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Risk Control in the Smoked Tilapia Production Process Using the HIRARC and FTA Methods

Mia Nur Faidah[1], Inggit Marodiyah[2]
[1,2]Muhammadiyah University of Sidoarjo, Indonesia

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ABSTRACT

Objective: *The aim of this research is to determine what factors cause work accidents and determine appropriate and effective risk control strategies.* ***Method:*** *The methods used to carry out the analysis are the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) and FTA (Faut Tree Analysis) methods.* ***Results:*** *The results of this research are able to reduce the risk of danger arising from work accidents by requiring workers to wear gloves and boots during the production process.* ***Novelty:*** *In the process of producing smoked tilapia there is a risk of dangers that have the potential to cause work accidents. The dangers that often occur are cuts on the hands, injuries to the hands during production activities and exposure to sparks due to lack of caution. Therefore, it is necessary to make efforts to prevent work accidents and work-related diseases, one of which can be done by means of risk analysis.*

INTRODUCTION

Sidoarjo is famous for its milkfish and shrimp products. Both are often sold and served smoked or sold fresh. Beside milkfish and shrimp from ponds, tilapia is also produced in large quantities by pond farmers in Sidoarjo, especially in Penatarsewu Village. Many tilapia fish from the ponds in this area are made into smoked tilapia for processing. The smoked tilapia produced is not only delicious but also has a good production process due to the availability of raw materials from the community ponds in Penatarsewu Village [1]. In the production process and activities carried out in the smoked tilapia MSME, there are risks from potential hazards that could lead to workplace accidents. This workplace accident is often caused by worker negligence and a lack of risk management during the production process. Work accidents can have fatal consequences for workers and can hinder activities in the production process. Beside the smoke from the smoking process, which can disrupt the respiratory health of workers and, if not addressed, will eventually lead to respiratory infectious diseases. Smoking fish is also done using a traditional tool consisting of a combination of brick and iron stoves arranged together. Sufficient self-awareness is needed for workers and business owners when performing a work activity to prevent potential workplace accidents during the production process. With the high number of workplace accidents, business owners must implement good risk management to minimize the occurrence of accidents [2].

Every job inherently carries the potential for hazards. If these hazards are not controlled and addressed, they can potentially lead to fatigue, musculoskeletal

complaints, and injuries. Therefore, it is crucial to control hazards by identifying potential causes of hazards in the work area [3].

Risk management is the activity of managing uncertain activities and potential uncertainties, so in the future, improvement strategies need to be implemented for its management development [3]. There are several factors that affect occupational safety risks, such as the influence of the work environment, weather, and humans [4]. Work accident risk management can use the Hazard Identification, Risk Analysis, and Risk Control (HIRARC) approach and Fault Tree Analysis (FTA). Risk management in this MSME is very minimal, or not applied at all, because the tools used are still traditional and considering that this company is still an MSME and not a large-scale company.

This HIRARC method is divided into three (3) stages: risk identification, risk value calculation, and determining steps to control production risks based on the data that has been collected [5]. The HIRARC method is a stage for identifying all hazards in each work area with the aim of minimizing hazards and workplace accidents [6]. Risk identification was conducted by interviewing and observing MSME owners in Penatarsewu Village. Risk identification is the effort to identify potential occurrences during the production process [7].

HIRARC aims to identify potential risks and understand the various hazards in each operational process caused by deviations in production processes within SMEs [8]. Beside the HIRARC method, the FTA (Fault Tree Analysis) method is also used. The Fault Tree Analysis (FTA) method is a deductive technique for identifying, evaluating, and modeling the reciprocal relationships between events that lead to failure or undesirable states. It is a scientifically proven technique that models complex system interactions in an easy-to-read visual model [9]. Previous research on risk control in the production process includes Roberta (2022), who found that the HIRARDC and FTA methods can be used to reduce the level of risk, starting with risks at a moderate level and decreasing to a low level, and that risks with a high value can be reduced to a moderate value [10]. Akhmad Ari Hidayat (2020) used the HIRARC and FTA approaches to assess the safety of work processes at PT. Mitra Karsa Utama for fiber optic network installation projects, with risk levels ranging from extreme to high and low [11]. There has been no previous research on risk management in the production process of the Smoked Mujair MSMEs in Penatarsewu village. Therefore, it is hoped that this research can minimize risks in the production process that could lead to workplace accidents.

Research Objectives: (1) To determine the factors causing workplace accidents using the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method. (2) To determine appropriate and effective risk control strategies during production.

