Risk Mitigation of Fresh Milk Supply Chain Based on Vulnerability Analysis in Boyolali Regency, Indonesia

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ABSTRACT

Fresh milk in Boyolali Regency is currently unable to meet the demand of the processing industry because the quantity is limited and the quality is below the standard. The large number of activities at each tier and the long supply chain flow for fresh milk have the potential to cause a decrease in quality and quantity, making it vulnerable to risk. Therefore, this research aimed to analyze risk management in supply chain and provide mitigation proposals. Data were collected by in-depth interviews with 51 respondents using purposive and snowball sampling techniques. The variables examined include supply chain flow of fresh milk, risks at each tier, causes and impacts of risks, as well as likelihood, severity, and capacity to manage risk. Data processing used ISO 31000:2018 and the Rapid Agricultural Supply Chain Risk Assessment (RapAgRisk) method to assess risk vulnerability. The results showed that in Boyolali Regency, fresh milk supply chain consists of four tiers, namely farmers, as well as milk couriers, collectors, and processors, comprising processing industry and street vendors. Mitigation proposals were given for nine risks in the categories of high, moderate, and low vulnerability. These risks include high animal feed prices, low forage availability, cows being attacked by foot and mouth disease (FMD), adulteration of fresh milk, the amount of fresh milk received by couriers and collectors fluctuating, rejection, sudden demand, and excess stock of fresh milk. Subsequently, risk mitigation proposals were provided to maintain quality and increase fresh milk production.

Keywords: Fresh milk; ISO 31000:2018; RapAgRisk; risk mitigation; supply chain

INTRODUCTION

Fresh milk production in Indonesia is recognized to have an increasing trend evidenced by the production from 2015 to 2019. The largest increase was observed in 2016 due to a rise in the dairy cow population by 2.95% or 15,284 heads (Center for Data and Information Systems, 2017). However, the increase has not been able to meet the high demand of milk processing industry. The quality of fresh milk also cannot meet the industry standards, leading to a gap in supply from the upstream and demand from the downstream.

In supply chain, there are many actors and activities associated with the complex system (Burgess and Sunmola, 2021). Smooth operations will be disrupted when there are problems with supply chain (Zubair and Mufti, 2015). In the context of fresh milk, various activities can cause the quality to decline at every tier. Milking process, handling, storage, transportation, and long supply chain are susceptible to quality degradation such as changes in color, odor, taste, viscosity, and pH. Each tier has the potential to experience a decrease in quantity and quality which can crease risks in supply chain.

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Risks can occur during supply chain activities, causing damage and instability due to unprofitable operational activities (Dai and Liu, 2020). One example is the activity of delivering milk, which has the possibility of delays in supply from collectors to the processing industry. Delays in supply cause changes to the production process schedule, majorly due to vehicle damage and uncertain travel conditions.

Based on the problems above, research on supply chain risk management needs to be carried out to identify risks and vulnerabilities in fresh milk supply chain. In addition, by considering the results of risk assessments and vulnerabilities in supply chain, risk mitigation proposals can be made. It is expected that mitigation proposals can prevent risks properly and reduce potential losses experienced.

METHODS

Framework

Fresh milk supply chain can experience problems due to the perishable and non-durable nature, the length of supply chain, as well as the different treatment from farmers. A major obstacle faced by actors is the quality and quantity of milk which does not meet processing industry standards, resulting in inadequate supply. This is attributed to the rejection due to changes in color, odor, taste, pH, and inappropriate fat content. Another obstacle arises when dairy cows are attacked by disease which causes supply to decrease. Risks can lead the quality and quantity of fresh milk decrease. Therefore, to prevent risks and reduce losses experienced by supply chain actors, four stages can be carried out, namely identifying tiers in fresh milk supply chain, as well as identifying, analyzing, and providing risk mitigation proposals (Figure 1).

Data Collection

The research was conducted in Boyolali Regency, Central Java from June to September 2022. Data was collected through in-depth interviews conducted for 30 minutes to 1 hour 30 minutes with 51 respondents consisting of farmers (36 people), milk couriers (5 people), milk collectors (5 people), and milk processors including processing industry (2 people) and street vendors (3 people). The methodology used was purposive and snowball sampling. Specifically, snowball sampling was used to obtain information regarding the flow of fresh milk supply chain, while purposive sampling was used to determine respondents to obtain information about risk identification. The respondent criteria included milk farmers, couriers, and collectors in Boyolali Regency, milk processing industries in Central Java Province, and street vendors who have been running a business for a minimum of three years. These criteria were determined to obtain information from

