Lambasting Louis: Lessons from Pasteurization

JOSEPH H. HOTCHKISS
Cornell University
Ithaca, NY

Despite extensive lay, regulatory, political, and scientific discussions and reviews of recombinant DNA technology (*i.e.* biotechnology) and its application to food and agriculture, worldwide opposition remains. Human and environmental safety and socio-economic concerns have been discussed and debated in rational and scientific detail, yet opposition remains fervent. Is this opposition due, somehow, to the unique nature of biotechnology, or should it be expected with any new technology, especially when applied to food, agriculture, and the environment? Or is there a general distrust of new technologies that are not widely understood and for which there is little direct individual experience or for which the benefits seem obscure? If it is, at least in part, due to a general distrust of technology, how might we better plan for such debates? It may be useful to look back at past controversies.

Providing food has always been one of the major applications of basic science. It should not be surprising that one of the foremost applications of advances in biology has been food, along with medicine. One hundred and thirty-five years ago, Louis Pasteur and others were also making striking discoveries in basic biology leading to the field of microbiology. Major discoveries over the past three decades have, likewise, led to biotechnology. The application of Pasteur's discoveries to food and agriculture was controversial, just as the application of biotechnology is today.

LOUIS PASTEUR

Pasteur did not discover microorganisms. He made the immensely important observation that they were not a consequence of disease, decay, and putrefaction—as was the common scientific opinion at the time—but were, in fact, the causes of these problems, and that eliminating them could eliminate the problem. This knowledge led to revolutionary changes in medicine and food preservation, not the least of which was the understanding that relatively mild heating kills microorganisms and substantially improves the safety and quality of foods without destroying desirable nutritional and sensory characteristics. The process of heating perishable foods to make them safer and last longer while retaining nutritional and eating quality was, as we all know, named after Pasteur. As a good Frenchman, he applied his discovery to the preservation of that most important beverage: wine. According to McCulloch (1936), in order to "prove" the effectiveness of his process, Pasteur shipped a cargo of pasteurized wine around the world in 1868 on the French frigate, La Sybile, "without spoilage of a single bottle." Pasteur later applied his mild heating method to beer preservation, but there is no evidence that he applied it to milk.

It can be reasonably argued that pasteurization ranks, along with mass immunization and water purification, as among the most significant developments in public heath during the early twentieth century. Nevertheless, in spite of overwhelming evidence that pasteurization was beneficial, there was fervent opposition in the late nineteenth and early twentieth centuries. This opposition delayed widespread implementation for 30 years or more, and undoubtedly resulted in the unnecessary loss of thousands of lives (Pirtle, 1926). Opposition was so strong that some companies pasteurized milk in secret (McCulloch, 1936).

The early scientific work on pasteurization and microbial thermal death and the many time-temperature recommendations for several pathogenic organisms associated with milk have been reviewed (Westhoff, 1978; Holsinger *et al*., 1997). For many years there was no consensus on the time-temperature combination to inactivate the major milk-born threat, *Mycobacterium tuberculosis*. Values ranged from 50 to 100∞C for 1 min to 6 h. North (1921) pointed out that thirty-one different heating recommendations were made between 1890 and 1920. Pasteurization times and temperatures were not based on rigorous thermal death studies, but generally on the "complete" destruction of *M. tuberculosis* as measured by infectivity.

The current time-temperature requirements for pasteurization were set in the 1950s, based on "complete destruction" of *Coxilla burnetti* (Q fever) in milk containing 100,000 infectious guinea-pig doses. This organism cannot be enumerated directly, therefore, studies were based on number of infectious doses in laboratory animals (Enright *et al*., 1957). This approach to thermal death might not withstand current scientific scrutiny were it not for pasteurized milk's safety over the past four decades. Scientific uncertainty about the most appropriate time-temperature combination for milk remains even today, and current research may determine that there is need for further adjustment (Grant *et al*., 2001). Pasteurization and biotechnology, like other applications of science, share a degree of scientific uncertainty.

