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Risk and Damage Analysis of Nile Tilapia (*Oreochromis niloticus*) Commodities During The Shipping Process at Selili Fishing Port, Samarinda, Indonesia

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Abstract: Tilapia is a freshwater fish commodity widely preferred by consumers in Samarinda. Due to high market demand, fish farmers have to increase the number of tilapia shipments to meet it. The Selili Fishing Port (PPI Selili) is a port where tilapia farmers can market their fish to consumers on a large scale. Transporting tilapia in open vehicles and exceeding their load capacity can cause damage to tilapia products. This study aimed to identify the sources of hazards and risks associated with the use of open vehicles for tilapia transport. Data were collected through direct observation and interviews and analyzed using Hierarchical Task Analysis (HTA), Hazard Identification and Risk Assessment (HIRA), organoleptic testing of Nile tilapia quality, and descriptive analysis. The results of this study showed that there are three stages in the tilapia shipping process: the loading stage, with six potential hazards; the transportation stage, with three potential risks; and the unloading stage, with five potential hazards that can reduce tilapia quality. Organoleptic testing showed that the tilapia remained acceptable and fit for consumption, with the highest score of 8.00 recorded during loading and the lowest during unloading, 7.00. This study provides information on the sources of hazards and risk levels in the activity of transporting tilapia in open vehicles, presented in HTA and HIRA tables.

Keywords: *hierarchy task analysis, tilapia, risk identification, risk assessment*

Introduction

Tilapia (*Oreochromis niloticus*) is a freshwater fish commodity that has the potential for development in fisheries in Indonesia [1]. This is because tilapia are easy to breed, tolerant of the environment, and able to survive in high salinity [2]. In addition, tilapia has complete nutritional content, such as high protein content and low fat and calories, and is enriched with omega-3 and omega-6 fats [3]. Market demand for tilapia in Indonesia reached 1.35 million tons, with a production value of IDR 33.62 trillion in 2021. Tilapia is also a mainstay commodity for maintaining national food security [4].

The demand for tilapia is high in Samarinda City, East Kalimantan. The demand for tilapia comes from various groups, including restaurants and household consumers

in Samarinda City. Marketed tilapia come from Loa Kulu District, Kutai Kartanegara Regency, which is the center of freshwater fish production around Samarinda City. The high demand for tilapia commodities causes farmers to make frequent deliveries every day. Tilapia shipments are directed to the Selili Fishing Port (PPI Selili), the only fishing port in Samarinda City. PPI Selili is a class D fishing port that serves not only as a fish landing place but also as a fish auction site for both sea and freshwater fish, such as tilapia.

Tilapia deliveries are made in open cars (pickups), and most delivery vehicles are open. In addition, the carrying capacity of vehicles that deliver tilapia from Loa Kulu to PPI Selili is often exceeded to reduce shipping costs and maximize load capacity in each shipment. These conditions indicate that tilapia delivery activities using open cars may harm commodity transport. According to

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Pratama *et al.* [5], improper fish distribution processes pose a potential hazard, leading to reduced fish quality.

The potential hazards are diverse, ranging from fish handling to the use of open vehicles, which can pose a risk to the tilapia commodities being transported. Damage can occur to the physical tilapia being transported due to microbial contamination, which can cause a decrease in the quality of tilapia [6]a. If this happens continuously, it can lead to losses for farmers in terms of lower selling prices and a loss of consumer confidence in the quality of the tilapia being marketed. Therefore, proper handling, including awareness of potential hazards, needs to be performed during tilapia shipping activities using open vehicles to minimize the risk of damage to the transported tilapia. This study was conducted to identify potential hazards and assess the risk level in tilapia delivery activities using open vehicles, providing a reference for risk mitigation measures implemented as early as possible to prevent damage to the transported tilapia.

Method

Data Collection Method

The data collection methods used in this research were interviews and field observations, conducted with transporters at PPI Selili. The field observation method involved taking pictures and documenting the processes and stages of transporting tilapia commodities in open vehicles. The interview was conducted using a questionnaire containing general questions about the completeness of the vehicle unit during delivery and at all stages of the tilapia delivery to PPI Selili. The determination of the number of samples used the census method. The census method is a step taken to collect samples by including all members of the population source [7].

