PROBLEMS ASSOCIATED WITH THE EVALUATION OF ULTRA-HIGH-TEMPERATURE PROCESSES FOR THE PASTEURIZATION OF MILK AND MILK PRODUCTS[1]

R. B. READ, JR.

Milk and Food Research,
Robert A. Taft Sanitary Engineering Center,
U. S. Public Health Service, Cincinnati, Ohio

Several developments in the dairy industry have created interest in thermal processes that permit greater lethality to bacteria than conventional pasteurization processes, yet minimize deleterious chemical changes in the milk being processed. The shelf life of milk has been of concern to processors for many years; in fact, the heating of milk to prevent its souring before it reaches the consumer was carried out secretly by dairies prior to the general acceptance of pasteurization. Accordingly, a heating process, or what is today a pasteurization process, has been recognized for many years as being of economic importance to the processor because, in addition to its public health function of inactivating pathogenic microorganisms that may be present in the raw milk supply, it increases the shelf life of the product.

With the pasteurization of cream-line milk, significant increases in either time or temperature over the legal pasteurization standard could not be used successfully because of impairment of cream line. The development and wide acceptance of homogenized milk led to rapid deemphasis of cream line, permitting pasteurization above the temperatures required for public health reasons. With the consolidation of dairy plants in the United States and the attendant increase in distances required for distribution of the pasteurized product, processors have generally increased the temperature for pasteurizing homogenized milk above the minimum legal standard to gain a greater bacterial kill as well as other desirable chemical changes and, by doing this, to increase the shelf life of the product. With the vat and high-temperature short-time process, the upper limit of temperatures and/or times that can be used is governed by the production of off-flavors caused by overheating the product. Research on pasteurization times and temperatures has shown that bacteria are more sensitive to relatively high temperatures for times of a few seconds or less than are the chemical changes that produce an objectionable heated flavor in milk. Accordingly, interest has arisen in the pasteurization of milk by processes that use relatively high temperatures for short periods of time. These processes have been given the general label of ultra-high-temperature (UHT) pasteurization. Although many definitions have been suggested for UHT pasteurization, only processes involving final heating temperatures from 190° to 270°F with holding times shorter than 2 seconds should be considered UHT processes. The upper limit of 270°F was selected because, in general, thermal processes for milk involving final heating temperatures higher than 270°F are designed not to pasteurize but to sterilize.

Although many time-temperature combinations in the UHT range of pasteurization are unquestionably as effective from a public health standpoint as the time-temperature combinations used for existing pasteurization processes, a few problems must be solved before UHT processes can be generally accepted. Pasteurization at 194 F in the Vacreator, although a UHT process, will be excepted from consideration because standards have been set for pasteurization with this equipment.

Several general types of equipment are available to the dairy industry for operation in the UHT range. Of these, most interest appears to be centered on plate heat exchange similar to that used for high-temperature short-time pasteurization (HTST) and on steam injection. The problems associated with the evaluation of these two processes are somewhat different and for this reason will be discussed separately.

PROBLEMS ASSOCIATED WITH THE EVALUATION OF UHT PASTEURIZATION BY PLATE HEAT EXCHANGE

In plate-type pasteurizers operated in the UHT range of times and temperatures, evaluation problems include *(a)* selection of a time-temperature combination or combinations for UHT pasteurization, *(b)* development of a control system so that the lag time in the flow-diversion valve, temperature-sensing element and controller combined is not greater than the holding time of the process, *(c)* determination of the effect that flow conditions at the holding tube entrance have on holding time, and *(d)* development of suitable procedures for determining the response speed of the flow-diversion valve and controller in the field.

[1]Presented at the annual meeting of the INTERNATIONAL ASSOCIATION OF MILK, FOOD AND ENVIROMENTAL SANITARIANS, INC., October 22-25, 1963, Toronto, Canada.

Time-temperature combinations for UHT

Pasteurization is practiced, at least in part, to ensure that viable pathogenic microorganisms in dairy products will not reach the consumer. Accordingly, when new processes are proposed one of the first considerations must be of time-temperature combinations that will satisfy public health requirements. When the data on thermal inactivation of bacteria, rickettsiae, viruses, and molds, are reviewed, it is apparent that virtually no data exist on thermal inactivation with heating times shorter than 2 seconds.

When standards of time and temperature for UHT are considered, it appears that two approaches are possible. The first would be to wait until satisfactory data are available and then designate time-temperature combinations. This is objectionable since it is believed that a number of years will elapse before thermal inactivation data are available for the majority of the pathogenic microorganisms that may be in milk. The second approach is to extrapolate the existing data and add a wide margin of safety so that it would be inconceivable for any microorganism to be inactivated by an existing process and to survive the new process. This approach has the advantage of temporarily circumventing the "data hurdle", but may be disadvantageous to some processors in that the selected time-temperature combinations cannot be applied to all products because of product damage from high heat processing. Also implicit in the latter approach would be a continuing reappraisal of the time-temperature combinations for UHT pasteurization as more data on the thermal inactivation of microorganisms become available.

