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Comprehensive Hazard Identification and Risk Assessment (HIRARC) in the Coffee Production Process: A Case Study of Kopi Lanange Jagad

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A B S T R A C T

Occupational Safety and Health (OSH) plays a critical role in maintaining safe and sustainable production, particularly in small-scale agro-industrial operations such as coffee processing. This study applies the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) framework to evaluate workplace hazards at Kopi Lanange Jagad, a micro-scale coffee producer in Malang Regency, Indonesia. Field observations and structured interviews were conducted to identify potential hazards across four production stages—roasting, grinding, sieving, and packaging. Quantitative measurements were also taken, including ambient temperature, noise level, and airborne dust concentration, to provide empirical data for risk evaluation. The findings identified a total of 12 hazards, classified into three risk categories: high (25%), moderate (50%), and low (25%). The roasting process exhibited the highest risk score (R = 18.4), with average workplace temperatures reaching 85°C–120°C, significantly exceeding the national occupational limit of 30°C for moderate workloads (Permenaker No. 5/2018). The grinding stage also presented considerable hazards, with airborne dust concentrations averaging 2.4 mg/m³, approaching the Ministry of Manpower's threshold limit value (TLV) of 3 mg/m³. Manual packaging was associated with ergonomic strain, where workers lifted 15–20 kg sacks repeatedly, leading to potential musculoskeletal disorders. Risk evaluation revealed that existing control measures such as natural ventilation and sporadic use of personal protective equipment (PPE) were insufficient to ensure worker safety. To reduce these hazards, the study recommends implementing engineering controls such as local exhaust ventilation and machine insulation, combined with administrative measures including job rotation, scheduled rest breaks, and regular safety training. Ensuring consistent PPE use especially heat-resistant gloves, dust masks, and ear protection can further mitigate residual risks. Overall, the application of the HIRARC framework at Kopi Lanange Jagad demonstrates its effectiveness as a low-cost and practical tool for identifying, prioritizing, and managing occupational hazards in small-scale coffee industries. Implementation of the proposed control strategies is projected to reduce total workplace risk by 35–40%, improving both worker well-being and operational productivity.

Keywords: Occupational Safety and Health (OSH), HIRARC, Coffee Production, Hazard Assessment, Risk Control, Small-Scale Industry.

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1. Introduction

Occupational Safety and Health (OSH) is an essential aspect of sustainable industrial operations, ensuring that production activities are performed safely and efficiently while minimizing occupational hazards. In developing economies, particularly in Indonesia, OSH implementation in small- and medium-scale industries remains a significant challenge due to limited resources and a lack of awareness. The coffee processing sector is no exception; it often involves manual and semi-mechanical operations that expose workers to a variety of hazards such as extreme heat, airborne dust, mechanical vibration, repetitive motion, and chemical exposure from cleaning agents. Without structured safety management systems, such conditions increase the likelihood of accidents, injuries, and long-term health disorders among workers [1][2].

Indonesia ranks among the top coffee-producing countries globally, with a large proportion of its production handled by smallholder farmers and micro-enterprises. These small-scale processing units, typically characterized by traditional roasting and manual packaging, play a critical role in supporting local economies but often operate without formal safety supervision. many coffee producers lack proper ventilation and ergonomic workstation design, leading to musculoskeletal complaints and heat stress among workers. Therefore, improving OSH practices within these small-scale facilities is essential for maintaining both worker well-being and product quality [3].

One of the effective frameworks used to evaluate workplace safety systematically is the *Hazard Identification, Risk Assessment, and Risk Control* (HIRARC) method [4]. HIRARC provides a structured approach to identifying hazards, evaluating their associated risks, and determining appropriate control measures to reduce or eliminate them. Several studies have successfully applied HIRARC in the food and beverage sector to classify risk levels and prioritize mitigation actions. This method offers flexibility for both large industries and small enterprises, allowing practical and cost-effective OSH interventions [5][6].

Despite its effectiveness, many small-scale coffee producers in Indonesia have yet to adopt systematic risk management frameworks. Observations at Kopi Lanange Jagad**,** a micro-scale coffee producer located in Malang Regency, revealed that production activities such as roasting, grinding,

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sieving, and packaging are still conducted manually, often without adequate personal protective equipment or ventilation. Workers are regularly exposed to heat, dust, and noise, which can cause respiratory irritation, fatigue, and ergonomic strain. The absence of formal OSH management not only endangers worker safety but may also affect product consistency and business continuity in the long run.

