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A 100-Year Review: A century of dairy processing advancements—Pasteurization, cleaning and sanitation, and sanitary equipment design[1]

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ABSTRACT

Over the past century, advancements within the mainstream dairy foods processing industry have acted in complement with other dairy-affiliated industries to produce a human food that has few rivals with regard to safety, nutrition, and sustainability. These advancements, such as milk pasteurization, may appear commonplace in the context of a modern dairy processing plant, but some consideration of how these advancements came into being serve as a basis for considering what advancements will come to bear on the next century of processing advancements. In the year 1917, depending on where one resided, most milk was presented to the consumer through privately owned dairy animals, small local or regional dairy farms, or small urban commercial dairies with minimal, or at best nascent, processing capabilities. In 1917, much of the retail milk in the United States was packaged and sold in returnable quart-sized clear glass bottles fitted with caps of various design and composition. Some reports suggest that the cost of that quart of milk was approximately 9 cents—an estimated $2.00 in 2017 US dollars. Comparing that 1917 quart of milk to a quart of milk in 2017 suggests several differences in microbiological, compositional, and nutritional value as well as flavor characteristics. Although a more comprehensive timeline of significant processing advancements is noted in the Appendix Table A1 to this paper, we have selected 3 advancements to highlight; namely, the development of milk pasteurization, cleaning and sanitizing technologies, and sanitary specifications for processing equipment. Finally, we provide some insights into the future of milk processing and suggest areas where technological advancements may need continued or strengthened attention and development as a means of securing milk as a food of high safety and value for the next century to come.

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A CENTURY OF MILK PROCESSING ADVANCEMENTS

One of the first dairy histories, written in 1899, stated, "No branch of agriculture has made greater progress than dairying during the nineteenth century… It is now regarded as among the most progressive and highly developed forms of farming in the United States" (Alvord, 1899). If the author had foreseen the revolutionary advances occurring in the next hundred years, he likely would have reiterated this sentiment.

One hundred years ago, in 1917, most of the world was enmeshed in the throes of World War I. Expansion of railroads and the beginning of farm to city migration was changing the landscape of the United States and Europe. Cities such as New York, Boston, Philadelphia, Chicago, and London were growing at rapid rates. Dairy processing, especially that of raw fluid milk, was at a turning point. By 1917, pasteurization was beginning to gain acceptance as a means of preserving milk and controlling milk-borne disease. In Denmark and Sweden, commercial pasteurization of milk was common as early as the mid-1880s, due in part to the early recognition by Danish butter makers of its merits (Herrington, 1948b; Westhoff, 1978). However, cities in the United States were much slower to openly embrace pasteurization techniques, despite evidence of some commercial pasteurization occurring covertly as early as the late-1890s (Herrington, 1948b).

In 1902, only 5% of the milk supply of New York City was heat treated, but by 1914, this number had risen to 88% (Jordan, 1913; Ayers, 1916). However, it would take several more years for pasteurization to become commonplace in smaller cities. Herrington cited the percentage of US cities pasteurizing at least half of their milk supply in 1915 at 77.8% for populations >500,000, 30% for 100,000–500,000, 16.7% for 25,000–50,000, and 6% for 10,000–25,000. These proportions would rise over the next few years to 100, 91.9, 80, and 45.7%, respectively, in 1924 (Herrington, 1948b).

The automation of cream separation, bottle washing, filling, and capping marked the beginning of the modern industrialization of milk processing. The first automatic bottle machine was patented in 1907, and power cappers and fillers began to be used commercially starting in 1913 (Henderson, 1971b). Mechanical bottle washers were first introduced in 1895, and then improved with soaker-type bottle washers in 1906 (Henderson, 1971b). Industrialization of these dairy processes brought the establishment of milk food safety and sanitation standards. At the same time, better cleaning agents became available and widely used. Chlorine-type bleach began to be used for sanitizing equipment surfaces in 1912 (Henderson, 1971b).