Review and extrapolation of existing data indicate that a time-temperature combination selected from the semi-logarithmic extrapolation of the existing time-temperature combinations for ice cream mix (155 F, 30 min; 175 F, 25 sec) appear to meet the criteria for the second approach to the data problem for processes involving plate-type heat exchangers. An infinite number of times and temperatures can be selected in this way, but this is undesirable since a large number of time-temperature combinations for UHT would cause confusion in the field. Two combinations of time and temperature for UHT pasteurization extrapolated from the combinations for ice cream mix (155 F, 30 min; 175 F, 25 sec) are 191 F for 1-second hold and 201 F for a 0.1-second hold. Interest has been expressed in a temperature standard for a 3-second process. If the foregoing criteria are used, a holding temperature of 185 F is indicated for a 3-second holding time. These combinations of time and temperature would be applicable to all products (milk, chocolate milk and drink, skim milk, cream, and ice cream mix) pasteurized in plate-type heat exchangers. Sufficient data may, however, prove that these combinations of times and temperatures are more severe than necessary for public health reasons. Available data on heated flavor in milk indicate that no serious problems should be experienced by UHT processors.

It has been suggested that the extrapolated line formed on semi-logarithmic paper by connecting the existing time-temperature combinations for milk (145 F, 30 min; 161 F, 15 sec) be used to determine the UHT time-temperature combinations for milk pasteurization. This line has a "slope" (z value) of 7.7 F, however, vegetative cells of bacteria have been shown to have higher z values than 7.7 F. As a result, the existing milk pasteurization times and temperatures cannot be extrapolated into the UHT pasteurization range and used for time temperature combinations for these processes.

Control response time

In a plate heat exchanger pasteurization process, the total response time of the flow diversion valve and its controller cannot exceed the holding time of the process. For example, for a process with a holding time of 1 second and with the temperature-sensing element of the flow diversion valve located at the inlet of the holding tube, the flow diversion valve and its controller must react in a total time of 1 second or less to prevent the forward flow of underheated milk. For modern instrumentation, a 1-second response time should not be difficult to meet; however, no commercial controller and flow-diversion-valve system designed for milk and milk products is known that has a response time of 1 second or less. If the system has a faster response time than the holding time of the process, a time delay relay will have to be used to prevent the flow diversion valve from going from the diverted to the forward flow position until the product passing through the valve is adequately pasteurized.

Timing the holding tube

For processes with holding times of a minimum of 3 seconds, it is believed that the existing techniques of timing the holding tube can be used if the timing device is modern and has an integral timer. With holding times of 1 second or less, attempting to measure holding times in the field appears impractical because of the limitations of existing instrumentation for this purpose. Accordingly, for the shorter holding times, holding tube lengths must be calculated. If industry practice in regard to sizing holding tubes for the various HTST heat exchanger capacities is continued, the approximate length of the holding tube for the typical plate heat exchanger will be 8 inches for each second of holding time. Actual conditions for an individual heat exchanger can produce large variations from this generalization.

For a 1-second holding time, the length of the holding tube will be extremely short and, from a practical standpoint, probably will be the length of tube required to go from the bottom part of a terminal block to a flow diversion valve connected to the top part of the same terminal block. With such a short holding tube, perturbations in flow caused by an elbow or reducer at the inlet of the holding tube can produce significant alterations in flow conditions and, from this, changes in holding time. With entrance perturbations, the residence time of the fastest particle may be less than a calculated value; in fact, the residence time may be less than a measured value if the timing probes are located at the center of the holding tube.

PROBLEMS ASSOCIATED WITH THE EVALUATION OF UHT PASTEURIZATION BY STEAM INJECTION

As with UHT pasteurization by plate heat exchange, steam injection can be used to produce a satisfactory pasteurization process. Most designs for steam injection include a plate heat exchanger for preheating the product and possibly for regeneration purposes, plus a steam injector, holding tube, and vacuum chamber(s) for removing the water injected as steam and for cooling the product. The vacuum chambers are usually followed by a plate cooler to complete the cooling of the pasteurized product. Before this process can be universally accepted, several problems must be resolved. One of the first is to establish the general sequence of types of equipment that will be used for the process. Once the process is identified in terms of sequence of general types of equipment and procedures for processing milk and milk products, then the public health significance of each of the steps used in the process can be more specifically evaluated. At this time some general problems can be identified that pertain to most of the equipment proposed for UHT pasteurization by steam injection. Some of these are *(a)* satisfactory controls for the flow diversion valve or flow stop used in the process, *(b)* determination of mixing length after steam injection, *(c)* prevention of vapor formation in the holding tube, *(d)* selection of proper controllers and location of sensing elements for these controllers, and *(e)* time-temperature standards for UHT by steam injection.

Controls for flow diversion or flow stop

The problems of flow diversion or flow stop controls with steam injection are somewhat similar to those of UHT by plate heat exchange except that with steam injection a more precipitous drop in temperature can be anticipated upon steam failure because of the difference in the mass of a steam injector and that of the heating section of a UHT plate heat exchanger. Response times have been determined by measuring time required for the controlling device to traverse 63% of a step change. With plate heat exchangers, step changes in temperature do not occur and the 63% requirement appears realistic for plate heat exchange processes. With steam injection, a step change in temperature can occur so that a controller and flow-diversion-valve system that meets the speed of response requirements of the testing procedure in current usage will not necessarily guarantee the prevention of forward flow of underheated products. Accordingly, response time requirements for the sensing-element controller, and flow-diversion-valve system used on steam injection equipment may have to be more rigorous than those similarly used in plate heat exchangers.

