

Risk Mitigation of Oyster Mushroom Production and Distribution Using Method Failure Mode and Effect Analysis (FMEA)

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ABSTRACT

The production process of making raw materials for horticultural commodities has various risks, both internal and external, and if it occurs, it will hinder the company's goals. This research aims to analyse and measure risks in the production and distribution of oyster mushrooms and determine actions to mitigate risks. The research method used purposive and snowball sampling. Data were analysed using descriptive analysis through interviews and quantitatively through risk analysis and Failure Mode and Effect Analysis (FMEA) methods. The study results indicated that risks occur from the nursery stage to distribution to consumers. Risk mapping that needs to be watched out for: *Mucor spp* disease, baglogs attacked by crepe pests, damaged baglogs in the incubation section, and incorrect and irregular watering and fertilization. The risks in distribution analysed are the risk of heavy losses, physical damage, and unsold goods. The most significant risks in the distribution process were heavy losses and physical damage to mushrooms at the farmer level during the sorting process, and physical damage at the retailer level during the sorting process due to the presence of old, wet, and yellowing mushrooms, as well as unsold mushrooms. Production is mitigated by cleaning around the mushroom house, burning diseased baglogs, arranging baglog entry and exit times to facilitate the sorting process, and implementing routine work direction and evaluation. Mitigation of unsold risks during distribution: making a purchasing plan according to previous sales results, selling remaining mushrooms at a lower price than the purchase price, and using PBP and VBP packaging.



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1. Introduction

Oyster mushrooms in Greek are called pleurotus, which means side shape or sideways position between the leg and the cap. It is called an oyster because of its resemblance with oyster shells (*clam shell*) in shape or body. Oyster mushrooms are wood fungi that often grow abundantly in forest areas on old tree trunks. Oyster mushroom cultivation in Indonesia only started in 1988 and there were not many farmers or entrepreneurs at that time (Huda et al. 2023).

The Central Statistics Agency (2021) noted that mushroom production in Indonesia was 90.42 tonnes in 2021. The amount of oyster mushroom production dropped drastically by 97.27% compared to 2020 which was 3,316.32 tonnes. Looking at the trend, Indonesian mushroom production has fluctuated from 2014-2021. Domestic mushroom production recorded its highest figure in 2016, namely 40,914.33 tons. Based on region, East Java is the region with the largest mushroom production in 2021, namely 41,58.3 tons.

Mushroom cultivation is carried out by individual farmers and on a company scale. The large risks that must be borne tend to be a factor that has the potential to harm farmers or companies, so that oyster mushroom farming tends to be unsustainable. Oyster mushrooms have a fairly high risk of damage because of their easy nature damaged (Ordon, 2022; Ramadhan et al., 2021; Afandi et al. 2019). The dominant risk occurs in distribution activities. Based on the results of observations of the physical properties of the fungus Potentially easy to cause losses, namely weight loss, physical damage and not sold in the distribution process. Research on marketing distribution risks, especially on oyster mushroom commodities, was carried out by Wulandaari et al. (2022), Zheng et al (2021) and Handayani & Nadya, (2019), but this has never been done identify the level of loss which should be calculated as internalization costs in distribution costs. The losses that arise can be reduced through risk mitigation.

This research is important because this risk has never been identified at the loss level, which should be calculated as internalization costs and distribution costs. Next, mitigation is carried out to reduce the level of loss. Therefore, research is needed to solve the following problems: What are the risks, and how significant are the risks in oyster mushroom distribution, and what is the potential loss value of production and distribution risks? What mitigation measures are being implemented to prevent these risks?. The research objectives for the formulated problem were risk identification, risk analysis, loss value analysis for oyster mushroom production and distribution, and determining mitigation measures to anticipate the risks. The novelty of this research is the identification of oyster mushroom production and distribution risks, the determination of the loss value resulting from these risks, and the development of mitigation plans for oyster mushroom production and distribution risks.

