Research on Risk Control in Coffee Milk Beverage Production Based on HACCP and FMEA

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Abstract. This study aims to identify hazards and potential risks at each stage of coffee milk beverage production through a combined approach of HACCP (Hazard Analysis and Critical Control Points) and FMEA (Failure Mode and Effects Analysis). It proposes risk control measures and determines the production process's CCPs (Critical Control Points). The analysis of the production process categorizes it into five parts: "Raw Materials and Auxiliary Materials Inspection", "Preprocessing of Coffee Milk Beverages", "Post-Processing of Coffee Milk Beverages", "Physical Hazard Detection", and "Allergen Hazard Prevention." Through the CCP decision tree and RPN value calculation, hazards, including physical, chemical, biological, and allergenic hazards, were accurately identified. The results show seven CCPs in coffee milk beverage production. First, chemical hazards from pesticide residues, heavy metal contamination, and excessive food additives during raw material acceptance and mixing. Second, biological hazards from mycotoxins and pathogenic bacteria during roasting and sterilization. Third, physical hazards from metal and plastic residues and allergenic hazards from allergens during processing and packaging. Finally, the study presents specific prevention and corrective plans using HACCP teams and planning charts, effectively reducing production risks and ensuring product quality and consumer safety.

1 Introduction

As one of the world's three major beverages, second only to tea and water, coffee has become increasingly popular in China, evolving into a favoured daily drink among many Chinese consumers [1]. Unlike the Western preference for black coffee, Chinese consumers prefer combining coffee with dairy products such as milk, creating rich-tasting coffee milk beverages and offering a more diverse sensory experience [2]. However, China's industry standards for coffee beverages are currently underdeveloped, and it lacks specialized management and technical expertise. China's coffee trade deficit has also been steadily expanding [3], highlighting the urgent need for standardization and upgrading within the coffee industry. Therefore, establishing a standardized production system for coffee milk beverages is of significant practical importance for enhancing food safety in coffee products and promoting the overall advancement of the coffee industry.

Hazard Analysis and Critical Control Point (HACCP) is a preventive system designed for process control, primarily aimed at protecting food and consumers from chemical, physical, and biological hazards by systematically identifying and managing critical control points(CCPs) [4]. HACCP is widely recognized as an international standard for food safety prevention and control, with extensive research confirming its effectiveness [5-6]. Numerous countries' food regulatory authorities mandate the application of specific HACCP procedures for various food products, including meat, juice, dairy, infant formula, seafood, and canned goods, to ensure proper food safety, protect public health, and prevent outbreaks of foodborne illnesses [7].

Failure Mode and Effect Analysis (FMEA) is a proactive risk assessment tool that primarily functions by identifying failure modes, assigning corresponding risk levels, and developing necessary control measures for unacceptable risks, thereby reducing risks to an acceptable level [8]. Antonio Scipioni and colleagues were the first to integrate FMEA with HACCP in a food company in 2002, using FMEA to quantify and identify severe risks on the production line. They then applied corrective actions based on the HACCP system, such as regularly replacing printers and maintaining packaging machines, to reduce the likelihood of risk occurrence, ensuring product safety and improving overall production efficiency [9]. Biljana Aleksic and others applied FMEA to produce ultrafiltration cheese. FMEA was used to conduct a quantitative analysis that revealed major risks occurring early in the cheese supply chain, such as during the raw milk receiving stage. They proposed improvement measures to optimize risk prioritization within the supply chain [10]. Joanna Trafialek and her team also highlighted in their research that FMEA provides a systematic risk assessment tool that helps managers identify weaknesses within the HACCP system, enabling them to focus on monitoring and improving these areas [11]. Therefore, using FMEA to establish a sustainable quality risk management model,

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combined with the HACCP system, offers both scientific theoretical support and practical feasibility for controlling food safety risks in the production process of coffee milk beverages, ensuring the quality of these products in a swift, systematic, and comprehensive manner.