Pasteurization Defined

Modern pasteurization is the application of sufficient heat to a product for a period of time in order to destroy pathogenic microorganisms, yet leave the product acceptable from sensory and nutritional standpoints (Lewis and Heppell, 2000). This latter point distinguishes pasteurization from other heat-based processes that destroy microorganisms at the expense of product acceptability. We now know that microorganisms generally die in a logarithmic fashion when exposed to heat (Figure 1). One log cycle reduction in survivors gives a 90% reduction in numbers. The time required to complete this 90% reduction, the "D" value, is dependent on the specific organism and the temperature to which it is heated, as well as on the medium in which it is heated. This means that total microbial destruction is not possible, only that some number of log-cycle reductions (D values) can be achieved and that authorities must decide how many log reductions are required to adequately protect public heath. Typically, food products are subjected to sufficient heating for a period of time to give reductions of five to twelve D values. Thus, pasteurization is not a guarantee of absolute safety, but a matter of risk reduction. Some degree of risk must be accepted. Statistically, pasteurization leaves behind some number of pathogenic organisms. Again, this is similar to biotechnology, which also carries inherent hazards for which we must be willing to accept some degree of risk.

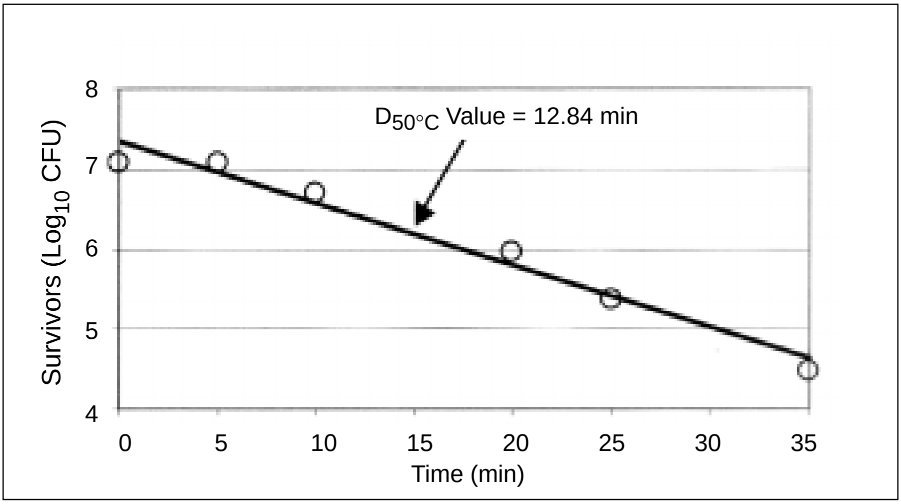

Figure 1. Thermal death-rate curve for *Pseudomonas fluorescens* in milk at 50°C. One D value equals the time to give a 1-log (ten-fold) reduction in survivors, in this case 12.8 min.

Microorganisms differ greatly in their sensitivity to heat, and, thus, the combination of time and temperature that is sufficient to kill one species may have little effect on others. Pasteurization, like biotechnology, is not a single entity, but has been developed into a complex group of related technologies. The appropriate heat treatment depends on the desired outcome and product.

MILK IN THE NINETEENTH CENTURY

Today, we think of milk as one of the safest foods available, and guard its integrity and wholesomeness with near-religious fervor. But this has not always been so. In the nineteenth century, in the words of Stenn (1980): milk "was as deadly as Socrates' hemlock." It was one of the very few animal foods that was almost universally consumed without heating or refrigeration, and was less of a health risk when consumed within a few hours of collection. But, as cities grew larger in the industrial revolution of the mid-1800s with mass immigration to the United States, the time and distance between collection and consumption increased. In the early 1800s, dairy cows were commonly found within residential areas of American and European cities. As the cities grew, dairy farming became more rural and milk transportation took longer, hence the term "milk run" became synonymous with frequent stops as made by trains of the latter half of the nineteenth century. Rosenau (1912) pointed out that urbanization increased the time between collection and consumption from a few hours to more than forty-eight without refrigeration. Given the nature of milk as a microbial growth medium, one can only imagine the microbial condition of raw milk kept at ambient temperature for two days.

Then, as today, milk was seen as important in infant nutrition and, as such, it held a special place in the hierarchy of foods. It was surrounded with superstitions such as the belief that thunder was responsible for curdling, as the following demonstrates (Belcher, 1903):

> *The prevailing belief that a thunderstorm is the cause of milk souring is one instance of misunderstanding. The fact that it is easy to purchase milk which will not sour during a thunderstorm should suggest to the consumer that there must be some other reason. And the reason is the presence of lactic acid forming bacteria in milk.* ***It is not disputed that milk sours during a thunderstorm, but the cause is not the thunderstorm itself, but certain conditions accompanying it, which are favorable to the action of lactic acid bacteria.*** *(emphasis added)*

In the latter half of the nineteenth century, scientists who followed Pasteur began to investigate the microbiology of milk and its possible relationship to human disease, especially to the scourge of the day: tuberculosis. In the United States, the yearly death rate from this disease in the early twentieth century was 160,000 and, of a population of 90 million, about 6 million could expect to die from it. Typhoid fever claimed 25,000 per year (Rosenau, 1912). These and other often-fatal infectious diseases including gastroenteritis, scarlet fever, cow pox, milk sickness, diphtheria, septic sore throat, Malta fever, foot and mouth disease, anthrax, contagious abortion, and rabies were, at least partially, linked to raw milk.