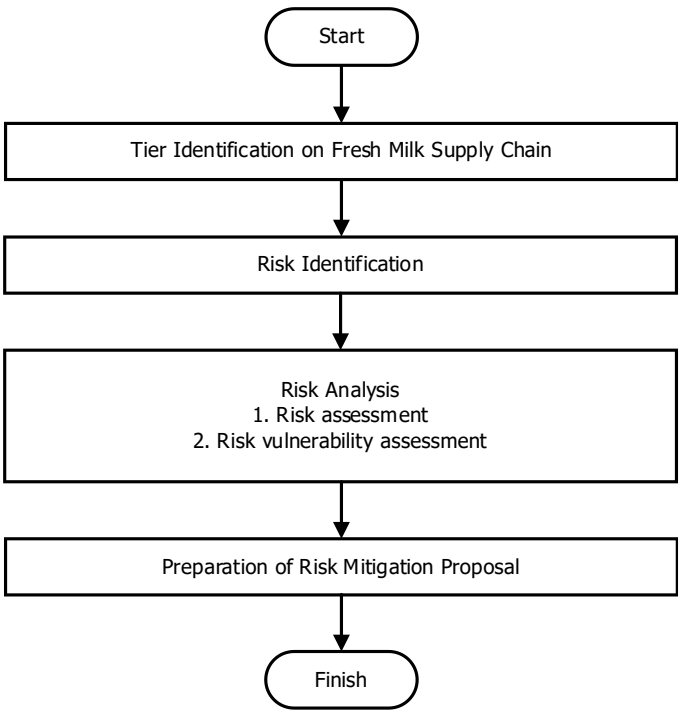

Figure 1. Research stages

experienced respondents. The data collected include supply chain flow of fresh milk, risks at each tier, causes and impacts of risks, as well as likelihood, severity, and capacity to manage risk.

Research Stages

Risk management process was carried out using ISO 31000:2018 and the Rapid Agricultural Supply Chain Risk Assessment (RapAgRisk) method was used to assess vulnerability. ISO 31000:2018 "Risk Management" established a reference framework for implementing risk management in organizations and various contexts (Molinos-Senante et al., 2023). This process consisted of risk identification, analysis, and mitigation. Risk vulnerability assessment using RapAgRisk aimed to support the results of previous analysis carried out by mapping the likelihood and severity values on risk map. This is because, in RapAgRisk, there is a capacity to manage risk which can determine the owner's ability to implement management. Therefore the results of the analysis can be used as consideration in preparing risk mitigation.

In-depth interviews were conducted to identify actors in milk supply chain. Generally, risk identification is the first stage of the management process. At this stage, observation and in-depth interviews were used to identify risks that may occur to understand the cause, impact, likelihood, severity, and capacity to manage risk. The likelihood and severity values were mapped on risk map to analyze risk. The mapping results and the capacity to manage risk value were mapped to vulnerability risk event matrix. The likelihood, severity, and capacity to manage risk values were obtained from a Likert scale from 1 (very low) to 5 (very high). An explanation of each Likert scale is presented in Tables 1, 2, and 3. Determining the likelihood, severity, and capacity to manage risk values was based on the results of risk owner assessment including farmers, milk

Table 1. Likert scale for likelihood values

Scale	Level	Likelihood description	
		Qualitative	Semi qualitative
1	Very low	Almost impossible to happen.	Happens every two years or more.
2	Low	It's unlikely to happen.	Happens once every year.
3	Moderate	Likely to happen.	Happens once every month to once every three months.
4	High	Most likely to happen.	Happens once every week to once every two weeks.
5	Very high	Almost certainly will happen	Happens every production period.

Source: Aleksic, et al. (2022) (modified)

Table 2. Likert scale for severity values

Scale	Level	Description of severity	
		Qualitative	Semi qualitative
1	Very low	Almost does not disrupt the continuity of business processes, causing no impact and almost no financial loss, hence product quality decreases but can still be used.	Losses on business assets are no more than 20%.
2	Low	Has the potential to disrupt the continuity of business processes with minimal impact and result in financial losses that are not too large, hence only a few consumer desires are not fulfilled.	Losses on business assets between 21% to 40%.
3	Moderate	Quiet disrupts the continuity of business processes with a moderate impact, resulting in financial losses that are not too large, hence some consumer desires are not fulfilled.	Losses on business assets between 41% to 60%.
4	High	Disrupting the continuity of business processes with moderate impact, resulting in large financial losses, and many consumer desires not being fulfilled.	Losses on business assets between 61% to 80%.
5	Very high	Severely disrupts the continuity of business processes with severe impacts, resulting in huge financial losses, and product quality that cannot be consumed.	Losses on business assets of more than 80%.