RESEARCH METHOD

A. Time and Place of Research

This research was conducted in Penatarsewu Village, Tanggulangin District, Sidoarjo. This research began in October 2023 and will continue until March 2024.

B. Data Collection

There are two types of data that will be used during the research: secondary data and primary data.

1. Secondary Data

   Secondary data was obtained from distributing questionnaires to business owners and workers at smoked tilapia MSMEs in Penatarsewu Village.

C. Research Flow

The following is the research flow used to solve the problem during the study, using a flowchart diagram:

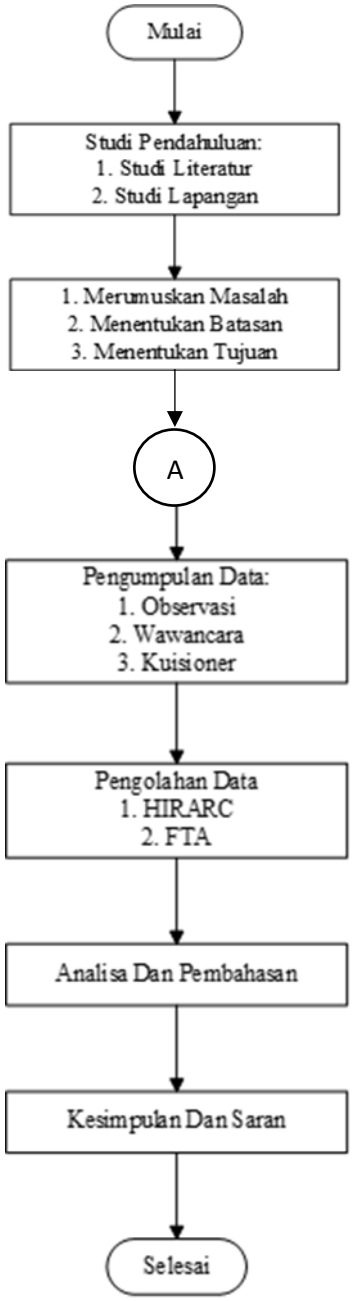

Figure 1. Flowchart Diagram.

Research Steps:

1. This research began with a literature study conducted by reviewing various books, journals, and reports related to the problem being addressed. During

the literature study, direct surveys and interviews were also conducted with MSMEs to observe the production process and identify factors influencing risks during production.

2. The results of observations and interviews with MSME owners were used as a basis for problem formulation, determining the scope of the discussion, and defining the research objectives.
3. After conducting environmental observations, data collection was carried out through interviews with sources, who were MSME workers and owners. Then, a research questionnaire was prepared.
4. After the data was collected, it was processed using the HIRARC and Fault Tree Analysis (FTA) methods to identify factors influencing potential risks and the highest risk levels.
5. Finally, analysis was performed, and conclusions and recommendations were drawn from the data processing. This chapter contains the conclusion of the research, which will be used for consideration in future studies.

D. HIRARC (Hazard Identification, Risk Assessment, and Control)

The HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method is used to assess risks and categorize the level of hazards in the workplace. The level of risk that can occur usually depends on the type of industrial site and technology, as well as the risk controls implemented. Things that need to be considered when using the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method approach are assessing conditions that appear to be significant threats, evaluating whether existing controls are sufficient, and the improvement and prevention processes previously carried out [12].

HIRARC (Hazard Identification, Risk Assessment, and Risk Control) is divided into 3 stages, namely [8]:

a. Hazard Identification
   The process of identifying all hazards present in a work environment. Sources of danger are divided into 5 factors: man, method, material, machine, and environment.
b. Risk assessment
   Conducting an assessment by considering the likelihood of potential events and their severity, so that a risk rating can be determined.

The purpose of risk analysis is to determine the magnitude of the risk by considering how often it is likely to occur and the severity of the potential consequences of the defect.

Table 1. Likelihood Level Scale.

Level	Description	Information
1	Rare	Almost never occurs
2	Unlikely	Rarely occurs
3	Possible	It can occur once in a while

Level	Description	Information
4	Likely	Often occurs
5	Almost Certain	Can occur at any time

Source: [7]

From the table above, it can be seen that a likelihood level of 1 means the risk almost never occurs, a likelihood level of 2 means the risk rarely occurs, a likelihood level of 3 means the risk can occur occasionally, a likelihood level of 4 means the risk occurs frequently, and a likelihood level of 5 means the danger risk can occur at any time.

Table 2. Severity Level Scale.

