Chapter

Recent Advances and Application of Biotechnology in the Dairy Processing Industry: A Review

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Abstract

Worldwide continuous demand for milk and milk products triggers different stakeholders in the dairy sector, which leads to the establishment of modern dairy farms, processing companies, and the invention of artificial intelligence. This dramatic change in the sector boosted milk production and reduce the impact of dairying on the environment. There has been a tremendous improvement in all unit activities such as separation, standardization, pasteurization, homogenization, and packing due to modern innovations in the fluid milk processing business. Advanced technologies in milk processing are applied to extend the shelf life, enhance the nutritional quality and safety of dairy products and health advantages without altering its physicochemical characteristics. Generally, the use of recent technologies in milk production has a significant impact to address the demand for milk and milk products, poverty alleviation, reducing GHG emissions, and other global challenges. The dairy industry can benefit greatly from new advancements and innovations in modern biotechnology, such as rDNA technology, transgenics, probiotics, bio preservatives, recombinant enzymes, starter culture, and improved bioprocess engineering tools by producing novel foods customized for specific consumers. While biotechnology brings incredible benefits, it also persuades a potential impact on health and the environment. Therefore, its application needs great intention.

Keywords: biotechnology, dairy product, milk, technology, processing

1. Introduction

While milk production per cow has risen dramatically in the last three decades through research that emphasizes efficient and sustainable milk production alongside productivity improvement, farmers still seek the wisdom of attempting to increase milk production with long production years in order to alleviate their fear of dairy cows' short productive lifespan. Moreover, achieving maximum productivity using scarce natural resources is the greatest challenge for dairy farmers, which can be addressed by implementing dairy farming innovations on every farmer's farm. The application of innovations at all stages of production, from fodder cultivation to milk marketing, is a critical need in today's world [1]. As a result, scientists and researchers devise a variety of innovations to increase resource efficiency and/or provide information to farmers. In the last two decades computerized or automated technologies, such as computerized feed delivery and milking systems, on-farm computers to manage dairy records, automatic take-offs for milking units, and a holding pen with an udder washer that uses computer hardware and software, have been discovered. Moreover, Pulsed electric fields, high hydrostatic pressure, high-pressure homogenization, ohmic and microwave heating, microfiltration, pulsed light, UV light processing, and carbon dioxide processing are some of the emerging dairy processing technologies that could reduce energy consumption and greenhouse gas emissions [2]. The efficiency of processing technologies is also enhanced by using bacteriocins. Furthermore, milk processing has a significant impact on small-scale dairy producers to generate higher cash incomes than selling raw milk and offers better opportunities to reach regional and urban markets. Milk processing can also help to deal with seasonal fluctuations in milk supply [3].

Despite the fact that achieving expected animal productivity at a lower cost for greater economic returns is dependent on the ability to transfer these innovations from the lab to the field in the dairy farming system, innovations have a significant impact in overcoming the sector's current challenges. Consequently, to raise milk production with minimal GHG emissions, improved animal husbandry techniques should be adopted in smallholder household dairy farms [1] along with technological innovations.

Biotechnology's application in the dairy industry has a substantial role that improve milk production, animal health, and food processing. Genetically modified microorganisms such as bacteriocins and probiotics have been associated with lowering the risks of type 2 diabetes, metabolic syndrome, and heart disease, as well as better weight management [4]. Besides, probiotic products contain microorganisms that are viable, specific, and effective in critical nutritional physiology systems. *Lactobacillus, Bifidobacteria, Saccharomyces,* and *Streptococcus* are some of the bacteria found in fermented dairy products [5, 6]. Bio-preservation with natural preservatives has a positive effect on consumer health promotion in addition to improving food safety and shelf-life as a technological effect [4].

Furthermore, the application of technology has had a significant impact on addressing several challenges faced by the food industry on food safety, preservation, nutrition, and allergies, food security, changing consumer needs, environmental concerns, economic viability, and policy reforms. Dairy processing companies around the world need efficient, low-cost, and automated innovations to increase profits and meet the demand of a wide range of products. Therefore the aim of this paper is to recapitulate and combine the different information on current development in milk production and processing.

2. Overview of the global dairy industry

Global milk production trends increases dramatically in the last 30 years from 530 million tonnes in 1988 to 843 million tonnes in 2018 [3]. Over the next ten years, global milk production is expected to increase at a rate of 1.6 percent each year (to 997 Mt. by 2029), outpacing most other major agricultural commodities [7], however, the expected growth remains tight in 2022, with only a 0.6 percent increase projected and EU countries produced below the expectation, especially New Zealand and Australia [8]. Moreover, the global milk production reported in January 2022 was lower by 1.6%

than the previous year's counterpart [9]. USDA is estimating just a 0.7% rise in milk production in 2022, which is bullish for milk prices.