2. Methods

2.1. Research Location and Time

This research was conducted from June to September 2023 at oyster mushroom-producing companies and several market locations in the West Java region. The research location was selected in the mushroom production center area at the foot of Mount Salak, West Java, because the biophysical conditions in the area support the growth of mushrooms, making it suitable for mushroom cultivation. Apart from that, the socio-economic conditions of the area are supported by the skills of farmers or mushroom cultivation companies, and the area is close to the target market. The research location has characteristics and problems that are worthy of further research because oyster mushrooms are a vegetable in great demand by the public.

2.2. Data Types and Sources

The data collected is primary and secondary. Primary data was obtained directly from primary sources through observation and in-depth interviews with parties involved as producers in the Company and as marketers of oyster mushrooms, namely collectors and retailers located in the Bogor City traditional market area, Cicurug Market, and Parungkuda Market in the Sukabumi Regency area. Meanwhile, secondary data was obtained from previous research, scientific journals, literature studies, the Central Statistics Agency, and reports from oyster mushroom-producing companies.

2.3. Respondent Collection Method

Respondents were determined using the snowball sampling method, consisting of three mushroom farmer respondents, two leaders of the Moen Farm company in the mushroom production and marketing divisions, three suppliers, two distributors, and six retailers in the traditional market area of Sukabumi Regency and Bogor City.

2.4. Data Analysis Methods

2.4.1. Qualitative and Quantitative Analysis

Data analysis was carried out using qualitative and quantitative methods. Qualitative analysis was carried out through a descriptive approach by conducting direct observations in the field and in-depth interviews with respondents to answer the research objectives. Quantitative analysis is used to analyze the level of distribution risk and the amount of loss using *Microsoft Excel* through the formulation of the FMEA method (Premisis, 2019).

2.4.2. Failure Mode and Effect Analysis (FMEA) Analysis

Failure Mode and Effect Analysis (FMEA) is a step-by-step approach to identifying all possible failures during a product or service's manufacturing or assembly process (Premisis, 2019). The goal of FMEA is to take action to eliminate or minimize failures, starting with the highest priority failures. Data is analysed in tabular form using Failure Mode and Effects Analysis (FMEA), which shows the causes of production and distribution priorities assessed in FMEA. The factors assessed in FMEA are occurrence, severity, and detection using a Likert scale by assigning a score to the risk source from 1 to 5. Score 1 for the answer has minimal effect, Score 2 for the answer has no effect, Score 3 for the answer has quite an effect, Score 4 for the answer has an effect, and Score 5 for the answer has a very effect.

Results Likert scale is described using a scale semantic differential. After scoring, grade Risk Priority Number (RPN) and Risk Score Value (RSV) calculated using the following formula:

$$\text{RPN} = \text{Occurrence score (Occ)} \times \text{severity score (Sev)} \times \text{Detection score (Det)}$$

$$\text{RSV} = \text{Occurrence score (Occ)} \times \text{severity score (Sev)}$$

The higher the RPN value, the higher the risk of this event. Pareto RPN and RSV graphs are then created to analyze risks, find root causes, resolve problems, and compare overall results. After the RPN and RSV scores of the main causes of each are known, the risks are grouped using a transmit diagram. The transmit diagram is created based on the RPN critical value and the RSV critical value (Stock & Lambert, 2017). A risk is categorized as a critical risk if it has critical RPN and RSV values. To get the critical value, the formula used is:

RPN critical value = (Total RPN/number of risk causes) RSV critical value = (Total RSV/number of risk causes). The Critical Values of RPN and RSV are divided into four parts in the transmit diagram. The critical value of RPN can be seen in Figure 1.