In 1886, Soxhlet described a heating apparatus for pasteurizing milk at home, and, in 1889, the Prussian-born physician Abraham Jacobi (the first professor of pediatrics in the United States) brought Soxhlet's ideas to this country with the goal of improving the health of infants. Later, he and Henry Koplix (a pediatrician in New York City) became convinced that pasteurization would save children's lives. Later work by M.J. Rosenau of Harvard Medical School and C.E. North, among others, began to define the thermal death of bacteria in milk.

In the nineteenth century, high infant mortality was considered a fact of life. Rates, both in the United States and Europe were, by today's standards, unfathomable. The United States census of 1900 found infant mortality rates as high as 40% (North, 1921). In Baltimore alone, 3,000 infant (<5 years of age) deaths per year were reported (Knox, 1906). One third of all deaths were of infants. In 1905, infant deaths totaled >105,000, of which 39,000 resulted from diarrhea (Hygienic Laboratory, 1909). In 1920, infant mortality rates were seventy-two to 203 per 1,000 infants in twelve major cities in the United States (North, 1921). The current rate is <0.8%.

In the nineteenth century, high infant mortality was considered a fact of life. Rates, both in the United States and Europe were, by today's standards, unfathomable.

Undoubtedly, this high death rate had multiple causes, but careful epidemiological studies were not undertaken. Studies in the United States and Europe, however, suggested that diet was a particularly important source of fatal infections. Savage (1912) reviewed the compelling evidence that milk caused significant numbers of infectious-disease cases. The high rates of death due to diarrhea, and increases in deaths in warm months, also provided clues. Studies in England compared death rates of "suckled" infants to those fed "cow's milk only" (Tables 1–3). Breast-fed infants died at a rate of 6.2% compared to 36% for those fed only cow's milk. This difference was even greater when only the first 3 months of life were considered. While we now know that breast milk has many advantages, such as passing on immuno-stimulants, they are not great enough to explain these differences. The evidence that milk was a transmitter of diseases such as tuberculosis, typhoid fever, scarlet fever, and "septic sore throat" was, even by the epidemiological standards of the day, incontrovertible.

TABLE 1. RELATIONSHIP BETWEEN MILK SOURCE AND INFANT MORTALITY FROM DIARRHEA IN BRIGHTON, ENGLAND, 1903–1905 [CENSUS OF 10,308 HOUSEHOLDS (SAVAGE, 1912)].

Milk source	Age at death (months)			
	0–3	3–6	6–9	9–12
	(% infant mortality)			
Breast only	1.9	1.3	—	—
Bovine only	92	69	25	22
Unknown	2	4	2	2

TABLE 2. FRACTION OF 1-YEAR-OLD INFANTS DYING FROM DIARRHEA[a] WHEN FED DIFFERENT MILK SOURCESIN BRIGHTON, ENGLAND, 1903–1905 (SAVAGE, 1912).

Milk source	Percent
Breast only	6.5
Bovine only	36
Condensed	30
Unknown	8

[a]121 of 1,259 infants died in the first year of life.

TABLE 3. INFANT (<1 YEAR) MORTALITY IN THE SUMMER MONTHS FED DIFFERENT MILK SOURCESIN BRIGHTON, ENGLAND, 1903–1905 (SAVAGE 1912).

Milk source	Percent
Store milk	19
Condensed	20
“Good bottled”	9
Central distributed milk	3
“Best bottled”	0
Breast only	0

Knowing what we now know about diseases, there is little doubt that milk was a very dangerous food in the late nineteenth and early twentieth centuries. As late as 1942, G.S. Wilson reviewed the broad range of infectious diseases transmitted through milk, and pointed out that they caused thousands of deaths in Great Britain annually, and concluded that milk was "probably the most dangerous article in our dietary" (Wilson, 1942). In an article titled "White Poison," Atkins (1992) reviewed milk quality in London at the beginning of the twentieth century, and concluded that *E. coli* counts were more than 1 million per milliliter. Current standards in the United States require fewer than ten coliform (fecal) bacteria per milliliter. Stenn (1980) estimated that residents of Berlin, Germany consumed 300 pounds of "cow dung" daily in their milk due to the poorly hygienic conditions in which dairy cows were kept. Scarlet fever was widespread, and transmitted via the milk supply (Wilson, 1986). It is not surprising that a cartoonist of the day portrayed milk as a harbinger of death (Figure 2).