On the other hand, milk production growth is predicted to decline by 0.5 percent per year in the European Union (EU) and reach 162 million tonnes by 2031. However, organic milk production in this region is predicted to increase (to 8% by 2031), resulting in economic gains, environmental benefits, and improved animal welfare [10]. The growth of average global milk production is achieved by improving the dairy cow production performance than the number of herds. Besides the large volume of milk consumed in the form of fresh dairy products, including pasteurized and fermented products, due to a significant increase in milk product demand in developing nations, the proportion of worldwide fresh dairy products consumption is predicted to rise over the next decade OECD [11]. In developed countries, processed dairy products are preferred, whereas, in underdeveloped countries, fresh dairy products account for more than 75% of the average per capita daily intake of milk solids. In underdeveloped countries, regional differences are enormous, with fresh dairy product consumption ranging from 99% in Ethiopia to 5.8% in the Philippines OECD [11].

Furthermore, according to Minj *et al*. [12], the production, storage, and distribution of various types of dairy products, as well as the management of dairy-related data, are significantly influenced by global milk production and processing. According to literature evidence, various processing technologies have been used to produce several types of milk and milk products. Market milk, flavored milk, cream, butter, butter oil/ghee, condensed and evaporated milk, milk powder, fermented milk, yogurt, cheese, ice cream, and indigenous dairy products are among the most common processed dairy products. The major processing technologies necessitate a robust setup for continuous production and maintaining final product quality [12].

2.1 Revolutions in milk production and milking

Manual or hand milking is a time-consuming, labor-intensive process and the milk preserving process is also unsanitary, moreover, a bacterial infection in milk can occur as a result of a manual process. Wondatir [13] proposed a novel robotic milking technology that can grab the milking claws of cows. Introducing auto-milking has solved this problem more efficiently through lowering costs and manpower, automatically preserving the milk by using various smart cooling tanks. Few models of low-cost, nonelectric milking machines are also developed considering the locality and need of dairy farms. Milk that did not fit for human consumption is diverted to a separate container. The sensors in the automatic milking machine play important role in detecting the readiness of teats for milking and also identify impurities, color, and quality of milk. The majority of auto-milking systems rely on two components: a computer and specialized herd management software. This material can perform activities such as collecting the animal, cleaning the animal before milking, attaching the milking equipment, extracting milk, removing the equipment, and routing the animal out of the special area Muhammad Osama [14]. The robotic feeding system can calculate the effectiveness of feed for milk production as well as a cow's nutritional requirements.

The invention and introduction of highly efficient automatic milk meters that built into robotic milking systems of cows are extremely important to control the main technological parameters in the process of milking (live weight, temperature, electrical conductivity, and so on) [15, 16]. Additionally, it is also a remarkable role to determine different stages of lactation, heat periods, somatic cell count, motor activity, and other zootechnical registration parameters. Viguier et al. [17] revealed the use of SCC as an alternative method of detecting mastitis. Hereafter numerous sensors are used in the production of high-quality milk and the use of microchip technologies has resulted in faster results. Furthermore, with these technologies, you will be able to diagnose mastitis more successfully with more effective tests and results with a wider angle and more accurate results. Milk conductivity and milk appearance are commonly used on farms. Other methods, on the other hand, provide another early mastitis detection for a quick and accurate decision to cure the disease.

Moreover, an automatic milking system has a priceless impact not only on milking but also on management systems including feeding, cow traffic, cow behavior, grazing, milk quality, and animal health by using electronic devices or sensors. A large number of research studies have reported analyses of AMS impact on specific aspects such as milk yield/quality [18, 19], animal behavior/health/welfare herd management [20] performance, and labor efficiency [21, 22]. Some studies reported a 2 to 12 percent increase in milk production in cows milked 2+ times per day in AMS compared to cows milked twice per day in traditional milking parlors. However, the result of Hansen et al. [23] revealed that the use of AMS did not show an increase in milk production, especially for prim parous cows [24–26].

The machine can monitor the state of herd productivity and express milk analysis is a critical condition for effective milk production and industry competitiveness. Express analysis of each animal's milk allows you to assess the animal's health and productivity with confidence. The data obtained from the automated machine will be processed and used to control the level of productivity and identify problems for immediate corrective action [27].

The first commercial AMS in dairy farms was introduced in the Netherlands in the 1990s, and about 50,000 units were adopted worldwide by 2020 [28]. AMS is mainly concentrated in Europe (90%), Canada (9%), and other countries (1%). However, it is expected that by 2025, 50% of dairy cows in North-Western Europe will be equipped with AMS [29].

To recapitulate, the innovation of robotic milking machines is useful in eliminating the pressure on human labor and maintaining a hygienic milking process with remarkable improvement in milk production, as well as managing every aspect of management and reproduction in the farm by incorporating an automated milk meter on it.

