Universidad de Guayaquil

Facultad de Ingeniería Química

INQUIDE
Ingeniería Química y Desarrollo
https://revistas.ug.edu.ec/index.php/iqd

ISSN – p: 1390 –9428 / ISSN – e: 3028-8533 / INQUIDE / Vol. 06 / Nº 02

# Risk assessment and control measures for machinery in a food production company.

*Evaluación de riesgos y medidas de control en maquinaria en una empresa de producción de alimentos.*

Jayling Selena Fu-López [1] *; Juan Daniel Calva Valarezo [2] ; Hugo Alfredo Pérez Benítez [3] ; Franklin Vicente López Rocafuerte [4] & Jaime Patricio Fierro Aguilar [5]

Recibido: 06/04/2024 – Aceptado: 09/06/2024 – Publicado: 01/07/2024

*Autor para la correspondencia.

**Abstract.**
The study analyzed the risks in machinery in a food plant using the HRN matrix to design a safety system based on criticality. Information was collected and each task was analyzed with the HRN matrix to determine criticality. A risk assessment matrix was created, and risks were ranked and prioritized. Action plans were formulated for critical risks, such as guarding and training requirements. The results showed the criticality of certain equipment, such as the laminating machine. Ten percent of the tasks involved high risk, highlighting the need for control. It was concluded that the safety system based on criticality is feasible and would improve safety. A replicable methodology was provided for other plants to analyze risks and implement similar systems. The proposed system has a high potential impact by reducing accidents and absenteeism. It was recommended to analyze the performance of the system, perform a cost-benefit analysis, and extend the model to other critical sectors.

**Keywords.**
Industrial safety; HRN Matrix; Productivity; Criticality; Hazards; Machine guarding; Machine safety.

**Resumen.**
El estudio analizó los riesgos en maquinaria de una planta alimenticia mediante la matriz HRN, para diseñar un sistema de seguridad basado en criticidad. Se recopiló información y se analizó cada tarea con la matriz HRN para determinar criticidad. Se creó una matriz de evaluación de riesgos y se clasificaron y priorizaron. Se formularon planes de acción para riesgos críticos, como requerimientos de guardas y capacitación. Los resultados evidenciaron criticidad de ciertos equipos como la laminadora. El 10% de las tareas implicaban alto riesgo, resaltando la necesidad de control. Se concluyó que el sistema de seguridad basado en criticidad es factible y mejoraría la seguridad. Se brindó una metodología replicable para que otras plantas analicen riesgos e implementen sistemas similares. El sistema propuesto tiene alto impacto potencial al reducir accidentes y ausentismo. Se recomendó analizar desempeño del sistema, realizar análisis costo-beneficio y extender el modelo a otros sectores críticos.

**Palabras clave.**
Seguridad industrial; Matriz HRN; Productividad; Criticidad; Riesgos; Protección de máquinas.

## 1. Introduction

Industrial safety has become a priority to ensure the integrity of workers and the productivity of manufacturing companies. The identification and control of risks associated with machinery operation is a key element in this matter. This study proposes the design of a specific machinery safety system for a food production plant, through the criticality evaluation of equipment [1].

To achieve the objective, it is first proposed to perform a risk analysis on the machinery using the HRN matrix methodology to identify critical equipment; then establish control measures, guard requirements, and training schedule to mitigate risks; and finally evaluate the technical and economic feasibility of implementing the proposed safety system in the food plant [2].

Through the use of methodologies such as the HRN matrix, a detailed risk analysis is performed and technical, administrative, and training measures are established to mitigate critical risks. The proposed system seeks to reduce accidents and absenteeism, improving safety conditions and productivity in the company. This article lays the groundwork for implementing this proactive safety approach in other plants in the food and beverage sector.

### 1.1.- Industrial Safety

Industrial safety is a discipline that identifies, evaluates, and controls occupational hazards to prevent material damage and accidents. It is important for the integrity and competitiveness of companies and requires commitment from all levels of the organization [3].