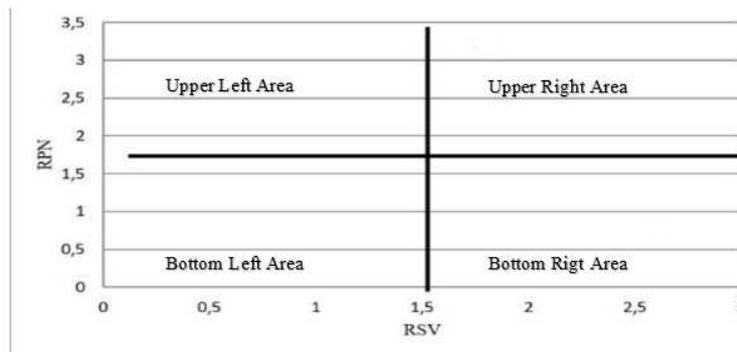


Figure 1 Scatter Diagram Critical Values of RPN and RSV
 Source: Kim & Zuo (2018)

Caption:

Top right area: top priority risk categories. If risks in this area occur, they will threaten the achievement of company goals. Top left area: risk categories that occur regularly and do not significantly hinder the achievement of company goals and targets. Bottom left area: low RPN values and RSV values. This means that risks in this area tend to be overlooked so that companies do not need to allocate resources to manage them. Bottom right area: a risk area that rarely occurs, but if it occurs it will result in the company's goals and the risk of the company's targets not being achieved.

3. Results and Discussion

Results section is provided prior to the discussion section. Each section stands alone as a subtitle. The findings and discussion should be written in not less than 60% of the entire body of the manuscript.

3.1. Results

3.1.1. Identify the Causes of Distribution Risk

The distribution channel for oyster mushrooms is carried out by manufacturers, suppliers, distributors and retailers. Distributors act as controllers who distribute to retailers, and retailers act as sellers to retailers or final consumers. Distribution of oyster mushrooms is packaged in one bag containing 5 kg and sold at a price of IDR 12,000/kilogram, both to suppliers, distributors and retailers who buy directly from producers.

Each distribution actor bears the risk caused by uncertainty in supply and demand, but the retailer bears the biggest risk, namely physical damage, weight loss of mushrooms, and the risk of not being sold (Table 1).

Table 1 Causes of Risk for Distribution of Oyster Mushrooms

Distribution Actors:	Causes of Risk:
Supplier	Supply uncertainty
Distributor	Uncertainty of market demand
Retailers	- Physically damaged - Weight Loss - Not sold

Table 2 assessed each market player's causes of oyster mushroom distribution risks.

Table 2 Assessment of the Causes of Oyster Mushroom Distribution Risk for Each Market Player