Source: Aleksic, et al. (2022) and COSO (2012) (modified)

Table 3. Likert scale for capacity to manage risk values

Ranking	Definition
1	Some are effective but the approaches tend to be expensive and unsustainable.
2	Between 1 and 3.
3	Effective but not yet affordable and sustainable.
4	Between 3 and 5.
5	Very effective and has a high probability of sustainability.

Source: Jaffee, et al. (2010)

couriers, collectors, and processors, which comprise the processing industry and street vendors. The results of risk analysis, namely prioritized risk categories, were used to develop mitigation. The preparation of risk mitigation was obtained from literature research as well as the results of discussions with experts and risk owners.

RESULTS AND DISCUSSION

Fresh Milk Supply Chain

The results of purposive and snowball sampling showed that supply chain for fresh milk in Boyolali Regency consists of four tiers, namely farmers, as well as milk couriers, collectors, and processors, comprising processing industry and street vendors. Fresh milk supply chain flow in Boyolali Regency is shown in Figure 2. The supply chain flow is different from those in the research of Daud et al. (2015). In this research, there were three tiers consisting of farmers, KUD (Cooperative), and another tier, namely milk processing industry and retailers. Meanwhile, in research by Annie Rose Nirmala et al. (2022), there were six tiers, namely milk producers, cooperatives, bulk coolers, processing industries, retail outlets, and consumers.

Fresh milk supply chain flow in Boyolali Regency is different from the flow found in previous research, primarily due to the different conditions of the research locations. The existence of milk courier tier causes the flow of supply chain to become longer, which can have an impact on reducing milk quality.

In the fresh milk supply chain in Boyolali Regency, bacterial measurements are only carried out at the milk collector tier using the TPC test. The TPC test is carried out if there is a request from the industry and the test