Industrial safety must be comprehensive, prioritized, and committed to by all. It should be equally considered by all

[1] Investigador independiente; fujayling@gmail.com ; https://orcid.org/0009-0002-0003-1424, Guayaquil; Ecuador.
[2] Investigador independiente; juan_calva1999@hotmail.com ; , Guayaquil; Ecuador.
[3] Universidad de Guayaquil; hugo.perezb@ug.edu.ec ; https://orcid.org/0000-0001-7460-4032, Guayaquil; Ecuador.
[4] Universidad de Guayaquil; franklin.lopezr@ug.edu.ec ; https://orcid.org/0000-0002-0645-1756, Guayaquil; Ecuador.
[5] Universidad de Guayaquil; jaime.fierroa@ug.edu.ec ; https://orcid.org/0000-0003-2725-8290, Guayaquil; Ecuador.

ISSN – p: 1390 –9428 / ISSN – e: 3028-8533 / INQUIDE / Vol. 06 / Nº 02

members of the company, regardless of their function or hierarchical level [4].

### 1.2.- Machines and Mechanisms

A machine is a device created by humans to facilitate work and reduce effort. Machines can be simple, performing work in a single step, or compound, performing work in several steps [5]. Simple machines have been known since antiquity and are used to compensate for a resistive force or perform weightlifting under more favorable conditions. Compound machines are formed by a combination of simple machines [6].

A simple machine is a device that performs work in a single step. The four most common simple machines are the wheel, the lever, the inclined plane, and the screw [6]. The wheel is a circular device that facilitates the movement of heavy objects. The lever is a rigid bar that rests on a point and is used to multiply force. The inclined plane is a flat surface with a slope, used to lift heavy objects. The screw is an inclined plane wrapped around a cylinder, used to move heavy objects in a vertical direction [6].

Compound machines are combinations of simple machines. Compound machines are used to perform more complex tasks that cannot be performed by a single simple machine [6].

### 1.3.- Machinery Safety

Machine safety is a fundamental principle that seeks to ensure the health of workers. To this end, machines must meet certain minimum safety requirements from their design. It is necessary to take precautions during the use, installation, repair, and maintenance of machines [7].

Machinery safety is important to prevent serious injuries or even death. Machines can cause a variety of injuries, including crushing, impacts, cuts, burns, and electrocutions [8].

To prevent accidents, workers must evaluate the risks associated with the use of machines and implement safety measures to mitigate these risks. These measures may include: Installing machines safely; Selecting appropriate machines for the task; Installing all safety guards; Developing a safe work system for the use and maintenance of the machine [9]. Workers must take safety measures to prevent accidents with machines. These measures include: Installing machines safely, Selecting appropriate machines for the task, Installing all safety guards, Developing a safe work system for the use and maintenance of machines. Workers should receive constant training on machine safety and follow safety instructions.

Safety measures for workers include: Wearing required clothing and PPE, Checking proper machine maintenance, Using the machine correctly [10].

Therefore, workers should not: Generate distractions for operators using machines, Wear loose clothing, rings, chains, pendants, or even loose long hair; Remove machine guards; Use an application or machine that has danger signs or labels [11].

Production machines can be dangerous, so it's important to take measures to ensure worker safety. These measures include:

- Risk assessment: Before using any machine, a risk assessment should be carried out to identify potential associated hazards.
- Proper maintenance: Machines must be kept in good working condition through a regular maintenance program.
- Training and education: All workers who operate machines must receive adequate training on their safe use.
- Guards and safety devices: It is essential to have appropriate guards and safety devices on machines.
- Supervision and monitoring: Constant supervision of workers operating machines is essential to ensure they follow established safety measures [12].

### 1.4.- Worker Safety and Health

Worker safety and health is an important issue in Ecuador. Each year, thousands of workers are injured or fall ill at work, which has a significant impact on workers, companies, and society as a whole [13].