2.2 Recent advances in milk processing or dairy industry

In the last two decades, major technological advances in the fluid milk processing industry have been observed, with a significant improvement in all unit operations such as separation, standardization, pasteurization, homogenization, and packaging. Besides, many advances have been made in terms of production capacity, automation, and sanitary operation [30]. Traditionally, milk is processed by heating it to a specific temperature for a fixed period of time, which results in a significant reduction in the microbial population [31]. However, recently developed nonthermal processing methods are ideal for milk and other food staff with higher performance of eliminating microorganisms or any other biological entities without causing a significant temperature rise, thereby preventing a chain of undesirable reactions in foods [31]. High-pressure processing (HPP), microfiltration, centrifugation, pulsed electric field (PEF), ultraviolet light (UV), and cold plasma processing are among the widely used nonthermal processing. Moreover, automated technologies have also been developed to reduce labor costs and losses during processing, including automated clean-in-place (CIP) system, inclined film scraped surface heat exchanger (ISSHE), automated spray dryer, membrane processing (ultra filtration (UF), reverse osmosis (RO), micro-filtration (MF), nano filtration (NF), and electrodialysis). Ultrasonic processing or sonication is a promising alternative technology in the food industry as it has the potential to improve the technological and functional properties of milk and dairy products. Furthermore, High-intensity ultrasound (HIU) is a promising emerging technology, specially designed for economy, simplicity, and energy efficiency. HIU has multiple benefits either in the processing or evaluation of products [32]. It also offers a great potential to control, improve, and accelerate processes without damaging the quality of food and other products.

2.2.1 High-pressure processing (HPP)

A nonthermal method of food and dairy product preservation and sterilization in which a product is subjected to extremely high pressure, causing some microbes and enzymes in the food to be inactivated [33]. Research on raw milk treated with high pressure has shown that HPP treatment produces raw milk of comparable quality to pasteurized milk, as it is equally successful in eradicating pathogenic and spoilage microorganisms. When compared to foods with a higher pH, such as milk, HPP proved effective at inactivating bacteria in both high- and low-acid food systems. It may influence the qualities of treated milk by modifying the fundamental features of milk ingredients [34]. In the food and dairy sector, high-pressure processing is a unique alternative to thermal processing [33] that includes a treatment chamber, a pressure generating system, a pressure transmission medium, and a pressure intensifier [34]. HPP was performed at 680 MPa for 10 minutes at room temperature and the number of microorganisms was reduced by 5–6 log cycles.

2.2.2 Pulsed electric fields (PEF)

The fundamental principle of PEF technology is the use of short pulses of high electric fields with durations ranging from microseconds to milliseconds and intensities ranging from 10 to 80 kV/cm. Short pulses (1–10 μs) generated by a high voltage (5–20 kV) pulse generator have been used to treat biological material or food placed between two electrodes installed 0.1–1.0 cm apart in a treatment chamber separated by an insulator [35].

The processing time is calculated by multiplying the number of pulse times with effective pulse duration. The applied high voltage results in an electric field that causes microbial inactivation. When an electrical field is applied, electrical current flows into the liquid food and is transferred to each point in the liquid because of the charged molecules present ([36]; as cited by [33]). PEF treatment has achieved a reduction in the microflora of milk with a shelf life similar to that of high temperature, short time (HTST) pasteurized milk.

The ability to control the amount of ohmic heating in food preservation (low-temperature processing) is the main benefit of PEF technology in liquid food pasteurization. This avoids the Maillard reaction, which affects the functional properties of food such as color, taste, and smell [37]. PEF is also effective in the inactivation of microorganisms such as *Salmonella typhimurium*, *Listeria innocua*, and *E. coli* up to 5.0 log cycles [38].

The method is highly scalable and can be incorporated into existing food processing lines. In comparison to traditional heat pasteurization technology, it is more energy-efficient [39]. Furthermore, PEF treatment chambers can be easily adapted to existing continuous-flow production lines for liquid food pasteurization [40]; however, achieving a homogeneous treatment may be an issue [41]. The main disadvantage of PEF technology is its effectiveness and efficiency, which are largely dependent on the liquid conductivity and viscosity [42].

2.2.3 Ultra-sonication

It refers to the application of sound waves at the frequency (˃ 16 kHz) greater than the upper limit of human hearing through liquid, solid, or gases, which causes the formation of small bubbles (known as cavitation). While droplets reach the required size range, they collapse under near-adiabatic conditions, resulting in significant conditions both within the droplets and in the surrounding liquid that include intense shear forces, turbulence, and micro streaming effects. These ultrasound-induced physical effects are increasingly being used in food and dairy processing industries, its application is used to enhance whey ultrafiltration, extraction of functional foods, reduction of product viscosity, homogenization of milk fat globules, crystallization of ice and lactose, and the cutting of cheese blocks [33].

The use of ultrasound in traditional dairy processes has the potential to bring significant cost savings and improved product qualities to the dairy sector. Furthermore, as compared to other new technologies, the use of ultrasound as a processing technique has been deemed safe [43]. These technologies include low- and high-intensity ultrasounds. Low-intensity ultrasounds have been used to determine, evaluate, and define the physical features of foods, whilst high-intensity ultrasounds have been utilized to speed up specific biological, physical, and chemical processes during the handling and transformation of food products [44].