All five transporters in the population were surveyed. The census method was chosen because of the small sample size, which allowed it to be taken as a whole and strengthened the information provided by the sources. The interviewees were workers (drivers) in tilapia delivery activities at PPI Selili. Data from field observations and interviews were then analyzed using the HTA (Hierarchy Task Analysis) method to identify the activities performed during tilapia shipping using open vehicles. In addition, this method can identify the sources of danger that arise in tilapia shipping activities. Furthermore, the data were analyzed to determine the level of damage to the tilapia commodity and to identify

and control the sources of danger in the delivery of tilapia using the IBPR (Hazard Identification and Risk Assessment) method. The IBPR method serves as the basis for OHS management, tailored to the level of risk in the work environment. Organoleptic testing was conducted on fresh tilapia to demonstrate a decrease in quality due to potential hazards, in accordance with SNI 2346:2006.

Data Processing Method

Descriptive analysis is a research method that describes an object based on data obtained under actual conditions [8]. According to Marhamah *et al.* [9] Descriptive analysis is a technique for analyzing data by describing it without drawing conclusions. Descriptive analysis was used to document all process conditions and activities during tilapia delivery using open vehicles. The results of the observations, in the form of pictures and interviews, are then described to identify potential hazards arising during shipping activities.

Hierarchy Task Analysis (HTA) is a method for explaining an activity by dividing it into sub-activities, so that each activity can be described in detail. According to Lestari *et al.* [6], the HTA method can be used to identify an activity and can also be used to determine the sequence of an activity and identify the potential hazards that arise in an activity [10]. The application of the HTA method involves several steps:

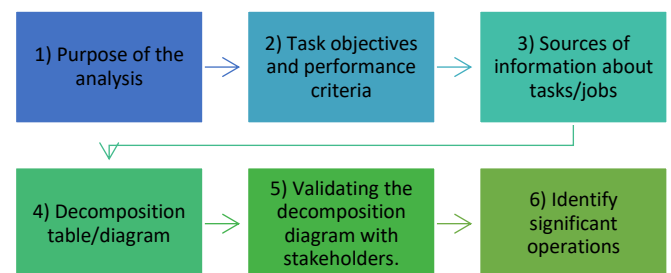


Figure 1. Stages of the application of the Hierarchy Task Analysis method [11]

Figure 1 was used to identify the activities carried out during tilapia delivery, including loading, travel, and unloading preparations. Potential hazards can be observed from field observations of several activities carried out during shipping. Hazard Identification & Risk Assessment, commonly known as hazard identification and risk assessment (HIRA), is a method used to determine potential hazards that cause losses in a particular activity. Risk assessment is performed using the following formula:

$$\text{Risk} = \text{Severity} \times \text{Probability} \quad (1)$$

Table 1. Tabel Risk Matriks

Probability x Severity		Severity				
		1	2	3	4	5
Probability	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Table 2. Risk Level

Risk Matrix Value	Risk Level
1 – 8	Low
9 – 15	Medium
16 – 25	High

Table 3. Risk Opportunities

Code	Probability	Description	Percentage
1	Very rarely	Occurs $\leq$ 3 times in 1 month	<20%
2	Rarely	Occurs $\leq$ 5 times in 1 month	21% - 40%
3	Occasionally	Occurs $\leq$ 10 times in 1 month	41% - 60%
4	Frequently	Occurs $\leq$ 15 times in 1 month	61% - 80%
5	Very Frequently	Occurs $\geq$ 15 times in 1 month	>81%

Table 4. Risk Severity

Code	Severity	Description	Percentage
1	Very Low	1 parameter changed	<10%
2	Low	2 parameters changed	11% - 30%
3	Moderate	3 – 4 parameters changed	31% - 50%
4	High	5 parameters changed	50% - 70%
5	Extreme	6 parameters changed in 1 month	>71%

The results of the organoleptic testing conducted in the first and last sub-activities will be used to determine the relationship between the potential risks arising and the quality degradation of fresh tilapia during delivery by open vehicles. The tables listed above were used for risk identification and risk assessment methods. **Table 1** is used

to determine the potential hazards and their impacts. **Table 2** lists the risk categories determined based on the multiplication in **Table 2**.

