

CONTAMINANT IN MILK AND MILK PRODUCTS: A REVIEW

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Abstract

*Milk and dairy products are rich in essential nutrients but face contamination risks that threaten food safety and public health in Nigeria. This review identifies microbial, chemical, and physical contaminants as major hazards. Microbial contaminants like *Staphylococcus aureus*, *Salmonella* spp., and *E. coli* result from poor hygiene and inadequate processing, with total plate counts limited to $\leq 1.0 \times 10^5$ CFU/mL for raw milk. Chemical contaminants, including heavy metals (lead, cadmium), pesticides, veterinary drug residues, and mycotoxins (e.g., aflatoxin M1), pose chronic health risks like cancer and neurotoxicity, with strict maximum residue limits (MRLs) (e.g., 0.02 mg/kg for lead). Physical contaminants like dirt and metal fragments further degrade quality. Vulnerable groups, especially children, face higher risks due to greater milk consumption and lower toxin tolerance. Mitigation strategies include enforcing MRLs by agencies like National Agency for Food and Drug Administration and Control (NAFDAC) and Standard Organization of Nigeria (SON), improving hygiene, public awareness, and adopting rapid detection technologies. The review recommends aligning Nigerian standards with international benchmarks (e.g., Codex Alimentarius, EU) for safer dairy production. Collaborative efforts among policymakers, producers, and consumers are crucial to safeguarding health and preserving milk's nutritional benefits. Addressing these challenges requires stringent regulations, better practices, and stakeholder cooperation.*

Keywords: *Milk contamination, microbial hazards, heavy metals, aflatoxins, food safety.*

Introduction

Milk and dairy products are an important source of vital nutrients for human beings (FAO, 2010; Fusco and Quero, 2014). Milk supplies nutrients such as proteins, fats, carbohydrates, vitamins, and minerals in moderate amounts and in an easily digestible form. Due to its nutritive value, milk is significant for both infants and adults (Sukumaran *et al.*, 2014). Factors such as the breed of cows, stage of lactation, feed, and season of the year determine the composition of milk.

Food safety is critical in maintaining people's health for disease control and preventing food contamination, which can cause food intolerance and food poisoning as reported by Abedi *et al.* (2019). As defined by the World Health Organization (WHO) and Food and Agriculture Organization (FAO), "food safety is a science-based discipline, process or action that prevents food from containing substances that could harm a person's health" (FAO and WHO, 2003). Dairy products such as cream, butter, ghee, fermented milk, yoghurt, cheeses, and traditional milk products nono (sour milk), kindirmo (sour yoghurt), man-shanu (local butter), cuku (Fulani cheese), and wara (Yoruba cheese) are beneficial. Consuming at least three dairy products per day has a positive impact on energy and nutrient intakes, as well as on vitamin D, magnesium, and calcium, compared with the intakes of people who consume fewer servings of dairy products per day (Leksir *et al.*, 2019). Milk and dairy products can contain residues of hazardous chemical or biological pollutants with potential hazards for consumers Shar *et al.*, 2021; Feizi *et al.*, 2022; Nemati (2021). The risk of biological pollutants derives from cattle milking include the exposure of udders to the

environmental pollutants, storage, equipment, and dirty pipes Hashemi *et al.*, (2019) ; Noori *et al* (2022). Chemical pollution of milk comes from use of veterinary products, feed contaminated with toxins, agrochemicals, and improper use of chemicals during processing, Fatehi *et al.*, 2018; Pajohi-Alamoti *et al.*, (2013-2014).

The most reported contaminants that threaten the safety of milk are pathogenic microorganisms (14.57%), heavy metals (22.18%), antibiotics (22.18%), pesticides (22.05%), and mycotoxins (9.97%) (Givens, 2020). Therefore, heavy metals stand out among contaminants (Givens, 2020). Toxic heavy metals cause damage by enhancing the production of free radicals in several organs (brain, liver, kidney, and heart) and interfering with cellular mechanisms against oxidation. Their toxicity is largely related to age, sex, routes of exposure, daily intakes, duration of exposure, and frequency of intake. These residues in milk are of particular concern, even in low concentrations, because milk is widely consumed by infants and children (Anadose *et al.*, 2014).