2.2.4 Cold plasma (CP)

Cold Plasma is an electrically powered gaseous state consisting of charged particles, free radicals, and some radiation that is known as the fourth state of matter. An electrical discharge [45] produces a partially or totally ionized plasma made up of photons (basically), ions, free electrons, and atoms in their fundamental or excited states. These species are classified as either "light" (photons and electrons) or "heavy" (remaining constituents) [46, 47].

Currently, CP undergoing extensive testing for the preservation of perishable commodities such as milk and milk products. The use of cold plasma (CP) techniques to preserve milk and milk products has been pushed as a revolutionary nonthermal technology. CP not only preserves the nutritional value of the food but also inactivates germs, eliminating the risk of resistance. Cold plasma was also discovered to disrupt enzymes involved in browning (color change) processes and the production of an off-flavor [48].

2.3 Membrane separation technology

It is a method of separating a liquid into two streams using a semipermeable membrane. The two streams are called retentate and permeate, respectively. Specific components of milk and whey can be separated using membranes with different pore sizes. Membrane filtering technology offers a variety of applications in the cheese industry, including boosting nutritional quality, improving compositional control and production by increasing total solid content, using whey during cheese manufacturing, and minimizing the need for rennet and starter culture. Concentrating milk before manufacturing cheese opens up a new market for the cheese industry, lowering costs and speeding up the entire process [49]. Membranes in the cheese industry concentrate the cheese milk, increasing yield and quality while controlling whey volume. It is now possible to recover growth factors from whey because of advancements in membrane technology [50]. Membrane filtration can basically be divided into four main technologies, which are as follows:

2.3.1 Microfiltration (MF)

Microfiltration is a membrane filtration technique that uses a membrane with an open structure and is powered by low pressure. The membrane allows dissolved components to pass while rejecting the majority of non-dissolved components. Microfiltration is widely used in the dairy industry to reduce bacteria and spores, remove fat from milk and whey, and standardize protein and casein.

2.3.2 Ultrafiltration (UF)

Ultrafiltration is a membrane filtration process that operates at medium pressure. Ultrafiltration works by passing most dissolved and non-dissolved components through a membrane with a medium open structure while rejecting larger components. UF is widely used in the dairy industry for whey protein concentration and milk protein concentration as well as standardization.

2.3.3 Nano-filtration (NF)

Nano-filtration is an intermediate step in the high-pressure membrane filtration process. In general, nano-filtration is a type of reverse osmosis in which the membrane has a slightly more open structure that allows primarily monovalent ions to pass through. The membrane rejects divalent ions to a large extent. Nano-filtration is primarily used in the dairy industry for specialized applications such as partial demineralization of whey, lactose-free milk, and whey volume reduction.

2.3.4 Reverse osmosis (RO)

Reverse osmosis is a high-pressure, membrane-based filtration process that uses a very dense membrane. In theory, only water passes through the membrane layer. Reverse osmosis is commonly used in the dairy industry for milk and whey concentration or volume reduction, milk solids recovery, and water reclamation.

2.4 Application of biotechnology in dairy processing

Recent biotechnological breakthroughs have emerged as a significant tool for developing quality features in livestock products, such as dairy and dairy-based products. In most developing nations, biotechnology has been used to improve food processing by using microbial inoculants to improve qualities such as flavor, scent, shelf life, consistency, and nutritional content of meals and dairy products. Probiotic food products are a rapidly expanding segment of functional food that has been well received by consumers. The food sector, on the other hand, is striving to offer a variety of probiotic foods other than dairy products with potential health benefits [51].

Moreover, modern biotechnology has brought up new and exciting opportunities in the dairy industry, making milk and milk products more accessible to the poor and meeting the demands of a larger population. Since the dairy industry's primary responsibility is to provide consumers with high-quality, nutritional, and affordable dairy meals, biotechnological intervention at various stages of milk production and processing has become a foregone conclusion [52]. It has provided us with delicious, nutritious, wholesome, handy, shelf-stable, and safe foods. As long as research and development efforts continue, biotechnology will inevitably have a greater impact on the food we eat. It has enormous potential for expanding the variety and quality of food available to humans, especially more healthy and appealing foods. It also appears likely that it will continue to provide benefits to food processing and safety monitoring as new technologies develop at a faster rate. Furthermore, the biotechnological application has a remarkable role in dairy product bio-preservation, probiotics manipulation, and production; enzyme production; milk derived bioactive peptides and other functional ingredients; and starter cultures technology and genetic manipulation.

2.4.1 Bio-preservation

Although recent advances in innovative modern technologies implemented in food processing and more stringent microbiological food-safety standards have reduced the incidences of foodborne illnesses and product spoilage, they do not completely eliminate the possibility of health risks associated with such foods. As a result, the food industry is always exploring novel techniques and methods to produce minimally processed, ready-to-eat food that retains its nutritional value, taste, and flavor. Bio-preservation like bacteriocin is an ideal choice to preserve ready-to-eat processed foods without altering their nutritional and chemical properties.