Table 3 presents the risks and opportunities associated with tilapia delivery activities using open vehicles. **Table 4** presents the severity of risks posed by potential hazards affecting the transport of tilapia commodities.

Results And Discussion

General Condition of Transport Vehicle

The vehicle unit used for the tilapia delivery from Loa Kulu to PPI Selili Samarinda is an open truck commonly used to transport necessities, such as groceries. This vehicle is a type of open vehicle (pickup) without a cover or protection at the top of the vehicle, so the cargo at the back of this vehicle is exposed to direct sunlight. The impact of the transportation mode on the quality of fresh fish products is a relevant topic for discussion. Deviations from the optimal storage temperature inevitably lead to reduced product quality and shortened shelf life, resulting in a decrease in product value [12]. Vehicle units used in tilapia delivery activities from Loa Kulu to PPI Selili. All fish transport vehicles or vessels must be certified by authorized personnel, and the design of the vehicle must ensure that it does not contaminate the fish with anything, for example, fuel. In addition, fish should not be exposed to sunlight during transportation or at high ambient temperatures, and should be handled with care at all times to avoid bruising and damage [13]. Supervision of fish transport vehicles at PPI Selili Samarinda is still relatively lacking; therefore, vehicles that are not specially designed for transporting fishery commodities, such as vehicles without covers or protectors, are still used. Five vehicles were used to deliver tilapia from Loa Kulu to PPI Selili, and none had protection (Knopf), so tarpaulins were added to protect the tilapia during delivery. The open vehicles are shown in **Figure 2**.

**Figure 2.** Open Vehicle Used for Delivery

The vehicle can accommodate a maximum of 18 Styrofoam boxes of tilapia, with each box measuring 75 × 42 × 32 cm. A rope was provided to each vehicle for tying the cargo, and the cargo was protected with a tarp once loading was complete. The use of tarpaulins on top of the cargo aims to protect it from sunlight during shipping. The use of tarpaulins to protect goods during transportation from direct sunlight and rain is essential; they are most widely used in agriculture, where they provide strong protection for products. Tarpaulins are used to protect food and other humanitarian goods from direct sunlight and rain during transportation [14]. In addition, the use of tarpaulins is recommended to protect products from challenging climatic conditions, such as rain and direct sunlight [12]. The activities of workers involved in shipping begin with loading, delivery, and unloading. The process of this open vehicle delivery activity is illustrated in **Figure 3**.

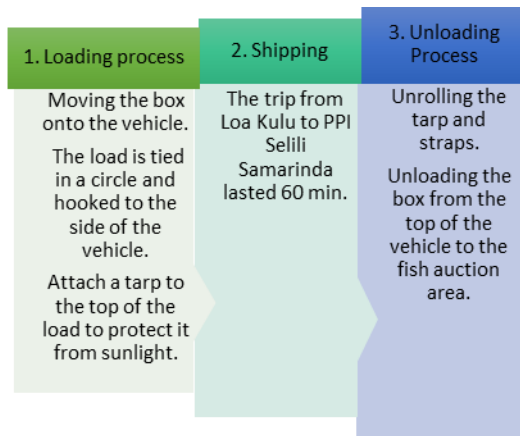


Figure 3. Tilapia delivery process by an open vehicle

The activities carried out by workers in the shipping process are divided into three steps: loading at the Loa Kulu location, loading 27 boxes of fresh tilapia, and handling the load. Next, the delivery from Loa Kulu to PPI Selili Samarinda took 60 minutes, and the unloading at

PPI Selili involved unloading 27 boxes of fresh tilapia to the Fish Auction area.

Hazard Identification in Tilapia Delivery Activities

Based on field observations of tilapia delivery activities using open vehicles, this activity is grouped into three sub-activities: loading, delivery, and unloading.