In 2021, there were more than 30,000 workplace accidents in Ecuador, causing more than 1,000 deaths and more than 20,000 lost workdays. The annual cost of occupational injuries and illnesses in Ecuador exceeds 1 billion dollars.

The Government of Ecuador has taken measures to improve worker safety and health, including enacting laws and regulations, creating supervisory bodies, and promoting worker and employer participation [14]. However, much remains to be done to reduce occupational injuries and illnesses. To this end, it is important that workers and employers work together to promote a culture of prevention and awareness at all levels [15].

### 1.5.- Occupational Risks

Occupational risks are conditions or situations present in the work environment that have the potential to cause harm, injuries, or illnesses to workers. These risks can be classified into four main categories: physical, chemical, biological, and ergonomic [16].

**Hazard Identification and Assessment** The first step in ensuring worker safety and health is to identify existing hazards in the workplace. A variety of methods can be used to identify hazards, such as workplace inspections, review of safety records, worker interviews, and risk analysis tools [17].

**Risk Control**
Once hazards are identified, control measures must be implemented to mitigate them. These measures may include:

- Engineering measures: These measures focus on eliminating or reducing the hazard at the source. For example, a barrier can be installed to prevent workers from coming into contact with a physical hazard, or a ventilation system can be used to control exposure to chemical substances.
- Administrative measures: These measures focus on changing work procedures or work organization. For example, a safe work procedure can be established for performing a specific task, or training can be provided to workers on how to work safely.
- Personal Protective Equipment (PPE): PPE are items used to protect workers from hazards. PPE should be used whenever it is not possible to eliminate or reduce the hazard through engineering or administrative measures [18].

**Risk Mitigation Strategies**
Occupational hazards can be mitigated through a variety of strategies, which can be classified into three main categories:

- Engineering controls: These controls involve modifying the workplace or equipment to reduce or eliminate hazards.
- Administrative controls: These controls involve changing the way work is done to reduce the risk of injuries and illnesses.
- Personal Protective Equipment (PPE): PPE is used to protect workers from hazards that cannot be eliminated or reduced through technical or administrative controls [19].

**Safety Training**
Safety training is fundamental for workers to be able to identify and avoid hazards, and to correctly use PPE. Training should be provided to all workers, regardless of their position or responsibilities [20].

**1.6.- Machinery Safety Systems in Factories** Industrial machinery can be dangerous for workers if not properly maintained or handled. Therefore, it is essential to implement safety systems on machines to prevent accidents and injuries [21].

The most common safety systems in industrial machinery are:

- Guards: Physical barriers that prevent workers from accessing dangerous areas of the machine.
- Interlocks: Devices that ensure the machine cannot start if the corresponding guard has not been put in place [22].
- Emergency stop buttons: Buttons that allow the machine to be quickly stopped in emergency situations.
- Warning signs: Signs that alert workers to potential hazards associated with the machinery.
- Personal Protective Equipment (PPE): Equipment that protects workers from hazards inherent to machinery and work processes [23].

The proper implementation and maintenance of these safety systems is essential to ensure a safe work environment in factories and protect the health and well-being of workers [24].

**1.7.- Risk Assessment**
Risk assessment is a process to identify, analyze, and evaluate hazards in the workplace, determine the likelihood of adverse events, and assess possible consequences. Its aim is to implement preventive measures to control and reduce risks, ensuring a safe environment [25]. Its main advantages are accident prevention, improved safety culture, reduced legal liabilities, and increased efficiency.

The stages of the assessment are: hazard identification through inspections, risk evaluation considering probability and consequences, determination of controls and safety measures, application of controls, and periodic monitoring and review [26].

There are qualitative assessments, which classify risks as high, medium, or low, and quantitative assessments, which assign numerical values. Useful tools include hazard checklists, risk assessment matrices, and specialized software programs [27].

**1.8.- HRN Matrix**

The HRN (Hazard Rating Number) method is the main tool used to quantify and qualify the level of risk in machinery. Also known as the Risk Rating Number, this method allows for classifying a risk to determine whether it is acceptable or not [28].