Farmers extensively use pesticides to increase the production of crops, vegetables, and fruits. Intensive use of pesticides has resulted in trace contamination of air, water, and soil with their residues. These pesticide residues can be absorbed by milk-producing animals, such as cows, through contaminated feed, water, and inhaled air. Milk is the most versatile organic food product of animal origin. Pesticide residues, being highly lipophilic, are primarily stored in fatty tissues in cows and are later excreted through milk fat. As a result, consumers are at risk of exposure to these pesticide residues as they accumulate in fresh milk and fat-rich dairy products (Shanmugam *et al.*, 2015; Chizzolini *et al.*, 2005).

Milk-borne pathogenic bacteria pose a serious threat to human health, and constitute about 90% of all dairy- related diseases Ryser, (1988). *Staphylococcus aureus*, *Salmonella spp.*, *Listeria monocytogenes*, *Escherichia coli* O157:H7 and *Campylobacter* are the main microbiological hazards associated with raw milk consumption as reported by Claeys *et al.* (2013).

The main target of this review to provide a comprehensive report on the contaminants in milk and milk products in Nigeria.

Review of Related Literature

Composition of Milk Protein

Milk contains two primary types of proteins: casein and whey. Casein constitutes about 80% of the total protein content in milk, while whey makes up the remaining 20% (Smithers, 2008). Both proteins are rich in essential amino acids, such as leucine, isoleucine, and valine, which are crucial for muscle synthesis, immune function, and overall metabolic health (Hoffman and Falvo, 2004). Additionally, milk contains bioactive peptides that have been shown to exhibit antimicrobial, antioxidant, and antihypertensive properties (Korhonen and Pihlanto, 2006).

Table 1: Proximate Composition of bovine, caprine and ovine Milks (per 100 g of milk)

Proximate Components	Bovine		Caprine		Ovine	
	Average	Range	Average	Range	Average	Range
Energy (kcal)	62	59–66	66	58–74	100.00	93–108
Water (g)	87.8	87.3–88.1	87.7	86.4–89.0	82.10	80.7–83.0
Total protein (g)	3.3	3.2–3.4	3.4	2.9–3.8	5.60	5.4–6.0
Total fat (g)	3.3	3.1–3.3	3.9	3.3–4.5	6.40	5.8–7.0
Lactose (g)	4.7	4.5–5.1	4.4	4.2–4.5	5.10	4.5–5.4
Ash	0.7	0.7-0.7	0.8	0.8-0.8	0.90	0.9-1.0

Source: (USDA, 2009); FSA (2002)

Contaminants in Milk and Milk Products

Microbial contaminants in milk

Microbial contamination remains a critical threat to milk safety, with pathogens entering through direct contact during milking, environmental exposure, or post-processing mishandling. Raw milk is particularly vulnerable, hosting diverse bacterial species such as *Staphylococcus aureus*, *Mycobacterium*, *Pseudomonas* and *Klebsiella* due to inadequate farm hygiene and mastitis infections in dairy cattle Owusu-kwarteng *et al.* (2020). Pasteurization, while effective against many vegetative bacteria, fails to eliminate spore-forming organisms like *Bacillus cereus* and heat-resistant pathogens such as *Listeria monocytogenes* and *Salmonella enterica*.

Table 2: Maximum residues limit for different microbial contaminants in milk and milk products

Microbial Contaminant	Raw Milk	Pasteurized Milk	Fermented Milk	Cheese	References
Total plate count(CFU/mL or g	$\leq 1.0 \times 10^5$	$\leq 1.0 \times 10^4$	$\leq 1.0 \times 10^5$	$\leq 1.0 \times 10^5$	NIS256(2015)
Escherichia coli (E. coli)	Absent in 1 mL	Absent in 1 ML	Absent in 1g	Absent in 1g	CODEX STAN193
Staphylococcus aureus (CFU/ML or g	≤ 100	≤ 10	≤ 100	≤ 100	NAFDAC(2019)
Salmonella spp.	Absent in 25mL	Absent in 25ML	Absent in 25g	Absent in 25g	SON(2015)
Listeria monocytogenes	Absent in 25mL	Absent in 25mL	Absent in 25g	Absent in 25g	IDF(2013)33

Viral

Viruses can enter milk and dairy products through various routes:

Infected Animals: Milk can become contaminated directly from cows, goats, or sheep that are infected with viruses (e.g., foot-and-mouth disease virus, bovine leukemia virus).