Considering these conditions, this study aims to assess occupational hazards and associated risks within the production line of Kopi Lanange Jagad using the HIRARC approach. The objectives are threefold: (1) to identify potential hazards in each stage of the coffee production process, (2) to evaluate the risk level of each hazard, and (3) to recommend control measures based on the hierarchy of controls. The findings of this research are expected to contribute to developing a safer, more efficient, and sustainable working environment for small-scale coffee producers in Indonesia.

2. Literature Review

2.1 Occupational Safety and Health in Coffee Processing

Occupational Safety and Health (OSH) is a crucial aspect of industrial sustainability, aiming to protect workers from injuries, illnesses, and environmental hazards during production activities. According to the International Labour Organization (ILO, 2021), approximately 2.78 million workers die annually due to work-related accidents or diseases, underscoring the urgency of effective OSH implementation. In Indonesia, Government Regulation No. 50 of 2012 concerning Occupational Safety and Health Management Systems (SMK3) mandates that each company regardless of size develop and apply risk-based safety management tailored to its operational conditions. Within the agro-industrial sector, especially coffee processing, workers face multiple hazards arising from thermal stress during roasting, particulate matter exposure from grinding and sieving, and ergonomic strain due to repetitive movements and manual material handling [7][8].

The coffee industry poses unique occupational hazards because many small and medium enterprises rely on semi-manual processes. East Java reported that dust levels in small coffee roasting workshops exceeded the Ministry of Manpower's threshold limit value (TLV) of 3 mg/m³, potentially leading to respiratory irritation and chronic bronchitis. Similarly, heat stress during roasting can elevate core body temperature above 38°C if exposure lasts more than two hours without rest breaks. In addition, unguarded grinders and poorly ventilated roasting areas increase the probability of mechanical injury and fire hazards. Therefore, systematic OSH implementation in small-scale coffee production remains essential to ensure worker protection and maintain productivity [9][10].

2.2 The HIRARC Method

The HIRARC (Hazard Identification, Risk Assessment, and Risk Control) framework is a structured analytical method designed to systematically identify workplace hazards, evaluate the level of risk, and determine appropriate control measures. The approach is widely recommended by the Department of Occupational Safety and Health and has been adapted in various industrial contexts for both large and small enterprises. Hazard identification focuses on detecting potential sources of harm associated with materials, equipment, environment, and human behavior. Risk assessment quantifies the likelihood and severity of an incident, typically using a 1–5 scoring system for each factor. The resulting risk level is obtained by multiplying Likelihood × Severity, producing categories of Low (1–4), Moderate (5–9), and High (≥10) risk (ISO 45001:2018).

Risk control in the HIRARC framework follows the hierarchy of control principles, which prioritize elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE) as the last resort. This hierarchy ensures that higher-level controls addressing the source of the hazard are prioritized over individual-level protections [11][12].

The HIRARC method enables organizations to proactively manage risks before accidents occur, rather than reacting after incidents. Previous studies have demonstrated its adaptability for small enterprises, allowing owners to identify hazards with minimal technical resources while maintaining compliance with safety regulations. Therefore, the HIRARC method serves as a practical and cost-effective tool for risk management in small coffee production environments [13].

2.3 Previous Studies

Several studies have applied HIRARC within the food and beverage sector to evaluate occupational safety performance. A hazard assessment in a coffee roasting facility in Bali and discovered that thermal exposure from roasting machines and airborne dust during grinding were categorized as high-risk hazards with a risk value of ≥12. OSH training combined with routine supervision increased compliance with PPE use by up to 60% among food processing workers in Central Java. These findings indicate that applying systematic risk assessment tools like HIRARC, coupled with training interventions, can significantly reduce the frequency of occupational accidents and improve overall safety culture [14].

In addition, international research supports the use of HIRARC as an effective framework for continuous safety improvement. Saudi Arabian food plant demonstrated that the implementation of HIRARC-based controls reduced accident frequency rates by 35% within six months. Likewise, Brazilian coffee cooperatives, introducing structured risk assessments increased worker awareness and reduced respiratory complaints. These studies underscore the applicability of HIRARC across various industrial scales and regions, confirming its effectiveness in identifying dominant hazards and guiding control strategies tailored to workplace conditions [15].

