Chapter

Milk-Borne Diseases

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Abstract

Milk is a rich source of vitamins, minerals, and other vital nutrients. Potassium, B12, vitamin D, and calcium are nutrients that are lacking in many foods. Milk is also a rich source of magnesium, zinc, vitamin A, and thiamine (B1). In addition to lactose and fat, milk is an excellent source of protein and contains numerous fatty acids, including conjugated linoleic acid (CLA) and omega-3 fatty acids. The primary sources of pathogens in milk and dairy products are animals, human handlers, equipment in contact, environmental sources, and water used in preparation. However, milk borne diseases, since early time, played a principal role in public health. This chapter is divided into the following parts: mammary Glands, the phases of mammary gland secretion after birth, nutritive value of colostrum, nutritive value of milk, major sources of milk contamination, milk-borne diseases, techniques used in milk preservation, milk testing and quality control, prevention of milk-borne diseases, and conclusions.

Keywords: milk, diseases, preservation, food safety, milk-borne diseases, milk contamination, quality control

1. Introduction

In mammals, including humans, mammary glands are exocrine glands that produce milk to nourish infants. Mammals are named after the Latin word *mamma*, which means "breast." Mammary glands are unique to mammals, serving the purpose of synthesizing, secreting, and delivering milk to the new-born.

The mammary glands are the medical term for the breasts. However, breasts are unique to humans. Although there are over 5000 mammals on the planet, *Homo sapiens* are the only life forms with permanent breasts [1].

2. The phases of mammary gland secretion after birth

After birth, only the mammary glands produce milk. The hormones progesterone and prolactin are released during pregnancy. By interfering with prolactin, progesterone inhibits lactation in the mammary glands. During this time, small amounts of colostrum, a pre-milk substance, are produced. The mammary gland is accountable for lactation and milk production. Colostrum, transitional milk, and mature milk are the three phases of breast milk. Each one is essential for the baby's nutrition [2].

2.1 Phase 1: colostrum

The initial milk is produced between 2 and 4 days following birth. It is referred to as "liquid gold" due to its golden hue and its immense value for your infant.

2.2 Phase 2: transitional milk

Beginning approximately 2–5 days after birth and lasting approximately 2 weeks. Transitional milk is produced when mature breast milk replaces colostrum gradually.

2.3 Phase 3: mature milk

From approximately 10 to 15 days after birth, until the end of milk production, the fat content of mature milk changes.

3. Nutritive value of colostrum

3.1. Increased energy levels.
3.2. Lower risk of upper respiratory illness.
3.3. Reduced risk of intestinal damage from anti-inflammatory drugs.
3.4. The increased ability of the body to burn fat and increase muscle.
3.5. Acceleration of injury healing.
3.6. Increased vitality and stamina.
3.7. Have significant anti-aging properties and is seen to promote longevity [3].

4. Nutritive value of milk

4.1. Building and maintaining bones and teeth.
4.2. Preventing cardiac diseases.
4.3. Keeping the blood pressure at a normal rate.
4.4. Protecting against some types of cancer, such as colon cancer.
4.5. Minimizing the possibility of developing diabetes.
4.6. Keeping and improving the performance of the nervous system.
4.7. Helping in growth.
4.8. Improving the digestion process.
4.9. Increasing immunity.
4.10. Protecting eyesight [4].
4.11. Maintaining the skin, hair, and sensitive membranes.
4.12. Treating the dehydration.
4.13. Providing the body with energy.

5. Major sources of contamination of milk

5.1 Animals

Because several diseases can be transmitted to humans through milk, the health of dairy animals is a crucial factor. These microorganisms can be transmitted directly from the mammary gland or indirectly through body discharges that can drop, splash, or be blown into milk.

5.2 Handlers

Diseases, such as typhoid, scarlet fever, diphtheria, septic sore throat, and infantile diarrhea can be transmitted by contaminated hands or by coughing, sneezing, and talking while milking or handling milk at the farm level.

5.3 Environment

During different stages of production and processing, the environment of a dairy farm may also introduce pathogens into milk products. Pathogens and spoilage-causing microorganisms in milk may be significantly influenced by contaminated water, fodder, and milk-handling vessels and containers, as well as other unhygienic conditions at the farm and plant [5].

6. Milk-borne diseases

Microbes can contaminate milk in two ways:

1. Endogenous transfer, wherein the microorganisms are excreted along with the milk.

2. Exogenous transfer, in which microorganisms are introduced during or after milking, either from the human during milking, from the udder skin, from the environment (equipment, dust, feces), or during milk processing, transport, and storage. In the majority of developed nations, pollution appears to occur after pasteurization [6, 7]. Pathogenic bacteria in milk pose a significant threat to human health and are responsible for approximately 90% of all dairy-related diseases [8].