Human Handling: Inadequate hygiene practices among milk handlers can introduce human viruses (e.g., norovirus, hepatitis A virus, and rotavirus).

Environmental Contamination: Contaminated water, equipment, or improper pasteurization can introduce viruses into milk products. (Cliver, and Matsui, 2002)

Common Viruses Present in Milk and Dairy Products

- i. Hepatitis A Virus (HAV): Linked to raw milk and dairy products, leading to liver infections.
- ii. Norovirus: Causes gastroenteritis and can spread through contaminated dairy products.
- iii. Rotavirus: A leading cause of diarrhea in children, potentially present in raw milk.
- iv. Foot-and-Mouth Disease Virus (FMDV): Affects livestock and can be present in milk from infected animals OIE, (2021).
- v. Bovine Leukemia Virus (BLV): Found in cow's milk, though its risk to humans is debated.

Table 3: Maximum residue limit for different virus in milk and milk product

S/N	Viruses	MRLs	References
1	Hepatitis A virus	Absent in 25ml or 25g	FAOandWHO2006
2	Norovirus	Absent in 25ml or 25g	FAOandWHO2006

Effect Microbial Contamination on milk and milk products

Microbial contamination represents one of the most significant risks in milk production. Pathogens such as *Salmonella*, *Listeria monocytogenes*, and *E. coli* can cause severe foodborne illnesses. These microorganisms can enter milk through contaminated equipment, poor hygiene, or infected animals (Oliver et al., 2005). Spoilage microorganisms, including bacteria, yeasts, and molds, can also degrade milk quality, resulting in off-flavors, odors, and reduced shelf life (Chambers, 2002).

Veterinary Drugs.

Antimicrobial drugs are administered to treat bacterial infections or employed prophylactically to prevent spread of disease, or to augment growth and yield in animals and animal products. All antimicrobial drugs administered to dairy animals enter the milk to a certain degree. The most frequently and commonly used antimicrobial drugs are antibiotics used to combat mastitis-causing pathogens and include penicillins, cephalosporins, tetracyclines, macrolides, aminoglycosides, quinolones, and polymyxins. A general concern linked to the widespread use of antimicrobials is the potential development of antibiotic-resistant pathogens, which may then complicate human treatment. Also, sensitive individuals may exhibit allergic reactions to residues of antibiotics and/or their metabolites, as mainly seen with B-lactam antibiotics (Bhandari *et al.*, 2005; Fuquay and Fox 2011). Application of hormones to animals may serve a number of purposes such as increased food production, medical treatment, or improved reproductivity. It has been suggested that dairy products that contain hormones (such as IGF-I) could increase breast cancer risk (Moorman and Terry, 2004). Additionally, investigations have shown that bovine growth hormone (BGH), which is sometimes administered to dairy cattle to increase milk production, results in increased concentrations of IGF-I in cow milk (Prosser *et al.*; 1989; Outwater *et al.*; 1997; Yu and Rohan 2000).

Effect of antibiotics on milk and milk products

Antibiotic residues in milk can inhibit the growth of starter cultures used in fermented products like yogurt and cheese, leading to production failures (Beyene, 2016).

Effects of antibiotics on humans

Humans consuming food contaminated with a mixture of antibiotics are subjected to various health threats such as carcinogenicity, mutagenicity, and teratogenicity effects of antibiotics.

Table 4: Recommended Antibiotics in milk and milk product

Antibiotics	NAFDAC(2021) (µg /kg)ppb	(WHOandFAO2006) µg /kg
Tetracycline	100	100
Pennicillins eg. Pennicillins G	4	4
Sulfonamides	100	
Aminoglycosides eg. Streptomycin	200	200
Macrolides eg. Erythromycin	50	40
Quinolones eg enrofloxacin	100	

Pesticides

Pesticide residues in milk may have a number of potential sources, including environmental (water, soil, and air drift), contamination of the animal feed (fodder), or dairy animals in their direct living environment to protect them against disease vectors (mites, ticks, and insects).