Commerce Actors	CR	Risk events in Distribution activities	SCORE					
			Sev	Occ	Det	RPN	RSV	
Moen's Farm	Weight Loss							
	d.a1	Delivery	1	1	1	1	1	
	d.a2	Sorting	4	5	4	80	20	
	d.a3	Sell merchandise	1	1	1	1	1	
	Physical Damage							
	d.b1	Delivery	1	1	1	1	1	
	d.b2	Sorting	4	4	4	64	16	
	d.b3	Sell merchandise	1	1	1	1	1	
	Not sold							
	d.c1	Delivery	1	1	1	1	1	
	d.c2	Sorting	1	1	1	1	1	
	d.c3	Sell merchandise	1	1	1	1	1	
		Total		15	16	15	151	43
	Supplier	Weight Loss						
c.a1		Delivery	1.3	1	1.3	1.69	1.3	
c.a2		Sorting	1.6	1	1	1.6	1.6	
c.a3		Sell merchandise	1.3	1.6	1.3	2.7	2.0	
Physical Damage								
c.b1		Delivery	1.3	1	1	1.3	1.3	
c.b2		Sorting	2	1	1.3	2.6	2	
c.b3		Sell merchandise	1	1	1.3	1.3	1	
Not sold								
c.c1		Delivery	2	1	1.6	3.2	2	
c.c2		Sorting	1.6	1.3	1	2.08	2.08	
c.c3		Sell merchandise	1	1.3	1	1.3	1.3	
		Total		13.1	10.2	10.8	17.8	14.6
Wholesaler / Distributor		Weight Loss						
	b.a1	Delivery	1.5	1	2	3	1.5	
	b.a2	Sorting	1	1	1	1	1	
	b.a3	Sell merchandise	1.5	1	1.5	2.2	1.5	
	Physical Damage							
	b.b1	Delivery	1.5	1	1	1.5	1.5	
	b.b2	Sorting	1	1.5	1	1.5	1.5	
	b.b3	Sell merchandise	2	1	2	4	2	
	Not sold					0	0	
	b.c1	Delivery	1	1.5	1	1.5	1.5	
	b.c2	Sorting	1	1	1.5	1.5	1	
	b.c3	Sell merchandise	2	1	2	4	2	
		Total		12.5	10	13	20.2	13.5
	Retailer	Weight Loss						
a.a1		Delivery	1.5	1.3	1	1.9	1.9	
a.a2		Sorting	2.5	2	4.5	22.5	5	
a.a3		Sell merchandise	1	1.3	1	1.3	1.3	
Physical Damage								
a.b1		Delivery	1	2	1	2	2	
a.b2		Sorting	3.3	4	3	39.6	13.2	
a.b3		Sell merchandise	2	1	1	2	2	
Not sold								
a.c1		Delivery	1	1	1	1	1	
a.c2		Sorting	1.3	1.8	1	2.34	2.3	
a.c3		Sell merchandise	3.8	2.6	4.5	44.4	9.8	
		Total		17.4	17	18	117.1	38.6
		Total All					306.1	109.8
	Critical Point					8.5	3.0	

Source: Processed August 2023

Caption: CR = Cause of Risk, Sev = Severity, Occ = Occurrence, Det = Detection, RPN = Risk Priority Number, RSV = Risk Score Value.

After assigning values to the causes of risk distribution, several risk causes have high RPN values. *Risk Priority Number* (RPN) is calculated to determine which risks are priorities that must be addressed immediately. After the highest RPN has identified the cause of the risk, the risk is plotted on a Pareto diagram which can be seen in Figure 2.

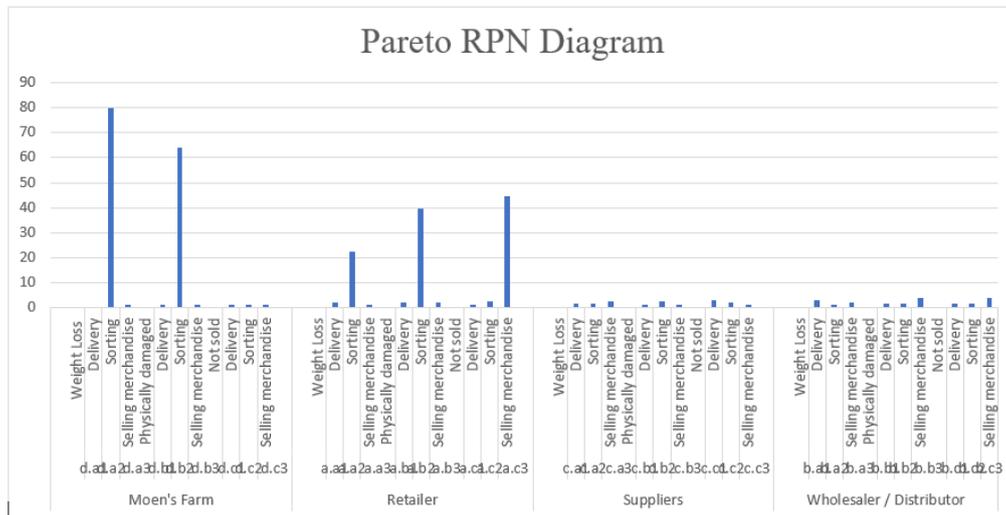


Figure 2 Pareto RPN Diagram for Moen's Farm Oyster Mushroom Distribution
Source: Processed August 2023

The risk is calculated by Risk Score Value (RSV) to determine the value of the highest cause of failure. The RSV diagram can be seen in Figure 3.