2 Coffee milk beverages

2.1 Product description of coffee milk beverages

Coffee milk beverage products, primarily referring to ready-to-drink milk coffee, are typically made using coffee extract or coffee powder as a base [12-13]. These are blended with milk, milk powder, condensed milk, flavourings, and other ingredients, followed by sterilization and packaging.

Sensory indicators: The colour is a uniform light brown with a fine and smooth texture. The mouthfeel is smooth without any graininess, and the aroma of coffee and milk is rich and well-balanced. The taste has a moderate sweetness and balanced acidity and bitterness, leaving a long-lasting aftertaste.

The specific product description of coffee milk beverages is shown in Table 1.

Table 1. Product Description of Coffee Milk Beverages.

Product Specifications	Indicator Status
Product Description	Coffee Milk Beverage
Morphological Characteristics	Liquid form, with a uniform light brown or dark brown colour, good lustre, and no visible layering or sediment on the surface.
Physicochemical Indicators	Food additives should comply with the relevant provisions of GB 2760, "National Food Safety Standard—Standards for the Use of Food Additives." The milk powder used should meet the requirements of GB 19644 "National Food Safety Standard—Milk Powder."
Production Method	Made from coffee and milk as primary ingredients, combined with sugar and other supplementary ingredients, and processed through mixing, homogenization, heating, cooling, and packaging.
Intended Use	Beverage
Explanation of the Label	Complies with the requirements of GB 7718—2011 "General Standard for the Labeling of Prepackaged Foods." The labelling includes the product name, grade, standard number, producer, place of origin, shelf life, packaging date, storage conditions, and other relevant information.

2.2 Production Process of Coffee Milk Beverage

The process flowchart is shown in Fig. 1. The steps of roasting, grinding, and extraction can be omitted when using coffee powder.

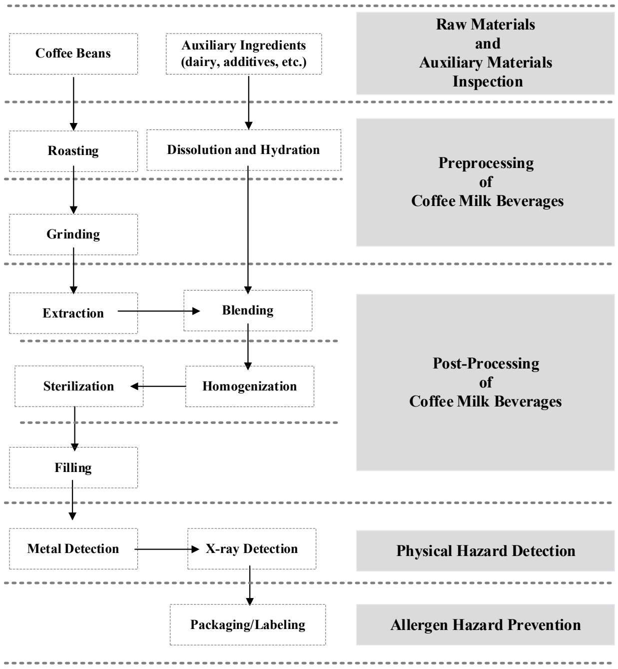

Fig. 1. Process of Coffee Milk Beverages.

3 HACCP analysis of coffee milk beverages based on FMEA

3.1 Risk assessment of coffee milk beverages based on FMEA

The traditional HACCP system has subjectivity and limitations in risk assessment, often failing to systematically identify and quantify potential failure modes, such as equipment malfunctions or operational errors, throughout the production process. Additionally, HACCP lacks in-depth analysis of systemic issues, making it difficult to ensure preventive management across the entire process, which may result in the oversight of certain latent risks [14]. In the HACCP system, significant hazards identified through hazard analysis require the determination of critical control points (CCPs) for control, and the correct and thorough identification of CCPs is fundamental to controlling significant hazards. FMEA, as a quantitative method for analyzing failure cause-and-effect relationships, can assess potential failure modes and their impact on the entire system, thereby accurately identifying hidden risks in the production process of coffee milk beverages [15-16]. Therefore, the FMEA method is used to identify CCPs within the HACCP system.

