J. Dairy Sci. 100:9987–10013
https://doi.org/10.3168/jds.2017-12981

A 100-Year Review: Yogurt and other cultured dairy products[1]

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ABSTRACT

The history of the last 100 years of the science and technology of yogurt, sour cream, cultured butter, cultured buttermilk, kefir, and acidophilus milk has been one of continuous development and improvement. Yogurt leads the cultured dairy product category in terms of volume of production in the United States and recent research activity. Legal definitions of yogurt, sour cream and acidified sour cream, and cultured milk, including cultured buttermilk, are presented in the United States Code of Federal Regulations and summarized here. A tremendous amount of research has been done on traditional and novel ingredients, starter cultures and probiotics, mix processing, packaging, chemical aspects, physical and sensory properties, microstructure, specialized products, composition, quality and safety of yogurt and various manufacturing methods, addition of flavorings, viscosity measurements, and probiotic use for sour cream. Over time, there have arisen alternative manufacturing methods, flavor problems, addition of flavorings, and use of probiotics for cultured buttermilk. Many health benefits are provided by yogurt and other cultured dairy products. One hundred years of testing and development have led to wider uses of cultured dairy products and new processing methods for enhanced shelf life and safety. Future research directions will likely include investigating the effects of probiotic dairy products on gut microbiota and overall health.

Key words: cultured dairy products, yogurt, food safety, starter culture and probiotic, 100-year review

INTRODUCTION

Various cultured dairy products are formed by the conversion of lactose in milk to lactic acid by the use of starter cultures. Starter cultures have been used in the sense of inoculating fresh milk with small quantities of sour milk long before anything about bacteriology was known. Consumption of various fermented milk products by people in different regions of the world living under primitive sanitary conditions, especially in hot climates, was desirable because their high acidity kept these products safe by destroying pathogenic organisms (Nicholls and Nimalasuriya, 1939).

A critically important early advancement in bacteriology was the first observation of bacteria by Antonie van Leeuwenhoek in about 1675 (Orla-Jensen, 1921). Swithinbank and Newman (1903) reported that Andry, as early as 1701, noticed that living organisms are present in sour milk.

Lactic acid was first studied in 1780 by Carl Wilhelm Scheele (Van Slyke and Hart, 1904). Louis Pasteur declared that lactic acid could be formed from sugar fermentation by yeast (probably actually lactic acid bacteria) in 1857, as described and referenced by Manchester (2007). Whether credit should be given to Louis Pasteur or to Pierre Jacques Antoine Béchamp (for his work on inversion of sucrose in 1855) for the first demonstration of fermentation by living organisms was a subject of controversy between these 2 scientists (Manchester, 2007). Joseph Lister, known for his work in showing the critical importance of antiseptic technique during surgery, also studied milk souring by lactic fermentation and believed that milk sugar is converted into lactic acid (Lister, 1878). The older view was that casein was the ferment.

During the 1800s, it was debated whether true fermentation of organic liquids was caused by organisms that they contain. Lister, like Pasteur, believed that organisms caused fermentation but acknowledged that some distinguished physiologists and pathologists at that time believed that fermentation such as putrefaction was not necessarily caused by bacteria (Lister, 1878). Lister (1873) first isolated the organism that he called *Bacterium lactis*, later renamed *Streptococcus lactis* (Orla-Jensen, 1919), and now referred to as *Lactococcus lactis* ssp. *lactis* (Schleifer et al., 1985); this organism converts lactose into lactic acid. Lister was not sure if this was the only bacterium that could undergo lactic acid fermentation.

A history during the 1800s and early 1900s of the use of butter starters for souring that can occur under

Received April 3, 2017.
Accepted August 1, 2017.
[1]This review is part of a special issue of the *Journal of Dairy Science* commissioned to celebrate 100 years of publishing (1917–2017).
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the right conditions was provided by Knudsen (1931). The introduction of the thermometer for use in cream ripening by Segelcke in 1860 and improved recordkeeping for use of definite quantities of starter for definite quantities of cream improved the control of cream souring (Knudsen, 1931). Many other advancements in cultures, ingredients, processing, and packaging were developed over time to improve cultured dairy products. Today, cultured dairy products are fermented with lactic acid bacteria, including species of *Lactobacillus*, *Streptococcus*, *Lactococcus*, and *Leuconostoc* (Appendix Table A1). Yeasts are also used in manufacturing kefir and koumiss.