The effectiveness of the HRN method lies in obtaining a function that relates the severity of damage to the probability of occurrence for a given number of exposed workers, based on an identified risk related to a considered hazard.

Thus, the HRN method enables a quantitative assessment of the risk level. This allows for prioritizing risks and focusing control efforts on those that are most critical. For this reason, the HRN method is widely used as a valuable tool in machinery risk management [29].

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**Quantifying Hazard Levels in Machines with the HRN Method**

To quantify the hazard levels in a machine using the HRN method, all present risks and hazards must first be identified (e.g., lack of electrical grounding, finger crushing risk, inadvertent actuation risk, etc.).

Next, the following formula is applied for each identified hazard:

**HRN = LO x FE x DPH x NP**

Where:

- HRN = Quantified Risk Level
- LO = Likelihood of Occurrence
- FE = Frequency of Exposure to Risk
- DPH = Severity of Potential Harm
- NP = Number of People Exposed to Risk

The parameters and variables represented in each element of the formula are listed and quantified in the following tables.

For the likelihood of occurrence (LO) of an accident, levels ranging from 0.033 to 15 are used, according to the table below:

**Table 1.- Likelihood of Occurrence (LO)**

| | | |
|---|---|---|
| 0.033 | Almost impossible | May occur in extreme circumstances |
| 1 | Highly unlikely | But possible |
| 1.5 | Unlikely | Although conceivable |
| 2 | Possible | But not usual |
| 5 | Some possibility | Could occur |
| 8 | Probable | Not surprising |
| 10 | Very probable | Expected |
| 15 | Certain | Without a doubt |

For the exposure frequency

**Table 2.- Frequency of Exposure (FE)**

| | |
|---|---|
| 0.5 | Annually |
| 1 | Monthly |
| 1.5 | Weekly |
| 2.5 | Daily |
| 4 | Hourly |
| 5 | Constant |

For the degree of possible injury (DPH):

**Table 3.- Severity of Potential Harm (DPH)**

| | |
|---|---|
| 0.1 | Scratch / Abrasion |
| 0.5 | Laceration / Cut / Mild Illness |
| 1 | Minor Bone Fracture - Fingers / Toes |
| 2 | Serious Bone Fracture - Hand / Arm / Leg |
| 4 | Loss of 1 or 2 Fingers / Toes |
| 8 | Amputation of Leg / Hand, Partial Loss of Hearing / Vision |
| 10 | Amputation of 2 Legs or Hands, Partial Loss of Hearing / Vision in Both Ears / Eyes |
| 12 | Permanent or Critical Illness |
| 15 | Fatality |

The number of people is given by:

**Table 4.- Number of People Exposed to Risk (NP)**

| | |
|---|---|
| 1 | 1 – 2 people |
| 2 | 3 – 7 people |
| 4 | 8 – 15 people |
| 8 | 16 – 50 people |
| 12 | More than 50 people |

The table below shows the risk levels that can be obtained through the application of the HRN formula.

**Table 1.- HRN (Hazard Rating Number)**

| Resultado | Riesgo | Evaluación. |
|---|---|---|
| 0 – 1 | Aceptable | Consider possible actions. Maintain protective measures. |
| 1 – 5 | Muy bajo | |
| 5 – 10 | Bajo | Ensure current protective measures are effective. Improve with complementary actions. |
| 10 – 50 | Significativo | |
| 50 – 100 | Alto | Actions must be taken to reduce or eliminate the risk. Ensure the implementation of protections or safety devices. |
| 100 – 500 | Muy alto | |
| 500 – 1000 | Extremo | Immediate action to reduce or eliminate the risk. |
| Mayor que 1000 | Inaceptable | Stop activity until the risk is eliminated or reduced. |

The color grading ranges from green for acceptable HRN results to red for levels that are unacceptable and require immediate intervention. It is important to note that this color variation was defined by the author of this study. These colors were chosen because they resemble traffic lights, making the severities found in the assessment much clearer.