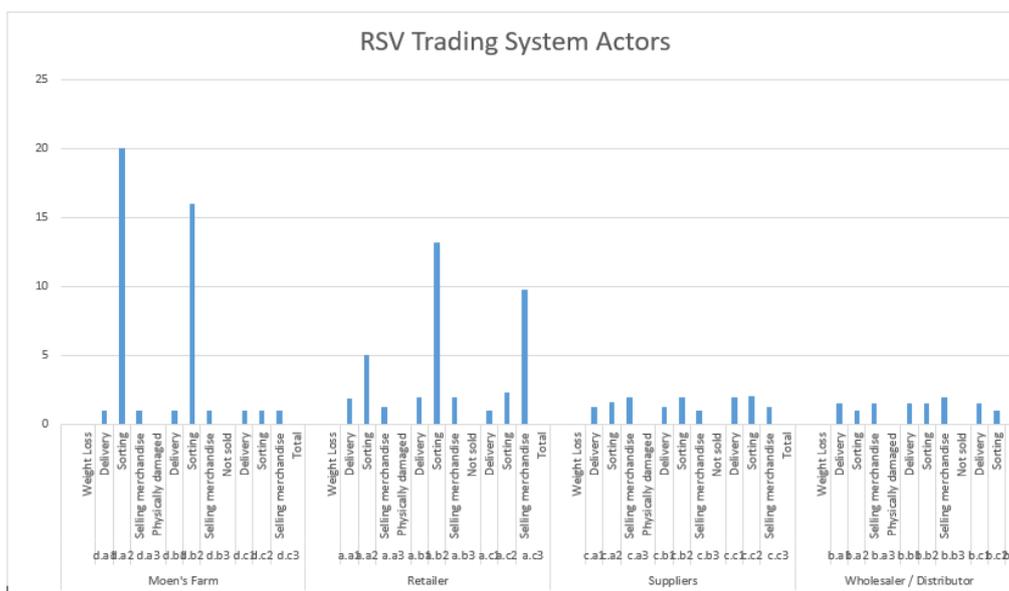


Figure 3 Pareto RSV Diagram for Oyster Mushroom Distribution
Source: Processed August 2023

The RSV score shows the cause of the highest risk which indicates the risk of shrinkage during the sorting process at the farmer level, physical damage due to sorting at the retailer level, physical damage due to the sorting process at the farmer level, unsold mushrooms at the retailer level, weight loss at the retailer level and the lowest is at the supplier and distributor

level. After making the RPN and RSV Pareto diagrams, the critical value is calculated by dividing the total value of each by the number of risks, namely 36. So, the critical value of $RPN = 306.1/36 = 8.5$ and critical value $RSV = 109.8/36 = 3.0$. By knowing the critical values of RPN and RSV, a scatter plot is then created to determine the distribution of risk causes according to these critical values which can be seen in Figure 4.

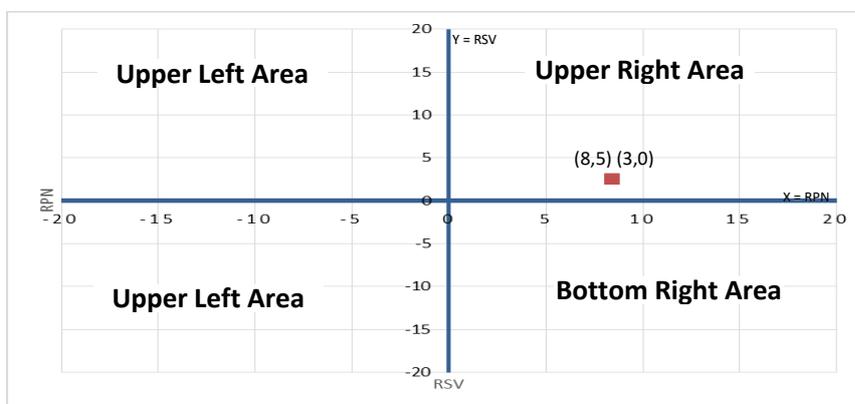


Figure 4 Risk Transmission Diagram for Moen's Farm Oyster Mushroom Distribution

The transmit diagram shows the critical values of RPN and RSV are at the top right with RPN values of 8.5 and RSV 3.0, meaning the risk must be handled immediately because it has high RPN and RSV values at the top right.