Figure 2. "I drink to the general death of the whole table."
(This cartoon won a prize from the American Medical Association, ca. 1910.)

Some of the most compelling evidence for the dangers of raw milk came from New York City and the work of Nathan Straus, a wealthy principal owner of Macy's department store. Reportedly, he lost a child and was convinced it was due to milk. Although he had no scientific training, he became interested in the thermal treatment of milk after meeting Jacobi, and installed a pasteurization unit in 1897 on Randall's Island at the city's asylum for children. The mortality rate in 1897 at the asylum was an astounding 44%. After the introduction of pasteurized milk in 1898, the rate dropped to 20% and further dropped to 16.5% by 1904 (Straus, 1917). The introduction of pasteurization was the only major change during this period.

The success at Randall's Island convinced Straus that he could save more children's lives through milk pasteurization, so, between 1899 and 1910, he set up depots across the city to dispense free or low-cost pasteurized milk to families with infants. While it is impossible to know the precise impact of milk pasteurization, the infant mortality rate fell from 12 to 3.8 per 1,000 between 1893 and 1916. The then-commissioner of health in New York City stated that there could be "little doubt" that the major factor in this reduction was "the compulsory pasteurization of milk" (Straus, 1917).

Some in the young field of public health believed that raw milk was a carrier of disease and that pasteurization offered a solution. In discussing the causes of "food poisoning" Jordan (1917) pointed out that "of all foods, milk is the most likely to convey disease," and "the amount of illness traceable to milk far exceeds that ascribable to any other food." Knox (1906) found that 30% of the 10,000 deaths per year in Baltimore in the early years of the twentieth century were of infants under 5 years, and concluded that 1,000 of these infant deaths were due to milk consumption.

The headlines of the day were likewise critical of the milk supply. Nearly every week the *New York Times* carried articles on the hazards of milk (Figure 3). Headlines such as "Public Health and Infected Milk" appeared as early as 1873.

As we now know, pasteurization is effective at controlling pathogenic bacteria to the point that milk is now one of the safest of all foods. According to the Centers for Disease Control and Prevention in Atlanta (CDC, 2000), between 1993 and 1997 only 207 of 86,058 (0.2%) were confirmed food-disease cases—and no deaths—were traced to milk. It is likely that some, if not most, of these cases were related to the still legal practice of selling raw milk, which, in recent years, has been implicated in outbreaks of human disease (Steele, 2000).

Resistance to Pasteurization

For decades, strong and adamant opposition succeeded in stalling moves to make pasteurization mandatory in many parts of Europe and in North America. The opposition came from almost all quarters, including the medical community, the dairy industry, dairy technologists, and the milk-consuming public.

- Public Health And Infected Milk, September 10, 1873.
- Milk—Pure and Impure, July 21, 1874.
- Milk as a Spreader of Disease, Editorial, October 25, 1878.
- Milk—Cow with Rabies: Milk Sold on Staten Island, June 14, 1887.
- Milk, A Source of Disease, April 20, 1890.
- Cattle—Tuberculosis Contracted from Diseased Milk, March 3, 1894.
- Milk—Disease Transmitted: Pasteurization Urged" May 24, 1896.
- Milk—Deaths Due to Milk, August 19. 1903.
- Coblenz—E.L. James Says Death Rate of Children Under 5 Has Increased in Last 6 Years and that Milk is Lacking, January 8, 1919.
- Diphtheria—2 Deaths, Traceable to Milk, Occur in Greenwich, March 4, 1920.

Figure 3. Selected headlines from the *New York Times* concerning milk and disease 1873–1920.

Wing (1897) advised that the use of pasteurization was an "open" question and that "official" herd inspection was a better safeguard than pasteurization or sterilization. He advised that the main culprit in milk-borne disease was the dairyman "who is careless in regard to the cleansing of his utensils." Bailey (1909) described pasteurization in terms of contemporary agricultural practices in the Cyclopedia of American Agriculture, but suggested that it be used only when outbreaks of contagious disease were attributable to milk.