**Timeframes to Adapt Machinery to Occupational Safety Standards**

The previous chart should be used to prioritize action. It is advisable to define the timeframe for taking action to reduce each result range. Therefore, the following is proposed:

- For the range from 0 to 5, seek improvement without a defined deadline.
- For the range from 5 to 50, act on risk reduction within the next 4 months.

- For the range from 50 to 1000, act within a maximum of one week.
- For the range greater than 1000, activities should be immediately stopped.

Following the presented guidelines ensures better control over machinery-related occupational accidents, thus preventing harm to workers' lives and financial losses to companies.

***Safe Modes of Operation and Maintenance***

Safe modes of operation and maintenance are essential for the safety of workers and equipment, helping to prevent accidents and damage. Common modes include lockout/tagout to prevent activation during maintenance, isolation to prevent the release of hazardous materials, personal protective equipment such as goggles and gloves, and safe work practices [30].

General principles to ensure safety include planning to identify hazards, communicating risks and safe practices, training workers, inspecting equipment, and documenting activities. Adhering to these measures helps protect workers and equipment. It is also crucial to use proper tools, follow manufacturer instructions, maintain order and cleanliness, be aware of hazards, take breaks, and report unsafe situations [31].

***Zero Access Principle***

The zero access principle is a safety approach aimed at preventing any physical contact between people and dangerous machine parts [32]. Various protection methods, such as physical barriers, interlocks, and proximity sensors, are used to achieve this. The goal of zero access is to create a "fail-safe" system where it is physically impossible for anyone to contact a dangerous machine part, even if they make a mistake.

***Modes of Intervention***

Modes of intervention range from working completely outside machine protections to interventions requiring the dismantling of components or the presence of hazardous energies. Each mode involves specific challenges and considerations in terms of occupational safety [33].

***Mode 0: Zero Access, Working Outside Protections***

- Prevents accidental or deliberate physical access to dangerous, energized parts.
- Requires tools, keys, or passwords to disable or remove protections.
- Ensures personnel safety and protection against ejected or falling objects.

***Mode 1 and 2: Interventions Through or Within Protections***

- Require safety systems based on initial risk assessment.
- Before intervening, stop equipment using normal stop controls, not lockout or emergency stops.
- In Mode 1, the body prevents the closing of guards and equipment restart.
- In Mode 2, one of the safety control systems must be locked.

***Mode 3: Interventions Requiring Dismantling (Perform LOTO)***

- All sources of hazardous energy must be locked out and tagged out (LOTO).
- Release any stored hazardous energy.
- All personnel must follow the LOTO procedure.
- Each employee places their own lock and tag; use group locks if necessary.

***Mode 4: Interventions Requiring Hazardous Energy.***

- Identify activities involving hazardous energy and attempt to mitigate them.
- Only allowed if no safer alternative is available.
- Authorized and trained personnel must follow a safe procedure.
- Restrict access to the work area.
- Minimize the number of people and duration of the intervention.
- Use "hold-to-operate" controls from a safe distance.

**2. Materials and Methods.**

**Methodology**

The methodology employed in this study consisted of the following stages:

1. Literature Review. -

Initially, a review of secondary sources was conducted to gather relevant information serving as the theoretical framework and state-of-the-art on the study topic.

2. Data Collection. -

Detailed information about the production machinery in the food factory was gathered through:

- Company records
- Direct observation of machines in operation
- Pre-stored data in internal systems

3. Risk Analysis. -

Each activity performed on the machines was analyzed using the Hazard Risk Number (HRN) matrix to identify hazards, assess risks, select protection methods, and determine machinery criticality. The steps involved:

- Identification of potential hazards
- Evaluation of probability and severity of each risk
- Selection of appropriate protection methods
- Creation of the HRN matrix with all information
- Definition of machinery criticality based on risk level

4. New Evaluation Matrix. -

A new matrix was developed to identify hazards, probability, and severity for each piece of machinery.