Some of the more common and well-known cultured dairy products include yogurt, sour cream and dips, cultured buttermilk, acidophilus milk, and kefir. A list of many other lesser-known cultured dairy foods available in specific countries or regions can be found in Chandan (2006) and at https://en.wikipedia.org/wiki/Fermented_milk_products. Consumers generally have a positive perception of yogurt. As a result, annual per capita yogurt consumption increased from 0.1 kg in 1970 to 1.2 kg in 1977 in the United States (Tamime and Deeth, 1980), and production of yogurt has increased from 982.6 million pounds in 1990 to about 4,742.1 million pounds in 2015 (International Dairy Foods Association, 2017) in the United States. Sour cream production has increased from 935.4 million pounds in 2003 to about 1,316.5 million pounds in 2015, and buttermilk sales have decreased from 1,140 million pounds in 1960 to about 513 million pounds in 2015 in the United States (International Dairy Foods Association, 2017). Because of the recent economic importance of yogurt as well as the large number of published articles, the emphasis of this review paper will be on yogurt (Appendix Table A1), with less coverage on other cultured dairy products, including sour cream, cultured butter, cultured buttermilk, kefir, acidophilus milk, and the probiotic dairy beverage Yakult (Yakult Honsha Co., Tokyo, Japan).

YOGURT

History and Legal Description of Yogurt

For an early method of yogurt manufacturing, Heineman (1921) described the manufacture of yogurt as boiling milk in clean earthenware vessels over a slow fire to reduce the volume of milk from about one-fourth to more than one-half (so that the final volume is between less than 50% to 75% of the original volume), cooling to 45 to 50°C, adding a small amount of product from a previous lot, wrapping the vessels containing this mixture in skins and cloths to maintain a uniform temperature for 10 to 12 h before being ready for consumption. For modern methods of yogurt manufacturing, yogurt mix with an appropriate fat content (typically <0.5, 1, or 3.25%) and total solids content (typically 12 to 15% and adjusted by adding nonfat dry milk) is homogenized, pasteurized [typically at 90 to 95°C for close to a minute to a few minutes (HTST) or at about 85°C for 30 min (vat)], and cooled to 40 to 45°C before pumping into a vat (often cylindrical-shaped on the top and cone-shaped on the bottom). The mix is then inoculated with *Streptococcus salivarius* ssp. *thermophilus* (traditionally and hereafter referred to as *Streptococcus thermophilus*) and *Lactobacillus delbrueckii* ssp. *bulgaricus* (traditionally and hereafter referred to as *Lactobacillus bulgaricus*). The inoculated mix may then be immediately pumped to a yogurt filler for filling into cups, with or without fruit puree already present in the bottom of the cup, and the cups are then sealed. The filled and sealed cups are then transferred to a warm room for incubation. When the yogurt reaches the appropriate pH (typically about 4.5), the yogurt cups are transferred to refrigerated storage (cup or sundae-style yogurt). Instead of immediate pumping to a yogurt filler, the inoculated mix may be allowed to incubate within the vat until the pH reaches the appropriate value, typically about 4.5. The inoculated mix is then stirred and cooled to about 20°C before pumping to a fruit feeder for adding fruit (for fruit-flavored yogurt) and then to a yogurt filler for filling into cups and then cup sealing. The cups are then transferred to refrigerated storage. More details of these procedures are provided by Kosikowski and Mistry (1997).

Yogurt has evolved over time. The industrial production of yogurt incorporating microorganisms was started by Isaac Carasso in 1919 (http://corporate.danone.co.uk/en/discover/our-businesses/fresh-dairy-products/brand-detail/?tx_bidanonesitemarques_pi1%5Buid%5D=324&cHash=0c2732c382f800736405ab84df99142f). During the 1920s and 1930s, yogurt milk was described as having poor flavor because of its high acidity (Winkler, 1929; Nordsiek, 1938). Before the 1960s, yogurt was only found in a few grocery or health food stores (Kroger, 1975). Today, many forms of yogurt can be found including plain yogurt, fruit flavored yogurt (including fruit-on-the-bottom and blended forms), whipped yogurt, granola-topped yogurt, drinkable yogurt, frozen yogurt, and Greek yogurt with varying fat contents (regular, low fat, and nonfat). The order for the US sales of spoonable yogurt flavors includes strawberry, blueberry, vanilla, peach, plain, raspberry, honey, banana and strawberry, black cherry, berry, pineapple, cherry, key lime, lemon, and banana (Cassell, 2014). Earlier in the decade, sales of Greek yogurt grew rapidly. Future trends for yogurt include sugar reduction