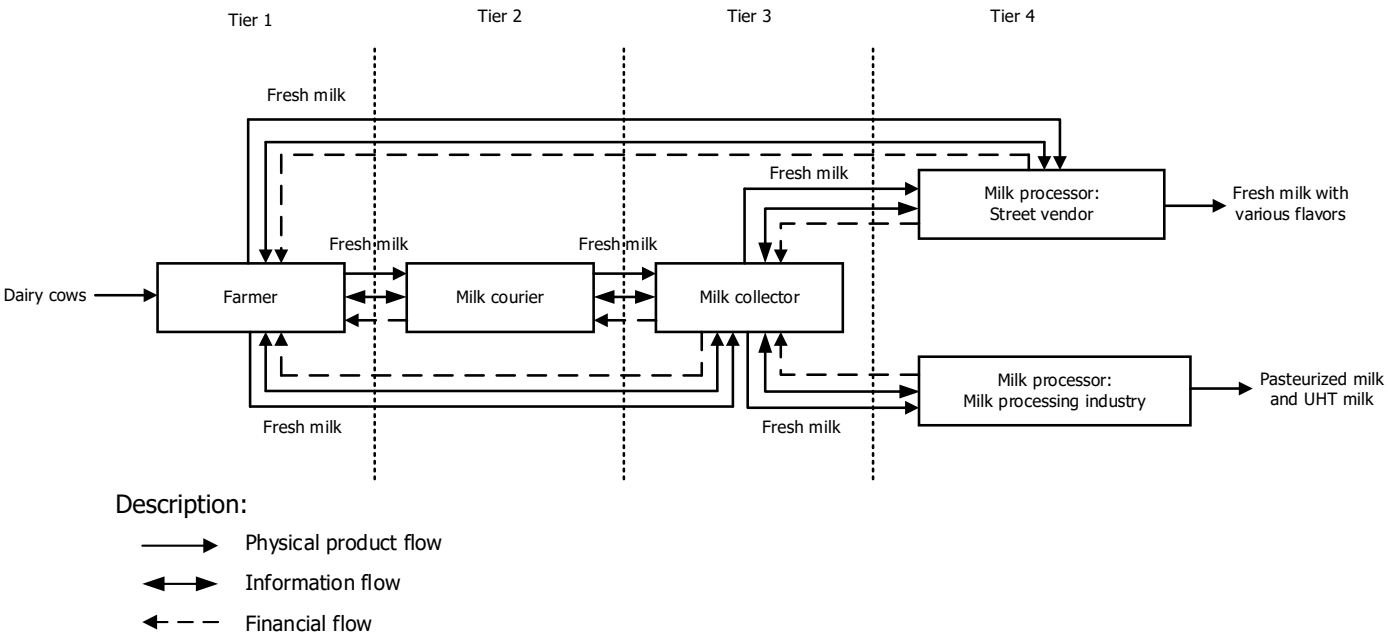

Figure 2. Supply chain flow of fresh milk in Boyolali Regency

results are confidential. Senarath and Adikari (2017) stated that microbial contamination could occur at every point of milk handling, from the farmer to the cooling center, where the high total bacteria and total coliform count in the samples tested shows contamination. According to Arjadi et al. (2017), the Total Plate Count (TPC) test results for fresh milk samples from farmers, milk couriers, and KUD were above SNI (1×10^6 CFU/mL). The TPC test obtained from farmers, milk couriers, and KUD tier was 6,588,625 CFU/mL, 9,230,625 CFU/mL, and 13,209,375 CFU/mL. The high values can be caused by the long delivery duration for milk, starting from milking process to the KUD (Nurhayati et al., 2016). The delivery duration from the farmer to the KUD can take 2-2.5 hours depending on distance, geographical conditions, and awareness of the transportation duration impact on milk quality (Amentie et al., 2016). Delivery duration exceeding 2 hours can cause damage and decrease milk quality because fresh milk can only last for 2 hours at room temperature (Pramesti and Yudhastuti, 2018). Therefore, a long supply chain flow accelerates the decline in the quality due to the long waiting duration at room temperature.

Packaging that is not airtight can cause damage and decrease in quality. During the collection process from the farmer, fresh milk is put into the can with frequent opening and closing, thereby triggering contamination through workers, air, and equipment. The longer the delivery duration, the greater the bacteria growth, and fresh milk will be damaged. *Escherichia coli* bacteria cause contamination in milk, leading to high TPC results. The bacteria grow at temperatures of 10-40 °C with an optimum temperature of 37 °C. At the optimum temperature, the bacteria divide into two every 20 minutes (Pramesti and Yudhastuti, 2018).

Farmers are the first actors in the upstream supply chain of fresh milk, usually keeping one to five dairy cows with milk output of 10-15 L per day. The determination of fresh milk selling price from farmers is based on the quality (Setiyowati, 2020).

Milk couriers are independent businesses owned by individuals and function as the second actor in supply chain, helping collectors to get fresh milk from farmers. When collecting fresh milk, the couriers visit the farmers or collection points one after the other using a pick-up truck or motorized vehicle. In this research, fresh milk was collected twice a day, specifically morning and evening.

Milk collectors are the third actors in supply chain who collect fresh milk from couriers and farmers. Fresh milk is taken from the farmers twice a day, morning and evening at the location which is far from collectors. Furthermore, milk collectors sell to the processing industry and street vendors.

At milk processing tier, there are two supply chain actors, namely the industry and street vendors. The processing industry obtains fresh milk from various collectors and processes into pasteurized or UHT milk. The amount of fresh milk delivered by collectors varies depending on the availability. Meanwhile, street vendors process fresh milk by providing various flavors. These individuals obtain fresh milk directly from collectors and farmers then transport using pick-up trucks or motorized vehicles.

Fresh Milk Supply Chain Risk Assessment

Risk Identification

Risk management process begins with identification in which dangers, threats, possible failures, and undesirable events related to the activity are identified (Laine et al., 2021). Table 4 shows a list of risks obtained. Risks can lead the quality and quantity of fresh milk to decrease. Quality decrease such as sub-standard quality occurs due to changes in color, odor, taste, pH, and inappropriate fat content, which can lead to rejection or sale at a low price. Meanwhile, quantity decrease occurs due to a decrease in the amount of fresh milk that actors deposit and receive.

Risk identification was carried out by observation and in-depth interviews with supply chain actors. This in-depth interview aimed to obtain information on risks that may occur, causes, impacts, likelihood, severity, and capacity to manage risk. Risk determination was carried out based on literature including books and journals, as well as conditions in the field namely the outbreak of foot and mouth disease (FMD) along with other problems. This is appropriate to the principles of ISO 31000:2018 stating that the implementation of risk management is based on historical and current data information.

Based on the identification carried out, 20 risks were obtained and none was related to financial and price aspects. This is due to the payment system which should be made every 10 days and the possibility for farmers to borrow from milk collectors when sudden needs arise to avoid impacting operational activities. The price of fresh milk is determined based on quality, hence, the price does not change significantly.