5. Risk Classification and Prioritization. -

Risks were classified and prioritized based on the previously determined probability and severity.

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6. Action Plans. -
Specific, feasible, and measurable action plans were formulated to mitigate identified critical risks.
7. Training. -
A training program was conducted for personnel on the study topics to reinforce their knowledge in safety.

**Materials.**

- For Literature Review:
  - Academic databases such as Scopus, Web of Science, etc.
  - Books, scientific articles, and other secondary sources on industrial safety and risk analysis.
- For Data Collection:
  - Physical and digital records of the company about the machines.
  - Observation and measurement equipment for on-site analysis (cameras, lux meters, sound meters, etc.).
  - Company specialized software with pre-stored data.
- For Risk Analysis:
  - HRN methodology and its formats.
  - Risk analysis software.
  - Digital matrix for documenting results.
- For New Evaluation Matrix:
  - Probability and severity risk matrix format.
  - Software for quantitative risk analysis.
- For Risk Prioritization:
  - Risk criticality matrix.
  - Risk acceptability criteria.
- For Action Plans:
  - Plan formulation methodologies (5W2H).
  - Project management software (MS Project).
- For Training:
  - Audiovisual material on industrial safety.
  - Computer and audiovisual equipment for sessions.
  - Manuals and guides for participants.

**3. Results.**
**Analysis of Results**
Currently, the company operates 3 traditional cookie production lines. Line "6" has been considered as the pilot line due to its modernization, consisting of 7 main equipment units that facilitate the production process. Figure 1 illustrates a layout of the cookie area.

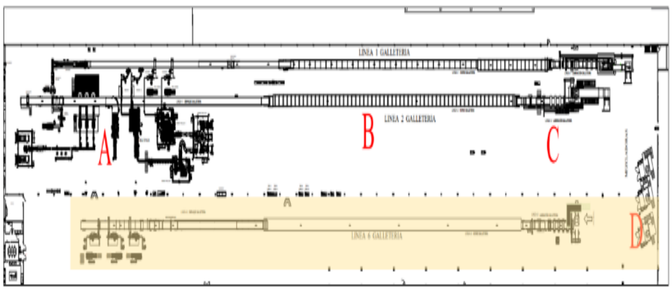

Fig. 1 Layout of the Area

A: Biscuit Packaging
B: Biscuit Ovens
C: Biscuit Lamination
D: Biscuit Mixers

For the development of action plans and necessary control methods, a multidisciplinary team with predefined roles has been assembled:

- SHE Coordinator: Responsible for analyzing the methodology.
- Mechanical Technician: Reviews the feasibility of implementing engineering controls.
- Electrical Technician: Reviews the feasibility of implementing engineering controls.
- Line Manager: Reviews and approves the collected information.
- Operator: As the process owner, their participation is crucial to validate any proposal.
- Thesis Authors: Information gathering and proposal development.

Based on the developed information, an information matrix has been created detailing the activity, hazards, area risks, and risk analysis using the zero access matrix and HRN matrix.

**Task Monitoring**
A format has been developed to record activities in the cookie manufacturing process considering the area, equipment, task performed, description, frequency, intervention mode, controls, and action plans. Through information gathering with operators, the frequency, number of exposed individuals, and procedures for each workstation have been documented. Additionally, the possibility of mitigating existing risks is evaluated, totaling 208 identified tasks.

**Table 6 - Number of Tasks Recorded per Equipment**

| N. | Equipment | Tasks |
|---|---|---|
| **1** | Dough Mixer | 15 |
| **2** | Laminator | 55 |
| **3** | Oven | 20 |
| **4** | Oil Bath | 25 |
| **5** | Conveyors | 18 |
| **6** | Cavannas | 57 |
| **7** | Sealer | 17 |
| | **Total** | **207** |

According to Table 6, the total number of tasks recorded for each equipment in the food factory is shown. Some observations:

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- The laminator and the cavannas have the highest number of recorded tasks (55 and 57 respectively). This indicates that they are complex equipment with numerous processes and intervention points.
- The oven, oil bath, and dough mixer also have a relatively high number of tasks (20-25), suggesting they are critical equipment in the process.
- The conveyors and sealer have the fewest number of tasks (17-18), indicating they are simpler equipment or have fewer critical intervention points.
- In total, 207 tasks are recorded across the 7 equipment types. This gives an idea of the scope of the production system.
- Analyzing the number of tasks per equipment type is useful for gaining an initial understanding of the criticality and complexity of each machine. This information should be supplemented with other data for designing the safety system.