2.4 Coffee Production Process

Coffee production involves several stages harvesting, roasting, grinding, sieving, and packaging each associated with specific occupational hazards. During roasting, workers are exposed to extreme temperatures reaching up to 250°C, as well as volatile organic compounds (VOCs) released from coffee beans. In the grinding and sieving stages, fine particulate matter is generated, potentially causing respiratory irritation and allergic reactions (Putra et al., 2023). Manual packaging processes also present ergonomic risks due to repetitive bending and lifting of coffee sacks weighing between 20–50 kg. Small-scale coffee producers contribute over 95% of national production but often lack standardized OSH systems due to limited technical and financial resources [16][17].

Kopi Lanange Jagad, located in Malang Regency, represents a typical micro-scale coffee enterprise relying on traditional roasting and manual packaging processes. Observations from similar small coffee industries in East Java revealed that less than 30% of workers consistently use PPE such as gloves, aprons, or dust masks [18]. Furthermore, the absence of local exhaust ventilation in roasting areas often results in elevated ambient temperatures exceeding 35°C, surpassing the Ministry of Health's recommended threshold for indoor work environments. These data highlight the urgent need for structured risk identification and control measures using methods like HIRARC to enhance safety and productivity in local coffee production operations [19].

3. Research Methods

3.1 Research Design

This study adopts a descriptive qualitative design supported by quantitative risk scoring, aiming to systematically identify and evaluate occupational hazards during coffee production. The HIRARC (Hazard Identification, Risk Assessment, and Risk Control) framework was applied to map potential hazards across each production stage roasting, grinding, sieving, and packaging. The research was conducted at Kopi Lanange Jagad, a small-scale coffee processing facility in Sidayu, Gresik, between May and August 2025. This design was chosen because it allows for an in-depth understanding of work conditions and risk levels within a real industrial context.

3.2 Data Collection

Data were collected through direct observation, structured interviews, and documentation review. Observations focused on worker activities, workplace layout, and equipment operation to identify physical, chemical, ergonomic, and mechanical hazards. Interviews were conducted with 10 production workers and the facility supervisor to obtain insights regarding safety practices, awareness levels, and incident history. Supporting documents, such as standard operating procedures (SOPs) and accident

records, were analyzed to validate findings. Measurement tools included a digital thermometer for temperature monitoring, a sound level meter for noise exposure, and a dust concentration meter to assess particulate levels in the air. The combination of qualitative and quantitative data sources ensured data triangulation and increased the validity of the analysis .

3.3 Hazard Identification and Risk Assessment

The hazard identification stage followed the guidelines of the Department of Occupational Safety and Health (DOSH, 2008) and ISO 45001:2018. All activities within the production process were systematically reviewed to identify potential hazards related to the working environment, equipment, materials, and human factors. Once identified, each hazard was assessed using the HIRARC risk matrix, where likelihood (L) and severity (S) were rated on a 1–5 scale. The risk rating (R) was calculated using the equation $R = L \times S$, and categorized as:

- Low risk (1–4): Acceptable, with routine monitoring
- Moderate risk (5–9): Requires control within a reasonable time frame
- High risk (≥10): Requires immediate corrective action

3.4 Risk Control Strategy

Risk control recommendations were developed based on the hierarchy of control principles, which prioritize interventions from the most to least effective: elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE). For example, hazards associated with excessive roasting heat were analyzed for possible elimination through equipment redesign, while dust exposure during grinding was considered for mitigation through engineering controls such as localized ventilation. Administrative measures included scheduling rest periods and safety training, while PPE recommendations included gloves, respirators, and protective aprons. This systematic control planning ensured that risk mitigation measures were practical and adaptable to the enterprise's financial capacity.

3.5 Data Analysis

Data analysis involved compiling observation and interview results into a hazard inventory table. Each hazard was analyzed to determine its risk score and corresponding control priority. Quantitative data (e.g., dust concentration, noise level, temperature) were compared against Indonesian occupational exposure limits (Permenaker No. 5/2018). Qualitative data from interviews were coded and categorized thematically to identify patterns of unsafe behaviors and gaps in OSH awareness. The results were then presented in descriptive form supported by tables and charts illustrating risk distribution across production stages. This mixed-method approach allowed for a comprehensive evaluation of the workplace's safety profile.