Loading Stage

The tilapia loading process was the first subactivity performed during tilapia delivery using open vehicles. This process is the beginning of identifying potential hazards that arise during delivery. During loading, several potential hazards arise that can damage tilapia transported by open vehicles. These potential hazards are divided into sources of danger from tools and materials, worker behavior, and the work environment. As shown in **Table 6**, the highest potential hazard based on the risk assessment is the use of ice cubes in the form of fractions, which have parts that are sharp enough to injure the surface of the tilapia skin when combined with the tilapia, which can become a medium for the growth of spoilage bacteria. This is in line with the statement that the cooling media for fishery products can use slurry ice, which is better used to maintain a product shelf life of 12 days [15], [16].

In addition, the loading process, which is carried out outdoors without a roof to protect the vehicle and cargo, poses a potential hazard by exposing the tilapia directly to sunlight, thereby accelerating decay. This is supported by the fact that temperature is the most important environmental factor affecting the level of damage and postharvest life [17]. Temperature during storage and transportation has a great influence not only on the quality and shelf life of food, but also on the nature and distribution of water in the muscles [12]. Risk identification and risk assessment in the loading process sub-activities are shown in **Table 6**.

Table 6. Risk identification and risk assessment of the loading process sub-activity

Code	Type of Potential Hazard	Activities	Potential Hazards	Consequences	Risk Factors			
					P	S	Risk Index	
1. Loading Process								
1	Tools and Materials	Use of dirty transport boxes	Causes of bacterial contamination in tilapia	Reducing the quality of tilapia	4	3	12	
		Use of a fragile rope to tie the box	Causes the box to fall to the floor or the roadway	Causes physical damage to tilapia	4	2	8	
		Use of a fragile cover tarpaulin	This causes the tarp to be transparent to sunlight	Tilapia can be exposed to sunlight for a long time, which causes spoilage	4	3	12	
		Use of broken ice cubes	Causes cuts on the surface of the tilapia's skin	Surface damage to fresh tilapia	5	4	20	
	Employee	Loading process without PPE	Causes occupational accidents for workers	Impact on tilapia if the box falls due to worker negligence	4	2	8	
	Work Environment	The loading process was carried out during the day at a location that did not have a roof	Causes direct sun exposure to the tilapia	Causes a faster spoilage process in tilapia fish	5	4	20	

Shipment Stage

Shipping is the second subactivity performed when shipping tilapia in open vehicles. In this delivery activity, there are a few potential hazards, with the most frequent being potholes on the road during the tilapia delivery from Loa Kulu to PPI Selili Samarinda. Vehicles carrying full-capacity loads can cause tilapia to fall off due to shaking caused by potholes. Previous research shows that vehicle speed and pothole road conditions can cause shocks to transported fishery products, which can lead to damage to those products [18]. Another problem encountered in the shipping process is the use of vehicles that do not meet the standards for shipping fishery commodities [19]. Poor handling of fish along the supply chain can cause severe physical damage or contamination [12]. Factors influencing the decline in

the quality and nutritional value of fishery products include a lack of infrastructure, non-compliance or negligence, a lack of awareness about proper handling and transportation of raw materials and final products, a lack of knowledge regarding proper drying temperature and time, the use of insecticides, unhygienic conditions, a lack of adequate sanitation, high moisture content in final products, low quality of raw materials, and improper packaging and storage [20], [21]. Problems associated with quality deterioration stem from poorly insulated storage facilities and a lack of awareness of quality's importance. Prolonged exposure of harvested fish to high ambient temperatures, as well as unhygienic handling and transportation, accelerates spoilage [22]. The risk identification and risk assessment of the delivery sub-activities are shown in **Table 7**.

Table 7. Risk identification and risk assessment of delivery sub-activities

Code	Type of Potential Hazard	Activities	Potential Hazards	Consequences	Risk Factors		
					P	S	Risk Index
2. Shipment							
1	Tools and Materials	Delivery by open vehicle	Open vehicles can also expose tilapia to sunlight and dust	Reducing the quality of tilapia	4	3	12
	Employee	Driving an open vehicle with a load that exceeds its capacity	Carrying a vehicle at high speed	Impact on the likelihood of tilapia slipping out of line	3	1	3
	Work Environment	Driving an open vehicle without a cargo cover	Potholes and sun exposure	The possibility of tilapia falling off the top of the vehicle when traveling through potholes exists	5	4	20

Unloading Stage

The unloading process is the final subactivity of the tilapia delivery activity using open vehicles. Based on field observations, several potential hazards arise during unloading activities at PPI Selili, including issues related to tools and materials, worker behavior, and the work environment. The highest potential hazard arises in the work environment: the tilapia box unloading process is carried out in an open field, which can expose the tilapia to sunlight and potentially accelerate tilapia decay. Fish quality is affected by several factors, such as temperature, handling practices, and initial microbial counts, given the persistent food safety hazards associated with various types of fish due to the formation of biogenic amines, particularly histamine.