Bacteriocins are antimicrobial peptides that are deemed harmless since they are easily destroyed by mammalian gastrointestinal proteolytic enzymes. Furthermore, the majority of bacteriocin producers belong to lactic acid bacteria (LAB). Bacteriocins, whether purified or secreted by bacteriocin-producing bacteria, are a wonderful alternative to chemical preservatives in dairy products because they pose no health risks. Bacteriocins can be added to dairy products in purified/raw form, as a bacteriocin-producing LAB in the fermentation process, or as an adjuvant culture. Bacteriocins and bacteriocin-producing LAB have been used to control pathogens successfully in milk, yogurt, and cheeses in a number of cases. One of the most recent development is the inclusion of bacteriocins, whether directly as purified or semipurified form, or as bacteriocin-producing LAB, into bioactive films and coatings that are directly applied to food surfaces and packaging [53].

2.4.2 Probiotics

Probiotic is a relatively recent term that means "for life," and it refers to bacteria that have been connected to beneficial effects in humans and animals. The probiotic microorganisms are primarily *Lactobacillus* and *Bifidobacterium* strains, but *Bacillus*, *Pediococcus*, and several yeast strains have also been identified as suitable possibilities [54]. Sour/fermented milk, yogurt, cheese, butter/cream, ice cream, and infant formula all contain probiotic bacteria. These probiotics are either used as a starter culture alone or in combination with traditional starters, or incorporated into dairy products after fermentation, where their presence confers many functional characteristics to the product (such as improved aroma, taste, and textural characteristics), as well as many health-promoting properties [55].

Milk and milk products, particularly fermented dairy foods, are thought to be excellent carriers of probiotic strains, which allows to express their health-promoting functions to the greatest extent possible. Probiotic microorganisms can be concentrated and added in small amounts directly to food or a milk product, where they can grow. Yogurt is a well-known example of probiotic-rich functional dairy food. Probiotic yogurt, also known as bio-yogurt, should contain living bacterial cultures. Probiotics have been used to treat intestinal disorders as dietary supplements and oral agents. Probiotics have appeared recently as among the most precious bugs due to their ability to express a plethora of novel health-promoting functions that are strain-specific. Immunomodulation, restoring the balance of disturbed gut flora, strengthening the mucosal barrier function, and preventing lactose intolerance are the most notable probiotic functions. However, the focus at the moment is on researching probiotics as potential biotherapeutics for chronic inflammatory metabolic disorders such as diabetes, CVD, obesity, irritable bowel disease (IBD) and syndrome (IBS), Ulcerative Colitis (UC), Crohn's disease (CD), acute diarrhea, serum cholesterol reduction, shortening the duration of respiratory infections, blood pressure control, colon cancer, and urinary tract infection (UTI), among others.

2.4.3 Biotechnology and enzyme production

Enzyme production is a new field that answers the needs of the food processing industry by drastically lowering investment and processing costs. Enzymes are a biotechnological processing tool whose action in the food matrix may be manipulated to produce high-quality products. Moreover, the application of biotechnology has a significant role to produce enzymes used in the food and dairy industries, microbial protease, lipase, and galactosidase are enzymes that come from beneficial microorganisms. Their thermoresistance, thermostability, and thermoacidophilic qualities brought a particular interest to food producers [56].

The industrial production of enzymes for use in food processing dates back to 1874 when Danish scientist Christian Hansen extracted rennin (chymosin) from calves' stomachs for use in cheese manufacturing. Bovine chymosin was the first enzyme to be produced through biotechnological approaches in *E. coli*. Since then, genetic manipulation has been used to make tailor-made enzymes for specific consumer requirements. Now enzymes can be produced through recombinant DNA technology in large quantities for their subsequent application in the food industry (**Table 1**).

Some microorganism strains have been genetically modified to boost their capacity for enzyme synthesis under ideal conditions. In most situations, changed genes from other kingdoms of microorganisms can be found in GM microorganisms that generate enzymes. Bio-based compounds such as glucoamylase, lipase, –amylase, pectinase, antibiotics, amino acids, lactic acid, nucleic acid, and polysaccharides are created utilizing GM starting cultures. For example, one of the DNA codes for chymosin, which causes milk to curdle or coagulate during cheese fermentation, was cloned into bacteria (*Escherichia coli*), yeast (*Kluyveromyces lactis*), and mold (*Bacillus niger*) (*Aspergillus niger*). In Thailand, modified *E. coli* is being utilized to produce lysine, with the goal of increasing yield in less time [58].

2.5 Future application of biotechnology in the dairy industry

In the past, biotechnology has made substantial contributions to the dairy sector from animal genetic improvement to milk product processing. Thus, the following areas are some examples of possible applications of biotechnologies in future scenarios.