**Modes of Intervention**

Identifying tasks in each equipment allows categorization based on the level of exposure to exposed parts to determine the likelihood that operators may suffer accidents during their daily tasks. Table #7 shows the number of tasks performed under different modes of intervention.

**Table 7 - Intervention Modes by Equipment**

| Equipment | Tasks | Mode 0 | Mode 1 | Mode 2 | Mode 3 | Mode 4 |
|---|---|---|---|---|---|---|
| Dough Mixer | 15 | 2 | 4 | 3 | 3 | 3 |
| Laminator | 55 | 6 | 8 | 5 | 13 | 23 |
| Oven | 20 | 1 | 0 | 0 | 15 | 4 |
| Oil Bath | 25 | 14 | 0 | 0 | 5 | 6 |
| Conveyors | 18 | 0 | 0 | 0 | 9 | 9 |
| Cavannas | 57 | 12 | 17 | 0 | 27 | 1 |
| Sealer | 17 | 16 | 0 | 0 | 0 | 1 |

According to Table 7, the different intervention modes per equipment in a food factory are shown. Some observations include:

- The Laminator has the highest number of tasks (55) and the most interventions in the most critical modes (Mode 4 with 23 and Mode 3 with 13). This indicates that the Laminator is a highly important and critical equipment for the process.
- The Oven has few interventions in the most critical modes (Mode 4 with 15 and none in Mode 3). However, it has 20 tasks, which still indicates its relevance.
- Conveyors and the Sealer have the lowest number of tasks (17-18) and few or no interventions in critical modes. They are important but not as critical equipment.

- Criticality analysis considering total tasks and intervention modes is key to prioritizing equipment in the security system design. According to this table, the Laminator and Cavannas appear to be the most critical.

**Risk Assessment**

To assess risks, a matrix was developed categorizing hazard, intervention mode, exposure frequency, access ease, likelihood of occurrence, and severity of injury. An analysis was also conducted with activity type, description, hazard, risk, initial risk level according to HRN (probability, exposure, severity, persons exposed), controls to be applied, and the timeline for resolution to establish a work schedule.

The first activity in the matrix involves lifting the kneading trough, associated with mechanical risks due to mechanical handling of loads. This activity is performed several times per shift, depending on production demand, thus the exposure frequency is high (4). The operator can easily access this area (3), making it "highly likely" for an injury to occur, with potential for a "recordable" injury requiring medical treatment (2). This results in a "high risk" score.

In the HRN Evaluation Matrix, the probability of strikes occurring when lifting the kneading trough is possible but uncommon (2), as it is a routine activity, operators are constantly exposed (5), the severity of injury could lead to loss of limb (4), and two people are exposed. As a result, there is a score of 80, indicating a high risk that should be addressed within a week.

**Table 8 - Identified Risk Levels**

| Equipment | High Risk | Medium Risk | Low Risk | Total |
|---|---|---|---|---|
| *Mixer* | 1 | 0 | 14 | 15 |
| *Laminator* | 9 | 12 | 34 | 55 |
| *Oven* | 3 | 1 | 16 | 20 |
| *Oil Bath* | 4 | 0 | 21 | 25 |
| *Conveyors* | 3 | 5 | 10 | 18 |
| *Cavannas* | - | 1 | 56 | 57 |
| *Sealer* | - | 0 | 17 | 17 |
| **Total** | **20** | **19** | **168** | **207** |
| **% Risk** | 10% | 9% | 81% | 100% |

Según la Tabla 8, se muestran los niveles de riesgo identificados en las tareas de cada equipo:

- 81% of the registered tasks have low risk, 9% medium risk, and 10% high risk. This indicates that the majority of tasks are low-risk.
- The laminator has the highest number of high-risk tasks (9), followed by the oil bath (4). These appear to be the most critical equipment in terms of safety.