Food authorities have established stricter guidelines and measures to address histamine production caused by unhygienic fish handling and poor temperature control [23], [24]. Some factors that contribute to spoilage are species-specific. Fatty fish, such as tuna, mackerel, sardines, bonito, and anchovies, are rich in histidine. Histamine can accumulate when these species are exposed to inappropriate temperatures during storage or transportation [25]. In addition, the use of river water to wash tubs on open vehicles after unloading can cause bacterial contamination, as unclean river water may contain various types of bacteria that can degrade the quality of fishery products [26]. Risk identification and risk assessment in the unloading process subactivities are shown in **Table 8**.

Table 8. Risk identification and risk assessment in the unloading process subactivity

Code	Type of Potential Hazard	Activities	Potential Hazards	Consequences	Risk Factors		
					P	S	Risk Index
3. Unloading Process							
3	Tools and Materials	Using a wet board to place the tilapia box	Wet and dirty boards contain a large number of bacteria	Reducing the quality of tilapia due to bacterial contamination	4	3	12
		Use of river water to wash vehicles after transportation	River water can be a source of contamination for fish transported during subsequent shipping processes.	Causes bacterial contamination of tilapia	3	3	9
	Employee	Unloading process without PPE	Causes occupational accidents for workers	Impact on tilapia if the box falls due to worker negligence	4	2	8
	Work Environment	Unloading was performed in an open field	Direct sunlight exposure on transported tilapia	Causes a faster spoilage process in tilapia fish	4	4	15
		Placing tilapia boxes on dirty and wet floors	Wet and dirty floors can be sources of bacterial contamination	Reducing the quality of tilapia due to bacterial contamination	3	4	12

The three sub-activities in the delivery of tilapia by open vehicles identified six potential hazards in the loading process, three in the delivery process, and five in the unloading process. Furthermore, this potential hazard is supported by organoleptic testing of tilapia, where, during the loading process, sub-activity in Loa Kulu yielded a value of 8.00, indicating that the acceptance of fresh tilapia remains in the acceptable and consumable category. Then, the results of organoleptic testing of tilapia during the unloading process sub-activity at PPI Selili obtained a value of 7.00, indicating that the acceptance of fresh tilapia remains in the acceptable and

consumable category. Previous research states that the evaluation results of the organoleptic characteristics of anchovies provide an average score between 7.00 and 8.00, while with a score of more than 6.00, the fish is categorized as good quality and suitable for consumption [27]. Organoleptic testing of tilapia after delivery from Loa Kulu to PPI Selili was still above the score set for the acceptance of consumer fish in accordance with the Indonesian National Standard, where the limit of acceptance of fresh fish is 7.00 to 8.00 [28]. Organoleptic testing is shown in **Figure 4**.