Opposition was based on four general arguments (Wilson, 1942):

- It was reasoned that milk pasteurization was deceptive and not needed if milk was properly handled. Pasteurization would mask low-quality milk, conceal evidence of dirt and filth, remove any incentive to produce clean milk and cull diseased animals, and legalize ineffective dairy practices. The efficiency and effectiveness of pasteurization was questioned based on observations that in some cases it appeared to work well and in others not at all. These differences, no doubt, resulted from differences in recommended time-temperatures. Although the precise times and temperatures were not known with certainty, there was sufficient understanding of the technology to broadly implement pasteurization (Kilbourne, 1916). Equipment to heat-process milk was widely available by 1901, when Monrad (1901) described in detail the technology to pasteurize, cool, and ship milk.
- The agricultural industry in particular worried that pasteurization would disrupt the economic status quo. There was fear that mandatory pasteurization would place the cost of milk beyond the means of too many Americans, and would put small producers out of business. Only the large companies would be able to afford the process. Milk was already too expensive for many, and was consumed in greater amounts by the wealthy

(who suffered the ill effects of the raw product). The sentiment was asserted that people have a "right" to drink raw milk if they wish.

- One of the most common arguments against pasteurization was that it adversely affected milk composition and its organoleptic properties. It was said to "ruin" the flavor and "take the life out of milk." It must be remembered that milk then, as today, held a special place as a food.
- Ironically, the most vehement opposition may have been from the medical community who argued that pasteurization would diminish the health benefits associated with milk, particularly in infants. The concern was that pasteurization would destroy the nutrients. Understanding of human nutrition was just beginning in the early part of the twentieth century. One focus was on milk's "anti-scurvy" properties of milk.

The exact nature of scurvy and its relationship to vitamin C was largely unknown, but physicians had made the observation that raw milk could have anti-scurvy activity that was lost upon heating. Hess (1920) suggested that whereas milk heated in the home was not adversely affected, commercial pasteurization would destroy the anti-scurvy activity. We now know that raw milk contains a small amount of vitamin C (<2% of the current RDA per serving) and that excessive heating can reduce this low level. It is possible that even this small amount would be sufficient to ward off scurvy in an infant whose total intake of vitamin C was borderline.

Another health-related objection was connected to tuberculosis. It was clear that this was an infectious disease, but its precise cause and vehicles were not understood. Cattle also suffered from tuberculosis, but there were differences between the organisms infecting humans and cattle. Some suggested that bovine tuberculosis was not transmittable to humans and, therefore, milk could not be a vehicle. Some suggested that exposure to bovine tuberculosis had a protective effect on humans.

Other objections were less scientific. It was suggested that pasteurization interfered with nature, that infants failed to thrive on pasteurized milk, and that pasteurization would give a false sense of security because bacteria grew rapidly when added to pasteurized milk. These objections came not only from the fringe, but often from mainstream science. Comments on pasteurization by McCollum (1918) in a nutrition text are illustrative:

> *Milk which has been pasteurized at 165°(F) is more liable to induce scurvy than either boiled milk, or milk which has been pasteurized at lower temperatures, as 140–145° for thirty minutes. The most satisfactory explanation for these results seems to be found in the bacteriological condition of the milks treated in the various ways described. . . . These results strongly support the view that there is a bacteriological factor involved in the causation of scurvy, and emphasizes the importance of securing clean milk, and of having it so handled as to insure its delivery in a good bacteriological condition.*

Hess (1920) agreed:

> *It has become increasingly evident that in the course of pasteurization milk loses an important measure of antiscorbutic vitamine* [sic].

Proponents of pasteurization countered these objections by arguing, as did Savage (1912) in England and Rosenau (1912) in the United States, that milk was the cause of significant human disease and that pasteurization would make it safer. Savage (1912) argued that four strong lines of evidence linked milk to disease:

> *The incidence is upon those who drink a particular supply of milk* (disease outbreaks are traceable to specific milk supplies).
>
> *Outbreaks are explosive in nature* (large numbers of outbreaks occur simultaneously).
>
> *Incidence falls upon the milk-consuming part of the community* (segments that tend to consume more milk have higher disease incidence, and milk consumption and disease correlate with economic status).
>
> *Milk drinkers in particular houses are attacked* (milk consumers have a higher incidence than non-consumers living in the same household).

In 1909, the United States Hygienic Laboratory published a collection of papers on the relationship between milk and the public health, by epidemiologists, bacteriologists, dairy chemists, sanitarians, and dairy-processing specialists (Hygienic Laboratory, 1909): the cost in lives from milk-borne disease was immense and the answer readily available. Yet, broad implementation was decades away.