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- The oven also has a significant number of high-risk tasks (3). It's another important equipment to consider.
- Cavannas and the sealer have no detected high-risk tasks. They are apparently the least critical equipment.
- Overall, the laminator, oven, and oil bath should be prioritized in the safety system design due to their higher risk levels.
- Task-level risk analysis is crucial to identify critical points to manage on each machine.

**Guard Requirements**
After analyzing the risks, it was determined that guards need to be installed to prevent access to exposed parts. For this, it's necessary to engage a contractor specializing in designing, testing, and installing these guards.

Operators perform daily tasks near the equipment, exposing them to risks of entrapment and burns. Therefore, it is considered necessary to install fixed guards on equipment like the laminator that can only be removed by technicians for maintenance purposes.

**Training Schedule**
For the development of this section, the specifications of Second Supplement No. 309 were taken into consideration. [34]
The schedule outlines the topics to be covered and the proposed dates for training personnel to reinforce knowledge in machinery safety, as well as to disseminate changes in safety protocols.
Staff planning is done in advance, with three rotating shifts each week. The schedule is organized so that all shifts can receive the same training, lasting a maximum of 40 minutes without interrupting their activities. Table #10 details the topic, responsible person, and week in which the training will commence upon project approval.

**Table 9.- Training Schedule**

| Topic | Facilitator | Week | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Hazard Identification | Assistant 1 | X | X | X | | | | | | | | | |
| Intervention Modes | Assistant 2 | | | | X | X | X | | | | | | |
| Machinery Safety | Assistant 3 | | | | | | | X | X | X | | | |
| SHE Maps Update | Assistant 4 | | | | | | | | | | X | X | X |

According to Table 9, the machinery safety training schedule spans 12 weeks and includes the following topics:

- Risk Identification (3 weeks): Conducted by Assistant 1 in weeks 1, 2, and 3.
- Modes of Intervention (3 weeks): Led by Assistant 2 in weeks 4, 5, and 6.
- Machinery Safety (3 weeks): Facilitated by Assistant 3 in weeks 7, 8, and 9.
- SHE Maps Update (3 weeks): Assistant 4 in weeks 10, 11, and 12.
- The schedule reflects a progressive training approach, starting with basic risk concepts and progressing to more specific aspects of machinery safety. The final update aims to reinforce procedures established in the new system.
- The 12-week duration allows for thorough reinforcement of concepts and ensures adoption by the workers. The schedule appears appropriate and aligned with the identified training needs from the previous analysis.

**4. Conclusions.**
This study enabled a detailed analysis of machinery-related risks in a food production plant using recognized methodologies such as the HRN matrix. Findings highlighted the criticality of certain equipment, notably the laminator, which showed the highest number of high-risk tasks.

Risk-level evaluation demonstrated that while the majority of registered tasks were low-risk, a significant percentage (10%) posed high risks to worker safety. This underscores the need for implementing control measures for critical tasks.

The study concludes that a machinery safety system based on risk assessment is feasible and can substantially enhance worker conditions. Proposals such as guard requirements and the training schedule support this proactive approach to prevention.

The research provides a replicable methodology for other industrial plants to analyze risks and implement machinery safety systems. The formats and tools presented facilitate the adoption of this proactive approach to industrial safety. The proposed machinery safety system based on criticality has the potential to significantly reduce accidents, absenteeism, and associated costs. The study lays the groundwork for improving industrial safety in the manufacturing sector globally.

Future research directions should include evaluating the performance of the implemented system, conducting cost-benefit analyses of adopted measures, and expanding the model to other sectors with critical machinery in food production lines.

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