A hazard analysis is conducted for the medium- and high-risk processes in producing coffee milk beverages, followed by a quantitative FMEA analysis of significant hazards to identify their critical points. The risk calculation is shown in Equation (1).

$$R=S\cdot O\cdot D \quad (1)$$

In the equation, S represents the severity of the consequences caused by the hazard; O represents the frequency of occurrence of the hazard; D represents the detectability of the hazard; R (RPN) represents the risk level of the hazard.

Combined analysis of HACCP and FMEA, as shown in Fig. 2.

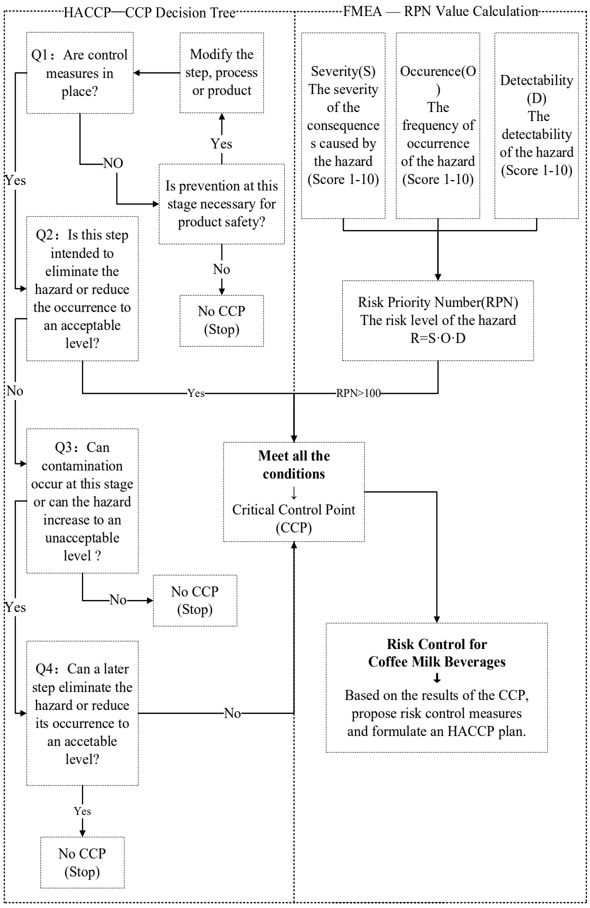

Fig. 2. Combined analysis of HACCP and FMEA.

3.2 Establishment of hazard analysis worksheets based on FMEA

Based on the hazard analysis table for the coffee milk beverage production process and the calculated RPN values from the FMEA hazard assessment, seven stages—raw and auxiliary material inspection, roasting, blending, sterilization, metal detection, X-ray detection, and packaging/labelling—are identified as critical control points (CCPs). A hazard analysis worksheet for the coffee milk beverage production process has been established, as shown in Table 2.

3.2.1 Potential hazards in each stage

Biological Hazards: As a tropical crop, coffee is highly susceptible to contamination by fungi that produce mycotoxins, such as Aspergillus ochraceus, Aspergillus niger, and Aspergillus carbonarius [17]. These fungi can produce ochratoxin A, which interferes with protein synthesis and DNA and RNA synthesis [18] and can persist through subsequent processing steps, posing health risks to consumers. Therefore, special attention should be paid to the residues of these fungi during the receiving and roasting stages. Additionally, the coffee raw materials and auxiliary ingredients are prone to contamination by other pathogens, such as Salmonella and parasites, during transportation and storage. Some bacteria also exhibit significant heat resistance. Consequently, residual microorganisms represent a significant hazard.