6.1 Milk-borne prionic diseases

6.1.1 Bovine spongiform encephalopathy (BSE)/mad cow

In light of a recent study demonstrating prion replication in the mammary glands of scrapie-infected sheep with mastitis, the presence of PrPC in milk suggests that milk from TSE-infected animals may serve as a source of PrPSc [9]. The presence of scrapie infectivity in milk was independent of mammary gland pathology or PrPSc accumulation, and these animals had a substantial accumulation of immunohistochemically (IHC) detectable PrPSc within the LRS at the time of sampling [9].

6.2 Milk-borne viral diseases

6.2.1 Hepatitis viruses

Hepatitis E virus (HEV) is the leading global cause of acute viral hepatitis. It infects approximately 20 million people annually, resulting in 70,000 deaths [10, 11]. However, milk contains several substances, such as fats, casein, whey proteins, and lactose, that interfere with the extraction of viral nucleic acid and the recovery of enteric viruses [12].

6.2.2 FMD

The FMD virus is spread through direct or indirect contact with infected animals, animal secretions or excretions (including sperm and milk), mechanical vectors (humans, horses, dogs, cats, birds, and vehicles), and air movement over land or water [13].

6.2.3 Cowpox

The cowpox virus is closely related to the virus that causes smallpox, variola. Cowpox virus causes lesions on the teats and adjacent areas of the udder of cows and is transmitted between herds via milking.

6.2.4 Pseudo cowpox (milkers nodule)

Milker's granulomas, also known as pseudovariola, is a viral epidermis disease caused by a bovine-origin para poxvirus infection. In most cases, the infection is occupational and primarily manifests itself throughout milking. Its self-limiting nature contributes to the disease's underreporting and failure to seek treatment [14].

6.2.5 ORF

Humans contract ORF via direct contact with infected animals or fomites. Although it is commonly believed that this disease is transmitted through direct contact, it is unknown whether other transmission routes exist. Researchers have detected ORF virus in the saliva and milk of goats without clinical ORF symptoms [15].

6.2.6 Tick-borne encephalitis viruses

In sheep and goat's milk, tick-borne encephalitis viruses are more prevalent than in cow's milk. This virus is also resistant to LTLT treatments, but it is susceptible to HTST pasteurization. Transmission via consumption of untreated milk or milk products from livestock exposed to ticks in endemic areas is a known route of infection, and the incubation period may be shortened by 2–3 days in this instance [16].

6.2.7 Rift valley fever virus

RVF can infect humans through vector bites and consumption of raw meat and/or unpasteurized milk. Transmission between humans has not yet been documented.

Approximately, 50% of infected humans exhibit no clinical symptoms, while the remainder may develop influenza-like symptoms.

6.3 Milk-borne bacterial diseases

6.3.1 Anthrax

There are three types of anthrax infection: cutaneous (skin), pulmonary (lungs), and gastrointestinal (stomach and intestines).

Itching where the skin has been exposed is the first sign of skin (cutaneous) infection. A sizable boil or sore then appears. A dark scab has formed over the wound. The infection can spread to the lymph nodes and bloodstream if left untreated. Unlike the Inhalation, first symptoms, which include fever, fatigue, malaise, a cough, and chest pains, the inhalation/second symptoms only include a cough. In 2–5 days, a high fever, rapid heart rate, and severe difficulty breathing will ensue. Inhaling anthrax is frequently fatal. The first symptoms of gastroenteritis include fever, severe abdominal pain, loose, watery stools, bloody diarrhea, and bloody vomiting. Transmission between individuals is extremely uncommon.

6.3.2 Botulinum

The majority of botulism cases caused by dairy products are specifically linked to cheese products. Cheese products are not frequently involved in botulism incidents; however, due to the high risk of occurrence of this disease, it is necessary to take control measures during manufacturing and home preparation [17].

Food-borne botulism is an acute paralytic disease caused by a bacterially produced toxin. Ingestion of food containing this toxin or the development of spores in the intestines of young children may cause this disease [18]. There are approximately 180 described species within the genus Clostridium. *C. botulinum* can be divided into four distinct phenotypic groups, designated as I–IV.

6.3.3 Brucellosis

Brucellosis is a classic example of an infection transmitted through milk. Brucella is an intracellular, gram-negative, short-rod bacterium that primarily infects animals and humans. With 12 validated species, the genus is undergoing taxonomic expansion at present. With a widespread global distribution in domestic livestock and wildlife, the six most important species are *B. melitensis, B. abortus, B. canis, B. suis, B. ovis,* and *B. neotomae.* Brucellae can survive freezing and thawing, but repeated cycles of freezing and thawing diminish the viability of the cells [19]. Its survival outside the host is as follows: carcasses and organs—up to 135 days, paper—32 days, soil—125 days, blood at 4°C—180 days. Susceptible to moist heat (121°C for a minimum of 15 minutes) and dry heat (160–170°C for a minimum of 1 hour). Period of incubation/ extremely variable, 5–60 days, occasionally several months. There is no evidence of human-to-human transmission [20].

