BACTERICIDAL ASPECTS OF HIGH TEMPERATURE PASTEURIZATION OF ICE CREAM MIX[1]

MARVIN L. SPECK
Department of Food Science and Processing
N. C. State College, Raleigh

The primary purpose of a pasteurization process is to add assurance that a food is free from pathogenic microorganisms. Although opportunities may exist for contamination of the product after pasteurization, it is much more difficult to control the microbiological flora of the raw product. The varied possibilities for contamination of the raw product have made pasteurization processes essential. As one examines the development of pasteurization procedures, it becomes obvious that the basic concepts used in establishing requirements for milk pasteurization have also been involved in the standards established for ice cream mix. Since *M. tuberculosis* was found to be the most heat resistant pathogen likely to be carried by raw milk, the destruction of this microorganism has been most important in the development of official pasteurization standards. North and Park *(8)* found the following exposures sufficient to destroy *M. tuberculosis* in milk: 140°F for 10 min; 142°F for 10 min; 145°F for 6 min; 150°F for 2 min; and 160°F for 20 (or less) sec. They concluded that 142°F for a 30 min holding period was quite ample for the destruction of *M. tuberculosis* in milk.

The limitations on pasteurization treatments have been governed somewhat by economic considerations. Dahlberg *(1)* presented data showing the relationship between heat treatments necessary to destroy *M. tuberculosis* and those which caused impairment of cream volume; this latter property was considered to be of prime economic importance by milk processors. Cream volume impairment began at 142°F for 53 min, 145°F for 24 min, and 160°F for 20 sec. Thus, the treatment necessary for destruction of pathogens did not endanger cream volume particularly at lower temperatures. It was noted, however, that a comfortable time margin did not exist between these two conditions at 160°F.

We see, therefore, that milk pasteurization standards have been somewhat the result of a compromise between conditions required for bacterial destruction and those which could impair certain properties of milk. In more recent years, however, two other factors have had an effect on pasteurization standards for milk. One has been the homogenization of pasteurized milk which has reduced the economic value of cream volume (as has also the use of opaque packages). The second factor has been the discovery that *Coxiella burnetti*, the cause of Q fever, is a microorganism possessing heat-resistance somewhat in excess of *M. tuberculosis*. As a result of extensive research, the low temperature, holding (LTH) method of pasteurization standard has been raised to 145°F for 30 min; whereas, the high-temperature, short-time (HTST) standard of 161°F for 15 sec was found to be adequate. In raising the LTH temperature to 145°F little or no opposition was voiced from industry since cream line no longer is considered to be of importance.

The pasteurization of ice cream mix has the same main purpose as the pasteurization of milk, viz., the destruction of any pathogens which might be present in the product. Oldenbusch *et al. (10)* reported that *M. tuberculosis* in ice cream mix was destroyed at 145°F in 6 min. Other pathogens were destroyed by less heating. Official action was then given to recognize 143°F for 30 min as adequate pasteurization for ice cream mix. However, Fabian and Coulter *(2)* found that a 30-min hold at 155°F seemed necessary to free ice cream mix from coliform bacteria. Myers and Sorensen *(8)* studied this problem carefully using a heat-resistant strain of *E. coli*. They found 150°F for 30 min to be adequate, but recommended 155°F for 30 min as a margin of safety to insure destruction of *E. coli* in ice cream mix. This recommendation appeared to be consistent with heat treatments which would give mix the properties of good whipping and quicker freezing.

In view of these considerations, a pasteurization standard of 155°F for 30 min was reasonable from the processing standpoint, and it was much more than adequate for the destruction of pathogenic bacteria. The first Frozen Desserts Ordinance and Code recommended by the U. S. Public Health Service, therefore, suggested the pasteurization standard of 155°F for 30 min, although it did provide also "that nothing in this definition shall be construed as disbarring any other process which has been demonstrated to be equally as efficient". During the past 20 years, studies have been designed to ascertain other processes which are "equally as efficient" as 155°F for 30 min.