At the farmer tier, four risks tend to occur, one of which is mastitis in dairy cows. Mastitis reduces the quality and quantity of fresh milk because it is clotted and pale white, preventing consumption. In cases when the disease is severe, the production of fresh milk will also decrease. Mastitis usually causes the quality of milk to become poor and impedes milking process although this is also based on the condition of fresh milk and cows

(Christi et al., 2022). Risk of low forage availability can cause a decrease in fat content, implying that the quality will also decrease. Fat content decreased because the forage grass given was different (Wirjatmadja et al., 2020). Moreover, there is also risk of FMD which can reduce fresh milk production (Adjid, 2020). Diseases in milk are caused by biological and environmental factors.

Three risks may occur in milk couriers tier based on the results of identification carried out through in-depth interviews with supply chain actors. Risk of counterfeiting fresh milk can be attributed to farmers' dishonesty, making milk couriers unaware of the water or other ingredients' addition. Adding fresh milk to water will cause the constituent dry materials to change and the specific gravity to become abnormal, leading to changes in the freezing point (Christi et al., 2022). Risk of milk rejection may occur due to the presence of antibiotics. Meanwhile, risk of fluctuating amounts of milk received can also occur at the collector tier. This risk is attributed to different lactation periods of dairy cows, inappropriate milking processes, and animal health.

At milk collector tier, seven risks can occur due to the antibiotic content in fresh milk, damage to vehicles used to transport milk from farmers, changes in operational activities of the processing industry, and sub-standard quality. An example of risks at milk collector tier is that the quality received varies. Furthermore, milk collectors receive fresh milk from different farmers and each uses various rearing and milking methods depending on habits, including the types of feed given. Some farmers combine concentrate with additional feed (tofu dregs, pollard bran, cassava, salt, and minerals), while others only use concentrate feed (tofu dregs and pollard bran). Certain farmers clean milk udder before milking, but some carry out milking immediately without first cleaning the udder. However, the capacity of milk collectors to handle fresh milk is limited. Mixing fresh milk inappropriately can cause a decrease in quality (Daud et al., 2015).

Table 4. List of fresh milk supply chain risks in Boyolali Regency

Tier	Supply chain actors	Risk code	Risk description
Tier 1	Farmer	R.1.1.	Risk of dairy cows developing mastitis.
		R.1.2.	Risk of high animal feed prices.
		R.1.3.	Risk of low forage availability.
		R.1.4.	Risk of cows being attacked by FMD.
Tier 2	Milk courier	R.2.1.	Risk of adulteration of fresh milk.
		R.2.2.	Risk of fresh milk received will fluctuate.
		R.2.3.	Risk of rejection of fresh milk.
Tier 3	Milk collector	R.3.1.	Risk of fresh milk received will fluctuate.
		R.3.2.	Risk of fresh milk supplies coming too late.
		R.3.3.	Risk of fresh milk being contaminated with antibiotics.
		R.3.4.	Risks to milk quality received vary.
		R.3.5.	Risk of sudden demand.
		R.3.6.	Risk of accumulation of fresh milk in the cooling machine.
		R.3.7.	Risk of fresh milk rejection.
Tier 4	Milk processing industry	R.4.1.	Risk of fresh milk supplies coming too late.
		R.4.2.	Risk of fresh milk rejection.
		R.4.3.	Risk of fresh milk raw materials is less.
		R.4.4.	Risk of changes in the quality of fresh milk stocks.
Tier 4	Street vendor	R.5.1.	Risk of weather.
		R.5.2.	Risk of excess stock of fresh milk.

Description: Risk code consists of 1 letter and 2 numbers. The use of letters shows risk information for each tier. The first number shows the level of risk owner, 1 for farmers, 2 for milk couriers, 3 for milk collectors, 4 for milk processing industry, and 5 for street vendors. Meanwhile, the second number shows the sequence of risks at each tier.

At milk processing industry tier, four risks are likely to occur, namely, milk quality received does not meet or approach the established standards, the small number of suppliers, and the uncertain travel conditions. Meanwhile, at the street vendor tier, two risks can occur, namely weather and excess milk stock.

Compared to previous research, Table 4 shows that fresh milk supply chain in Boyolali Regency has different risks. The research areas used and various tiers of supply chain may lead to differences in risk. According to Annie Rose Nirmala et al. (2022), risks that can occur at the farmer tier include a low supply of dairy cows, seasonal fluctuations, increasing animal feed prices, and mastitis infection. At milk cooperative tier, there are financial risks, low milk procurement, illiteracy and ignorance about cooperative awareness, low-profit margins, delivery risks, process, quality, and control risks, as well as intense competition between milk cooperatives. At milk processing industry tier, there are risks of capacity constraints, communication distortions, damage and spills during transit, difficulties in network selection, financial and danger risks, intense competition, low-profit margins, logistics risks, unavailability of skilled workers, as well as fuel price volatility. According to Daud et al. (2015), at the farmer tier, there are biological risks from milk quality, natural risks from seasonal feed availability, and operational risks from inappropriate handling practices of fresh milk. At the KUD tier, there are operational risks from the practice of handling fresh milk, institutional risks from bulking practices, and operational risks from transportation.