6.3.4 Campylobacteriosis

Campylobacteriosis occurs infrequently in developed nations and frequently in developing nations [21]. In developing nations, campylobacter infections in children under the age of two are particularly common and often fatal. Over the past several years, the incidence of human campylobacter infection has steadily risen in nearly all developed nations [22].

The most common symptoms last between 2 and 10 days, including fever, cramps, weight loss, and acute diarrhea that is either watery or bloody. Recurrence between cases is conceivable. Also, possible are nausea, malaise, and vomiting.

Campylobacter is not typically transmitted from one person to another, but this can occur if the infected person does not wash their hands thoroughly after using the restroom. The bacteria will remain in the feces of infected individuals for several days to a week or longer [23].

6.3.5 Diphtheria

Diphtheria is a serious disease caused by *Corynebacterium diphtheriae* strains that produce a toxin (poison). The vast majority of infections are asymptomatic or have a mild clinical course, but in certain outbreaks, greater than 10% of those diagnosed with the disease may perish. Within the genus Corynebacterium, there are 176 species and 13 subspecies. Usually, the incubation period lasts between 2 and 5 days, but it can last as long as 10 days [24].

6.3.6 E. coli

E. coli O157 is the most common type of *E. coli* infection that causes illness in humans. In recent years, new pathogenic bacteria have emerged throughout the food chain. It has been reported, for instance, that new milk-borne bacterial pathogens with extremely severe health effects, such as *E. coli* 0157:H7, have emerged [25].

E. coli, *Escherichia coli*, is the type species for the genus Escherichia. *E. coli* bacteria belong to the family enterobacteriaceae and can cause illnesses transmitted through food and water. After exposure, the incubation period is typically 3 to 4 days, but it can be as short as 1 day or as long as 10 days. Communicability through contact with a person who has poor hygiene and does not regularly wash their hands.

6.3.7 Helicobacteriosis

H. pylori (*HP*) is among the most widespread human bacterial pathogens worldwide [26]. Numerous variables affect the prevalence of *H. pylori* infection, including socioeconomic status, geographic location, living conditions, and personal hygiene [27]. The main reservoir of *H. pylori* is infected individuals; however, the majority of these infections are asymptomatic [28]. The Greek study revealed a 20% prevalence of H. *pylori* in cow's milk, which is higher than our percentage [29].

Helicobacter pylori is the complete name for the type of bacteria known as *H. pylori*. "helico" refers to the helix or spiral shape of the bacterium. The word "helicopter" is also derived from helico, and the bacterium's flagella resemble those of a helicopter (whip-like appendages). *H. pylori* was initially discovered in the stomach's pylorus.

Clinically, infection with *H. pylori* is linked to chronic gastritis, peptic ulceration, duodenal ulcer, gastric cancer, and mucosa-associated lymphoid malignancies [28, 30]. The transmission of HP bacteria typically occurs through direct contact with saliva, vomit, or feces. Additionally, *H. pylori* may be transmitted through contaminated food or water [31].

6.3.8 Leptospirosis

Leptospirosis is a worldwide zoonotic disease caused by pathogenic Leptospira spirochaetes. A warm and humid environment allows pathogenic leptospires to live longer. Approximately 300 serovars have been categorized into 25 serogroups. There are seven major pathogenic species known.

Leptospirosis is the most prevalent zoonotic infection. The average incubation period is 7–10 days, ranging from 2 to 30 days.

6.3.9 Listeriosis

Listeria monocytogenes (L.monocytogenes) bacteria cause a severe infection called listeriosis (Lm). There are currently 17 known species of Listeria, but only two are considered pathogens: *L. monocytogenes* and *L. ivanovii*. Lm is divided into 11 serovars [32].

After about three weeks of incubation, pregnant women may develop an influenza-like illness that may affect the uterus. In addition, immune-compromised adults and the elderly are susceptible to listeriosis-related meningitis, brain infection, and severe blood infection [18, 33].

6.3.10 Nocardiosis

Since Nocardia spp. are soil-borne aerobic actinomycetes that can contaminate milk during milking, handling, storage, and transportation, their presence in raw milk is not unexpected. The Nocardiaceae family contains 85 species in total. Members of the genus Nocardia, particularly *N. asteroides* and *N. farcinica*, have been identified as rare causes of mastitis in dairy cattle and goats [34].

At any stage of the milk production process, milk can be contaminated. The food business operator (milk producer) is responsible for identifying these points and implementing control measures to prevent milk contamination [35].

