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Standards-based assurance of dairy product safety: Integrating production-process control with international and regional regulatory requirements

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Annotatsiya

Milk and dairy products are highly perishable and susceptible to microbiological, chemical, and mycotoxin hazards throughout the production chain, from primary milking through processing, distribution, and retail. This paper synthesizes international and regional normative requirements together with recent peer-reviewed evidence to outline a standards-based approach to dairy safety assurance. The regulatory backbone reviewed includes ISO 22000 food safety management systems, the codex alimentarius code of hygienic practice for milk and milk products, the eurasian customs union technical regulation on safety of milk and dairy products (TR CU 033/2013), and the European Union's maximum-level contaminant regulation for aflatoxin M1. These frameworks are mapped onto critical control points along a generic dairy production chain: farm-level feed and hygiene control, raw milk reception and testing, thermal processing, cold-chain maintenance, and traceability documentation. Recent occurrence surveys of aflatoxin M1 in milk and dairy products from multiple regions are reviewed to illustrate how monitoring evidence informs control-point prioritization, and documented experience with food safety management system implementation in the dairy sector is discussed to highlight recurring compliance gaps. The synthesis indicates that combining a certified management-system architecture with commodity-specific hazard monitoring, particularly for aflatoxin M1 and raw milk microbiological quality, offers a practical route to standards-compliant dairy safety assurance for producers operating under harmonized regional requirements.

Kalit so‘zlar

Dairy product safety, ISO 22000, HACCP, aflatoxin M1, food safety management system, TR CU 033/2013, milk production chain.

1. INTRODUCTION

Milk is one of the most nutrient-dense foods consumed worldwide, yet its high water activity, near-neutral pH, and multiple handling stages make it particularly vulnerable to microbiological, chemical, and mycotoxin contamination [2]. Aflatoxin M1 (AFM1), a hepatocarcinogenic metabolite excreted in the milk of animals fed aflatoxin B1-contaminated feed, illustrates how a single hazard can persist across the entire chain from feed to finished product [9,15,16]. International and regional standards have therefore developed a layered regulatory architecture: general food-safety management requirements under ISO 22000 [1], commodity-specific hygienic-practice guidance under the codex code of hygienic practice for milk and milk products [2], and binding regional regulation such as the Eurasian Customs Union's TR CU 033/2013 [3], reinforced by contaminant limits such as the EU's Regulation (EU) 2023/915 [6]. This paper synthesizes these normative documents with recent occurrence and management-system literature to outline standards-based control points for dairy production, with attention to requirements relevant to producers in Central Asian and Eurasian regulatory contexts.

2. MATERIALS AND METHODS

This is a narrative synthesis rather than a primary laboratory study. Four core normative documents were reviewed in full: ISO 22000:2018 [1], Codex CAC/RCP 57-2004 [2], TR CU 033/2013 [3], and Regulation (EU) 2023/915 [6]. These were supplemented with peer-reviewed literature retrieved through targeted searches for food safety management system performance in dairy processing and aflatoxin M1 occurrence surveys, prioritizing studies published between 2021 and 2026 to reflect current contamination patterns and regulatory practice, while retaining foundational sources published earlier where they remain the primary reference for a standard or concept. Hazards identified in the literature were classified into microbiological, mycotoxin/chemical, and management-system categories, and mapped onto the HACCP logic embedded in ISO 22000 and the Codex Code: hazard identification, critical control point (CCP) determination, critical limits, monitoring, and verification, applied across five generic chain stages - primary production, transport/reception, thermal processing, packaging/cold chain, and distribution.