Chemical Hazards: During the cultivation of coffee beans, pesticides are often applied to coffee trees and fruits to prevent pests and diseases or to treat plant diseases. This can lead to pesticide residues on coffee beans during transportation and storage. Excessive pesticide residues or prohibited substances can directly impact consumer health. Additionally, numerous studies have indicated that acrylamide, formed during the roasting of coffee beans, may also indirectly affect consumer health [19]. Therefore, the residual chemical components in coffee represent a significant hazard. In blending auxiliary ingredients, additives are used to improve product quality. However, if these additives exceed the prescribed standards or if banned additives are used, they can pose health risks to consumers. Consequently, improper use of additives in auxiliary ingredients is also considered a significant hazard.

Physical Hazards: During the production of coffee milk beverages, the wear and tear of equipment and tools may lead to foreign objects, particularly when using critical equipment such as coffee grinders. Over time, the metal components of such equipment (e.g., grinding discs or blades) can produce metal particles due to mechanical wear. This affects product quality and poses a potential threat to consumer health, as ingesting these foreign objects may cause physical injuries, such as cuts to the mouth or digestive tract. Additionally, foreign objects like glass or plastic may appear in various stages of coffee milk beverage production, such as during filtering or dissolving, due to the breakage or wear of utensils. If these foreign objects are not detected in time, they can enter the product and pose a risk of harm to consumers. Therefore, physical hazards are also recognized as significant hazards in the subsequent steps of production.

Allergen Hazards: The auxiliary ingredients may contain allergenic components, such as milk powder, which can directly impact the health of consumers with allergies. Therefore, allergens are considered a significant hazard.

3.3 Establishment of the HACCP management team for coffee milk beverage

The requirements of the HACCP food safety management system should establish an HACCP working group. This group is responsible for developing the HACCP plan and implementing and validating the HACCP system. The composition of the HACCP working group should include the relevant expertise and experience necessary to establish an effective HACCP system. Participation is required not only from the company's lower and upper management levels but also from frontline workers who possess specialized knowledge in relevant fields. This includes quality inspectors, operators, receiving inspectors, and quality supervisors. The specific composition of the HACCP management team is shown in Table 3.

3.4 Development of the HACCP plan for coffee milk beverages

By integrating FMEA quantitative analysis with the HACCP system, seven critical control points were identified in the production process of coffee milk beverages: raw and auxiliary material inspection, roasting, blending, sterilization, metal detection, X-ray detection, and packaging/labelling. Based on the division of responsibilities outlined in Table 4 by the HACCP team, specific risk mitigation measures for each critical control point were developed, including target, method, frequency, personnel, and corrective actions, as detailed in Table 4. The established HACCP quality control system for producing coffee milk beverages ensures that the beverages meet relevant quality standards.

Table 2. Hazard Analysis Worksheet for the Coffee Milk Beverage Production Process.