6.3.11 Pseudomoniasis

During storage, the microbiota shifts toward psychrotrophic microorganisms, which can degrade unpasteurized milk [36]. Pseudomonas has been identified as the most prevalent psychrotrophic bacteria in milk, making it one of the most important bacterial groups in the dairy industry. Pseudomonas spp. can grow between 4 and 42°C, with an optimal growth temperature above 20°C [37]. They are prevalent in various environments and are frequently associated with food spoilage, particularly that of raw milk. There are approximately 200 described species within the genus Pseudomonas.

6.3.12 Coxiellosis (Q-Fever)

The bacteria *Coxiella burnetii* causes Q fever, which can infect mammals, birds, reptiles, and arthropods. People can contract Q fever through infected milk and skin contact, but the vast majority of infections are spread through the air. *Coxiella burnetii* is a member of the coxiellaceae family. Approximately half of those infected with the Q fever bacteria will develop a flu-like illness. Human-to-human transmission is uncommon. Transmission of Q fever has been documented among hospital personnel and autopsy personnel.

6.3.13 Salmonellosis

Salmonellosis transmitted through milk is frequently associated with drinking unpasteurized or insufficiently pasteurized milk. Salmonella serovars can contaminate dairy products before, during, and after pasteurization [38, 39]. In general, salmonella strains are divided into two groups: typhoidal salmonellae (enteric fever) and non-typhoidal salmonellae. The typhoidal group includes strains that can cause typhoid fever or paratyphoid fever, including typhi, paratyphi A, B, and C, which are carried exclusively by humans and are also known as *Salmonella enterica* serotype typhi or S. paratyphi. Between 20 and 30 million people are infected annually, primarily in developing nations; in industrialized nations, it primarily affects travelers. The non-typhoidal salmonellae group includes all strains of Salmonella carried by humans, animals, poultry, wild birds, and flies that are not typhoidal. Salmonellae strains that are not typhoidal are the most common cause of food poisoning, typically resulting in acute, self-limiting gastroenteritis. Tens of millions of cases are reported annually, resulting in an estimated 100,000 deaths worldwide [40]. In various regions of the world, the predominant serotypes, foods associated with non-typhoidal salmonellosis, and non-typhoidal salmonellosis trends vary [8].

6.3.14 Shigellosis

Shigella's only natural reservoir is the human population, but prolonged outbreaks have occurred in primate colonies. Shigella spp. are gram-negative, rod-shaped, and pathogenic enterobacteriaceae bacteria. Shigellosis is a rapid-onset infection with symptoms. Particularly, it causes watery diarrhea, which typically occurs from 24 to 48 hours after ingestion of the causative agent.

6.3.15 Staphylococcosis

Staphylococcus aureus (*S. aureus*) or "staph" is a type of bacteria found on human skin, including in the nose, armpit, and groin. *S. aureus* is a significant zoonotic pathogen capable of causing severe infections in both humans and animals [41]. *S. aureus* causes about 40% of mastitis cases in some countries [42]. However, *S. aureus* may be released in the milk of infected dairy animals, endangering consumer safety [43].

6.3.16 Strep throat and scarlet fever

Streptococcus pyogenes bacteria cause an infection of the throat and tonsils known as strep throat. These bacteria cause acute pharyngitis, also known as strep throat. Strep Throat is a common cause of sore throat in children, but it is less common in adults. Typically, a mild infection, strep throat can be extremely painful. A strep throat patient may also develop a rash known as scarlet fever or scarlatina. The bacteria that cause scarlet fever release a toxin that causes the rash and red tongue. Scarlet fever primarily affects children aged from 5 to 15 years. Within the genus Streptococcus, roughly 100 species have been described. Numerous species within the genus Enterococcus were formerly categorized as streptococci; therefore, they are closely related. Group A strep can easily spread from the nose and throat to other people.

6.3.17 Tuberculosis

Tuberculosis (TB) is an ancient disease that poses a major threat to global health today. The tubercle bacilli are estimated to infect approximately 2 billion people or one-third of the world's population. However, infection with the organism does not always lead to disease, and only 5–10% of these people will develop the active disease each year [44]. The remaining 90% of infected individuals will experience a latent infection that may reactivate. In 2008, the World Health Organization (WHO) reported 9.4 million active tuberculosis cases and 1.3 million deaths worldwide [45].

TB is the thirteenth leading cause of death worldwide and the second leading infectious cause of death after COVID-19 (above HIV/AIDS). In 2020, 1.1 million children worldwide contracted tuberculosis. TB in children and adolescents is often neglected by healthcare providers and can be difficult to diagnose and treat [46].

