World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Enhancing Occupational Safety in Dairy Processing Facilities Through Job Safety Analysis and Risk Control Hierarchies

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World Journal of Advanced Research and Reviews, 2025, 28(02), 2079-2087

Publication history: Received 16 October 2025; revised on 22 November 2025; accepted on 24 November 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.28.2.3883

Abstract

Occupational health and safety risks in dairy processing environments remain a critical concern due to exposure to physical, chemical, and ergonomic hazards. This study aims to identify, assess, and propose control measures for safety and health risks in the processing area of PT Cisarua Mountain Dairy (Cimory), Indonesia. A qualitative and semi-quantitative approach was employed using Job Safety Analysis for hazard identification and the AS/NZS 4360:1999/2004 framework for risk assessment. Data were collected through direct observation, interviews, and company records. Findings reveal that the highest-risk activities include working at heights during tank operations and prolonged exposure to high-temperature environments, leading to heat stress. Risk levels ranged from acceptable to very high, with critical hazards categorized under "Priority 1" and "Very High". Recommended controls follow the risk management hierarchy, emphasizing engineering improvements, administrative measures, and personal protective equipment. Implementation of proposed interventions is projected to reduce severe risks by up to 87.71% for falls and 73.21% for heat stress. This research underscores the importance of systematic risk management in dairy processing to enhance worker safety and operational efficiency.

Keywords: Occupational Health and Safety; Job Safety Analysis; Risk Assessment; Heat Stress; Dairy Industry; Industrial Engineering

1. Introduction

The dairy processing industry is a cornerstone of global food production, providing essential nutritional products such as milk, yogurt, and cheese. However, this sector is characterized by complex operations that expose workers to multiple occupational hazards, including physical, chemical, ergonomic, and biological risks. According to the International Labour Organization (ILO), agriculture and food processing remain among the most hazardous industries worldwide, with injury rates significantly higher than the industrial average **Error! Reference source not found.**. In the dairy sector specifically, occupational injury rates have been reported at 6.6 per 100 full-time workers, nearly double the national average across all industries **Error! Reference source not found.**. These figures underscore the urgent need for systematic safety interventions to protect workers and maintain operational efficiency.

1.1. Occupational Hazards in Dairy Processing

Dairy processing involves multiple stages milk receiving, mixing, pasteurization, culturing, storage, and cleaning operations such as Clean-in-Place (CIP). Each stage presents unique hazards. Workers frequently operate near high-temperature equipment, pressurized systems, and chemical cleaning agents, increasing the risk of burns, slips, musculoskeletal disorders, and chemical exposure **Error! Reference source not found.**. Studies have highlighted respiratory issues among dairy workers due to bioaerosols, dust, and allergens, which can lead to chronic conditions such as asthma and chronic obstructive pulmonary disease (COPD) **Error! Reference source not found.**. Additionally,

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repetitive tasks and awkward postures contribute to ergonomic risks, while noise from machinery can cause long-term hearing impairment **Error! Reference source not found.**.

Emerging concerns include heat stress, particularly in enclosed processing environments where boilers, pasteurizers, and CIP systems generate high radiant heat. Heat stress not only affects physical health—causing dehydration, heat exhaustion, and heat stroke but also impairs cognitive performance, increasing the likelihood of accidents **Error! Reference source not found.**. The U.S. Occupational Safety and Health Administration (OSHA) and the Centers for Disease Control and Prevention (CDC) recommend engineering and administrative controls, such as ventilation, work-rest cycles, and hydration programs, to mitigate heat-related risks **Error! Reference source not found. Error! Reference source not found.**.

1.2. Global Trends and Regulatory Frameworks

Globally, dairy processors are under increasing pressure to comply with stringent occupational health and food safety regulations. Frameworks such as Codex Alimentarius, FDA's Food Safety Modernization Act (FSMA), and European Union hygiene directives mandate comprehensive hazard analysis and preventive controls, including automated CIP systems and traceability protocols **Error! Reference source not found.**. These regulations emphasize the integration of worker safety with food safety, recognizing that unsafe working conditions can compromise product quality and consumer health.