Level	Description	Information
1	Negligible	No injury occurs, small financial loss
2	Minor	Minor injury, small financial loss
3	Moderate	Moderate injury, requires medical treatment, large financial loss
4	Major	Severe injury > 1 person, large loss, production disruption
5	Catastrophic	Fatality > 1 person, very large financial loss and widespread impact, complete shutdown of activities

Source: [7]

From the table above, it can be seen that a severity level of 1 means there is no risk of injury, a severity level of 2 means there is a risk of minor injury, a severity level of 3 means there is a risk of moderate injury, a severity level of 4 means there is a risk of serious injury to more than one person, and a severity level of 5 means there is a risk of fatal injury to more than one person.

c. Risk control

Risk control involves managing exposure to hazards that will occur or have already occurred in the work environment, which is crucial for protecting workers. Risk control aims to minimize or eliminate hazardous risks. Risk assessment serves as a reference for implementing risk controls. The results of the risk assessment that has been conducted are used as a reference in risk control. The handling is done by identifying the potential risks that may arise, such as low, moderate, high, and extreme risks.

Table 3. Risk Level Scale.

Likelihood	Severity				
	1	2	3	4	5
5	M	H	H	VH	VH
4	M	M	H	H	VH
3	L	M	H	H	H
2	L	L	M	M	H
1	L	L	M	M	H

Source: [7]

From the table above, it can be seen that to determine the risk level scale, you need to look at the likelihood value and the severity value. For example, to determine the risk level scale, if the likelihood scale gets a value of 2 and the severity scale gets a value of 2, then the risk level is 4, which is a low risk level.

Explanation:

N: Negligible with a Risk Value of 1

L: Low with a Risk Value of 2 - 4

M: Moderate with a Risk Value of 5 – 8

H: High with a Risk Value of 9 – 16

VH: Very High with a Risk Value of 17 – 25

Table 4. Risk Level Categories.

Symbol Letter	Description	Action
L	Low Risk (Low hazard level)	Monitoring to ensure that control actions are implemented effectively.
M	Moderate (Moderate hazard level)	Requires attention and additional procedures.
H	High Risk (High/serious hazard level)	Needs attention from management and corrective actions.
VH	Very High (Very high hazard level)	Immediate corrective actions are required.

Source: [7]

From the table above, the symbol L (Low Risk) indicates a low level of danger, the symbol M (Moderate) indicates a moderate level of danger, the symbol H (High Risk) indicates a high level of danger, and VH (Very High) indicates a very high level of danger.

E. Fault Tree Analysis

The Fault Tree Analysis (FTA) method is a technique for identifying each stage of the production process that can lead to safety risks [13]. FTA is used to determine the causes of workplace accidents during the production process [14]. FTA is a method of analysis that graphically translates combinations of several errors that can lead to system failure [15]. This risk assessment uses the formula [16]:

$$S = L \times C \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Source: [16]

Description:

S = Risk score

L = Likelihood value

C = Severity value

This FTA method uses 2 main symbols. There are three types of events, namely:

1. Primary Event.

   A Primary Event is a stage in the product usage process that may fail. Primary Events are further divided into three categories:

a. Basic event
b. Undeveloped event
c. External event

2. Intermediate Event

An Intermediate Event is the result of a combination of failures and errors, some of which may be Primary Events. Intermediate events are located in the middle of a fault tree analysis.

3. Expanded events require a separate fault tree due to the complexity of their content. For a new fault tree, the expanded event is the undesired event and is placed at the top of the fault tree analysis.

Table 5. Fault Tree Analysis Symbols.

Symbol	Meaning	Symbol	Meaning
Basic Event	Event expected to occur	External Event	Basic initiation that does not require further development
Conditioning Event	Specify a condition that can be applied to various logic gates	AND Gate	Error resulting from all inputs
Undevelopment Event	The event was rescheduled again due to unavailable information	OR Gate	An error caused by one of the inputs occurring

Source: [17]

From the table above, the Basic Event symbol is used for further development, the Conditioning Event symbol is used for various logic gates, while Undevelopment is used for information that is not available for development. The External Event symbol is used for events that are expected to occur, the AND gate is used for errors that arise due to problems that occur, and the OR gate is used for errors that arise due to one of the problems that occur.

The steps for Fault Tree Analysis are as follows:

1. Identify Top Level Event

At this stage, identifying the types of damage that can occur (undesired events) to determine system errors. Understanding the entire system is achieved by studying all information about the system and its scope [18].

2. Creating an FTA Diagram or Fault Tree Diagram

A fault tree diagram shows how a top-level event can occur within a network [18].

3. Analyzing FTA (Fault Tree Analysis) or Fault Tree

Fault tree analysis is used to obtain clear information about a system and the necessary improvements [18].