In 1909, the United States Hygienic Laboratory published a collection of papers on the relationship between milk and the public health, by epidemiologists, bacteriologists, dairy chemists, sanitarians, and dairy-processing specialists (Hygienic Laboratory, 1909): the cost in lives from milk-borne disease was immense and the answer readily available. Yet, broad implementation was decades away.

Opposition to pasteurization exists today, disseminated on the Internet. Dr. Regan Golob, writing for the Dynamite Company, tells people that pasteurization "kills" milk. The "Milk Quiz" at the "Not Milk" Web-site indicates that the main reason for pasteurization is to "fool you." Proclaimed nutritionist Aajonus Vonderplanitz and a raw-milk farmer tells Internet surfers that "the bacteria-phobia has no empirical basis" and that there have been no clinical studies to prove or disprove the "theory" that pathogens in milk can cause disease in humans.

Parallels Between Then and Now

There are several parallels with the debate over biotechnology, and the solutions discussed in the early 1900s seem quite applicable today. In 1912, Rosenau debated what should be done about the opposition to pasteurization or, as he put it in his book, "The Milk Question." He called for patience, public and professional education, and cooperation between commercial, government, and scientific communities, and that all should let the "facts speak for themselves." Interestingly, he promoted the comparison of milk with other health issues such as water treatment, which apparently generated no opposition. This suggestion is similar to the contemporary view that technologies should be viewed in light of the magnitude of risk associated with implementation (or not). Decades later, Hill addressed strategies to deal with the still-strong opposition to pasteurization (Hill and San, 1947). He argued for the importance of public education on pasteurization and that scientists should strongly repudiate misinformation. He also counseled that facts overcome falsehoods, that credible authorities should speak out on the issues and present factual information based on unbiased research, and he admonished scientists to acknowledge imperfections and shortcomings.

These approaches do not seem much different from those proposed today, but there are notable instances where they appear to have been ignored. It is also instructive to note that the opposition to new technologies is not a new phenomenon associated solely with recombinant DNA technology. Recent examples range from food additives, coloring, and pesticides, to irradiation and packaging. It seems that opposition to technology in agriculture and especially consumer foods will occur no matter what the technology.

What lessons and strategies can scientists and technologists gain from this history? The most obvious is that controversy and opposition are likely to develop in response to the implementation (not discovery) of any new technology used in food and agriculture. Anticipation and planning should accompany technological development, and not be a reactive response. When controversy is not anticipated and planned for, technologists and scientists are forced into the position of reacting to the debate as framed by others, rather than being framers of the debate.

It is also instructive to note that the opposition to new technologies is not a new phenomenon associated solely with recombinant DNA technology. Recent examples range from food additives, coloring, and pesticides, to irradiation and packaging. It seems that opposition to technology in agriculture and especially consumer foods will occur no matter what the technology.

The controversy surrounding pasteurization also points to the importance of the media. For more than 40 years, the press has been generally in favor of pasteurization. It is important to educate the media early in the development stage and not to delay until implementation. Perhaps because of his experience in the retail business, Straus seemed to understand the importance of the press.

While it is essential that scientists educate themselves and their colleagues about new technologies, they cannot dismiss the importance of the broader audience. Professional societies with interests in food, agricultural, environmental, and health issues have produced a number of excellent overviews of, and discussion-pieces on, biotechnology, and have issued rational position papers (*e.g.* IFT, 2000). And several professional groups have been producing educational documents, technical summaries, and detailed reports for nearly a decade. The American Dietetics Association and the American Medical Association, among others, have also developed reports and positions on agriculture-related biotechnology. These publications are especially useful for educating groups with direct interest in the technology and with sufficient background to grasp the underlying science.

Unfortunately, these efforts are at times "preaching to the choir" in that they target groups willing to listen and to learn and to evaluate new technologies on their merit, and may miss lay audiences. This latter constituency may have little interest in the technical details—whereas most educational materials consist almost entirely of technical explanations—and be more interested in the broader implications. Among the most important questions for consumers are: Who benefits? Who is at risk? What will it cost? Who oversees the technology? What are the health and environmental risks? Powell (2000) pointed out the importance of understanding the audience's concerns in communication of risk to lay groups.

There is little evidence that those who developed and promoted pasteurization understood these lessons any more in 1901 than modern promoters of biotechnology do today. If influential groups (*e.g.* the press, see Figure 4) who are likely to oppose technology were considered early in the development process, rather only after controversy has erupted, implementation might involve a less arduous route. Strategies for early engagement of influential lay interests might foster easier transition from basic discovery to practical implementation.