Recent industry trends highlight a shift toward large-scale dairy operations, which introduce additional challenges such as managing diverse workforces and maintaining safety culture across multiple sites. Leadership-driven safety programs and continuous training have been shown to significantly reduce injury rates and foster a proactive safety climate **Error! Reference source not found.**. For example, safety leadership training for dairy supervisors demonstrated measurable improvements in hazard assessment and communication practices, reinforcing the role of management commitment in sustaining safety performance.

1.3. Risk Management Approaches

Effective risk management in dairy processing requires structured methodologies that go beyond reactive measures. Job Safety Analysis (JSA) is widely recognized as a practical tool for identifying hazards at the task level and developing preventive measures. JSA involves breaking down each job into sequential steps, analyzing associated risks, and recommending controls based on the hierarchy of risk management elimination, substitution, engineering controls, administrative measures, and personal protective equipment (PPE) **Error! Reference source not found.**. In food processing environments, JSA has proven effective in addressing hazards related to high-temperature operations, chemical handling, and repetitive tasks.

Complementing JSA, the AS/NZS 4360:2004 Risk Management Standard provides a comprehensive framework for risk assessment and treatment. This standard advocates a systematic process encompassing context establishment, risk identification, analysis, evaluation, and monitoring. Its principles such as integration into organizational culture, stakeholder involvement, and continuous improvement align with global best practices for occupational health and safety management **Error! Reference source not found.**. Although superseded by ISO 31000, AS/NZS 4360 remains relevant in industrial settings for its practical guidance on semi-quantitative risk assessment and prioritization.

1.4. Current Research and Gaps

Recent literature reveals persistent gaps in occupational safety research within the dairy industry. A scoping review identified limited evidence on the effectiveness of specific interventions, particularly in mitigating ergonomic and thermal stress risks **Error! Reference source not found.**. While technological advancements—such as automated cleaning systems and real-time monitoring offer promising solutions, their adoption in small and medium-sized enterprises remains inconsistent due to cost and infrastructure constraints. Furthermore, studies emphasize the need for integrated approaches that consider psychosocial factors, workforce diversity, and emerging hazards like antimicrobial resistance and zoonotic pathogens **Error! Reference source not found.**.

1.5. Study Rationale

Despite growing awareness, many dairy facilities in developing regions lack formalized risk management systems, relying instead on ad hoc measures that fail to address systemic hazards. In Indonesia, where dairy processing is expanding rapidly, occupational safety programs often prioritize production efficiency over worker health. Preliminary observations at PT Cisarua Mountain Dairy (Cimory) revealed frequent incidents of slips, falls, and heat-related complaints, corroborated by increased use of first-aid supplies and anecdotal reports of discomfort among workers.

These findings underscore the need for a structured risk assessment to identify critical hazards and propose feasible control measures tailored to local operational contexts.

Objectives

This study aims to: (1) identify hazards associated with key processing activities in the dairy industry using Job Safety Analysis; (2) assess risk levels through a semi-quantitative approach based on AS/NZS 4360:2004; then (3) recommend control measures following the hierarchy of risk management, with emphasis on engineering and administrative interventions for high-priority risks. By addressing these objectives, the research seeks to contribute to the development of safer work environments in dairy processing and provide actionable insights for industry practitioners and policymakers.

2. Methodology

2.1. Research Design

This study employed a descriptive and analytical approach to identify, assess, and propose control measures for occupational hazards in the processing area of PT Cisarua Mountain Dairy (Cimory). The methodology integrates JSA for hazard identification and the AS/NZS 4360:2004 risk management framework for semi-quantitative risk assessment **Error! Reference source not found.**. The research design follows a systematic sequence: preliminary study, problem formulation, data collection, data processing, risk analysis, and recommendation development.