Mixing length

By definition, pasteurization is a process of heating every particle of milk or milk product to a given temperature and holding it at that temperature for a given time. To identify the holding time, the time required for every particle of milk or milk product to reach the holding temperature must be determined. To do this, the mixing length required by the various designs of steam injectors must be known for a range of operating conditions. Instrumentation is available to obtain these data, and studies are underway in at least one laboratory in this country.

Prevention of vapor formation in the holding tube

With holding temperatures over the boiling point of the product, the holding tube must be under pressure to prevent product vapor formation with partial displacement of the holding tube and a reduction in holding time. With these processes, the holding tube can be kept under pressure by a valve at the discharge end. Since the setting of this valve can affect flow rates in the holding tube, this represents another potential problem in controlling processes.

Selection of proper controller for UHT pasteurization by steam injection

The location of the steam-controller sensing bulb for the steam injection unit is of considerable importance in the satisfactory control of this process. The bulb must be located so that control of the process results with minimum oscillation of the setting of the steam inlet valve. Severe cycling of this valve will result in slugs of product heated to different temperatures and create severe mixing problems in order to give a uniform product temperature at the inlet of the holding tube. Vacuum chambers must be controlled to prevent dilution or extensive concentration of the product being processed, however, controls for vacuum chambers are in extensive use today in connection with HTST equipment and appear directly applicable to UHT by steam injection.

Time-temperature standards for UHT by steam injection

The major portion of lethality to microorganisms in the steam injection UHT process is in the holding period since heating and cooling are effected in extremely short periods of time. Accordingly, when UHT by steam injection and UHT by plate heat exchange are evaluated in terms of microbial lethality, these two processes, although running at the same holding temperatures and holding times, may give substantially different results. As discussed in the section on UHT by plate heat exchange, very few directly applicable data are available on thermal inactivation of microorganisms, and therefore, any standards that could be considered at this time must contain what appears to be wide margins of safety.

Before time-temperature standards can be considered for UHT by steam injection, data must be available on the times and temperatures experienced by a particle of milk or milk product as it passes through a UHT steam injection system. From these data, lethality to microorganisms can be calculated and compared with the data available on the thermal inactivation of microorganisms. Once this is done, a judgement can be made whether the proposed UHT processes by steam injection produce only marginal microbial inactivation or contain a wide degree of safety over requirements indicated by the extrapolation of existing microbial inactivation data. As with UHT by plate heat exchange, any tentative time-temperature combinations for pasteurization must be subject to revision when more data are available.

In summation, the problems associated with the evaluation of UHT pasteurization by either plate heat exchange or steam injection appear superable. Of the two types of processes, UHT pasteurization by plate heat exchange with measurable holding times has fewer problems associated with process evaluation and control. It is hoped that if the UHT pasteurization process is of value to the dairy industry the problems associated with the control and evaluation of these processes can be resolved in the near future so that recommendations can be made for UHT pasteurization of milk and milk products.

THE NEXT 50 YEARS WITH IAMFES[1]

K. G. WECKEL

Department of Dairy and Food Industries
University of Wisconsin, Madison

One of the most promising ways to chart the character, the make-up, the objectives and the achievements of IAMFES in the next 50 years is to take bearings on the history of the organization in the past 50 years, and plot a course. It must be presumed the objectives of the Association and its members will be similar to those already stipulated in the Constitution of the Association. It can be easily surmised, however, that the methods of achieving the objectives of the professional members and the Association may be radically changed in the next several decades.

The life and survival of any nation, history shows us, are inevitably tied to the burden of taxes, however derived, whether by internal assessment or in military defeat. It is no secret there is now in this country a tremendously heavy burden of taxes which citizens of the present and the future must carry. There are two aspects of taxes the professional sanitarian of the future must conjure with: the first is whether services rendered to the citizen are desired or essential, and the second is whether the basically essential services are being done at the very least possible cost. There will be forced consideration of these two aspects as the pressures for necessary services and budgetary funds increase with population pressures projected for the future. Problems of environmental sanitation are bound to increase in the future, and activities, services, procedures and methods now considered essential and effective will be considered unnecessary and ineffective and will be replaced.

It is probable the techniques of routine regular inspection of products and premises, parts and pieces will give way to a system of surveillance through statistical sampling and monitoring equipment useful in providing information of a broad nature rather than about minutiae.

The concept of aesthetic evaluation plays an important though imponderable part in present day routine sanitation inspection work. The understanding of the profit effectiveness of aesthetic sanitation in modern food production of the future probably

[1]Presented at the 50th Annual Meeting of the INTERNATIONAL ASSOCIATION OF MILK AND FOOD SANITARIANS, INC., October 22-25, 1963 at Toronto, Canada.