REFERENCES

Atkins PJ (1992) White poison? The social consequences of milk consumption, 1850–1930. Social History of Medicine [Great Britain] 5 207–227.

Bailey LH (1909) Cyclopedia of American Agriculture; a Popular Survey of Agricultural Conditions, Practices and Ideals in the United States and Canada. New York: The Macmillan Company.

Belcher SD (1903) Clean Milk. New York: The Hardy Publishing Company.

CDC (2000) Surveillance for Foodborne-Disease Outbreaks—United States, 1993–1997. Surveillance Summaries. Atlanta: Centers for Disease Control and Prevention.

Enright JB et al. (1957) Thermal Inactivation of *Coxiella burnetii* and Its Relation to Milk Pasteurization. Public Health Monograph No. 47. Washington, DC: Public Health Service.

Grant IR et al. (2001) *Mycobacterium avium* ssp. *paratuberculosis:* its incidence, heat resistance and detection in milk and dairy products. International Journal of Dairy Technology 54 2–13.

Hess AF (1920) Scurvy, Past and Present. Philadelphia: J.P. Lippincott Company.

Hill H San FR (1947) Pasteurisation. London: H.K. Lewis & Co. Ltd.

Holsinger VH et al. (1997) Milk pasteurisation and safety: a brief history and update, Scientific and Technical Review of the Office International des Epizooties 16 441–451

Hygienic Laboratory (1909) Milk and its Relation to the Public Health. Bulletin, No. 56. Washington, DC: Government Printing Office.

IFT (2000) Introduction / Human food safety evaluation of rDNA biotechnology-derived foods / Labeling of rDNA biotechnology-derived foods / Benefits and concerns associated with recombinant DNA biotechnology-derived foods, in IFT Expert Report on Biotechnology and Foods (assembled reprints from Food Technology vol 54 August / September / September / October 2000). Washington, DC: Institute of Food Technologists.

Jordan EO (1917) Food Poisoning. Chicago: University of Chicago Press.
Kilbourne CH (1916) The Pasteurization of Milk from the Practical Viewpoint. New York: John Wiley & Sons.
Knox JHM (1906) The relation of the milk supply to infant mortality. The Johns Hopkins Nurses Alumnae Magazine 68–81. (Reprinted in the American Journal of Public Health 89 (1999) 408–409.)
Lewis M Hepple N (2000) The Continuous Thermal Processing of Foods. Pasteurization and UHT Sterilization. Caitherburg, MD: Aspen Publishers.
McCollum EV (1918) The Newer Knowledge of Nutrition; the Use of Food for the Preservation of Vitality and Health. New York: The Macmillan Company.
McCulloch EC (1936) Disinfection and Sterilization. Philadelphia: Lea & Febiger.
Monrad JH (1901) Pasteurization and Milk Preservation: with a Chapter on The City Milk Supply. Winnetka, IL: J.H. Monrad.
North CE (1921) Milk and its relation to public health, in A Half Century of Public Health (Ravenel MP ed) 237–289. New York: American Public Health Association.
Pirtle TR (1926) History of the Dairy Industry. Chicago: Mojonnier Bros. Company.
Powell DA (2000) Food safety and the consumer—perils of poor risk communication. Canadian Journal of Animal Science 80 393–404.
Rosenau MJ (1912) The Milk Question. New York: Houghton Mifflin Company.
Savage WG (1912) Milk and the Public Health. London: Macmillan & Co., Ltd.
Steele JH (2000) Commentary. History, trends, and extent of pasteurization. Journal of the American Veterinary Medical Association 217 173–176.
Stenn F (1980) Nurture turned to poison. Perspectives in Biology and Medicine Autumn 69–80.
Straus LG (1917) Disease in Milk: The Remedy—Pasteurization; The Life Work of Nathan Straus. New York: E.P. Dutton & Co.
Westhoff DC (1978) Heating milk for microbial destruction: A historical outline and update. Journal of Food Protection 41 122–130.
Wilson GS (1942) The Pasteurization of Milk. London: Edward Arnold & Co.
Wilson LG (1986) The historical riddle of milk-borne scarlet fever. Bulletin of the History of Medicine 60 321–342
Wing HH (1897) Milk and its Products; a Treatise Upon the Nature and Qualities of Dairy Milk, and the Manufacture of Butter and Cheese. New York: The Macmillan Company.

SOME FACTS ABOUT MILK

Germ changes and contamination of milk
Information important to women…

House wives and mothers should be versed in milk lore—modified milk sterilization and pasteurization…

…the prolific source of danger which is harbored in this fluid…

…severe epidemics of typhoid fever…owing their existence to the common source of tainted milk…

…it is no imperative that milk must be contaminated…

They (British and Americans), continue to drink milk…without protection from infection. It is true but strange that every savage nation on the globe that uses milk... has some form of protection.