Risk Analysis

Risk analysis is the second stage in carrying out management which aims to determine the categories existing at each tier (Guritno et al., 2019). The analysis started with mapping the likelihood and severity values on risk map. Figure 3 shows risk map of fresh milk supply chain in Boyolali Regency. In this supply chain, there was one risk with a high estimated loss due to high impact, namely FMD attacking cows. In addition, there were nine risks with moderate loss estimates and 10 with low loss estimates.

The results were used to assess vulnerability by mapping the previous risk and capacity to manage risk on the event matrix as shown in Figure 4. Vulnerability assessment was carried out to obtain priorities as a basis for determining whether risks that occur should be given special treatment or within tolerance limits. Determining the severity, likelihood, and capacity to manage risk values is based on the Likert scale in Tables 1, 2, and 3 obtained through in-depth interviews with risk owners. Farmers, milk couriers, and street vendors were considered business owners, milk collectors as chairman or representative party, and milk processing industry for the quality control section. Capacity and capability for farmers, milk couriers, and street vendors include running a business for a minimum of three years, milk collectors as chairman for a minimum of 10 years, or representative party in the field of receiving and sending fresh milk for a minimum of 2 years. Milk processing industry considered a quality control manager for a minimum of 9 years. For each risk, the likelihood, severity, and capacity to manage risk values

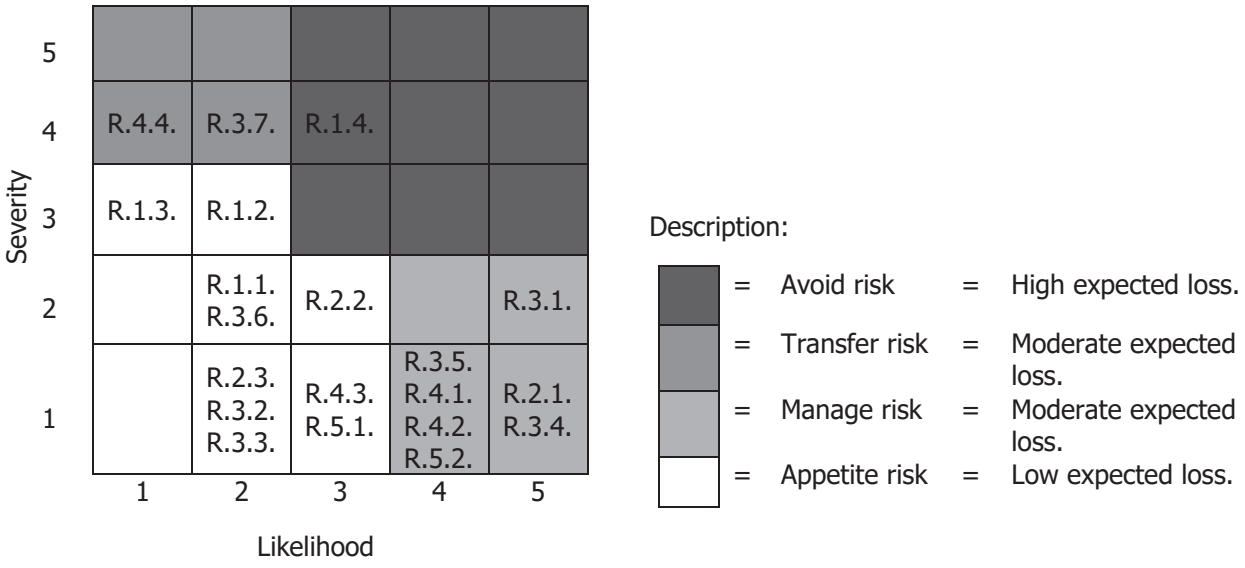

Figure 3. Risk map in fresh milk supply chain in Boyolali Regency

	Capacity to Manage Risk				
Expected Loss	1	2	3	4	5
High			R.1.4.		
Moderate				R.2.1. R.3.1. R.3.5. R.5.2.	R.3.4. R.3.7. R.4.1. R.4.2. R.4.4.
Low		R.2.2.	R.1.2. R.1.3. R.2.3.		R.1.1. R.3.2. R.3.3. R.3.6. R.4.3. R.5.1.