The very first or “pioneer” chemicals investigated since the 1960s were organochlorines (OC) such as the insecticide 1,1,1-trichloro-2,2-bis(4-chlorophenyl) ethane (DDT) and certain organophosphate (OP) insecticides. Consumption of these compounds could lead to some cancers such as breast cancer (Falck *et al.*, 1992; Hunter and Kelsey 1993). Although the applications of modern pesticides in agriculture to food and forage plants practically do not harm the animals and bear no risk of significant residues in milk, some residues (which are now highly regulated) might be found in milk and dairy products. Levels of OC pesticides, potentially contaminating milk via the environment, have been decreasing over the past decade(s) and international efforts are underway to further reduce environmental contamination (Fischer *et al.*, 2011; Fuquay and Fox 2011). In this relation, most of the developed countries have established maximum residue levels (MRLs) of pesticides in milk and milk products. Furthermore, heat treatment such as sterilization and pasteurization showed some degradation of pesticide residues. OC pesticides are fat soluble, so their residues were found predominantly in high-fat dairy products such as cream and butter. Reduction of pesticides in yogurt may be due to the heat treatment of milk and the activity of the starter bacteria. Therefore, generally, the consumption of milk products could be safer than that of raw milk (Donia *et al.*, 2010).

Table 5: Pesticides

Pesticides	Maximum residue limit (MRLs)(NAFDAC 2021) mg/kg(ppm)	(WHOandFAO2006) mg/kg
Organochloride pesticides eg DDT.	0.01-0.05	0.04
Organophosphate pesticides eg chlorpyrifos, malathion	0.01-0.05	0.01
Pyrethroids eg cypermethrin	0.01-0.05	0.05
Carbamates eg. Carbaryl, aldicarb	0.01-0.05	
Herbicides e g. Glyphosate	0.01-0.05	0.05

Effects of pesticides on milk and dairy products

Pesticide residues can alter the flavor of milk, reduce nutritional quality, and interfere with fermentation processes in yogurt and cheese production.

Effects of pesticides on milk consumers

The presence of pesticides above the permissible amount in milk and dairy products can cause abdominal pain, dizziness, and neurological symptoms in sensitive individuals. Long-term exposure can lead to hormonal disruption, carcinogenic effects, reproductive and developmental issues, and neurotoxicity (Jurewicz-Hanke (2008).

Heavy Metals

Technological progress, various industrial activities and increased roadway traffic have caused a considerable increase in environmental contamination. Cheng and Groose, (2002). Heavy metals enter the human body through inhalation and ingestion (Mendi, 2006). It is well established that lead and cadmium are toxic and children are more sensitive to these metals than adults. While copper and zinc are essential they can be toxic when taken in high doses (Tripathi *et al.*, 1999). Determination of the residual concentrations of metals in milk can be an important direct indicator of the hygienic status of the milk and/or of its derived products, as well as an indirect indicator of the degree of pollution of the environment in which the milk is produced (Licata *et al.*, 2004, Caggiano *et al.* (2005). Milk and dairy products constitute a major food, especially for infants and children, and relatively low levels of toxic elements can contribute significantly to dietary intakes and be hazardous for public

health (Taniwaki *et al.*, 2001). Heavy metals content of milk products are variable due to factors such as differences between species, geographical area, characteristics of the manufacturing practices and possible contamination from the equipment during the process Moreno *et al.* (1994).

Table 6: Maximum residue limit for Heavy metals in milk and milk product

Heavy metals	Maximum residue limit (MRLs) (NAFDAC2021)mg/kg	Maximum residue limit MRLs (FAOandWHO 2006)mg/L
Lead (Pb)	0.02	0.02
Cadmium (Cd)	0.01	0.01
Arsenic (As)	0.01	0.1
Mercury (Hg)	0.01	0.01
Zinc (Zn)		3-5
Copper (Cu)		3.5

Health effects of heavy metals on milk consumers and milk quality.

The effects of heavy metals on milk consumers are neurological effect, kidney damage, carcinogenic potentials and bone demineralization. The impact of heavy metals on milk quality it alter the nutritional and sensory quality of milk, also interfere with fermentation processes in cheese and yoghurt. (Muhib *et al.*, 2016)

Mycotoxins.