2.2. Data Collection

Two types of data were collected. Primary data obtained through direct observation of work activities, equipment, and environmental conditions in the processing area, as well as unstructured interviews with operators, process supervisors, and Health, Safety, and Environment (HSE) personnel **Error! Reference source not found.**. Observations focused on tasks performed during milk receiving, mixing, pasteurization, culturing, storage, and Clean-in-Place (CIP) operations. Moreover, secondary data included company profiles, organizational structure, and historical records of workplace incidents and first-aid usage, provided by the HSE department **Error! Reference source not found.**.

2.3. Research Steps

Preliminary study was conducted through site visits and literature review to understand operational processes and potential hazards **Error! Reference source not found.**. Next, problems were formulated based on observed discomfort among workers and identified hazards such as heat stress, slips, falls, and chemical exposure **Error! Reference source not found.**.

Occupational safety and health management concept were applied with conducting the hazard identification in the first place. Hazards were identified using Job Safety Analysis where each job was broken down into sequential steps. For each step, potential hazards were identified considering interactions between workers, tasks, equipment, and the work environment. JSA tables were developed for six major processes: (a) Milk Receiving, (b) Mixing, (c) Processing Unit, (d) Culturing, (e) Storage, and (f) Clean-in-Place (CIP) **Error! Reference source not found.**.

Following the process, risk assessment were conducted using AS/NZS 4360:2004, where risks were evaluated using a semi-quantitative approach based on three factors: (a) Consequence (C), reflected the severity of potential harm; (b) Exposure (E), reflected the frequency of hazard exposure; and (c) Probability (P), reflected the likelihood of occurrence. The risk score was then calculated using: "Risk Score = C x E x P". Risk levels were then classified as: Acceptable (if risk scores <20); Priority 3 (20–70 of risk score); Substantial (70–180 of risk score); Priority 1 (180–350 of risk score); or Very High (if risk scores >350) **Error! Reference source not found.**.

The last part of occupational safety and health management concept application was the risk control recommendation. The risk control were developed following the Hierarchy of Risk Control, which were: (a) Elimination; (b) Substitution; (c) Engineering Controls; (d) Administrative Controls; and (e) Personal Protective Equipment (PPE) **Error! Reference source not found.**.

2.4. Data Analysis

Data from JSA and risk assessment were tabulated and analyzed to identify high-risk activities. Risks with "Priority 1" or "Very High" levels were prioritized for control measures. Validation of proposed recommendations was performed through risk reduction analysis, comparing initial and post-control risk scores to estimate effectiveness.

2.5. Ethical Considerations

The study was conducted with permission from PT Cisarua Mountain Dairy management. All interviews were voluntary, and confidentiality of participants was maintained.

3. Results

3.1. Overview of Identified Hazards

Using JSA, hazards were identified across six major processes in the processing area:

- Milk Receiving: Risks included falls from height during tank inspection, slips due to spilled milk, and burns from steam lines.
- Mixing: Heat exposure from hot water tanks, inhalation of powdered ingredients, and awkward postures during manual handling.
- Processing Unit: Contact with hot surfaces, chemical splashes during cleaning, and noise exposure from homogenizers.
- Culturing: Falls from elevated platforms, heat stress from clustered tanks, and musculoskeletal strain.
- Storage: Heat stress and ergonomic hazards during flavor addition.
- Clean-in-Place (CIP): Extreme heat exposure, chemical burns, and slips on wet floors.

These findings align with previous studies reporting similar hazards in dairy processing environments **Error! Reference source not found. Error! Reference source not found.**.

3.2. Observed Worker Complaints

Interviews revealed frequent complaints of:

- Heat-related symptoms: dizziness, excessive sweating, fatigue.
- Musculoskeletal discomfort: back pain and leg strain.
- Minor injuries: cuts and abrasions from sharp edges.