6.3.18 Yersiniosis yersinia enterocolitica (non-pestis)

The most prevalent cause of enteric (intestinal) yersiniosis in humans is *Y. enterolitica*. However, rodents, rabbits, sheep, cattle, horses, dogs, and cats are also capable of harboring these strains. Infections caused by *Y*. *enterocolitica*, and, to a lesser extent, *Y*. *pseudotuberculosis* are referred to as Yersiniosis. Period of Incubation/4 to 6 days (range, 1–14 days).

6.4 Milk-borne protozoal diseases

Protozoa are heterotrophic, unicellular, eukaryotic organisms. Either they are free-living, or they are parasites. There are roughly 65,000 species of protozoans, which are categorized into various groups. Without a cell wall, there are numerous stages in the protozoan life cycle. There are infectious stages in the life cycle.

Protozoa inhabit an aquatic environment. They inhabit freshwater or saltwater. Some are free-living, while others are plant- and animal-parasitic. Some are anaerobic and inhabit the rumen or human intestines. However, the following protozoal diseases are transmitted through milk and dairy products.

6.4.1 Amoebiasis

Entamoeba histolytica (*E. histolytica*) is a parasitic extracellular protozoan that causes amoebiasis, an infection of the large intestine in humans. WHO estimates that 500 million people around the world are infected with Entamoeba; only 10% of these individuals have the species *E. histolytica*, while the remaining 90% have other non-pathogenic species. Amoebiasis is the fourth leading cause of death due to protozoan infections, accounting for between 40,000 and 100,000 deaths per year.

6.4.2 Cryptosporidiosis "crypto"

Cryptosporidiosis (or "crypto" for short) is a disease distinguished by watery diarrhea. Crypto is caused by the microscopic parasite cryptosporidium. There are numerous animal-infecting cryptosporidium species, some of which also infect humans. The parasite's outer shell protects it from chlorine disinfection and enables it to survive outside the body for extended periods. Crypto resides in the intestines of humans and animals infected with the virus. Infected individuals and animals will expel the parasites in their feces. A bowel movement from a human or animal infected with Crypto can release millions of parasites. From 7 to 10 days, with a maximum of 28 days, is the incubation period.

6.4.3 Giardiasis (lambliasis)

Several researchers have confirmed the presence of the parasite giardia in raw or unpasteurized milk and milk products. Most infections do not manifest symptoms. In symptomatic patients, nausea, chills, low-grade fever, epigastric pain, and sudden onset of watery diarrhea are possible. Chronic infections are possible, and diarrhea causes dehydration, malabsorption, weight loss, and pancreatic dysfunction. Incubation period/ 7 to 14 days giardiasis can be transmitted from person to person, particularly among those with poor feculo-oral hygiene, resulting in epidemics.

6.4.4 Toxoplasmosis (Toxoplasma gondii) (T. gondii)

T. gondii's life cycle includes three infectious stages: tachyzoites, bradyzoites contained in tissue cysts, and sporozoites contained in sporulated oocysts. Intermediate and definitive hosts, both of which are susceptible to infection, are infectious for all three stages of *T. gondii* [47].

Toxoplasma gondii tachyzoites have been discovered in the milk of several intermediate hosts, including sheep, goats, and cows, but only unpasteurized goat's milk has been linked to acute toxoplasmosis in humans. Additionally, in some hosts, tachyzoites can be transmitted to the offspring via the mother's milk if a woman is infected before she becomes pregnant, her unborn child is generally protected because she has immunity. If a woman is infected with Toxoplasma shortly before or during pregnancy, she can transmit the infection to her unborn child (congenital transmission). The infectious dose in intermediate hosts is as low as 10 sporulated oocysts [48].

6.5 Milk-borne parasitic diseases

Some parasites, including Taenia spp., can contaminate milk and transmit it to humans. The heavily regulated environment of milk collection in industrial farms is another source of infection. Moreover, soil contamination may cause the presence of soil-borne parasites in milk (e.g., Ascaris lumbricoides, Trichuris trichiura). To avoid these contaminations, it is necessary to maintain sanitary, pasteurized, and hygienic conditions [49–51].

6.6 Milk-borne fungal diseases

Fungal infections are responsible for 2–13% of all cases of mastitis in cows [52]. Usually, mycotic mastitis is not detected during the initial treatment attempt, and the administration of antibiotics may exacerbate fungal mastitis, as antibiotics, such as penicillin and tetracycline, serve as a source of nitrogen for numerous species of fungi [53].

6.6.1 Aspergillosis

Aspergillosis is caused by fungi of the genus Aspergillus that are filamentous. Although there are more than 300 known species within the genus, A. fumigatus is the most prevalent aspergillosis-causing fungus, followed by *A. flavus, A. terreus,* and *A. niger* [54].

These fungi are common in soil, decomposing plant matter, household and hospital dust, building materials, and on seeds and grains [55]. Concern exists regarding the potential health effects of aspergillus spores in the air; however, exposure to molds in indoor environments is not typically regarded as a risk factor in the etiology of this fungal disease [55, 56].