Process Step	Potential Hazards	Is it significant?	Judgment Basis	Preventive Control Measures	FMEA Hazard Evaluation				CCP or Not
					S	O	D	RPN	
Raw Material Acceptance	Biological Hazards: Contamination by toxin-producing fungi, moulds, yeasts, pathogenic bacteria, parasites, and other contaminants.	Yes	Caused by the inherent contamination of raw materials or spoilage during storage and transportation.	Control through Enterprise Standard Sanitation Standard Operating Procedures (SSOP)：Selection and Rejection Processes, with Controllable Subsequent Sterilization Procedures	5	4	2	40	
	Chemical Hazards: Contamination by pesticides, insecticides, heavy metals, and other pollutants.	Yes	Environmental pollution, unsound cultivation practices, and spoilage during storage and transportation lead to the production of bacterial toxins. Lack of knowledge regarding food standards and legal regulations.	Require suppliers to provide production compliance certificates for raw materials.	8	6	3	144	CCP
	Physical Hazards: Contamination by soil, stones, metals, weeds, branches, empty bean shells, and other contaminants.	Yes	Contamination Introduced through Raw Materials or During the Production and Transportation Processes	Control through Enterprise SSOP：Selection and Rejection Processes, with Controllable Subsequent Sterilization Procedures	4	6	2	48	
	Allergen Hazards: None	No							
Auxiliary Material Acceptance	Biological Hazards: None	No							
	Chemical Hazards: Contamination by antibiotics, heavy metals, melamine adulteration, and other pollutants.	Yes	Environmental Pollution and Spoilage during Storage and Transportation	Require suppliers to provide production compliance certificates for raw materials.	8	5	3	120	CCP
	Physical Hazards: None	No							
	Allergen Hazards: Contains allergenic ingredients.	Yes	Some auxiliary materials contain allergenic components, resulting in cross-contamination between those containing allergenic ingredients and those not.	Identify the product by its name and ingredients during the packaging and labelling processes. Separate auxiliary materials that contain allergenic components from those that do not during the ingredient preparation to prevent cross-contamination.	6	4	2	48	
Roasting	Biological Hazards: Contamination by mycotoxin-producing fungi, yeasts, and pathogenic bacteria such as *Salmonella* and *Escherichia coli*.	Yes	Improper temperature control during roasting may lead to the survival or proliferation of pathogenic bacteria.	Reduce residual microorganisms by controlling the temperature and duration of coffee roasting.	7	6	3	126	CCP
	Chemical Hazards: Contamination by harmful substances such as acrylamide.	Yes	Generated by the Maillard reaction during the coffee roasting process.	Control acrylamide residues within acceptable standards by regulating the roasting method and temperature.	5	5	3	75	
	Physical Hazards: None	No							
	Allergen Hazards: None	No							
Grinding	Biological Hazards: None	No							
	Chemical Hazards: None	No							
	Physical Hazards: Contamination by plastic, metal, glass fragments, and other debris.	Yes	Generated by the wear and tear of grinding machines.	Controlled by the company's SSOP: Regular inspection and timely replacement of grinding machines, ensuring subsequent processes remain manageable.	4	5	2	40	
	Allergen Hazards: None	No							
Filtration and Extraction	Biological Hazards: Contamination by pathogenic bacteria, such as *Salmonella*, *Escherichia coli*, and *Staphylococcus aureus*.	Yes	Inadequate cleaning and inspection of extraction machines and non-compliance with hygiene standards by operators.	Controlled by the company's SSOP: Ensure environmental and equipment hygiene, with subsequent sterilization processes under control.	6	4	2	48	
	Chemical Hazards: None	No							
	Physical Hazards: Filter paper fragments, plastic, and other debris contamination.	Yes	Generated by the wear and tear of extraction machines and filter media.	Controlled by the company's SSOP: Regular inspection and timely replacement of extraction machines and filter media, ensuring subsequent processes remain manageable.	4	5	2	40	
	Allergen Hazards: None	No							