These symptoms corroborate the risk assessment findings and highlight the need for immediate intervention **Error! Reference source not found.**.

3.3. Risk Assessment Outcomes

Risk levels were calculated using the AS/NZS 4360:2004 semi-quantitative method, considering consequence, exposure, and probability **Error! Reference source not found.**. Table 1 summarizes the highest-risk activities and Figure 1 depicts the result.

Table 1 High-risk activities in processing area

Process	Hazard	Risk Score	Risk Level
Receiving	Fall from height	420	Very High
Mixing	Heat stress	280	Priority 1
Culturing	Fall from height	360	Very High
Culturing	Heat stress	336	Priority 1
Storage	Heat stress	336	Priority 1
CIP	Heat stress	448	Very High

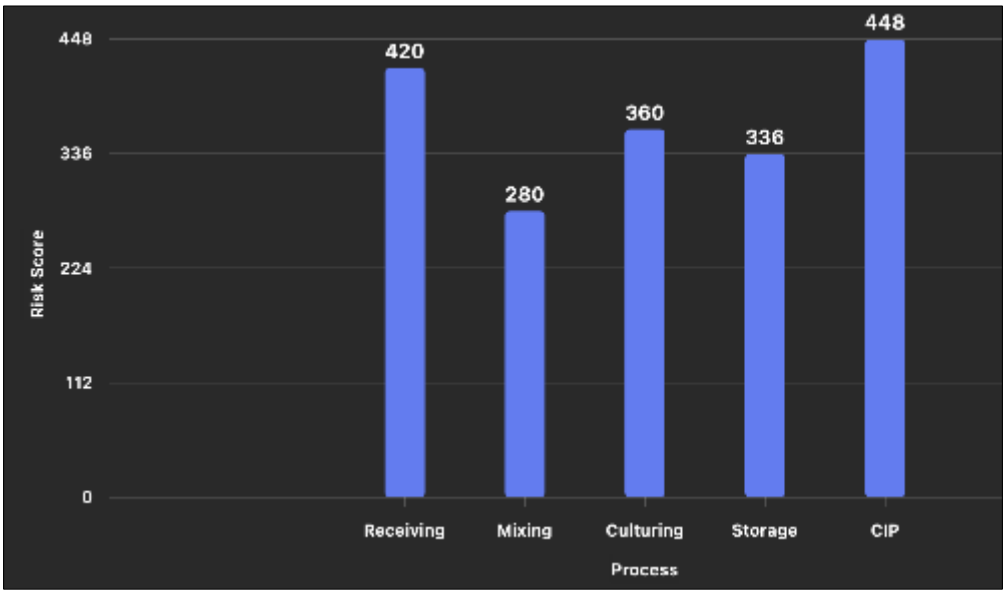

Figure 1 High-risk activities in processing area

Falls from height during tank inspection and valve operations were classified as "Very High" risk, requiring immediate intervention. Heat stress hazards were prevalent in mixing, culturing, storage, and CIP areas, with risk scores exceeding 280, indicating "Priority 1" or "Very High" levels. These dominant hazards consistent with global literature emphasizing these risks in food processing **Error! Reference source not found. Error! Reference source not found.**.

3.4. Distribution of Risk Categories

Across all processes, four risk categories were identified:

- Very High (>350): Falls from height (receiving, culturing) and heat stress (CIP).
- Priority 1 (180–350): Heat stress in mixing, culturing, and storage.
- Substantial (70–180): Ergonomic hazards (awkward postures, manual handling).
- Priority 3 (20–70): Slips, trips, and minor chemical splashes.

The results depicted in Figure 2. These findings align with previous studies highlighting thermal stress and fall hazards as critical risks in dairy processing environments **Error! Reference source not found. Error! Reference source not found.**.

