Science, **38**: 959-968. 1955.

10. Tracy, P. H., Pedrick, R., and Lingle, H. C. Pasteurization Efficiency of the Vacreator When Used on Ice Cream Mix. J. Dairy Science, **33**: 820-32. 1950.

11. Tracy, P. H., Tobias, J., and Herreid, O. E. Application of the Vacreator and Mallorizer for High-Temperature Short-Time Heating of Ice Cream Mix. Ice Cream Trade J., **47**: 76. 1951.

12. U. S. Department of Health, Education, and Welfare, Public Health Service: Milk Ordinance and Code — 1953 Recommendations of the Public Health Service (Third Printing).

13. Ibid. Frozen Desserts Ordinance and Code — Recommended by the U. S. Public Health Service, May 1940 Edition (Reprinted March 1958).

14. Ibid. Grade A Dry Milk Products — A Recommended Sanitation Ordinance and Code for Dry Milk Products Used in Grade A Pasteurized Milk Products. Supplement 1 to the Milk Ordinance and Code — 1953 Recommendations of the Public Health Service (1959 Edition).

15. Weber, C. W. Safety Factors of HTST Pasteurizers. J. Milk and Food Technol., **10**: 14-25. 1947.