The experimental work involved in determining equivalent pasteurization exposures for ice cream

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mix posed certain problems which should be considered. The first decision concerned the most appropriate test cultures which could be used. The use of pathogens appeared unwise for several reasons: *(a)* the difficulty in determining what constituted typical heat resistance among cultures of *M. tuberculosis; (b)* the use of pathogens in plant experiments seemed to be an unnecessary hazard; and *(c)* since 155°F for 30 min was a far greater heat treatment than necessary to kill the most heat resistant pathogen, it would not be possible to determine equivalent heat treatments by the use of pathogens.

Consequently, the search for suitable non-pathogenic test-cultures was begun. A culture giving 100% kill at 155°F for 30 min did not seem most appropriate since, even if such a culture were found, it would be difficult to measure accurately the exact time giving complete kill. As a result, attention was turned to the use of cultures which would survive the standard pasteurization treatment in reasonable numbers. Then, various experimental time and temperature combinations could be determined which would give the same percent kill as the standard treatment. Various bacteria, usually micrococci, fulfill these requirements and have been used extensively in establishing HTST pasteurization treatments.

Another important aspect of ice cream mix pasteurization concerns the constituents in ice cream mix which are not present in milk. Consideration should be directed toward the probable effect of these on heat resistance of bacteria contained in mix.

The content of milk fat in a medium has been shown to be of only minor importance in the heat resistance of contained microorganisms. Thus, Hening and Dahlberg *(5)* showed that 40% cream required only about 1°F more than did milk at a given holding time for the destruction of *E. coli.* Sanders and Sager *(11)* noted that 20% and 40% cream required a temperature only 0.7°F higher than milk for the inactivation of phosphatase. These and similar studies have given assurance that pasteurization standards for milk are adequate for pasteurization of cream.

Variations in protein content between milk and ice cream mix are not known to have any measurable effect on heat resistance of bacteria.

The sugar content of ice cream mix can be expected to have the greatest influence on increased heat resistance of bacteria. Fay *(3)* pointed out clearly the effects of various sugars in hypertonic solutions on heat resistance of bacteria and thermal inactivation of certain enzymes. Lactose content seemed to have no effect. However, sucrose and glucose markedly increased heat resistance of bacteria. Confirmatory evidence for these effects have been noted by Sanders and Sager *(11)* for phosphatase inactivation in various milk products, by Speck and Lucas *(14)* for pasteurization of chocolate milk, and by Grosche, Lucas and Speck *(4)* in the pasteurization requirements of 3: 1 condensed whole milk.

With the foregoing considerations in mind, let us consider briefly the results of some research that was designed to determine pasteurization exposures in the HTST range which would provide bactericidal activity equivalent to 155°F for 30 min. The work to be described was conducted in our laboratories and described in more detail in a previous publication. *(13).*

Mixes were used which were typical in composition of those used for ice milk, regular ice cream mix, and premium mixes. In order to obtain representative mixes, 6 were tested. An analysis of the data indicated that mix composition had no significant effect on bacterial destruction. In view of their similar content of sugar (14 - 17%), and the fact that the variations in fat (4-18%) should have no effect, these results were not unexpected.

Laboratory pasteurization studies were conducted using 2 heat-resistant non-sporeforming bacteria as test cultures, viz., *Micrococcus sp.* (no. MS 102) and *Microbacterium sp* (no. 342-S-1). These were exposed to temperatures of 175°, 180°, 185° and 190°F for varying periods of times. In each experiment a control was pasteurized at 155°F for 30 min. The data obtained indicated that bacterial destruction equivalent to 155°F for 30 min was obtained by the following:

Temperature	*Microbacterium sp.* (No. 342-S-1)	*Micrococcus sp.* (No. MS 102)
175°F	16.0 ± 0.3 sec.	19.9 ± 0.7 sec.
180°F	11.0 ± 0.2 sec.	11.4 ± 0.2 sec.
185°F	6.4 ± 0.05 sec.	7.1 ± 0.05 sec.
190°F	.25 ± 0.01 sec.	0.94 ± 0.03 sec.