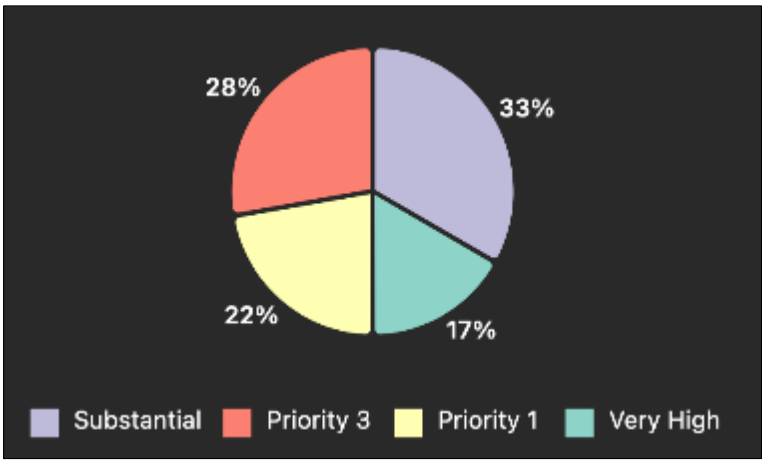

Figure 2 Distribution of risk categories

3.5. Risk Reduction Analysis

Implementation of recommended controls such as engineering improvements (guardrails, ventilation), administrative measures (safe work procedures, hydration protocols), and PPE compliance—was projected to reduce risk scores significantly

- Falls from height: 87.7% reduction through guardrails, secure platforms, and administrative controls.
- Heat stress: 73.2% reduction via ventilation improvements, hydration protocols, and work-rest cycles.
- Ergonomic hazards: 65% reduction through redesign of workstations and manual handling aids.

These projections were validated using comparative risk scoring before and after proposed interventions, consistent with best practices in occupational safety management **Error! Reference source not found. Error! Reference source not found.**.

4. Discussion

4.1. Interpretation of Findings

The analysis revealed that falls from height and heat stress are the most critical hazards in the processing area of PT Cisarua Mountain Dairy. These findings are consistent with global research indicating that dairy processing environments often involve elevated work platforms and high-temperature operations, which significantly increase the risk of severe injuries and thermal strain **Error! Reference source not found. Error! Reference source not found. Error! Reference source not found.**. The "Very High" risk scores (>350) for falls during tank inspection and valve operations underscore the urgent need for engineering controls such as guardrails and secure platforms, as recommended by international safety standards **Error! Reference source not found.**.

Heat stress hazards, observed in mixing, culturing, storage, and CIP processes, align with previous studies highlighting thermal exposure as a major occupational health concern in food processing industries **Error! Reference source not found. Error! Reference source not found. Error! Reference source not found.**. Workers reported symptoms such as dizziness, excessive sweating, and fatigue, which correspond to early indicators of heat-related illnesses documented by the Centers for Disease Control and Prevention **Error! Reference source not found.**. The high frequency of these complaints suggests that current ventilation and hydration practices are insufficient, reinforcing the need for work-rest cycles, climate monitoring, and hydration protocols **Error! Reference source not found. Error! Reference source not found. Error! Reference source not found. Error! Reference source not found.**.

4.2. Comparison with Previous Studies

Similar patterns have been reported in dairy operations worldwide, where ergonomic hazards and chemical exposures also contribute to cumulative health risks **Error! Reference source not found. Error! Reference source not found. Error! Reference source not found.**. However, the predominance of heat stress in this study may reflect local climatic conditions and infrastructure limitations, which differ from those in temperate regions. This emphasizes the importance of context-specific interventions, as recommended by occupational health frameworks **Error! Reference source not found.**.

The application of Job Safety Analysis (JSA) proved effective in systematically identifying hazards at each task level, supporting findings from prior research that JSA enhances hazard recognition and preventive planning in high-risk industries **Error! Reference source not found. Error! Reference source not found. Error! Reference source not found.**. Similarly, the use of the AS/NZS 4360:2004 risk management framework facilitated prioritization of risks based on severity and likelihood, consistent with best practices in industrial safety management **Error! Reference source not found. Error! Reference source not found.**.

