Chapter

Introductory Chapter: Overview of Trends in Dairy Science and Technology

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1. Introduction

Dairy science and technology is a field that encompasses the production and manufacturing of all dairy products as well as the machinery and methods used in the dairy industry. The largest part of the food supply chain is, by far, the dairy industry. This industry is an integral part of our food economy that not only supplies consumers with many ready-to-eat products such as milk, butter, and cheese but also produces many of the ingredients like milk powder and condensed milk that are found in processed foods. Milk itself has also become a key ingredient for the deployment of probiotics and the development of functional food products designed to improve consumer health. As such, dairy products have become an area of accelerated research and innovation, particularly in the areas of processing, sustainability, and health, and marketing strategy.

2. Historical reviews and developments

Milk has been a source of sustenance for newborn offspring since the emergence of mammals: all species of which produce milk to sustain their young [1]. Meanwhile, the practice of domesticating other mammalian species for milk production and consumption is so ancient; it predates written records [2]. In fact, prehistoric baby bottles have recently been uncovered in Bavaria, Germany, indicating that animal milk was used as far back as the Bronze Age to feed infants [3]. The discovery of animal milk as a food source was an important achievement because a sustainable food source that could meet human physiological needs for energy, water, and nutrients was then available [2]. All of the animal species originally exploited for milk, including cows, buffaloes, camels, sheep, yaks, goats, horses, and camels, are still used today for that purpose as milk and milk products continue to be a diet staple in many cultures around the world [4].

The role of milk in traditional diets varies according to climate. For example, milk does not play a role in the diet of many tropical cultures as much as in temperate Northern Europe, where far higher volumes of milk and milk products are produced and consumed [5]. This is most likely simply due to the fact that, with a lack of refrigeration, warmer climates make milk refractory to long-term storage [5]. In these warmer climate cultures, milk has traditionally been consumed immediately or otherwise preserved by boiling or processing into more stable products such as fermented milks [6].

Advances in the technology of milk production have occurred only relatively recently. The milk homogenizer was patented in 1899. This device was designed to break up milk globules in order to give milk the consistency that we take for granted today [7]. Automated milking systems appeared nearly a century later [8]. Milk production and biotechnology intersected in the 1990s with the advent of recombinant bovine growth hormones that were used to provoke an increase in milk production per cow [9] and the approval by the FDA of cloned animals for milk production in 2008 [10]. Recently, automated cell counters have emerged which can be used for the early detection of bovine mastitis [11].

Dairy product safety is an important issue because milk, being nutrient dense, not only serves as a medium that supports the growth of beneficial fermentative microflora [12] but is also a medium in which pathogenic species can proliferate [13]. The first dairy safety technologies included the invention of the process of pasteurization in the nineteenth century by Louis Pasteur, a technique adopted universally in the USA in 1917 [14]. The first milk safety packaging was glass milk delivery bottles invented by Henry Thatcher [15]. Milk tankers appeared in 1914 [16], and milk cartons became ubiquitous by 1974 [17]. In very recent years, cold pressure processing has been developed as an alternative to pasteurization [18]. Pulse electric field [19], ultra-sonication [20], and irradiation [21] have also been explored as alternatives. Meanwhile, dairy supply chains have become more centralized, leading to emerging issues in dairy safety. Hazard analysis and critical control point (HACCP) management programs have been developed to help neutralize biological, physical, and chemical hazards. HACCP mandates risk assessments at different points in the production process [22]. These programs demand continuous monitoring of the microbiota of both the dairy products and the production environment which has led to a new demand for rapid methods of microbiological detection and identification. As a result, novel rapid and high-precision techniques such as qPCR [23] and enzyme immunoassays [24] have been developed to identify milk pathogens such as *Campylobacter* and *Escherichia coli* O157:H7.

Another key achievement of mankind in the area of nutrition was the accidental discovery of bacterially fermented products from the milk of the domesticated species mentioned above [25]. Instead of being considered spoiled, these products entered the human diet as nutritional food products. Long before refrigeration existed and microbes were discovered, fermentation was adopted as an ancient method of preserving milk. As such, traditional fermented milk products are found in many cultures. These products include dadiah, the traditional fermented buffalo milk from West Sumatra; filmjölk, from Scandinavia; and the eastern European kefir.

Yogurt is the fermented milk product most widely distributed in the West and is thought to have been invented in 5000 B.C. Yogurt has also been known to be a health food for a long time: its health benefits are mentioned in the Vedas and in the Old Testament [26]. The type of yogurt we know today originated from the Balkans and is produced using a culture of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* bacteria. Yogurt was popularized in Europe and the USA in the first decade of the twentieth century by the scientist Élie Metchnikoff [27]. Metchnikoff believed that this fermented milk product promoted good health and ultimately longevity by supporting a balance of beneficial bacterial microflora in the gut [28]. The original hypotheses and observations regarding the first "probiotic" and the effects it had on health have since led to the proliferation of probiotic food products, supplements, and functional foods that we see on the market today. The number of these products has increased with the discovery of novel beneficial species of gut bacteria and the development technologies that can support the delivery of viable bacteria to the consumer [29]. However, there is some controversy over whether or not the species of bacteria found in the original Balkan product can be considered a probiotic.