Additionally, agriculture research had been on the rise since the late 1800s with governmental establishment of agriculture colleges and research institutions throughout Europe and the United States. Furthermore, cities across Europe and the United States were beginning to pass laws mandating some form of pasteurization or pasteurization standards as the link between fluid milk and some disease or illnesses began to be recognized. By 1898, pasteurization of all bottled milk was made compulsory in Denmark (Herrington, 1948b). In the United States, Chicago was the first major city to pass a mandatory milk pasteurization law in 1909, whereas New York was one of the last, in 1933 (Selitzer, 1976).

Research from the late 19th century by the celebrated German physician and microbiologist Robert H. Koch and others had linked the health of the cow to the transmission via fluid milk of certain diseases, including tuberculosis, diphtheria, typhoid fever, scarlet fever, anthrax, cholera, and foot and mouth disease (Freeman, 1896a,b; Calm and Shinert, 1899; Henderson, 1971d; Westhoff, 1978). Further advocacy work by Henry Koplix and Nathan Straus, Charles E. North, William D. Hoard (Hoard, 1918) and others (Selitzer, 1976; Westhoff, 1978) highlighted the role of milk spoilage and unsafe milk on increased fatality, especially in children, directly contributing to the creation and adoption of some food safety laws regarding pasteurization.

Although the concept of milk pasteurization was accepted and commercial pasteurization common by 1917, acceptable pasteurization standards had yet to be generally agreed upon (Appendix Table A1). The methods, temperatures, and timings for pasteurization were extremely varied. The first pasteurization in the United States was a type of early flash pasteurization, where continuous flow of milk was heated at around 71.1°C (160°F) for 30 to 60 s and then rapidly cooled (Westhoff, 1978). However, proper control of this process was not possible at the time due to the lack of automatic heat regulators and other technology to control the temperature and times (Selitzer, 1976). Additionally, when pasteurization was first introduced, the lactic acid–producing bacteria were essentially destroyed, allowing thermoduric bacteria to proliferate, resulting in the milk displaying a more proteolytic form of spoilage rather than acid development during storage (Herrington, 1948b). Because of these problems, initial attempts at flash pasteurization were quickly condemned by public health officials (Selitzer, 1976).

Another early method used widely during the first decades of the 1900s was the in-bottle method, where bottled milk was heated at 62.8°C (145°F) for 20 to 30 min (Westhoff, 1978). The in-bottle method received support because it eliminated contamination post-pasteurization; however, it was not as favored commercially. A less common method also used was the bottling hot method, where milk was heated at 62.8°C (145°F) for 20 to 30 min and then filled into pre-steamed bottles (Westhoff, 1978).

However, by 1917, the most common and accepted method of pasteurization was the holding method, although there was still significant in-bottle pasteurization (Westhoff, 1978). With the holding method, milk was heated in vats at 60 to 65.6°C (140–150°F) for 30 min. Commercial holder apparatuses became available around 1907 in the United States, but due to their prohibitive cost, other smaller regenerative heaters and pasteurizers were also developed simultaneously (Hall, 1976; Selitzer, 1976). In 1908, the double-tube regenerative holder, in which outgoing milk helped heat incoming raw milk to reduce heating and cooling costs, was introduced and was widely used in milk plants in France, Denmark, Italy, and other countries (Henderson, 1971e). In 1911, the coil vat was first used as a batch milk processer; and around 1913, the barrel heater was introduced (Selitzer, 1976).

The groundwork for official standards of milk pasteurization was also being determined during this time. Between 1890 and 1927, at least 31 different time/temperature combinations were recommended for adequate pasteurization, with the most common being 142°F (61.1°C) or 145°F (62.8°C) for 30 min (North, 1925; Westhoff, 1978). Additionally, inadequately pasteurized milk could result from variations in temperature, holding time, and flow rate simply due to the technology of the equipment at the time. Early work supported a low-temperature holding method and recommended 60°C for 20 min (Rosenau, 1909). In 1911, the National Committee on Milk Standards in the United States recommended 62.8°C (145°F) for 30 min (North, 1925; Westhoff, 1978) but this standard was still not consistently accepted. In 1913, other studies investigated the types of bacteria in raw milk and in same milk pasteurized at different temperatures (Ayers and Johnson,

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