3.2. Discussion

The risk of weight loss, physical damage and not being sold occurs at the retail stage which can be seen in Table 1. The causes include the condition of the mushrooms being old, the presence of mushrooms affected by pests and the condition of the mushrooms being wet. Physically damaged mold occurs during the sorting process at retailers. For every 5 kilograms of mushrooms, the most frequent risk of damage is an average of 0.5 kg (10%).

Based on Figure 2, it is known that the cause of distribution risk in the most extensive RPN assessment of the risk of oyster mushroom distribution is the occurrence of weight loss and physical damage to farmers caused by sorting after post-harvest oyster mushrooms, with an RPN value of 80. Meanwhile, the RPN assessment of the risk of physical damage due to the sorting process is 64. The condition of wet mushrooms, mushrooms attacked by pests, fallen mushrooms, and yellowing mushrooms due to old age are included in the types of oyster mushrooms that are rejected, so they are thrown away. Unsold mushrooms that occur at retailers got an RPN value of 44.4, while weight loss and physical damage due to sorting got an RPN value of 22.5. The presence of mold rejects at Retailers got an RPN value of 39.6.

Based on Figure 3, it is known that the cause of distribution risk in the most extensive RSV assessment of the risk of oyster mushroom distribution is the occurrence of heavy losses and physical damage to farmers caused by sorting after post-harvest oyster mushrooms with an RSV value of 20. Meanwhile, the RSV assessment of the risk of physical damage due to the sorting process is 16. The condition of soft mushrooms, mushrooms attacked by pests so that the color is brownish, mushrooms fall off, and mushrooms turn yellow because they are past the harvest period, are included in the type of oyster mushrooms that are rejected, so they are not sold. Mushrooms not sold at the retailer level got an RSV value of 8, while the sorting process has a risk of heavy losses of 6, and physical damage due to sorting got an RPN value of 16. The existence of Retailer risk gets an RSV value of 36.

Figure 4 shows the critical values of RPN and RSV in the scatter plot diagram to determine the distribution of risk causes based on critical values. The critical value is obtained

by dividing the total value of each by the number of risks, namely 36. Thus, the critical value of $RPN = 306.1/36 = 8.5$ and the critical value of $RSV = 109.8/36 = 3.0$.

The highest risk in the distribution of oyster mushrooms occurs at the farmer level, namely weight loss and physical damage during sorting during the oyster mushroom packaging process, the risk in the distribution channel occurs at the retailer level, namely unsold mushrooms and weight loss due to old, wet, yellow mushrooms and physical damage due to packaging (Hidayat et al, 2014). The risk is small at the supplier and distributor level distribution channels because there is no repackaging process. Oyster mushrooms are sent according to conditions, such as from Moen's Farm Plantation. The next risk experienced by retailers is that mushrooms are not sold. In line with research (Koencoro, 2020), the highest level of risk is at the farmer level: the risk of weight loss in sorting activities, with a score of 7.4. The risks faced by oyster mushroom distribution businesses will affect the losses they experience. The higher the level of risk, the higher the losses that will arise, which will impact the financial expenses that oyster mushroom distribution businesses will face (Azhra, 2021; Handayani, 2020). The risk of loss due to low productivity and distribution damage was studied by Mahari et al. (2020), who found that to meet market demand, it is necessary to develop mushroom cultivation methods that can guarantee increased productivity and quality of mushrooms, thereby reducing damage. The cylindrical baglog cultivation method is more profitable than wooden tray cultivation, increasing wood yields, cost efficiency, and reducing the risk of post-harvest damage.