Cheese was similarly discovered in ancient times when fermented milk was found to fractionate into a liquid and a coagulated solid that was protein rich. The liquid, known as whey, was drained, leaving a solid curd to be stacked and dried during an aging process to produce cheese [30]. Cheeses, particularly hard cheeses, maintain their nutritional value for long periods of time. In addition, because it contains little lactose, cheese can command an advantage over milk for consumers who are lactose intolerant [31]. In a later discovery, rennet, an enzyme found in the stomach lining of cows, was found to quicken the coagulation process. Medieval clergymen later tinkered with the aging processes and the use of rennet to give us the hard cheeses like Parmesan, Gruyère, Roquefort, and Munster [32]. Modern technologies have focused on standardizing milk inputs, such as by diafiltration [33], and creating cheeses with the functional properties taste, color, melt, and mouth feel that are considered desirable by the end user [34], such as by adding adjunct species during the fermentation process [35]. In addition, there are areas of intensive research with the aim of reducing production time. These include developing strategies for preventing bacteriophage infections that might slow the acidification process during fermentation by exploiting host bacteriophage resistance and defense mechanisms [36] and finding methods to speed up the curd drying process [37].

The functional properties associated with cheese include the following: flavor/aroma, which is a result, in part, of protein and fat content; viscosity, which is determined by the liquid phase of the milkfat; texture/mouthfeel, stretch, which depends on pH, relative fractions of colloidal calcium phosphate, and the proportion of casein proteins that remain intact; browning during baking, which occurs due to a reaction between lactose and proteins; and freezing ability, which is the ability to be frozen and retain physical properties. Research in the area of functional properties of cheeses is ongoing as new products are created in response to demands by the end user. For example, due to some of the negative health effects of saturated fats, low-fat alternatives have been developed. However, additives are needed to compensate for the lack of fats so that the properties of the cheese do not change with respect to normal fat cheese [38]. Another aspect of functionality is associated with the health benefits that the components of cheese provide. For example, beneficial bioactive peptides, oligosaccharides, and fatty acids are found in cheeses such as Parmesan and Gouda. The health benefits of these bioactives can include a reduction in hypertension and blood sugar as well as immune system modulation [39].

Modern industrial production of soft cheeses and Greek yogurt generates large quantities of liquid acid whey byproducts, which are environmentally unfriendly and costly to transport and dispose of [40]. One solution that has been attempted is to transfer liquid whey to farmers for use as a crop fertilizer [41]. However, transportation costs for high volumes are high. In addition, limited amounts of acid whey can be disposed of in this fashion because runoff can lead to acidification of nearby water supplies. Such additional contamination in water can lead to algal blooms and a resultant drop in dissolved oxygen which is lethal for aquatic animal species [42]. For this reason, a method for converting the liquid whey by-product into a usable product in other processed food products or to limit the production of whey [43] are active areas of research. Some possible solutions that have been proposed are to process the lactose found in this by-product for use as a sweetener [44] or to use microfiltration technologies to separate out specific proteins that can be used as functional ingredients in other food products [45]. However, the vast quantities of acid whey produced by the dairy industry remain an ongoing problem in search of innovative solutions.

3. Dairy foods in human nutrition

Recognizing the importance of milk in the human diet, the USDA has promoted the consumption of milk since at least the mid-twentieth century. For example, the National School Lunch Act of 1946 mandated that milk be included in subsidized school lunches. Meanwhile, the Child Nutrition Act of 1966 and the Special Milk Program led to the provision of free milk to schools that did not participate in other nutrition programs. In 1990, the Fluid Milk Promotion Act was passed in order to authorize the USDA to conduct campaigns to increase consumer purchases of liquid milk. Since then, the "Got Milk" campaign began in 1993 as a way to counter the rise in the consumption of sugary soft drinks as a primary beverage. This campaign was replaced by the "Milk Life" campaign in 2014 that emphasized lifestyle choices. In 2004, the "3-A-Day" advertising campaign was introduced which promoted a link between milk products and the health benefit of weight loss (this campaign was later discontinued in 2007 to due complaints to the Federal Trade Commission of the lack of evidence for this claim). Private initiatives were also carried out, such as the formation of Dairy Management, Inc. to promote the sale of milk. Beginning in 2015, the issue of low milk sales took particular prominence due to the drop in sales of dairy products vs. non-milk plant-based products. Since then, research into how best to promote the sale of liquid milk has been welcomed [46]. Another recent development in human nutrition is related to the establishment of "my plate." It replaced the USDA's MyPyramid guide on June 2, 2011, ending 19 years of USDA food pyramid diagrams. This clearly demonstrated that dairy foods become part of modern healthy diet.

The primary purpose of this book is thus to explore a cross section of current trends in dairy science with respect to safety, sustainability, processing, health, and marketing. Food safety risks in the dairy supply chain will be explored as well as systematic discovery of marketing messages designed to appeal to the dairy consumer. We will look at some of the technology improvements in manufacturing processes, the exploitation of waste products, and new frontiers in the production of functional cheese products. In addition, we also reopen the issue, originally proposed by Metchnikoff, that the species of bacteria found in yogurt is the reason for yogurt's health benefits, with an emphasis on the particular properties and benefits of *L. bulgaricus*, one of two primary species used in the fermentation of yogurt products. Other trends left unexplored are the search for antimicrobial targets that can be exploited in food safety applications [47, 48] and gaining a better understanding of the process of autolysis, which is fundamental to cheese making and probiotic stability [49], and the role of prebiotics in health promotion [50].

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