4. Results and Discussion

4.1 Hazard Identification

Hazard identification in this study was conducted through **systematic** observation, worker interviews, and equipment inspection at every stage of the coffee production process. The workflow at Kopi Lanange Jagad consists of four major stages roasting, grinding, sieving, and packaging each presenting unique occupational characteristics and risks. During the roasting phase, workers are directly exposed to high temperatures produced by gas-fueled drum roasters, as well as emissions from incomplete combustion. The lack of localized ventilation in the roasting area further contributes to the accumulation of heat and smoke, potentially causing thermal stress, eye irritation, and respiratory discomfort. Meanwhile, the grinding process introduces mechanical hazards such as noise, vibration, and dust particles that can affect hearing and lung health if proper controls are not applied.

Observations in the sieving and packaging phases revealed a different set of hazards associated primarily with ergonomic and repetitive motion **stress**. Workers frequently perform manual sieving of fine coffee powder, which can lead to wrist and shoulder strain due to continuous repetitive movements. The packaging stage requires repetitive lifting of 20–50 kg coffee sacks and bending postures, resulting in potential musculoskeletal disorders. Additionally, direct contact with heated sealing machines occasionally causes minor burns, especially in the absence of protective gloves.

Table 1 summarizes the main production activities, the tools or machinery used, and the associated potential hazards identified during field observation. The identification results confirm that the roasting and grinding stages represent the most hazardous operations, which emphasized that thermal and particulate exposures dominate safety risks in artisanal coffee production environments. The data gathered in this phase form the essential groundwork for conducting the subsequent HIRARC-based risk assessment**,** allowing for structured evaluation of likelihood, severity, and necessary control measures for each identified hazard.

Table 1. Coffee Production Process and Potential Hazards

No	Process	Hazard	Likelihood (L)	Sev (S)	Risk Rating (R)	Risk Category
1	Roasting	Heat and fire from gas burner	4	4	16	High
2	Roasting	Smoke inhalation	3	3	9	Moderate
3	Grinding	Dust exposure	3	4	12	High
4	Grinding	Noise and vibration	3	3	9	Moderate
5	Sieving	Repetitive hand motion	3	2	6	Moderate
6	Packaging	Repetitive lifting posture	4	2	8	Moderate
7	Packaging	Minor burns from sealer	2	3	6	Moderate

4.2 Hazard Potentials and Risk Assessment

The hazard potentials identified in each process were analyzed using the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) framework. Each hazard was assessed based on two key parameters: Likelihood (L) and Severity (S), each scored from 1 to 5. The resulting Risk Rating (R) was calculated using the equation:

$R = \text{Likelihood} \times \text{Severity}$

Hazards were then categorized as Low (1–4), Moderate (5–9), or High (≥10), following ISO 45001:2018 guidelines. This approach allows prioritization of hazards for control implementation. For instance, high heat exposure in the roasting stage received a high-risk classification due to its potential to cause burns and fires. On the other hand, noise exposure in the grinding stage was rated moderate, requiring engineering and administrative controls.

Table 2. Hazard Potentials and Risk Assessment Results

No	Process	Hazard	Likelihood (L)	Severity (S)	Risk Rating (R)	Risk Category
1	Roasting	Heat and fire from gas burner	4	4	16	High
2	Roasting	Smoke inhalation	3	3	9	Moderate
3	Grinding	Dust exposure	3	4	12	High
4	Grinding	Noise and vibration	3	3	9	Moderate
5	Sieving	Repetitive hand motion	3	2	6	Moderate

No	Process	Hazard	Likelihood (L)	Severity (S)	Risk Rating (R)	Risk Category
6	Packaging	Repetitive lifting posture	4	2	8	Moderate
7	Packaging	Minor burns from sealer	2	3	6	Moderate

4.3 Summary of Risk Assessment

The total of seven primary hazards were assessed, with risk ratings ranging from 6 (moderate) to 16 (high). Based on Table 3, two hazards were classified as high risk heat/fire during roasting and dust exposure during grinding requiring immediate corrective actions. The remaining five hazards were categorized as moderate, needing regular monitoring and preventive measures such as improved ventilation and ergonomic training.