6.6.2 Candidiasis

The global incidence of yeast infections in humans and animals has increased in recent years. Since animals may be a source of yeast infections for humans, it would be of great medical importance to determine the antifungal susceptibility profile of yeast isolates from milk and assess their pathogenic potential [57].

6.6.3 Cryptococcosis

Cryptococcus is the most common fungus that causes serious infection worldwide. Bovine mycotic mastitis caused by *Cryptococcus neoformans* has been reported by several researchers elsewhere worldwide. *C. neoformans* has also been isolated from ovine and caprine milk [58].

6.6.4 Mucormycosis

Zygomycosis is another name for mucormycosis. Mucorales fungi's natural ecological niche is soil and decomposing organic matter. However, indoor and outdoor air, foodstuffs, and dust also serve as reservoirs for these particles [59]. These invasive fungal infections (IFI) are caused by fungi belonging to the *genera Rhizopus*, *Mucor*, *Rhizomucor*, *Absidia*, *Lichtheimia*, *Apophysomyces*, *Cunninghamella*, and *Saksenaea* [60].

Mucorales fungi have a natural ecological niche in soil and decomposing organic matter. However, indoor and outdoor air, foodstuffs, and dust also serve as reservoirs for these particles [59].

6.6.5 Fusarium

Based on host associations, morphology, and molecular characterizations, it is estimated that the genus Fusarium contains at least 200 species distributed across 22 species complexes [61].

6.7 Mycotoxins and mycotoxicoses

Mycotoxin is derived from the greek word for fungus (mold), *mycos*, and the Latin word for poison, *toxicum*. Mycotoxins are highly diverse secondary metabolites produced by fungi [62]. Consequently, carcinogenic, teratogenic, tremorogenic, hemorrhagic, dermal, hepatotoxic, nephrotoxic, and neurotoxic effects occur, as well as acute cases resulting in death [63].

Aflatoxin, ochratoxin, patulin, zeralenon, trichothecene, and fuminosins are the most vital of these toxic effective metabolites [64]. There are more than 400 different mycotoxins produced by micromycetes. Although they are so many, most of them have not been described at all. However, mycotoxins that affect the human body, productive animals, and agricultural plants have been identified, systematized, and studied quite thoroughly [65].

Among consumers of milk and products, its processing, children, especially infants, and the elderly, are the most sensitive to mycotoxins. It is estimated that approximately 25% of the world's food supply is contaminated with mycotoxins [66].

Mycotoxins by their physicochemical properties are lipophilic substances, so their content can be quite high in different oils. Thus, palm and coconut oil used to produce dairy products (cheese, processed cheese, butter, margarine, and other spreads, sour cream, and ice cream) and baby food (breast milk substitutes, infant formulas, and milk porridge) can contain mycotoxins in various quantities [67].

6.7.1 Aflatoxins

The three species of Aspergillus *fungi A. flavus, A. parasiticus,* and *A. nomius* produce aflatoxins. Aflatoxin B1 is the most common form found in crops contaminated with aflatoxin, while B2, G1, and G2 are also commonly found among the approximately 20 aflatoxins. When cows, sheep, goats, and other ruminant animals consume feeds containing aflatoxins B1 and B2, the liver's metabolic process produces aflatoxins M1 and M2, which are then excreted in milk. Milk and dairy products are fundamental components of the human diet and may be the primary route by which aflatoxins enter the body (the consumption of contaminated milk and dairy products, particularly cheese, is a significant risk factor for consumers, especially infants and young children) [68].

6.7.2 Ochratoxin

OTA was classified as a human carcinogen by the International Agency for Research on Cancer (IARC) in 1993, based on the findings of numerous studies on the adverse effects and toxicity of ochratoxin (class 2B). The presence of ochratoxin in breast milk makes infants more susceptible to infection. It is chemically stable, and its 35-day half-life in humans is unaffected by normal food preparation temperatures [69].

6.7.3 Deoxynivalenol

Deoxynivalenol (DON) is one of several mycotoxins produced by certain Fusarium species that infect corn, wheat, oats, barley, and rice in the field or during storage. Humans are exposed either directly to plant-based foods (cereal grains) or indirectly to animal-based foods (kidney, liver, milk, and eggs) [70].

6.7.4 Zearalenonea

Zearalenone (ZEA), an estrogenic mycotoxin, is a mycotoxin produced by the fusarium fungus. Cereal-based foods, such as maize, sorghum, wheat, rice, barley, and oats, as well as nuts, corn, barley, hay, silage, soybean, and sesame, are the primary source of ZEA contamination [71].

