Risk analysis in bao bun production processes using FMEA and FTA methods: a case study

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ABSTRACT

Risks are present in every activity and could cause damage if not properly addressed. This research discusses how to identify risks that occur in the production process of the food industry. The characteristics of the goods, such as flavor, price, appearance, and availability, are met through the production process by transforming raw materials into products. The XX Bakery business experiences several risks at the production stage that reduce the quality of the product which potentially causes financial losses. Failure Mode and Effect Analysis (FMEA) is used to identify and assess the risks and their level of importance. There were 20 risks that occurred in the production process obtained through observation and interviews. The risks were then assessed based on severity, occurrence, and detection through a questionnaire to determine the Risk Priority Number (RPN) value. The Pareto chart shows which risks would result in a significant impact if given treatment. There were top 5 risks in which RPN values resulted in 80% of the total score. The risks are broken mixer with a score of 360, fluctuation of raw material prices with a score of 320, power outages with a score of 240, workers experiencing fatigue with a score of 144, and water supply stopped with a score of 60. The risks were then further analyzed using Fault Tree Analysis (FTA) to find their root causes. The results of the risk management processes serve as a base for consideration in forming proposals for corrective actions that improve risks—the implementation of the proposed improvements is expected to reduce losses that potentially be experienced by the business.

1. Introduction

An industry in developing its business certainly has the objective of gaining profits. To achieve this goal, business owners must pay attention to many things from the business they are running, one of which is the production process. Production is an activity to produces items or services by changing form of materials and adding or creating benefits (Artaya, 2018). In carrying out a production process, the company must be able to ensure that the products produced are in line with consumer desires. A company in carrying out its activities always finds its position dealing with various circumstances and decision making. One of the conditions faced is decision making involving risk (Kadim, 2017).

The object of this research is a food industry called XX Bakery which runs a business by producing bao buns. A Bao bun is a soft bun made from flour dough and given various stuffings. An industry in building its business certainly aims to make a profit. To achieve this objective, the owner

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must pay attention to many things in the industry being undertaken, one of which is the production process. Bao buns can experience several defects if there are errors at the production stage, such as a concave surface, blisters, brown spots, and shrinkage. The structure and texture of bao buns are also a concern as there is a risk of rough, uneven texture and crumbs separating from the parts of the skin. Products that have an unpleasant odor and are tasteless are considered less attractive to consumers (Huang & Miskelly, 2016). In executing production, the industry has experienced obstacles such as machine damage, changes in product quality, and production workers experiencing fatigue. Risks associated with product production must be evaluated and corrected in the early stages of production (Rezaee et al., 2018). Obstacles that occur can be anticipated by the risk management process to reduce or avoid losses received by the company.

Uncertainty is the main reason why there can be hesitation when making a decision. The hesitations experienced by decision makers are based on the presence of uncertain events that are occurring in the real field. Some of the uncertainty events that can be experienced are such as the gap between the plan and what happens in the implementation stage, the lack of data collected to operate according to plan, and the limitations in managing the goals to be achieved (Arta et al., 2021). Risk management plays a role in reducing uncertainty and its impact that can be felt by stakeholders.

Among the many industries that produce goods, the food industry is more exposed to risks in the production process. Exposure to risks in food production can result in unpleasing and unsafe products for consumers. Failure in food production can have an effect on consumer health and financial consequences that may be difficult to handle (Jahangoshai Rezaee et al., 2018) The food industry is also an industry that is sensitive to customer expectations such as taste, price, appearance, and availability. The production process is a stage carried out by food businesses to meet these expectations by processing raw materials into consumable products. It can be said that risk management is one of the most important aspects in the food industry.

The Failure Mode and Effect Analysis (FMEA) method is used to determine and evaluate potential failures and their effects then identify and prioritize actions to reduce risk (Stamatis, 2019). The identification stage helps in evaluating activities so that the process or product can improve over time (Press, 2003). In addition, Fault Tree Analysis (FTA) method is also used, which is an analytical method used for all combinations of undesirable causal events in a system that cause undesirable events. The FTA method provides a graphic that represents the logical relationship between undesirable events and their causes (Xing & Amari, 2008; Aljabar & Hasibuan). Risk management comes as a process to identify and measure risks, and develop a strategy to manage risks with available resources. The existence of risk management will assist companies in making risk-related decisions so that adverse consequences that affect the company can be minimized or eliminated (Kristina & Wijaya, 2017).

2. Method

The purpose of this study is to identify and assess the risks that occur in production. Then the risks with the highest priority will be further analyzed to find the causal event. This knowledge will then be used as a basis for consideration in developing improvement strategies that can be applied to the object of research.