Dairy production

- Recombinant bovine
- Recombinant vaccines
- DNA fingerprinting
- Embryo transfer technology
- Animal cloning
- Gene forming and transgenic

Dairy processing

- Food grade bio-preservatives
- Dairy enzymes/proteins
- Probiotics

Enzymes	Microorganisms	Application
Phytase	Aspergillus niger	Dair
Lipase		Baking, cheese flavor development
Lipase	Aspergillus oryzae	Cheddar cheese production
Chymosin	Escherichia coli K-12	Cheese
Chymosin	Kluyveromyces marxianus var. lactis	Cheese production
Microbial rennet	Mucor miehei	Baking, starch, cheese
Protease Starch,	Aspergillus usamii	brewing, meat tenderizer, milk coagulation, improvement of bread quality
β-Galactosidase (lactase)	LAB	Lactose intolerance reduction in people Prebiotic food ingredients

Source: Ghoshal [57].

Table 1.
Enzymes produced from genetically modified microorganisms using gene technology used in the dairy industry.

- Functional foods and nutraceuticals
- Dairy waste organization and pollution control

3. Conclusion

World dairy production and consumption were significantly increased in the last three decades, researchers and trend analysts claim that this growth will continue for the next few decades. However, in some countries especially in the EU, the number of cows is decreasing in recent years due to environmental, animal welfare, and other reasons. On the other hand, a number of technologies are invented and introduced to support the intensification of dairy farms. Recent technologies such as automatic milking machines, sensors, blockchain, and automatic feeders can provide significant improvements to milk production, environmental sustainability, and animal welfare in livestock agriculture. Similarly, sophisticated milk processing technologies have also been developed, which will have a remarkable role to produce dairy products that are wholesome and fit for human consumption. As well most recent processing technologies have a great potential for reducing GHG emissions during production, processing, and storage. Recently new biotechnological products are being developed for use in both animal production and food processing, dairy product bio-preservation, probiotics manipulation and synthesis, enzyme manufacturing, milk-derived bioactive peptides, other functional components production, and starter cultures technology and genetic manipulation are all examples of biotechnological applications. Conversely, the invention and application of these mysterious technologies were restricted in developed countries. Therefore, these advanced technologies should be more accessible to farmers around the world particularly to farmers in developing countries to improve milk production per cow, reduce higher GHG emissions, and feed growing populations.

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References

[1] Nimbalkar V, Verma HK, Singh J. Dairy farming innovations for productivity enhancement. In: Qureshi MS, editor. New Advances in the Dairy Industry. London, United Kingdom: IntechOpen; 2021. DOI: 10.5772/intechopen.101373

[2] Datta N, Tomasula PM. Emerging Dairy Processing Technologies: Opportunities for the Dairy Industry. West Sussex, UK: John Wiley & Sons; 2015

[3] FAO. Gateway to dairy production and products. 2022. https://www.fao.org/dairy-production-products/production/en/

[4] Amiri S, Aghamirzaei M, Mostashari P, Sarbazi M, Tizchang S, Madahi H. The impact of biotechnology on dairy industry. In: Applied Biotechnology Reviews, Microbial Biotechnology in Food and Health. London, UK: Academic Press; 2021. pp. 53-79. DOI: 10.1016/B978-0-12-819813-1.00003-7

[5] Gomes AA, Braga SP, Cruz AG, Cadena RS, Lollo PC, Carvalho C, et al. Effect of the inoculation level of Lactobacillus acidophilus in probiotic cheese on the physicochemical features and sensory performance compared with commercial cheeses. Journal of Dairy Science. 2011;**94**:e4777-e4786

[6] Minervini F, Siragusa S, Faccia M, Dal Bello F, Gobbetti M, De Angelis M. Manufacture of Fior di Latte cheese by incorporation of probiotic lactobacilli. Journal of Dairy Science. 2012;**95**:e508-e520

[7] OECD-FAO. Agricultural Outlook 2020-2029. 2020

[8] AHDB (Agriculture and Horticulture Development Board). 2022. Dairy market outlook

[9] Gindt K. Dairy Situation and Outlook. USA: The Board of Regents of the University of Wisconsin System; 2022

[10] European Commission. EU Agricultural Outlook for Markets, Income, and Environment, 2021-2031. Brussels: DG Agriculture, and Rural Development; 2021

[11] FAO. Global dairy industry and trends. International Magazine for Animal Feed & Additives Industry. 2021

[12] Minj J, Aparna SV, Kumari A. Dairy Processing: Advanced Research to Applications. Singapore: Springer; 2020

[13] Wondatir. Livestock production systems in relation with feed availability in the highlands and central rift valley of Ethiopia. 2010

[14] Akbar MO, Shahbaz Khan MS, Ali MJ, Hussain A, Qaiser G, Pasha M, et al. IoT for development of smart dairy farming. Journal of Food Quality. 2020;**2020**:4242805. DOI: 10.1155/2020/4242805

[15] Mishurov NP. Information management of dairy cattle breeding. Bulletin of VNIIMZh. 2014;**4**(16):41-48

[16] Tsoi YA, Mishurov NP. State and development trends of robotic equipment for milking cows. Rural Machinery and Equipment. 2019;**5**(263):2-9