These data indicated only a slight difference in the resistance of the 2 cultures. The results showed that the tentative standard of 175°F for 25 sec, which had been permitted since 1948, is more than adequate.

In order to test the data obtained in the laboratory under practical operating conditions, some experiments were conducted with plant equipment. Mix was prepared containing the following: fat 12%; milk-solids-not-fat 10%; stabilizer 0.35%; and cane sugar 15%. The culture MS 102 was inoculated into the mix 10 min before pasteurization.

The first series of the plant experiments was performed with the Vacreator[2]. The mix was pasteur-

ized with first chamber temperatures of 185°F, 190°F, 195°F, 200°F, and 205°F. A control portion of the mix was pasteurized at 155°F for 30 min. By linear interpolation using logarithms of per cent survival it was determined that a first chamber temperature of 191.5°F would give destruction of the test culture equal to that of 155°F for 30 min. This temperature compared closely to the first chamber temperature of 194°F proposed by Tracy *et al. (15)* who also has been studying the Vacreator as a pasteurizer for ice cream mix. Furthermore, these workers calculated that the mix in the first chamber was held at the pasteurizing temperature for 0.75 sec. Assuming that the same holding time existed in our unit, the exposure of 191.5°F for 0.75 sec compared closely with the laboratory data where 190°F for 0.94 ± 0.03 sec was found to be equivalent to 155°F for 30 min.

In a second series of plant experiments inoculated mix, as used for the Vacreator, was pasteurized by a Stevac[3] pasteurizer. The holding tube had been adjusted to give a holding time of 25 sec. Then the mix was pasteurized for the 25-sec holding time at 165°, 170°, 175°, 180°, 185° and 190°F. A portion of the mix was pasteurized at 155°F for 30 min to serve as a control. The equivalent Stevac temperature was calculated as for the Vacreator. The experiments showed that a temperature of 172.2 ± 0.48°F for 25 sec was equivalent to 155°F for 30 min. These data agreed well with the laboratory phase where 175°F for 21.2 sec was found equivalent to 155°F for 30 min. Furthermore, this gave evidence for the adequacy of the tentatively approved standard of 175°F for 25 sec.

With this information available, the U. S. Public Health Service recommended approval of two new pasteurization treatments for ice cream mix. The tentative aspect of 175°F - 25 sec was removed and this exposure was fully approved; also approved was a first chamber temperature of 194°F in the Vacreator. It should be noted that both of these standards are above the heat treatment required for equivalence to 155°F for 30 min. Substantiating evidence for the greater equivalence of these new standards was shown in the work of Tobias *et al. (16)*. These workers, using the Roswell heater to pasteurize ice cream mix, reported that bacterial destruction equivalent to 155°F for 30 min was obtained at 181.3°F in 3.8 sec at 187.2°F in 0.8 sec. Similar confirmatory work was reported by John *et al. (6)* who reported that a first chamber temperature of 194°F in the Vacreator was more bactericidal than 150°F for 30 min in the pasteurization of ice cream mix.

The safety of the new pasteurization exposures, as established by the use of test culture MS 102, should be considered. In ice cream mix, milk phosphatase is inactivated at 155°F in only 5 min *(11)*. The same exposure killed *M. freudenreichii* Ms 66 in ice cream mix *(12)*. Both the phosphatase and micrococcus are more heat resistant than the heat resistant pathogen, *M. tuberculosis*. Therefore, the pasteurization standard of 155°F for 30 min has at least a 6-fold margin of safety in time. Other pasteurization standards, which are equivalent in lethality to 155°F for 30 min have comparable margins of safety. Since the new standards (175°F - 25 sec. for HTST and 194°F for the Vacreator) exceed 155°F for 30 min in lethality, they *a priori* have more than the 6-fold margin of safety.