Primary data obtained in this research comes from observations, interviews, and questionnaire filling. The object of this research has a total production worker of two people who are also the owners of the business. Observations and interviews were conducted with one of the workers to identify any potential risk events that could occur in the production process. The list of risks that have been identified will then be assessed for severity (S), occurrence (O), and detection (D) by the expert to determine the value of Risk Priority Number (RPN).

$$RPN = S \times O \times D \quad (1)$$

Severity is a rating that refers to the seriousness of the impact caused by a risk. In cases where the severity of the impact varies, the worst-case scenario is used. The severity value scale can be seen in Table 1. Occurrence is a rating that refers to the estimated frequency of occurrence of a risk. Detection is a rating that refers to the likelihood that a control device will find a specific cause

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or failure mode to prevent the risk from occurring. The detection value scale can be seen in Table 3.

Table 1 Severity scale

Effect	Description	Rating
None	Might be noticeable by the operator (Process). Improbable/not noticeable by the user (Product).	1
Very slight	No downstream effect (Process). Insignificant/negligible effect (Product).	2
Slight	User will probably notice the effect but the effect is slight (Process and Product).	3
Minor	Local and/or downstream processes might be affected (Process). User will experience minor negative impact on the product (Product).	4
Moderate	Impacts will be noticeable throughout operations (Process). Reduced performance with gradual performance degradation. User dissatisfied (Product).	5
Severe	Disruption to downstream process (Process). Product operable and safe but performance degraded. User dissatisfied (Product).	6
High severity	Significant downtime (Process). Product performance severely affected. User very dissatisfied (Product).	7
Very high severity	Significant downtime and major financial impacts (Process). Product inoperable but safe. User very dissatisfied (Product).	8
Extreme severity	Failure resulting in hazardous effects highly probable. Safety and regulatory concerns (Process and Product).	9
Maximum severity	Failure resulting in hazardous effects almost certain. Non- Injury or harm to operating personnel (Process). compliance with government regulations (Product).	10

Source: *Guidelines for Failure Mode and Effect Analysis, for Automotive, Aerospace and General Manufacturing Industries,* 2003. (Press, 2003)

Table 2 Occurrence scale

Effect	Description	Rating
Extremely unlikely	Failure highly unlikely.	1
Remote likelihood	Rare number of failures likely.	2
Very low likelihood	Very few failures likely.	3
Low likelihood	Few failures likely.	4
Moderately low likelihood	Occasional failures likely	5
Medium likelihood	Medium number of failures likely.	6
Moderately high likelihood	Moderately high number of failures likely.	7
High likelihood	High number of failures likely.	8
Very high likelihood	Very high number of failures likely.	9
Extremely likely	Failure almost certain.	10

Source: *Guidelines for Failure Mode and Effect Analysis, for Automotive, Aerospace and General Manufacturing Industries,* 2003. (Press, 2003)

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Table 3 Detection scale

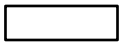
Effect	Description	Rating
Extremely likely	Controls will almost certainly detect the existence of the defect.	1
Very high likelihood	Controls have a very high probability of detecting the existence of failure.	2
High likelihood	Has high effectiveness for detection.	3
Moderately high likelihood	Has moderately high effectiveness for detection.	4
Medium likelihood	Has medium effectiveness for detection	5
Moderately low likelihood	Has moderately low effectiveness for detection.	6
Low likelihood	Has low effectiveness for detection.	7
Very low likelihood	Has lowest effectiveness in each applicable category.	8
Remote likelihood	Controls have a very low probability of detecting the existence of a defect.	9
Extremely unlikely	Controls will almost certainly not detect the existence of a defect.	10

Source: *Guidelines for Failure Mode and Effect Analysis, for Automotive, Aerospace and General Manufacturing Industries,* 2003. (Press, 2003)

After calculating the RPN value for each risk, the next step is to construct a Pareto Chart. The main concept in the chart is that the impact of causal factors that lead to a certain result is not the same, so identifying factors with high weights and working on them first will shorten the time and save costs to achieve the desired results. Pareto analysis uses the 80/20 principle, where 80% of the results come from 20% of the factors or causes that affect the results (Alkiayat, 2021). Risks that are listed as 80% of the contributors to the RPN will be analyzed for root cause events.

High-priority risks are further analyzed for causal events using Fault Tree Analysis (FTA). This method provides a logical framework for understanding how a system can fail (Xing & Amari, 2008). The results of this method are in the form of an organized graph that contains causal factors that contributes to the outcome of the top event. The symbols used can be seen in Table 4. Information about the causes is then used as one of the points of consideration in developing improvement proposals. A proactive approach to risk and its management will help the company to achieve progress that will lead to profitability (Hopkin, 2010).