[17] Viguier C, Arora S, Gilmartin N, Welbeck K, O'Kennedy R. Mastitis detection: Current trends and future

perspectives. Trends in Biotechnology. 2009;**27**(8):37

[18] Lessire F, Moula N, Hornick J, Dufrasne I. Systematic review and meta-analysis: Identification of factors influencing milking frequency of cows in automatic milking systems combined with grazing. Animals. 2020;**10**:913

[19] Masía FM, Lyons NA, Piccardi M, Balzarini M, Hovey RC, Garcia SC. Modeling variability of the lactation curves of cows in automated milking systems. Journal of Dairy Science. 2020;**103**:8189-8196

[20] Edwards JP, Kuhn-Sherlock B, Dela Rue BT, Eastwood CR. Short communication: Technologies and milking practices that reduce hours of work and increase flexibility through milking efficiency in pasture-based dairy farm systems. Journal of Dairy Science. 2020;**103**:7172-7179

[21] Karttunen JP. Occupational health and safety of Finnish dairy farmers using automatic milking systems. Frontiers in Public Health. 2016;**4**:1-11. DOI: 10.3389/fpubh.2016.00147

[22] Salfer JA, Siewert JM, Endres MI. Housing, management characteristics, and factors associated with lameness, hock lesion, and hygiene of lactating dairy cattle on Upper Midwest United States dairy farms using automatic milking systems. Journal of Dairy Science. 2018;**101**:8586-8594. DOI: 10.3168/jds.2017-13925

[23] Hansen BG, Stræte EP. Dairy farmers' job satisfaction and the influence of automatic milking systems. Journal of Life Science. 2020;**92**:100328

[24] Friggens NC, Blanc F, Berry DP, Puillet L. Review: Deciphering animal robustness. A synthesis to facilitate its use in livestock breeding and management. Animal. 2017;**11**:2237-2251

[25] Göncü S, Güngör C. The innovative techniques in animal husbandry. In: Yucel B, editor. Animal Husbandry and Nutrition. London, United Kingdom: IntechOpen; 2018. DOI: 10.5772/intechopen.72501

[26] Grothmann A, Nydegger F, Moritz C, Bisaglia C. Automatic feeding systems for dairy cattle—Potential for optimization in dairy farming. In: International Conference on Agricultural Engineering: Towards Environmental Technologies. 2010

[27] Tikhomirov IA, Skorkin. Experience of using milking robots in dairy cattle breeding on the example of farms in the Kaluga region. Bulletin of VNIIMZh. 2019;**1**(33):160-165

[28] Marcos L, Filho S, Lopes MA, Brito SC, Rossi G, Conti L, et al. Robotic milking of dairy cows: A review (Ordenha robotizada de vacas leiteiras: Uma revisão). Semina Ciências Agrárias. 2020;**41**:2833-2850

[29] Hansen BG, Herje HO, Höva J. Profitability on dairy farms with automatic milking systems compared to farms with conventional milking systems. International Food and Agribusiness Management Review. 2019;**22**:215-228

[30] Goff HD, Griffiths MW. Major advances in fresh milk and milk products: Fluid Milk products and frozen desserts. Journal of Dairy Science. 2006;**89**(4):1163-1173. DOI: 10.3168/jds.S0022-0302(06)72185-3

[31] Shrivastava SL, Banerjee S. Recent trends in milk processing—A short review. Approaches in Poultry, Dairy & Veterinary Sciences. 2017;**2**(1):11-13. DOI: 10.31031/APDV.2017.02.000527

[32] Dolatowski ZJ, Stadnik J, Stasiak D. Applications of ultrasound In food technology. Acta Scientiarum Polonorum Technologia Alimentaria. 2007;**6**(3):89-99

[33] Reena, Kumar A. Thermal and non-thermal treatment of milk: A review. International Research Journal of Engineering and Technology (IRJET). 2021;**8**(5):2330-2332

[34] Singh AK, Borad S, Meena GS, Sharma H, Arora S. High-pressure processing of milk and milk products. In: Chauhan OP, editor. Non-thermal Processing of Foods. 1st ed. Boca Raton, Florida, United States: CRC Press, Taylor & Francis Group; 2019. pp. 69-88. Available from: https://lccn.loc.gov/2018033439

[35] Sampedro F, Rodrigo D. Pulsed electric fields (PEF) processing of milk and dairy products. In: Datta N, Tomasula PM, editors. Emerging Dairy Processing Technologies: Opportunities for the Dairy Industry. West Sussex, UK: John Wiley & Sons; 2015. pp. 115-147

[36] Zhang Q, Barbosa-Canovas GV, Swanson BG. Engineering aspects of pulsed electric field pasteurization. Journal of Food Engineering. 1995;**25**:261-281

[37] Jaeger H, Janositz A, Knorr D. La Réaction de Maillard et Son Contrôle Pendant La Fabrication Des Aliments. Le Potentiel Des Nouvelles Technologies. Pathologie et Biologie. 2010;**58**:207-213