Description:

= Extremely vulnerable

= Highly vulnerable

= Moderate vulnerability

= Low vulnerability

= Limited vulnerability

Figure 4. Vulnerability risk event matrix in fresh milk supply chain in Boyolali Regency

mapped were obtained from the mode values of all respondents at each tier.

Based on Figure 4, risk of fresh milk supply chain is divided into high, moderate, low, and limited levels of vulnerability. Dairy cows are highly vulnerable to FMD, and the ability to face this risk is classified as moderate, with expected losses moderate to high. Risk of FMD can significantly reduce the production of fresh milk and the owner does not have a high ability to face this risk due to the rapid spread of the virus.

Risk of fresh milk received by couriers fluctuating causes moderate losses and moderate capacity to manage risk, leading to moderate vulnerability. Moreover, some risks have been handled by risk owners with moderate to high capacity. Vulnerability to these risks is low (low vulnerability). Risks will have limited vulnerability if they have been handled with high capacity.

Risk Mitigation Proposals

Risk mitigation proposals, considered the final stage in management comprise efforts to prevent risks from the beginning to the end of fresh milk supply chain. When risk occurs, mitigation can reduce the likelihood of future occurrence and impact (Jaffee et al., 2010). In this research, risk mitigation was prepared by considering the results of literature research and interviews with experts and risk owners.

The results of risk analysis were used to determine appropriate management and implemented based on priorities (Bilska and Kołożyn-Krajewska, 2019). Mitigation proposals are not provided for risks that fall into the limited vulnerability category, because these risks can still be tolerated and handled well. Meanwhile, risks other than those in the limited vulnerability category were given mitigation proposals to reduce severity due to risk owner's lack of capacity (Sari et al., 2021). In fresh milk supply chain, there are 11 risks in the limited vulnerability category and 9 risks in the high, moderate, and low vulnerability categories. Risk mitigation proposals are listed in Table 5.

At the farmer tier, several alternative feeds can be used to reduce risk of increasing feed prices. Mitigating this risk will enable farmers to use other feed available in the area and not solely rely on livestock feed which is currently expensive. Therefore, other feed substitutes that are easy to find and provide more feed can reduce risk of high animal feed prices (Annie Rose Nirmala et al., 2022).

Table 5. Risk mitigation for each risk in fresh milk supply chain

Supply chain actors	Risk code	Risk	Risk level	Risk mitigation
Farmer	R.1.2.	Risk of high animal feed prices.	Low vulnerability	- Participating in training on making complete feed to understand complete feed formulation, use alternative feed available around, and increase the production of fresh milk. (**) - Using alternative feed that is around. (*) - Adding minerals as additional feed to increase fresh milk production. (**)
Farmer	R.1.3.	Risk of low forage availability.	Low vulnerability	- Joining training on how to ferment feed from *kolonjono* or *odot*, sugar cane molasses, and salt. (**) - Joining training on silage making. (**) - Participating in training on making complete feed to understand complete feed formulation, use alternative feed available around, and increase the production of fresh milk. (**)
Farmer	R.1.4.	Risk of cows being attacked by FMD.	High vulnerability	- Implementing SOP that have been socialized by the department to reduce the spread of FMD. (**) - Adding minerals as additional feed to increase fresh milk production. (**) - Providing vaccines to cows hence the decline in fresh milk production can gradually improve. (**)
Milk courier	R.2.1.	Risk of adulteration of fresh milk.	Low vulnerability	- Providing education to farmers about the losses that will be borne when adding other ingredients that can affect the price of fresh milk deposited. (*) - When receiving fresh milk from farmers, the quality is checked more strictly. (*)
Milk courier	R.2.2.	Risk is that the amount of fresh milk received will fluctuate.	Moderate vulnerability	- Providing education to farmers on how to do proper milking and good hygiene and sanitation practices to prevent mastitis. (*) - Providing education to farmers on how to maintain the quality of fresh milk after milking hence it remains good. (*) - Improving quality control by checking the quality of fresh milk when received from farmers. (*)
Milk courier	R.2.3.	Risk of rejection of fresh milk.	Low vulnerability	- Advising farmers to separate fresh milk that contains antibiotics because it can affect the quality of other fresh milk. (***) - When receiving fresh milk from farmers, quality checks are carried out more strictly to prevent rejection. (*) - Handling fresh milk contaminated with antibiotics to separate it from fresh milk which does not contain antibiotics. (***)
Milk collector	R.3.1.	Risk of fresh milk received will fluctuate.	Low vulnerability	- Providing education to farmers together with the department on how to carry out proper milking and practice good hygiene and sanitation to prevent the occurrence of mastitis. (*) - Providing training to farmers together with related departments on how to make complete feed and other feed alternatives that can be used. (**) - Providing education to farmers and milk couriers in collaboration with milk processing industry on how to handle fresh milk after milking until distribution hence the quality remains good. (*) - When receiving fresh milk from farmers and milk couriers, quality checks are carried out more strictly to prevent rejection and inappropriate quality. (*) - Providing health facilities for farmers by providing medication to spray cow pens to prevent the spread of FMD. (***)