Oyster mushroom distribution businesses experience losses which can be included in marketing costs. The total loss value in the distribution process is 28.5%, consisting of risks at the supplier level of 25% due to the risk of weight loss and physical damage, while at the retailer level, the loss value is 3.5% due to the risk of weight loss, physical damage and the risk of not being sold. Meanwhile, at the distributor level, no risk fees are charged for the distribution process. The internalization of costs for risks in the oyster mushroom marketing process can be overcome with insurance premiums, where oyster mushroom distribution businesses can reserve costs to pay for the risks they face (Maesaroh, 2023; Yulanda, 2021).

Table 3 Percentage and Value of Losses for Mushroom

No	Distribution stage	Loss quantity (kg)	Loss value (price loss quantity x mushroom price)
1	Supplier	25 Kg/100kg (25%)	IDR. 225,000/Rp 900,000
2	Distributor	0 Kg/100kg (0 %)	IDR. 0
3	Retailer	3,5 Kg/100 kg (3,5%)	IDR. 31,500/Rp 900,000

Reserves in the form of agricultural insurance have been implemented in America where each livestock business insures a portion of the total the expected income can finance the impact of natural and climate risks as well as market risks that arise through market price fluctuations (Markovic & Kokot, 2018; Susanawati & Noviyanti, 2024). Modern risk management in agriculture is currently increasingly focused on guaranteeing total agricultural income (Frascarelli et al., 2021; Turvey, 2012). The approach to managing the white oyster mushroom business sustainably is also discussed by Silva (2024), who stated that the success of the white oyster mushroom business requires a holistic approach that combines proper cultivation with effective pre-harvest and post-harvest techniques to meet market demand.

Based on method use *Failure Mode and Effect Analysis* (FMEA) known highest risk based *Risk Priority Number* (RPN) and *Risk Score Value* (RSV). Mitigation to reduce the risk of mushroom weight loss at the Moen's Farm Plantation retail trader level is the need for vigilance in sorting so that unsuitable mushrooms do not enter the packaging. Meanwhile, risk management at the level of retailers who throw away mushrooms because they are not sold is by selling them cheaper, as is done by one retailer who sells the price of mushrooms below

the purchase price, especially to chicken noodle sellers and meatball sellers so that the losses incurred are not too large. Sami Abou Fayssal (2023) stated that risk mitigation to increase mushroom shelf life, freshness, and reduce weight loss is recommended, namely using Polyethylene plastic bag packaging (PBP) and Polypropylene vacuum bag packaging (VBP).

4. Conclusion

Based on the method of using Failure Mode and Effect Analysis (FMEA), it is known that the highest risk was based on the Risk Priority Number (RPN) with a score of 8.5 and Risk Score Value (RSV) with a value of 3.0 in the priority distribution, namely at the farmer and retailer levels. The causes of risk at the farmer level were weight loss and physical damage to mushrooms during the sorting process, while at the retailer level were weight loss, physical damage due to the sorting process, repackaging, and unsold mushrooms. The loss from all distribution activities was IDR 256,000 per IDR 900,000 or around 28.5%. Mitigation that needed to be done to prevent risks at the farmer level was to increase caution and vigilance in the mushroom sorting process, while at the retailer level, it was by reselling to other consumers at a cheaper price, such as chicken noodle and meatball sellers, so that the loss was not too significant. In addition, mitigation by preparing purchasing plans must also be carried out according to previous sales conditions. Practical suggestions and recommendations that can be given were the need for better and more careful handling at every stage of the distribution process, specially designed packaging with a combination of physical and airtight protective materials to maintain physical quality and a high level of freshness. In addition, it was also necessary to internalize costs of 28.5% in the distribution process to cover the value of losses due to risks during distribution.

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