3. RESULTS AND DISCUSSION

3.1. Hazard landscape in the dairy chain

Microbiological hazards dominate raw milk risk profiles because milk can carry zoonotic pathogens from the udder or the milking environment if hygiene is inadequate; the Codex Code of Hygienic Practice therefore specifies teat cleanliness, milking-equipment sanitation, and prompt cooling as primary-production control points [2]. Mycotoxin contamination, principally AFM1, represents a chemically distinct but comparably persistent hazard: recent surveys report AFM1 in 40% of milk and dairy product samples across Mediterranean countries over a 20-year period [9], in 48.1% of fermented dairy products on the Croatian market in 2025 [12], in 62.4% of milk marketed in Tirana, Albania [11], and in over 75% of milk samples from south-central and northwest China in 2023-2024, although only 1.55% exceeded the EU limit there [14]. By contrast, an eight-year monitoring program in Lombardy, Italy, found only 0.7% of 95,882 raw milk samples exceeded the EU AFM1 threshold, illustrating that sustained monitoring can hold contamination well below regulatory limits even in a historically

affected region [7]. Together these findings show that AFM1 prevalence varies sharply with feed quality, climate, and monitoring intensity rather than being a fixed regional characteristic.

3.2. Standards architecture and critical control points

ISO 22000 embeds HACCP within a broader food safety management system (FSMS), requiring hazard analysis, prerequisite programs, interactive communication along the supply chain, and continual system verification rather than isolated product testing [1,4]. The codex code of hygienic practice for milk and milk products operationalizes this at the commodity level, specifying that milk should not carry contaminants at levels that jeopardize public health, and detailing primary-production, transport, and processing controls consistent with the General Principles of Food Hygiene [2]. Regionally, TR CU 033/2013 translates these principles into binding microbiological, contaminant, and labeling requirements for milk and dairy products placed on Eurasian Customs Union markets, including differentiated criteria for raw milk, heat-treated milk, and infant-formula-grade products [3]. Pasteurization remains the archetypal CCP within this architecture: maintaining time-temperature combinations sufficient to inactivate vegetative pathogens is a critical limit that must be continuously monitored and independently verified. Because AFM1 is heat-stable and is not reduced by pasteurization, control of this specific hazard must occur upstream, at the feed and raw-milk stages, rather than at thermal processing [1,2].

3.3. Food safety management system implementation performance

Evidence from dairy-sector FSMS audits indicates that certification does not automatically translate into equivalent operational performance. A diagnostic assessment of dairy processing companies in Tanzania found that formally certified systems still showed gaps in core monitoring and verification relative to the riskiness of their operating context [5]. A broader review of auditing and food safety/quality standards likewise concludes that certification's value depends on how rigorously hazard analysis and corrective action are implemented in practice, not on certificate possession alone [4]. This is directly relevant to producers in transition and emerging dairy economies, where formal standards adoption may outpace the operational capacity needed to sustain the monitoring the standards require.

3.4. Practical recommendations for production-process control

Drawing on the standards and evidence reviewed, five control points merit particular attention in dairy production-process design. First, feed-quality control at the farm level is the primary lever against AFM1 carryover, since the toxin cannot be removed once present in milk [1,2]. Second, raw milk reception should include routine screening for AFM1 and key microbiological indicators before pooling, consistent with Codex primary-production guidance [2]. Third, pasteurization critical limits must be continuously monitored and independently verified as the principal microbiological CCP, while being explicitly recognized as ineffective against AFM1 [1,2]. Fourth, cold-chain maintenance from processing through retail should be documented as a prerequisite program under ISO 22000 rather than treated as a separate logistics function [1]. Fifth, traceability and record-keeping - covering feed sourcing, raw milk test results, processing parameters, and distribution - should be maintained in a form that supports both internal

verification and external conformity assessment against regional technical regulations such as TR CU 033/2013 [3].

4. CONCLUSION

Assuring dairy product safety requires combining a certified food safety management system with hazard-specific monitoring evidence, rather than treating standards compliance as a documentation exercise. The review presented here indicates that AFM1 and raw milk microbiological quality remain the hazard categories most consistently associated with contamination incidents and regulatory non-compliance in the dairy sector, and that both are most effectively controlled upstream of thermal processing. Because this synthesis is retrospective and literature-based, its conclusions should be treated as a framework for control-point prioritization rather than validated performance data for any specific facility. Future work should validate this framework against production data from national dairy processors, particularly under regional frameworks such as TR CU 033/2013, to establish context-specific critical limits and monitoring frequencies.

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