Process Step	Potential Hazards	Is it significant?	Judgment Basis	Preventive Control Measures	FMEA Hazard Evaluation				CCP or Not
					S	O	D	RPN	
Mixing and Dissolving	Biological Hazards: Contamination by moulds, pathogenic bacteria, and parasites.	Yes	Contamination during storage and transportation of auxiliary materials, non-compliance with hygiene standards by operators, and incomplete disinfection of equipment.	Controlled by the company's SSOP: Ensure environmental and equipment hygiene, with subsequent sterilization processes under control.	6	4	2	48	
	Chemical Hazards: None	No							
	Physical Hazards: None	No							
	Allergen Hazards: None	No							
Blending	Biological Hazards: Contamination by moulds, pathogenic bacteria, and parasites.	Yes	Operators are not adhering to hygiene standards, and equipment is being disinfected incompletely.	Controlled by the company's SSOP: Ensure environmental and equipment hygiene, with subsequent sterilization processes under control.	6	4	2	48	
	Chemical Hazards: Excessive use of food additives.	Yes	Whether food additives are appropriate and if the quantities exceed the permissible limits.	Food additives should comply with the GB 2760 "Standards for the Use of Food Additives."	8	5	3	120	CCP
	Physical Hazards: None	No							
	Allergen Hazards: None	No							
Homogenization	Biological Hazards: Contamination by moulds, pathogenic bacteria, and parasites.	Yes	Incomplete cleaning of the homogenizer.	Controlled by the company's SSOP: Ensure environmental and equipment hygiene, with subsequent sterilization processes under control.	6	4	2	48	
	Chemical Hazards: None	No							
	Physical Hazards: None	No							
	Allergen Hazards: None	No							
Sterilization	Biological Hazards: Contamination by moulds, yeasts, pathogenic bacteria, and parasites.	Yes	The sterilization temperature does not meet the required standards.	Control sterilization temperature and conduct regular monitoring.	8	6	3	144	CCP
	Chemical Hazards: None	No							
	Physical Hazards: None	No							
	Allergen Hazards: None	No							
Filling	Biological Hazards: Contamination by pathogenic bacteria and parasites.	Yes	Whether the filling machine and pipelines have been sterilized.	Controlled by the company's SSOP: Ensure environmental and equipment hygiene	6	5	2	60	
	Chemical Hazards: None	No							
	Physical Hazards: Contamination by plastic, metal, glass fragments, and other debris.	Yes	Damage to the filling machine.	Controlled by the company's SSOP: Regular inspection and timely replacement of the filling machine.	4	5	2	40	
	Allergen Hazards: None	No							
Metal Detection	Biological Hazards: None	No							
	Chemical Hazards: None	No							
	Physical Hazards: Contamination by metal fragments.	Yes	Metal contamination can result from the raw materials themselves or during their pre-processing stages.	Metal detectors can be used to eliminate this hazard.	7	6	3	126	CCP
	Allergen Hazards: None	No							
X-ray Detection	Biological Hazards: None	No							
	Chemical Hazards: None	No							
	Physical Hazards: Contamination by plastic, glass fragments, and other debris.	Yes	Glass, plastic or other contaminants may originate from raw materials or pre-processing stages.	X-ray detection can be used to eliminate this hazard.	7	6	3	126	CCP
	Allergen Hazards: None	No							
Packaging/Labeling	Biological Hazards: None	No							
	Chemical Hazards: None	No							
	Physical Hazards: None	No							
	Allergen Hazards: Contains allergenic components.	Yes	Some auxiliary ingredients contain allergenic components.	Some auxiliary ingredients contain allergenic components. These should be identified on the product packaging through printing or labelling.	8	5	3	120	CCP

Table 3. HACCP Team and Their Responsibilities.

Position	Role within the Team	Responsibilities
General Manager	Team Leader	Responsible for overseeing the preparation and formal implementation of the HACCP system; Developing the safety policies and expected goals for coffee milk beverage production; Reviewing and approving the overall HACCP plan; Managing and organizing the HACCP team.

Position	Role within the Team	Responsibilities
Deputy General Manager	Deputy Team Leader	Coordinating the division of tasks among HACCP team members; Assisting the Team Leader in implementing the management requirements of the HACCP system; Organizing internal audits and external reviews of the HACCP management system.
Head of Procurement Department	Sub-Team Leader	Responsible for supervising and auditing the procurement and receiving processes for raw and auxiliary materials; Managing and organizing the activities of the procurement department.
Purchasing Officer	Team Member	Participate in the specific implementation of the HACCP plan; Contribute to the review of records related to raw and auxiliary materials.
Receiving Inspector	Team Member	Participate in the specific implementation of the HACCP plan; Contribute to the investigation and handling of non-conforming raw and auxiliary materials.
Head of Production Department	Sub-Team Leader	Responsible for supervising and auditing the production process; Managing and organizing the activities of the production department.
Operator	Team Member	Participate in the specific implementation of the HACCP plan; Conduct regular training and ensure the implementation of the production process requirements.
Head of Quality Department 4o	Sub-Team Leader	Responsible for supervising and auditing product quality; Managing and organizing the activities of the quality department.
Quality Inspector	Team Member	Participate in the specific implementation of the HACCP plan; Conduct investigation and supervision of the production process; Participate in product quality supervision and the investigation and handling of quality issues.