6.7.5 Fusariotoxicosis

Fusariotoxicosis is a mycotoxicosis characterized by a complex of clinical symptoms and injuries to the digestive and genital apparatuses, central and hematopoietic-nervous system, and blood, all of which are caused by different toxins produced by specific fusarium species.

7. Techniques used in milk preservation

Milk and its products contain numerous nutrient components, making it an excellent medium for the growth of all microorganisms. Thus, various preservation methods are used to prevent the growth of microorganisms that cause milk to spoil and to preserve the nutritional qualities of milk. Several methods have been employed to restrict the growth of microorganisms in milk and milk products [72–74].

7.1 Heat treatment techniques

7.1.1 Pasteurization

Pasteurization is a method of food preservation involving the application of heat, typically at temperatures below 100 degrees Fahrenheit for a predetermined period. It aims to reduce the number of viable pathogens and spoilage-causing microorganisms to extend the shelf life of milk without diminishing its quality.

7.1.2 Thermization

Used to preserve milk by heating it at 57–68°C for 15–20 seconds and rapidly cooling it to 6°C. This method is effective against bacteria that cause spoilage, but it does not eliminate pathogens. The primary purpose of thermisation is to reduce the growth of psychrotrophic bacteria and increase the milk's shelf life.

7.1.3 Ultra-high temperature (UHT) (sterilization)

Sterilization is a method of food preservation involving the application of heat, typically above 100 degrees Fahrenheit for a predetermined amount of time, to kill nearly all bacteria, followed by packaging in airtight containers either before or after the heat treatment. After sterilization, milk can be stored at room temperature for a longer period.

7.1.4 Dehydration

Evaporation is the process of removing the water normally present in milk by applying heat under controlled conditions. This method reduces the water activity (a w) of milk to prevent the growth of microorganisms that cause spoilage.

7.1.5 Use of preservatives

Preservatives are substances with the ability to inhibit or slow the growth of microorganisms. These preservatives consist of natural, bio, and chemical agents.

7.2 Preservation of milk by using low temperature

The primary purpose of chilling is to reduce the rate of microbial growth and enzymatic activity, thereby extending the shelf life of milk and milk products. It has been combined with other food preservation techniques, such as irradiation and pasteurization, to increase the shelf life of milk and milk products. Milk, cheese, yogurt, and butter. are kept in a refrigerated storage facility. The temperatures range from 0 to 5°C. It has minimal effects on the nutritional value of food.

7.3 Additional methods for Milk preservation

High-pressure process (HPP), the components of microorganisms are destroyed by high pressure can inactivate pathogenic and saprophytic microorganisms.

Microwave heating is a method in which electromagnetic waves are used to generate heat in food.

Microfiltration is used to remove major numbers of bacteria from milk and extend its shelf life. It can be used in a combination with HTST pasteurization.

UV radiation and irradiation are electromagnetic radiation with a wavelength between 10 and 400 nanometers. For food preservation, gamma rays, X-rays, and accelerated electron beams are the sources of ionizing radiation.

Milk bactofugation or microfiltration is a centrifugation process that removes the bacteria present in milk.

Ultrasound ultrasonic is a high-power sound wave at frequencies between 16 kHz and 100 MHz. In this method, the sonic wave is passed through the milk and the changes occur in the pressure, which leads to cavitation, which causes gas bubbles in the liquid causing a bactericidal effect.

8. Milk testing and quality control

Good quality dairy products can only be made from good quality milk, so we can summarize the quality of milk as follows:

8.1 Color

The color of milk varies from bluish-white to pale yellow depending on the following factors: animal breed, type of feed, amount of fat, and amount of other TS in milk. The yellow hue of milk is caused by a pigment called carotene, which is synthesized from the green feed. The white color of milk is a result of the fat globules and colloidal proteins calcium caseinate and phosphate reflecting light. Another pigment known as riboflavin (vitamin B) or lactochrome gives separated milk or whey its bluish hue. However, cow's milk is yellow compared to the milk of buffaloes, sheep, and goats. The liver is primarily responsible for the transformation of carotene into vitamin A. In the case of buffalo milk, this transformation is complete, so buffalo milk is white. In the case of cow's milk, this conversion of carotene to vitamin A is incomplete; therefore, cow's milk is yellow.

8.2 Taste

Milk is slightly sweet. This is because lactose (milk sugar) is present in it. In milk, the sweetness of lactose is balanced by the saltiness of chloride.

8.3 Smell

When milk is extracted from an animal's udder, it has a distinct odor. Freshly drawn milk has a cowy odor that vanishes after a period of exposure. Certain metals, including copper, nickel, brass, bronze, etc., may harm the flavor of milk that comes into contact with them.