RESULTS AND DISCUSSION

The hazard identification process in the production process was carried out by direct observation of the smoked tilapia MSMEs in Penatarsewu village. Here is a breakdown of the hazard potential notes presented in the following table:

Table 6. Hazard Identification in the Smoked Tilapia Production Process.

Process, Activity, and Work Stages	Potential Hazard	Hazard Risk
Taking raw materials from suppliers	a. Crushed by raw materials	a. Bruised foot ii. Bleeding foot
The fish washing process from dirt	a. Slippery washing area	i. Worker slips
	b. Production process delayed	ii. Injury to body parts
	c. Fish container too small	iii. Hand cut
		i. Body part pain ii. Strain on hand
	d. Not wearing gloves	i. Hand injury
	e. Not using a mask	i. Shortness of breath from fish odor
Fish piercing process with wood	a. Not wearing gloves	i. Hand injury
Fish smoking process	a. Burning area too close to the worker	i. Hand burns from fire sparks
	b. Unregulated smoke disposal	i. Shortness of breath from smoke
		ii. Eye irritation from excessive smoke
Delay process	a. Excessive weight load	i. Muscle injury
		ii. Bruises from products falling on the body
Packaging area	b. Stapler injury	iii. Bleeding hand

Based on the data from the hazard identification results in Table 3.1, there are still many potential hazards that could harm workers in the smoked tilapia production process at the Penatarsewu village MSME. For each potential hazard found, there is an analysis of its causes, including human factors, work methods, and the surrounding environment. The next step is to conduct a hazard risk assessment using a 5x5 risk matrix

to obtain the final result, which is the risk level. The risk level assessment calculations are presented in the following table:

Table 7. Hazard Risk Assessment.

Hazard Identification				Risk Assessment			
No	**Process, Activities, and Work Stages**	**Potential Hazards**	**Hazard Risks**	**Likelihood**	**Severity**	**Risk Score**	**Risk Level**
1.	Raw Material Collection	Struck by Raw Materials	Bruised Foot	2	1	2	Low
			Bleeding Foot	2	1	2	Low
2.	Fish and Waste Washing Process	Slippery Washing Area Condition	Worker Slipped	3	1	3	Low
		Production Process Delayed	Injury to Body Parts	2	1	2	Low
			Finger Cut	3	2	6	Moderate
		Fish Size Too Small	Body Pain	2	1	2	Low
			Hand Strain	2	1	2	Low
		Not Wearing Gloves	Hand Injury	3	1	3	Low
		Not Wearing a Mask	Shortness of Breath Due to Fish Odor	3	1	3	Low
3.	Fish Skewering Process Using Wooden Sticks	Not Wearing Gloves	Hand Injury	4	2	8	Moderate

From the table above, the potential hazards during the raw material acquisition process are being struck by raw materials, and the resulting risks are: bruised legs with a score of 2, categorized as Low, and bleeding legs with a score of 2, also categorized as Low. The final step in the HIRARC method is the risk control process. Risk control is the stage of reducing and avoiding risks during the production process. Avoiding risk by eliminating the source of danger or by avoiding and stopping ongoing activities. The risk control process can be seen in the following table 3.3:

Table 8. Hazard Risk Control.

No	Potential Hazard	Control Solution				
		Elimination	Substitution	Engineering Control	Administrative Control	APD
	Collecting Raw Materials from the Supplier					
1	Bruised Foot					Wearing Standard Safety Boots
2	Bleeding Foot					Wearing Standard Safety Boots
	Fish Cleaning Process from Dirt					
1	Worker Slipped			Modifying the Floor Texture in the Washing Area	Installing a Wet Floor Warning Sign	Wearing Standard Safety Boots
2	Injury to Body Parts			Adding Wooden Platforms		
3	Finger Cut					Wearing Gloves
4	Body Pain			Adding a Trolley		
5	Hand Strain			Adding Break Time		
6	Hand Injury					Wearing Gloves
7	Shortness of Breath Due to Fish Odor				Installing a Mandatory Mask Sign	Wearing a Mask
	Fish Skewering Process Using Wooden Sticks					
1	Hand Injury					Wearing Gloves
	Fish Smoking Process					
1	Hands Exposed to Sparks			Adding a Cover		Wearing Gloves
2	Shortness of Breath Due to Smoke				Installing a Mandatory Mask Sign	Wearing a Mask
3	Eye Irritation from Excessive Smoke					
	Process Delay					

1	Muscle Injury	Adding Break Time	
2	Bruising on Body Parts Hit by Finished Products	Adding a Trolley	Wearing Standard Safety Boots
		Packaging Area	
1	Bleeding Hands		Wearing Gloves

From the risk control table above, the process of taking raw materials has two potential hazards: bruised feet and bleeding feet, which are improved by wearing standard safety boots. Based on the risk assessment results, three moderate-risk potentials were found, so further identification steps are needed to determine the root causes. These three potential hazards are cuts hands, hand injuries during the fish stabbing process, and exposure to sparks. The following image shows the FTA (Fault Tree Analysis) structure for the potential hand injuries during the fish stabbing process.