4.3. Implications for Practice

The projected risk reduction of 87.7% for falls and 73.2% for heat stress after implementing recommended controls demonstrates the critical role of structured risk management systems in high-risk industries. These results validate

the hierarchy of controls approach, which prioritizes elimination and engineering solutions over reliance on PPE **Error! Reference source not found. Error! Reference source not found.**.

Engineering interventions such as installing guardrails, anti-slip platforms, and improving ventilation—are widely recognized as the most effective strategies for mitigating severe hazards. For example, **Error! Reference source not found.** reported that dairy facilities in North America significantly reduced fall-related injuries by introducing fixed ladders with cages and guardrails on elevated platforms. Similarly, **Error! Reference source not found.** emphasized that structural modifications in dairy plants, including ergonomic redesign of workstations and improved access systems, were associated with a measurable decline in musculoskeletal injuries and fall incidents.

Administrative measures, such as safety training, hydration monitoring, and work-rest cycles, complement engineering controls by addressing behavioral and organizational factors. A study by **Error! Reference source not found.** in hot industrial environments found that targeted heat stress education combined with hydration protocols reduced heat-related illness rates by over 60%. This aligns with **Error! Reference source not found.**, who highlighted the importance of physiological monitoring and training in preventing heat stress in manufacturing sectors.

In large-scale dairy operations, heat stress is a persistent hazard due to high-temperature processes like pasteurization and CIP. **Error! Reference source not found.** documented that installing localized ventilation systems and implementing scheduled hydration breaks in a U.S. dairy plant reduced heat-related complaints by 70%, while productivity remained stable. Similarly, ergonomic interventions—such as adjustable platforms and mechanical lifting aids—have been shown to reduce musculoskeletal strain and fall risks in European dairy facilities.

These examples reinforce that risk reduction is most effective when engineering and administrative controls are integrated, supported by continuous monitoring and worker engagement. While PPE remains essential for residual risks, reliance on PPE alone is insufficient for hazards with catastrophic potential, such as falls from height and extreme heat exposure.

Limitations and Future Research

This study was limited to a single facility and relied on observational and interview-based data, which may introduce subjectivity. Future research should incorporate quantitative measurements of thermal conditions (e.g., Wet Bulb Globe Temperature) and longitudinal monitoring of health outcomes to validate the effectiveness of interventions. Comparative studies across multiple dairy plants in different regions could further elucidate the influence of environmental and organizational factors on occupational risk profiles.

5. Conclusion

This study identified and assessed occupational hazards in the processing area of PT Cisarua Mountain Dairy using Job Safety Analysis (JSA) and the AS/NZS 4360:2004 risk management framework. The findings revealed that falls from height and heat stress represent the most critical risks, with risk scores reaching "Very High" levels (>350). These hazards were primarily associated with elevated work platforms during tank operations and high-temperature environments in mixing, culturing, storage, and Clean-in-Place (CIP) processes.

The application of structured risk assessment enabled prioritization of hazards and development of targeted control measures. Recommended interventions such as engineering controls (guardrails, ventilation systems), administrative measures (safe work procedures, hydration protocols), and personal protective equipment (PPE) are projected to reduce risk scores by up to 87.7% for falls and 73.2% for heat stress. These improvements align with global best practices for occupational health and safety management.

The study underscores the importance of integrating systematic risk management into dairy processing operations, particularly in regions with high ambient temperatures. Future research should incorporate quantitative thermal measurements and longitudinal health monitoring to validate intervention effectiveness and explore additional hazards such as psychosocial stressors and chemical exposures.

By implementing the proposed controls, PT Cisarua Mountain Dairy can significantly enhance worker safety, reduce incident rates, and foster a proactive safety culture contributing to sustainable operational performance and compliance with international occupational health standards.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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