8.4 Acid-base equilibrium

The freshest milk has an amphoteric reaction. Fresh milk changes the color of red litmus to blue and blue litmus to red. The typical pH level of fresh milk is (6.6). When fresh milk is titrated with an alkali, it is found to contain between 0.1 and 0.17% acidity. This acidity is not the result of lactic acid (developed), but rather the presence of phosphates of milk proteins, citrates, and carbon dioxide in milk (natural).

8.5 Specific gravity of milk

At 15.5°C, the specific gravity of milk ranges from 1.025 to 1.032. (60 F). As milk fat is the lightest component of milk, the higher the concentration, the lower the specific gravity. The higher the proportion of SNF, the heavier the milk.

The specific gravity of skim milk ranges between 1.032 and 1.037, whereas the specific gravity of whole milk varies between 1.030 and 1.040. Variation in specific gravity is caused by differences in the number of various constituents.

8.6 Freezing point

Milk freezes between – 0.55 and – 0.56°C. Skim milk and whole milk have the same FP. Due to lactose and salts in the aqueous phase, milk has a lower FP than water.

8.7 Boiling point

Milk is slightly denser than water due to its solute content. Milk boils at a slightly higher temperature than water (100.17°C).

8.8 Viscosity

It is the opposite of fluidity and refers to the resistance to flow. Milk is 1.5 to 1.7 times more viscous than water because it contains solids. Whole milk has a viscosity of 2.0 CP at 20°C, while skim milk has a viscosity of 1.5 CP, and whey has a viscosity of 1.2 CP. However, heating milk to the temperature of pasteurization or agitating it reduces its viscosity.

8.9 Adhesiveness of milk

A piece of paper saturated with milk adheres to wood, glass, or flat metal surfaces. This characteristic is a result of the extensive use of casein in the production of casein glue, one of the strongest adhesives available.

8.10 Refractive index

The refractive index of milk is 1.35; the refractive index of water is 1. (1.33). Therefore, the addition of water would reduce the refractive index of milk.

8.11 Cream layer formation

When whole milk is allowed to stand, the fat rises to the surface and forms a layer of cream (this property is natural).

8.12 Foaming

Upon agitation, milk has the property of producing foam. When allowed to stand, the milk foam is unstable and degrades.

9. Prevention of milk-borne diseases

Milk contamination can occur at any stage of the production process. The milk producer is responsible for identifying these contamination points and implementing preventative measures [75].

However, the following points summarize the most crucial aspects of milk-borne disease prevention.

Personal hygiene of milkers, before and while milking and handling milk, hands must be washed and kept clean. Exposed skin wounds must be hygienically covered. Milkers must be kept clean at all times.

Animal identification, we must keep a constant record of each animal (medical records, feeding records, production records). Also, we must recognize each animal with an ear tag.

Animal housing, we must pay attention to the importance of housing on animal health, as well as the rest in comfortable stalls and animal houses should be provided with good natural ventilation.

Lactating Animals, if there is evidence that an animal is not in good health, particularly a genital tract discharge, enteritis with diarrhea, fever, or udder infection, the milk must not be consumed by humans. All animals, sleeping areas, and passageways must be kept clean and dry. Teats, udders, and adjacent areas must be cleaned before milking.

Milking center (parlor), must be kept in a state of cleanliness. Inadequate or improper cleaning, sanitizing, or both allow bacteria to remain and proliferate on equipment surfaces. This increases the number of bacteria in milk.

Milking equipment, equipment used for milking must always be kept clean and in good condition.

Assessment of milk quality, each animal's milk must be examined for physical and chemical irregularities, and if any are discovered, the milk must be rejected.

Milking operations, cleaning, pre- and post-milking disinfectants for teats. The entire area must be managed to ensure adequate levels of cleanliness. The approach and surrounding areas must always be kept clean. Doors must be kept shut. Walls and floors must be maintained in pristine condition.

Milking environment, some activities performed before milking, such as cleaning the floor, water, and feed trough, washing the cow, using a clean cloth to dry the udder after washing, discarding the first milk flow, and scrubbing the floor after milking, enhanced milk quality.

Milk storage and cooling, to prevent bacterial growth and protect milk from contamination during storage, it must be cooled immediately.

Water availability, potable (or clean) water must be available in the milking area for cleaning soiled teats and udders, equipment, hands, fittings, and floors during and after milking.

General considerations, to prevent contamination, it is necessary to control insects, rodents, and birds on the premises. Everyone involved in the production of milk must receive training in food hygiene, health risks, and equipment operation.

10. Conclusions

In conclusion, the primary sources of pathogens in milk and dairy products are the animal itself, human handlers, equipment in contact, environmental sources, and water used for washing equipment or product preparation. Milk and dairy products have been involved in many diseases or outbreaks in human customers, which requires educational knowledge and awareness regarding causative agents and monitoring sanitary techniques. Therefore, accurate hygienic precautions must dominate during milking, handling, and preparations.

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