Milk as used in large cities is a very different article from that used by primitive man. It is seldom perfectly fresh, pretty sure adulterated, and almost always dirty.

Until we are assured of absolute purity, we should resort to protection. Science has unmistakenly established the importance of this.

Figure 4. New York Times headline and excerpted article, September 22, 1895.

Q: Was pasteurization accepted differently in different countries, and are there lessons to be learnt from that?

A: It was controversial both in Europe and in the United States, but possibly less so in Europe, even as recently as post World War II. Since pasteurization makes milk last longer, it received a boost after the war. However, it remained controversial, certainly in the United Kingdom, whence comes much of my information.

Q: Considering that the concept of pasteurization was so hard to sell, against the reality of the high rates of infant mortality, what are your thoughts regarding biotechnology, the benefits of which are less obvious to the public?

A: Clearly, it is a harder sell. However, mind-set is important. People had always expected their children to die. Even educated individuals said that this was the way of the world. Many thought that infants died because they had “poor constitution.” I don’t know exactly what that was, but it was regarded in terms of it being better that they died. It is ironic that a lay person, Nathan Straus, raised this issue, rather than the medical community. With respect to biotechnology, people who are bringing it to practical use must tell the lay public why they are doing it, what it will do, who will benefit, and they must admit that profits are involved. It should have been stated much more forcefully that children were dying and that there was good evidence that it could be stopped by pasteurization.

With respect to biotechnology, people who are bringing it to practical use must tell the lay public why they are doing it, what it will do, who will benefit, and they must admit that profits are involved. It should have been stated much more forcefully that children were dying and that there was good evidence that it could be stopped by pasteurization.

Q: Have you considered writing this story for, say, the *New York Times* magazine or the *Atlantic Monthly* to obtain broad communication of this message to encourage people to draw their own conclusions as to where we are today?

A: That is an interesting question. Particularly on a lay level, I think there is an important lesson that technology in general should be judged by what it can and cannot do, and what its risks and benefits are.

Q: Were the business interests in pasteurization similar to or different from the business interests that underpin biotechnology?

A: Nathan Straus died poor, broken because the authorities made him shut down all of his pasteurization plants. He was Jewish, and had hoped to take the technology to what is now Israel. He made no money for this, and, in fact, lost most of his fortune in trying to promote it. Opposition to pasteurization came, in part, from the entrenched dairy industry—farmers and processors—which is different from the situation today. On the other hand, some companies did promote pasteurization, primarily Borden Foods, in Syracuse, New York.

Louis Pasteur began to understand pasteurization in 1865, however, violent opposition exists even today, as evidenced by what can be found on the Internet.

Q: Cheese is made with unpasteurized milk in Switzerland. I eat it when I can get it, because it is so good. I eat it knowing that there is some risk. One of your slides mentioned the "right" to consume unpasteurized milk. Do you agree with that, and are their parallels with people declaring that it is their right to choose GM foods or to avoid them?

A: Cheese is a poor analogy in that, if it is aged more than 60 days, the risk is substantially reduced. There is on-going argument on this issue between Europe and the United States. In the United States, all cheeses under 60 days of age have to be made from pasteurized milk. On the question of the right to drink "raw" milk, I think it is a societal question. Drinking such milk, and possibly eating such cheese, is to play food-poisoning roulette. As a society, where do we draw the line on what we protect ourselves from? In general, where the risk is high and technology exists to reduce that risk, we as a society should apply that technology. Where the risk is low, I believe that the technology again should be applied—but that is subjective and will be interpreted differently by different people. We have decided that the risk from unpasteurized milk is high. Roughly two-thirds of the states have made it illegal to sell it. Each case should be looked at in terms of risk versus benefit, and as a society that is why we elect supposedly very smart people to make such decisions for us. That brings some smiles.

Q: In your coverage of opposition to pasteurization you mentioned small-scale producers. Do you see a time when a similar issue will apply to biotechnology?

A: Yes I do, not for technological reasons, but for marketing reasons. We at Cornell put the gene-gun into a Winnebago and drove it around the state and let high-school students genetically modify plants. In other words, it is not a centralized technology, although it is centralized as a business. When I'm in Europe, I tell people that they should protest the fact that biotech is broadening the gap between the rich and the poor, and that biotech is not being applied where it is needed most: in the developing world.