Continued Table 5. Risk mitigation for each risk in fresh milk supply chain

Supply chain actors	Risk code	Risk	Risk level	Risk mitigation
Milk collector	R.3.5.	Risk of sudden demand.	Low vulnerability	- Providing education to farmers and milk couriers, carried out together with milk processing industry, on how to maintain the quality of milk after milking and distribution hence it remains good and can increase the stock and minimize rejection from milk collectors. (*) - Creating an SOP with milk processing industry regarding raw material procurement time limits and the number of sudden requests. (*)
Street vendor	R.5.2.	Risk of excess stock of fresh milk.	Low vulnerability	- Planning raw material requirements to estimate fresh milk to be purchased. (*)

Description: - Risk code consists of 1 letter and 2 numbers. The use of letters shows risk information for each tier. The first number shows the level of risk owner, 1 for farmers, 2 for milk couriers, 3 for milk collectors, 4 for milk processing industry, and 5 for street vendors. Meanwhile, the second number shows the sequence of risks at each tier.
(*) = literature research, (**) = expert opinion, (***) = risk owner has implemented it

Risk mitigation for milk couriers and collectors tier, includes education regarding the disadvantages of counterfeiting fresh milk, how to handle milk to ensure good quality, and increasing quality control when receiving from farmers. The aim of mitigating this risk is to increase the awareness of farmers as well as milk couriers and collectors to implement food safety practices for the prevention of microbiological, chemical, and physical hazards (Korale-Gedara et al., 2023).

Risk mitigation, which refers to education on correct milking, good hygiene, and sanitation practices to prevent the development of mastitis was carried out at milk courier and collector tier. Mitigating this risk can encourage farmers to implement good hygiene and sanitation practices. A microbiological evaluation showed that 95.5% of fresh milk samples tested had a total number of bacteria below SNI (1 x 10^6 CFU/mL) using good hygiene and sanitation practices (Wicaksono and Sudarwanto, 2016).

At milk collector tier, there was risk mitigation related to creating SOP with the processing industry regarding raw material procurement. Milk collectors and the processing industry do not use a contract system to procure raw materials and are only based on trust. Therefore, creating an SOP for the procurement of raw materials reassures both parties, and the availability of fresh milk in the processing industry can also be well maintained (Sari et al., 2018).

At the street vendor tier, risk mitigation was carried out by planning raw material requirements to estimate fresh milk to be purchased. Based on past sales performance, raw material requirements planning was conducted for higher forecast accuracy. According to previous research, the accuracy of sales forecasts is important in planning activities such as procurement, production, and delivery (Khamphinit and Ongkunaruk, 2016).

CONCLUSION

In conclusion, fresh milk supply chain in Boyolali Regency consists of four tiers, namely farmers, milk couriers, collectors, and processors, comprising processing industry and street vendors. Based on the results of risk assessment, nine risks require risk mitigation and are divided into high, moderate, and low vulnerability categories. At the farmer tier, there was risk of high prices of animal feed mitigated by using other alternative feed, low availability of forage was mitigated by following training in making complete feed and silage, while cows suffering from FMD was mitigated by administering vaccines as well as implementing SOP to reduce the spread of the disease. At milk courier tier, there was risk of adulterating fresh milk mitigated by carrying out stricter quality checks, risk of fluctuating fresh milk received was mitigated by providing education to farmers properly, good hygiene, and sanitation practices, as well as rejection of fresh milk was mitigated by separating milk contaminated with antibiotics from farmers and carrying out stricter quality checks. At milk collector tier, risk of fresh milk received fluctuating was mitigated by providing training

to farmers on how to make complete and alternative feeds as well as carrying out more stringent quality checks. Moreover, risk of sudden demand was mitigated by creating an SOP in milk processing industry regarding raw material procurement, time limits, and the number of sudden requests. At the street vendor tier, there was risk of excess stock of fresh milk which could be mitigated by planning raw material requirements.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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