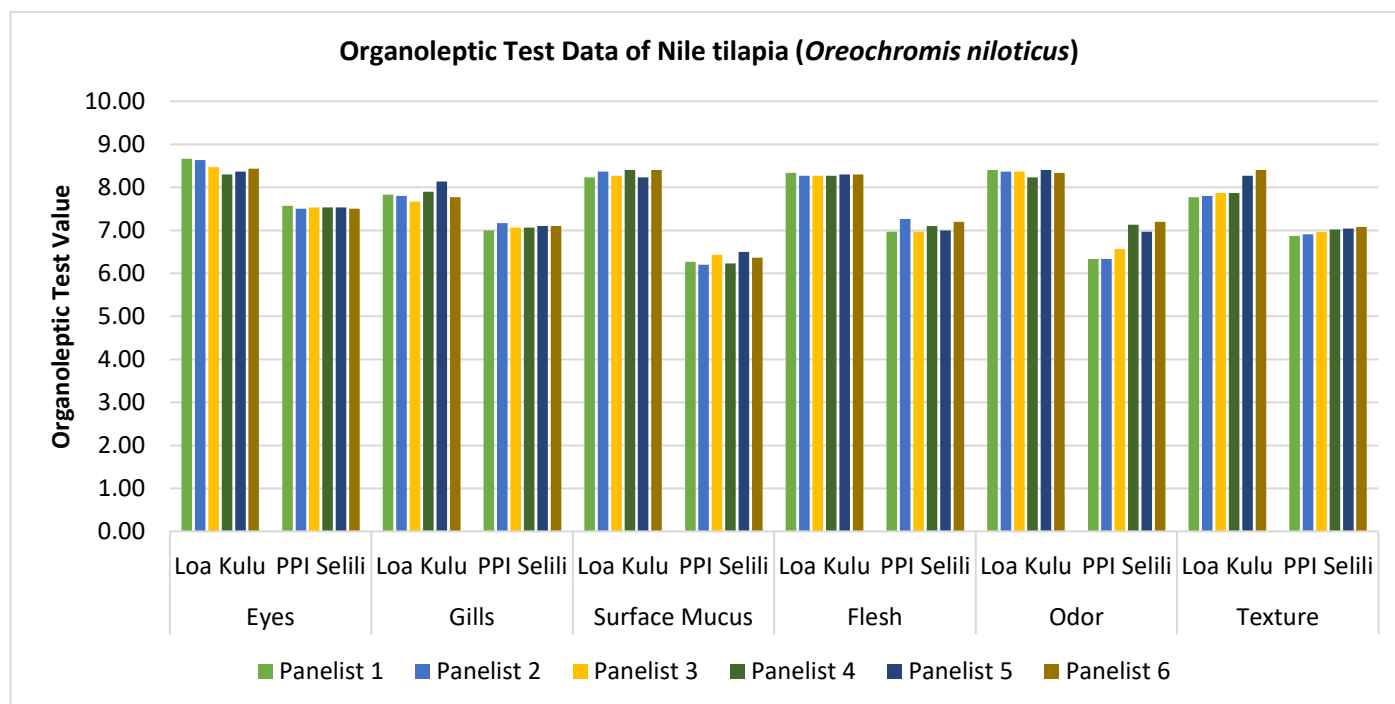


Figure 4. Tilapia Organoleptic Testing

Although there is no significant decrease in the quality of fresh tilapia, there is a slight decrease from the first sub-activity to the last in the delivery of tilapia by open vehicle. This is due to potential hazards in each sub-activity, such as the loading and unloading of fresh tilapia in an open field and the use of uncovered vehicles to transport tilapia, which accelerates the decay process.

Based on the risk assessment results, the impact on fresh tilapia ranges from 3 (lowest risk) to 20 (highest). The worst impact occurs in the use of broken ice cubes and the loading and unloading processes carried out in the field, which directly expose tilapia to sunlight. In addition, four potential hazards were identified from the three sub-activities categorized as low, six from the three sub-activities categorized as medium, and four from the three sub-activities categorized as high. Previous research stated that a total of 69 potential hazards arose during the tiger shrimp shipping process, from the start of the shipping preparation process to arriving at the unloading location [18]. Another study mentioned that there were 40 potential hazards in the lemur handling process [29]. The high potential hazard in the delivery of fishery products arises from the distance traveled and the stages of the delivery process.

Potential hazards can cause damage to fishery products, but contamination with spoilage bacteria also plays an important role in the spoilage process of fishery commodities. The presence of pathogenic bacteria is a major concern in seafood safety. These bacteria do not cause visible changes in fishery commodities to the naked eye, but they can cause foodborne illnesses ranging from nausea and vomiting to death. As the presence of pathogens cannot be visibly recognized in fishery commodities going to the market, consuming contaminated seafood poses a major risk to human health [30]. Fishery commodities can be contaminated by improper handling and processing conditions, even if caught in clean waters. For example, *Clostridium botulinum* type E is not usually found in fresh fish caught in unpolluted areas. However, this bacterium is a major problem in the seafood industry, as it can grow and produce toxins due to defective handling and processing [25].