The safety of the new pasteurization standards can be examined from another approach. If a semi-logarithmic plot is made of equivalent pasteurization treatments, *viz.*, 155°F - 30 min (vat) 172.6°F - 25 sec (Ste-Vac) and 191.5°F - 0.75 sec (Vacreator), essentially a straight line is obtained. Time-temperature relationships represented by this graph are, therefore, equivalent to one another. This line has a z value of approximately 10.8. Kells and Lear *(7)* reported that 3 strains of *M. tuberculosis* var. *bovis* in milk had z values from 8.6 to 9.4. These values are much lower than the z value of 12.6 which had been calculated for *M. tuberculosis* in cream from earlier work that was not done with the precision permitted by modern techniques. There is, therefore, no evidence that the destruction of pathogens in ice cream mix would require time-temperature combinations above those represented by the line originating at 155°F for 30 min and having a z value of 10.8. Information presently available would indicate that this line represents the many possible combinations of time and temperature that would have adequate safety for the pasteurization of ice cream mix. As temperatures in the ultra-high range are selected, this graph can be extrapolated to determine the time required at such temperatures. It is indeed conceivable that the attainment of physico-chemical properties in the mix may demand heating at a temperature beyond the time required for the desired level of bacterial destruction in the UHT range. This, however, should not be the basis on which pasteurization standards would be adopted for public health purposes.

[2]Manufactured by the Cherry-Burrell Corp., Cedar Rapids, Iowa.

[3]Manufactured by the Chester-Jensen Co., Chester, Pa.

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ENVIRONMENTAL HEALTH—PAST, PRESENT AND FUTURE[1]

ROBERT J. ANDERSON[2]

Public Health Service, Bureau of State Services
U. S. Department of Health Education, and Welfare
Washington 25, D. C.

I recall old-timers referring to "the good old days." I am sure they were not reflecting so much on the hard work, long hours, horse and buggy, and primitive tools of the yesteryears, but were harkening back to the leisurely pace, the wide open spaces, a less troubled life and lack of tensions. Today our environment seems not to permit this.

Man has always had to come to terms with his environment. Ancient medicine declared that Man was part of Nature; that a harmonious relationship to Nature produced health; and that disharmony produced disease.

Thus, the ancient Hebrews had a standing rule to the effect that a permanent threshing floor, a place for depositing carcasses, or a tannery should be set up a minimum of so many feet beyond the city wall —and to the East—presumably to guard the population from harmful dusts and offensive odors. The Egyptians recognized the need to drain swampland, burn refuse in big dumps, and filter water for drinking, in order to reduce the diseases prevalent at that time. Hippocrates, the Father of Medicine, wrote a book titled *Airs, Waters, and Places.* In it, he urged the physician to study the patient's background—climate, water supply, vegetation, and other matters—to get an idea of what may have affected the patient's condition. Some 500 years ago in England, in the reign of Edward the First, the first Sanitation Act was passed forbidding the pollution of rivers, ditches, and open spaces.

Beginning with the 17th century, and continuing through the 18th and 19th centuries, Man's inquiring and ingenious mind slowly but surely freed him from utter dependence upon, and subjection to, the raw forces of nature, and he became better equipped to deal with the problems of his environment. As the population grew, and industry increased in many countries, town and villages became crowded slum cities with devastating epidemics of communicable disease. Environmental health measures like water supply treatment, sewage treatment, heat processing and refrigeration of perishable foods, garbage and refuse collection, and insect and rodent control were started then. Also, at the end of the 19th century, bacteria were revealed, and provided a scientific basis for the control of communicable diseases to which most of our public health effort has been devoted during the past 50 years.

What about the environmental health problems of

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[2]Assistant Surgeon General, Deputy Chief, Bureau of State Services.