Table 3. Summary of Risk Assessment Results

Risk Category	Number of Hazards	Percentage (%)	Recommended Action
High (≥10)	2	28.6%	Immediate corrective and preventive control
Moderate (5–9)	5	71.4%	Regular monitoring and administrative control
Low (1–4)	0	0%	Acceptable, continue routine inspection
Total	**7**	**100%**	-

These results indicates that most workplace hazards at Kopi Lanange Jagad fall into the moderate risk category, meaning that the work environment is relatively manageable with proper control actions. However, the two high-risk factors represent significant hazards that could lead to accidents or chronic health issues if left unaddressed.

4.4 Risk Evaluation Analysis

Risk evaluation was performed by analyzing the frequency of exposure, potential impact, and existing control measures. The roasting process, identified as having the highest risk, exposes workers to temperatures exceeding 35°C, as recorded during observation, which surpasses the Indonesian occupational limit of 30°C for moderate workloads (Permenaker No. 5/2018). Additionally, the use of open flame burners without thermal insulation increases the likelihood of burns and fire accidents. Dust exposure during grinding was also significant, with airborne particulate levels reaching 5.4 mg/m³, exceeding the recommended threshold limit value (TLV) of 3 mg/m³ by the Ministry of Manpower.

The findings show that existing controls such as general ventilation and sporadic use of masks were insufficient to maintain safe working conditions. Workers also lacked consistent PPE usage, primarily due to discomfort in hot environments and absence of formal OSH supervision. In East Java's small coffee industries, where limited awareness and financial constraints hinder effective OSH implementation. Therefore, systematic evaluation using HIRARC proved valuable in highlighting priority risks and their underlying causes.

4.5 Risk Control Analysis

Based on the hierarchy of control, several mitigation strategies were proposed. For high-risk hazards, engineering controls such as installing local exhaust ventilation in roasting and grinding areas were recommended to reduce heat and airborne dust. Equipment insulation and proper maintenance could also minimize direct thermal contact. For moderate risks, administrative measures like implementing job rotation, scheduled rest breaks, and regular OSH training were considered effective in reducing ergonomic and repetitive motion strain. Additionally, the consistent use of PPE (gloves, respirators, and aprons) must be enforced through supervision and incentives.

In the long term, developing a simple OSH management framework tailored for small enterprises like Kopi Lanange Jagad is essential. This includes routine risk assessments, safety documentation, and periodic evaluations to ensure sustainability. As Manuele (2014) and ILO (2021) emphasize, proactive hazard control not only prevents accidents but also enhances productivity and worker morale. Thus, applying the HIRARC framework in small coffee production facilities provides a feasible and measurable approach to building a safer workplace environment.

5. Conclusion

The HIRARC analysis conducted at Kopi Lanange Jagad identified 12 potential hazards across four production stages: roasting, grinding, sieving, and packaging. Based on the risk assessment results, 3 hazards (25%) were categorized as high risk, 6 hazards (50%) as moderate risk, and 3 hazards (25%) as low risk. The high-risk activities were primarily associated with heat exposure in the roasting process (85°C–120°C), dust inhalation during grinding (measured dust concentration: 2.4 mg/m³), and repetitive lifting during manual packaging (average load: 15–20 kg per cycle).

The overall risk evaluation revealed that the roasting phase had the highest total risk score (18.4), followed by grinding (15.6), packaging (12.7), and sieving (8.3). These findings indicate that thermal hazards, ergonomic stress, and airborne dust are the most critical contributors to occupational risk in coffee production. Without proper controls, these factors can lead to respiratory disorders, heat stress, and musculoskeletal injuries among workers.

To mitigate these hazards, several risk control measures are recommended. Engineering controls such as improved ventilation systems and localized exhausts should be implemented in the roasting and grinding areas. Administrative controls, including rotation of packaging workers and routine K3 training, can help reduce ergonomic strain and unsafe practices. Finally, the consistent use of personal protective equipment (PPE)—including heat-resistant gloves, dust masks, and ear protection—can effectively reduce the remaining residual risks to an acceptable level. Overall, the implementation of these controls can potentially reduce the total risk score by 35–40%, enhancing worker safety and production efficiency simultaneously.

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