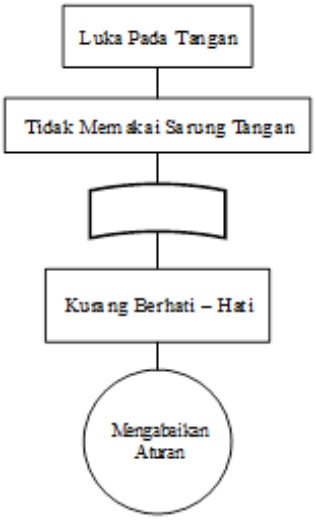

Figure 2. Fault Tree Analysis of Hand Injuries.

Based on the FTA above, it can be seen that the risk of hand injuries is caused by workers not wearing gloves and workers being less careful. The accident occurred because the workers did not comply with the rules set by the MSME. Improvements for the potential hazard of hand injuries during the fish stabbing process are made by using gloves for the workers and replacing the bamboo fish skewers with stainless steel fish skewers [10]. The potential hazards identified using the FTA method are hand cuts during the fish washing and cleaning process.

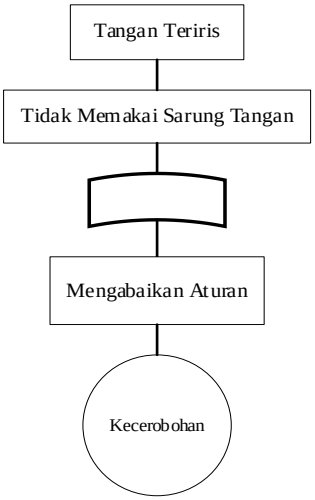

Figure 3. Fault Tree Analysis for Cut Hand.

Based on the above FTA, it can be seen that the risk of hand cuts is caused by workers not wearing gloves, and the accident occurred because the workers were too careless and not careful.

Improvements to the potential hazard of cut hands can be proposed as recommendations, such as mandating the use of gloves and adding wooden platforms to the fish cleaning process [10]. The potential hazard identified using the FTA method is the risk of being hit by sparks.

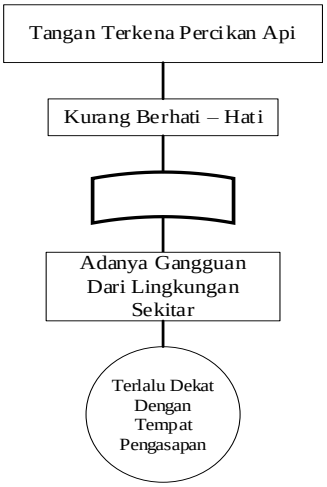

Figure 4. Fault Tree Analysis Exposed to Sparks.

Based on the above FTA, it can be seen that the risk of hands being hit by sparks is caused by workers being less careful and their concentration being disrupted due to the crowded and uncomfortable environmental conditions. The accident happened because the workers' seats were too close to the smoking furnace.

Improvements to the risk of exposure to sparks were made by installing covers over the smoking furnace area and requiring workers to use gloves and masks [10].

CONCLUSION

Fundamental Finding : The highest potential risks affecting the smoked tilapia production process are: first, hand injuries with a risk score of 8, which is classified as moderate risk; second, cut hands with a risk score of 6, which is classified as moderate risk; and third, hands exposed to sparks with a risk score of 6, which is classified as moderate risk. **Implication :** Risk control for potential hazards in the smoked tilapia production process includes requiring workers to use PPE. Developing standard operating procedures (SOPs) as a guide/reference for carrying out work, and placing warning signs for hazards and prohibiting joking while working. **Limitation :** There are several limitations in the research conducted, namely the number of respondents is not yet large and the survey population is only from a few MSMEs in Penatarsewu village, so the data analyzed cannot yet be generalized. **Future Research :** Therefore, further research can increase the sample size and expand the scope of the research object.

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Mia Nur Faidah
Muhammadiyah University of Sidoarjo, Indonesia

***Inggit Marodiyah (Corresponding Author)**
Muhammadiyah University of Sidoarjo, Indonesia
Email: inggit@umsida.ac.id