Several bacteria, including *Staphylococcus aureus*, are found during postharvest handling. During this process, fish are exposed to the pathogenic bacterium *Staphylococcus aureus* and its heat-resistant enterotoxins. These enterotoxins can survive fish

processing, posing a food safety hazard. According to Sivaraman *et al.* [31], significant contamination with *Staphylococcus aureus* was observed after preprocessing and during storage, with some strains showing methicillin resistance. There is growing evidence of the presence of microorganisms resistant to various antibiotics in fish [32]. Previous research also found that *Staphylococcus aureus* was present in post-harvest shrimp at PPI Selili Samarinda, due to decay and bacterial contamination that occur during land-based shipping for 12 hours of travel [18]. Consuming fish contaminated with antibiotic residues is likely to cause antibiotic resistance in humans, leading to unexpected health problems. Human exposure to post-harvest microbial contaminants is an ongoing food safety hazard that must be addressed through more effective, timely processing and preservation methods.

Microbial pathogens of pre-harvest origin in fish may also emerge as post-harvest pathogens, as they are carried to the market. *Escherichia coli*, *Salmonella* species, *Staphylococcus aureus*, *Clostridium botulinum*, *Listeria monocytogenes*, *Shigella* species, *Bacillus cereus*, *Campylobacter jejuni*, *Yersinia enterocolitica*, and histamine producers have been identified as common post-harvest pathogens affecting fish [33]. *Escherichia coli*, a common fecal-derived bacterium, tends to be found more frequently in poorly handled fish. *Escherichia coli* is an indicator of fecal contamination, and these bacteria can be transmitted to fish through contaminated aquatic environments [34]. *Salmonella* and *Staphylococcus aureus* species, which originate from human contact during handling, were found more frequently than other pathogens in market-consumed fish. As processing and transportation can lead to the transmission of *Staphylococcus aureus*, the implementation of good hygienic practices is essential, especially in retail markets [35]. Several researchers have reviewed fish spoilage and food safety hazards stemming from post-harvest microbiological contamination [36], [37]. The researchers separately identified contamination that occurred during the handling, storage, and transportation of the captured fish. The high genotypic and phenotypic diversity of *Escherichia coli* allows these bacteria to contaminate fish in both marine and freshwater environments before harvest and to appear in market products as post-harvest contaminants, releasing enterotoxins and Shiga toxins [37]–[39]. Although *Salmonella* is primarily a freshwater microorganism, its presence in coastal

waters and its emergence as a post-harvest contaminant following entry into fish at the pre-harvest stage have been noted. *Salmonella* can be found in large numbers in fish despite its low population in seawater [40]. *Clostridium* is generally a post-harvest contaminant that can withstand thermal processes below 100°C, posing a food safety hazard to fish products [41].

Opportunities for potential hazards that occur in fresh tilapia can increase in each subactivity if control is not carried out as early as possible. Potential hazards can be controlled using the results of identification and risk assessment, so that control is right on target. Risk control can be performed to minimize hazards. The methods used for risk control include elimination, substitution, engineering controls, administrative controls, and Personal Protective Equipment (PPE). In potential hazards caused by aspects of tools and materials, such as dirty transport boxes, a combination of risk control can be carried out: substitution, where transport boxes cannot be used, and a schedule for cleaning tools, which is an administrative control. Potential hazards caused by worker behavior can be controlled by providing Personal Protective Equipment (PPE) such as hand gloves and boots. Potential hazards arising from aspects of the work environment can be mitigated by relocating the unloading location from the middle of the field to a protected area.

Conclusions

Potential hazards in tilapia delivery activities using open vehicles include 14 hazards across the three delivery sub-activities: loading, delivery, and unloading. The highest potential hazard affecting the quality of fresh tilapia is the loading and unloading processes conducted in an open field. The risk assessment shows that the highest potential hazard is worth 6, which falls into the high category, so the controls that can be implemented are a combination of substitution and administrative controls, as well as providing PPE to workers.

Conflicts of interest

There are no conflicts to declare.

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