Dairy contamination by mycotoxins can be via fungus-infested (moldy) feedstuffs consumed by dairy animals. Aflatoxin M1 (AFM1) is the hydroxylated metabolite of aflatoxin B1 (AFB1) and can be found in milk and subsequently in other dairy products when lactating animals are fed with mold-contaminated feedstuffs. Mammals that ingest aflatoxin B1 (AFB1)-contaminated diets excrete amounts of the principal 4-hydroxylated metabolite known as aflatoxin M1 into milk (Prandini *et al.*, 2009). Aflatoxins are toxic, carcinogenic, and/or teratogenic to humans and animals. AFM1 is relatively stable in raw and processed milk products and is not destroyed by regular heat treatments including pasteurization. The International Agency for Research on Cancer (1994) classified AFB1 as a class 1 human carcinogen and AFM1 as a class 2B possible human carcinogen (Cathey *et al.*, 1994; Galvano *et al.*, 1996; Moss 2002). AFM1 is cytotoxic, as demonstrated in human hepatocytes in vitro and its acute toxicity in several species is similar to that of AFB1. AFM1 can also cause DNA damage, gene mutation, chromosomal anomalies, and cell transformation in mammalian cells in vitro, in insects, lower eukaryotes, and bacteria (Prandini *et al.*, 2009). Overall, the occurrence of AFM1 in milk makes it a particular risk for humans because it has both chronic and acute effects on human health. The acute symptoms of aflatoxins include vomiting, diarrhea, pyrexia, and abdominal pain. The chronic symptoms are related to liver cancer, hepatitis, jaundice, hepatomegaly, and cirrhosis (Turner *et al.*, 2000). It has been reported that aflatoxins may also play a role in Reye's syndrome, kwashiorkor, and suppressing of the immune system that, in turn, increases disease incidence (Scudamore 1998).

The effects of aflatoxins on consumers include teratogenic, mutagenic, carcinogenic, immunosuppressive, and hepatotoxic impacts. Aflatoxin poisoning can be acute or chronic, depending on the type of mycotoxin and the dose received by the organism (human). Acute poisoning carries significant health risks, including the potential for kidney damage and certain cancers, such as liver cancer. Conversely, chronic poisoning can result in depression, neurological disorders, and deficiencies in vitamins A and D.

The maximum residue limit (MRLs) for mycotoxins in milk and milk product according to the European Union is **0.05 µg/kg**(Osama. *et al.*, 2025) and **0.5µg/kg**(CAC 2023)

Physical contaminants

Undesired particles, such as dirt, hair, leaves, rubber, and paper, are considered physical contaminants that can be introduced into milk during milking. Dirt can enter raw milk through contaminated utensils, water supply, cow's udder, or even from the air. Hair may originate from the cow's body. The dairymaid can also be a source of physical contaminants due to bad habits during milking, such as chewing tobacco, gutkha, or betel leaves (FSANZ, 2016).

Effect of Physical Contaminants on dairy products

Physical contaminants like dirt, glass, or metal fragments can enter milk during milking or processing. These contaminants pose a direct physical risk to consumers and may damage processing equipment (FSANZ, 2016).

Conclusion

Milk and dairy products are vital sources of essential nutrients, including proteins, vitamins, and minerals, which support growth, bone health, and immune function. However, contamination poses significant risks to these benefits. Milk can be contaminated by Heavy metals (e.g., lead, cadmium) from environmental pollution, posing chronic toxicity risks, Antibiotics and veterinary drugs, which may cause antibiotic resistance or allergic reactions, Mycotoxins (e.g., aflatoxin M1), linked to carcinogenic and immunosuppressive effects, Microbial pathogens (e.g., *Salmonella*, *E. coli*), leading to foodborne illnesses, Pesticides, with residues accumulating in fat-rich dairy products. Contaminants in milk disproportionately affect vulnerable groups (e.g., infants, children) due to their lower tolerance and higher milk consumption. Chronic exposure can lead to organ damage, cancer, and developmental issues. While maximum residue limits (MRLs) exist for contaminants like heavy metals and antibiotics, enforcement and monitoring in regions like Nigeria need strengthening to ensure compliance. Contaminants disrupt dairy processing (e.g., antibiotics inhibit fermentation), reduce shelf life, and compromise consumer safety.

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