Table 4. Hazard Analysis Worksheet for the Coffee Milk Beverage Production Process.

Critical Control Point (CCP)	Significant Hazard	Critical Limit (CL)	Monitoring					Corrective Actions	Records	Verification
			Target	Content	Method	Frequency	Personnel			
Raw and Auxiliary Material Inspection	Chemical Hazards	Suppliers provide compliance certificates for raw materials, including heavy metals and pesticide residues. Suppliers also provide certificates of conformity for auxiliary materials, which should meet the relevant standards.	Certificates of Compliance for Raw and Auxiliary Materials	Excessive heavy metals, pesticide residues, antibiotics, melamine adulteration	View	Each batch	Acceptance personnel	Refuse to accept raw and auxiliary materials without a certificate of compliance; destroy any raw and auxiliary materials that fail random inspections.	Acceptance record of raw materials and accessories Certificate of Conformity of raw materials and accessories, etc.	The procurement department assigns different personnel to rotate and review relevant records daily. The person in charge shall observe the inspector's acceptance process of raw and auxiliary materials once a week. Inspectors conduct daily spot checks on pesticide residues in raw materials and monthly inspections on prohibited substances in auxiliary materials.
Roasting	Biological hazards	Different baking conditions are applied based on varying degrees of roasting. Light roasting: 190°C - 205°C, 8 to 10 minutes Medium roast: 210°C - 220°C, 10 to 12 minutes Deep roasting: 225°C - 230°C, 12 to 15 minutes	Baking temperature and time	Pathogenic bacteria, such as *salmonella* *E. coli*, *Staphylococcus aureus*; To produce some harmful substances such as acrylamide	Thermometer measurement of temperature	Each batch	Operator	Products that fail microbial testing shall be subjected to destruction.	Baking Condition Record Form Calibration Record Form for Thermometers and Timers "Correction Action Records," and so on	The production department assigns different personnel daily to verify the operation records for each baking session, including time, final temperature, and baking conditions. Quality inspectors conduct weekly calibration tests on thermometers and timers and document the results. The quality supervisor conducts weekly random inspections of the operations and record-keeping by bakers and quality inspectors and signs off for confirmation.
Blending	Chemical Hazard	The food additives used comply with GB 2760—2014 "Standards for the Use of Food Additives," GB 7101—2022 "National Food Safety Standard for Beverages," GB/T 30767—2014 "Coffee Beverages."	The usage and dosage of food additives	The dosage of food additives exceeds the standard	Review the additive usage record table	Each batch	Quality Inspector	Products with non-compliant levels of food additives shall be destroyed	Food Additive Weighing & Feeding Record Sheets, Electronic Balance Calibration Record, Corrective Action Record.	The quality department assigns different quality inspectors daily to verify whether the quantity and specifications of food additives comply with GB 2760-2014 "Standards for the Use of Food Additives". The quality inspector conducts calibration tests on the weekly scales and records the results. The quality supervisor conducts weekly random inspections of the operations, records of each quality inspector, and signs to confirm.