[38] Mosqueda-Melgar J, Elez-Martínez P, Raybaudi-Massilia RM, Martín-Belloso O. Effects of pulsed electric fields on pathogenic microorganisms of major concern in fluid foods: A review. Critical Reviews in Food Science and Nutrition. 2008;**48**:747-759

[39] Joannes C, Sipaut CS, Dayou J, Yasir SM, Mansa RF. The potential of using pulsed electric field (PEF) technology as the cell disruption method to extract lipid from microalgae for biodiesel production. International Journal of Renewable Energy Research. 2015;**5**:598-621

[40] Kandušer M, Belič A, Čorović S, Škrjanc I. Modular serial flow through device for pulsed electric field treatment of the liquid samples. Scientific Reports. 2017;**7**:8115

[41] Schottroff F, Knappert J, Eppmann P, Krottenthaler A, Horneber T, McHardy C, et al. Development of a continuous pulsed electric field (PEF) Vortex-flow chamber for improved treatment homogeneity based on hydrodynamic optimization. Frontiers in Bioengineering and Biotechnology. 2020;**8**:340

[42] Ivorra A, Villemejane J, Mir LM. Electrical modeling of the influence of medium conductivity on electroporation. Physical Chemistry Chemical Physics. 2010;**12**:10055-10064

[43] Chandrapala J. Ultrasound processing of milk and dairy products. In: Ashokkumar M, editor. Handbook of Ultrasonics and Sonochemistry. Singapore: Springer; 2015. DOI: 10.1007/978-981-287-470-2_66-1

[44] Chávez-MartínezA,Reyes-VillagranaRA, Rentería-MonterrubioAL,Sánchez-VegaR, Tirado-Gallegos JM, Bolivar-Jacobo NA. Low and high-intensity ultrasound in dairy products: Applications and effects on physicochemical and microbiological quality. Food. 2020;**9**(11):1688. DOI: 10.3390/foods9111688

[45] Fernández A, Thompson A. The inactivation of Salmonella by cold atmospheric plasma treatment. Food Research International. 2012;**45**:678-684

[46] Misra NN, Koubaa M, Roohinejad S, Juliano P, Alpas H, Inácio RS, et al. Landmarks in the historical development of twenty-first century food processing technologies. Food Research International. 2017;**97**:318-339

[47] Misra NN, Tiwari BK, Raghavarao KSMS, Cullen PJ. Nonthermal plasma inactivation of food-borne pathogens. Food Engineering Reviews. 2011;**3**:159-170

[48] Rathod NB, Kahar SP, Ranveer RC, Annapure US. Cold plasma an emerging non-thermal technology for milk and milk products: A review. International Journal of dairy technology. 2021;**74**(4):615-626

[49] Henning DR, Baer RJ, Hassan AN, Dave R. Major advances in concentrated and dry milk products, cheese, and milk fat-based concepts. Journal of Dairy Science. 2006;**89**:1179-1188

[50] Kumar P, Sharma N, Ranjan R, Kumar S, Bhat ZF, Jeong DK. Perspective of membrane technology in dairy industry: A review. Journal of Animal Science. 2013;**26**(9):1347-1358

[51] Sundarraj AA, Rajathi AA, Vishaal SC, Rohit D, Prakash MS, Sam AA, et al. Food biotechnology applications in dairy and dairy products. Journal of Pharmacy Research. 2018;**12**(4):520-525

[52] Padmavathi. "Modern biotechnology"—A tremendous application over today's dairy industry. International Journal of Advanced Studies. 2018;**3**(3):9

[53] Silva CCG, Silva SPM, Ribeiro SC. Application of bacteriocins and protective cultures in dairy food preservation. Frontiers in Microbiology. 2018;**9**(9):594

[54] Soccol CR, de Souza VL, Rigon SM, Pedroni MA, Yamaguishi CT, de Deae LJ, et al. The potential of probiotics: A review. Food Technology and Biotechnology. 2010;**48**:413-434

[55] Gao J, Li X, Zhang G, Sadiq FA, Simal-Gandara J, Xiao J, et al. Probiotics in the dairy industry—Advances and opportunities. Comprehensive Reviews in Food Science and Food Safety. 2021;**20**(4):3937-3982. DOI: 10.1111/1541-4337.12755

[56] Al-Manhel AJA. Application of microbial enzymes in dairy products: A review. Basrah Journal of Agricultural Science. 2018;**31**(1):20-30

[57] Ghoshal G. Biotechnology in food processing and preservation: An overview. In: Wolff AG, editor. Advances in Biotechnology for Food Industry. Handbook of Food Bioengineering. London, United Kingdom: Academic Press, Elsevier; 2018. pp. 27-54

[58] Enitan-Folami AM, Swalaha FM. 10 Application of biotechnology in the food industry. In: Ijabadeniyi OA, editor. Food Science and Technology: Trends and Future Prospects. Berlin, Boston: De Gruyter; 2020. pp. 235-277. DOI: 10.1515/9783110667462-010