Critical Control Point (CCP)	Significant Hazard	Critical Limit (CL)	Monitoring					Corrective Actions	Records	Verification
			Target	Content	Method	Frequency	Personnel			
Sterilization	Biological hazards	Adopting high-temperature instantaneous sterilization technology. Sterilization temperature 115 ~ 120 °C Sterilization time: 3 to 5 seconds. Microbial testing complies with GB 31607-2021.	Center temperature	Mold, yeast, pathogenic bacteria, Parasites and other pollution	Temperature measurement, timer control, microbial colony count	Each batch	Operator	Products that fail microbial testing during the process shall be destroyed.	Records of Each Operation and Sterilization Temperatures and Machine Conditions for Sterilization Correction Action Record	The production dept. Assigns staff daily to check sterilization records for compliance with time and temperature. And machine status. Quality inspectors weekly test and log sterilization machine results. The quality supervisor weekly spot-checks and signs off on operators' and inspectors' work.
Metal detection	Physical Hazard	Iron metal 1.3 mm≥Φ; Non-ferrous metal 1.5 mm≥Φ;	Metallic foreign body	Metal debris contamination	Metal Detector	Each batch	Operator	Samples with metallic foreign objects must be destroyed. Improperly functioning metal detectors require recalibration and reprocessing of previously detected products.	Metal Detector Detection Record Metal Detector Equipment Testing Record Correction Action Record	Operators calibrate metal detectors pre-production, post-production, and between product changes, documenting results. Personnel review metal detector logs weekly, and quality inspectors observe procedures, check sensitivity and document findings. The quality supervisor conducts random weekly inspections and signs off on operators' and inspectors' records.
X-ray machine detection	Physical Hazard	The product must not contain Sus304（spherical） Φ≥1.0 mm; Sus304（Linear） ≥0.4×5 mm; Ceramics Φ≥4.0 mm; Glass Φ≥4.0 mm;	Ceramics, glass	Pollution from ceramic and glass fragments	X-ray machine detection instrument testing	Each batch	Operator	If the X-ray detector is insensitive, identify and fix the issue to remove hazards. Reset it for accuracy and normal function. Halt production, isolate affected products, and evaluate and re-test. The quality supervisor will check corrective actions, analyze causes, and prevent recurrence.	X-ray Detector Testing Form Product X-Ray Detection Record Form Record of Correction Actions	Operators calibrate X-ray detectors pre-production, post-production, and between product changes, documenting results. Personnel review X-ray logs weekly, and quality inspectors observe operator procedures, check sensitivity, and document findings. The quality supervisor conducts random weekly inspections and signs off on records.
Packaging / Labeling	Allergen Hazards	Correctly print/stamp labels on the packaging that display the product name and ingredients.	Each product package must display the correct name and ingredients.	Allergens	Visually inspect a representative quantity of packaging/labels.	Each batch	Operator	If packaging lacks name/ingredient info, cease use. For finished products without labels, isolate and replace them with the correct packaging. The quality supervisor will review, analyze, and prevent recurrence.	Packaging/Label Inspection Record Form Record of Correction Actions	The quality supervisor monitors the on-site quality inspectors' operations and record-keeping daily and checks whether the labelling meets the requirements. The quality supervisor reviews the packaging/label inspection record sheet daily.

4 Conclusion

In summary, the integration of HACCP and FMEA systems allows for a comprehensive risk analysis throughout the entire production process, identifying seven critical control points in the production of coffee milk beverages: raw and auxiliary material inspection, roasting, blending, sterilization, metal detection, X-ray detection, and packaging/labelling. The results demonstrate that this approach effectively reduces the risk of hazards, ensuring food safety throughout the coffee-milk beverage production. The combination of HACCP and FMEA effectively identifies and controls key risks and control points in the production process, providing a solid theoretical foundation for ensuring food safety in coffee milk beverage production. Future optimization of the process can be achieved by employing methodologies such as the Six Sigma management tool DMAIC (Define, Measure, Analyze, Improve, Control), the PDCA Cycle (Plan-Do-Check-Act), and the SDCA Cycle (Standardize-Do-Check-Act), making the process even more aligned with operational workflows.

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