Table 4 Fault Tree Analysis symbols

Symbol	Name	Meaning
	*Basic event*	Stating the root cause of a risk event that cannot be analyzed further
	*Undeveloped event*	States events that cannot be analyzed due to lack of information
	*Intermediate event*	States events that can still be analyzed
	*Transfer symbol*	States further event descriptions are on another page
	*AND gate*	Output event occurs if all input events occur simultaneously
	*OR gate*	Output event occurs if any one of the input events occurs

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3. Result and Discussion

The results and discussion of this research are the result of observations, interviews with resource persons and data obtained from several literatures. The selected respondent who was the source of the interview and filling out the questionnaire was the business owner whom is also a production worker. Observations and interviews were conducted to identify what risks occur during the production process. The risk is then assessed for severity, occurrence, detection through filling out a questionnaire. The following are the results of identification and assessment using the FMEA method.

Table 5 Risk identification and assessment

Failure Mode	Kode	S	O	D	RPN
Low-grade raw materials	R1	5	2	2	20
Raw material damage	R2	5	2	2	20
Raw material price fluctuation	R3	8	4	10	320
Delayed arrival of raw materials	R4	3	2	2	12
Worker exposed to hot tool surface	R5	4	3	2	24
Broken mixing machine	R6	8	5	9	360
Power outage	R7	8	3	10	240
Production delay	R8	3	3	2	18
Dough does not rise properly in fermentation	R9	6	2	2	24
Dirty dough divider	R10	3	3	2	18
Dough is not cut perfectly	R11	2	3	2	12
Production workers are fatigued	R12	9	8	2	144
Dough does not rise properly in proofing	R13	6	2	2	24
Dough development time is prolonged	R14	3	3	3	27
The degree of cooking is not perfect	R15	6	2	2	24
Worker exposed to hot baking surface	R16	4	3	2	24
Error in removing the baking sheet from the steaming oven	R17	2	2	2	8
Error in checking the LPG gas	R18	9	1	2	18
Stoppage of water supply	R19	3	2	10	60
Contamination from storage	R20	6	2	2	24
Error in arranging the storage pan	R21	2	2	2	8

It was calculated that the total RPN values of the risks is 360. The risks that have been assessed will then be analyzed using a pareto diagram. The objective is to find the top 80% of RPN value generators that are prioritized. These results help to narrow the focus to determine the risks that can produce significant and beneficial results if given treatment and improvement. The results of pareto chart analysis can be seen in Figure 1.

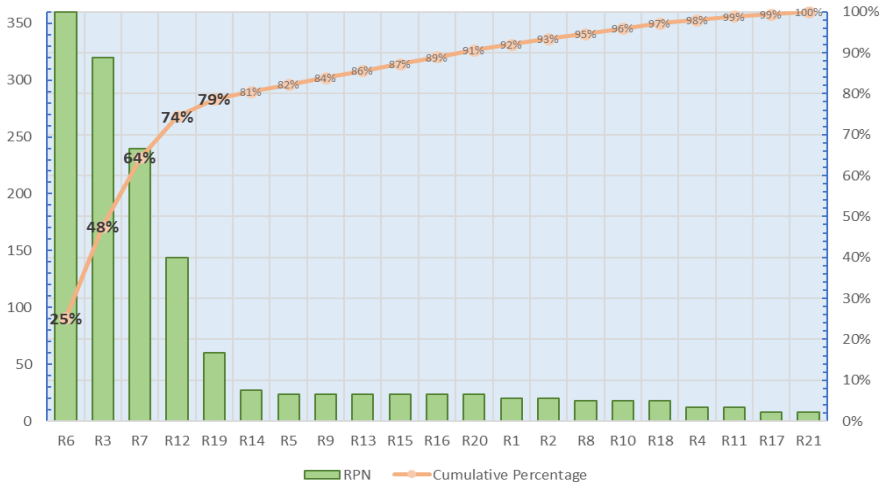

Fig 1. Pareto chart.

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Based on the results of data processing using pareto diagrams, it was found that there were 5 risks that caused about 79% percent of the RPN value. These risks are what then further investigated using FTA to find the cause of its occurrence. Based on the results of pareto chart, it is concluded that there are 5 risks that cause about 79% percent of the RPN value, which are broken mixing machine, raw material price fluctuation, power outage, fatigued workers, and stoppage of water supply. The risk of broken mixing machine has an influence on dough quality where if mixing occurs later than it should, not much heat can be transferred to maximize dough volume (Cauvain, 2015). In addition, production activities must also be temporarily stopped for an indefinite period of time because the machine must be subjected to maintenance. The risk of raw material price fluctuation will affect the production costs where there is a potential increase that must be covered, which can reduce profit margins and even a raise in the selling price of the product. The risk of power outage will affect the continuity of production because the mixer machine used cannot be operated due to the absence of electricity as a power source. The risk of fatigued production workers will affect workers' ability to perform their tasks safely and efficiently. There are concerns about worker safety and health (Safe Work Australia, 2013). The risk of stoppage of water supply can affect the continuity of the production process. Water is a vital resource in the food industry as it is used in various stages for product manufacturing, sanitization process, also production and manufacturing processes (Bhagwat, 2019). These five risks are considered to have a significant impact when given a response or improvement. The following is a combination of causes that produce the highest priority risks in this study.

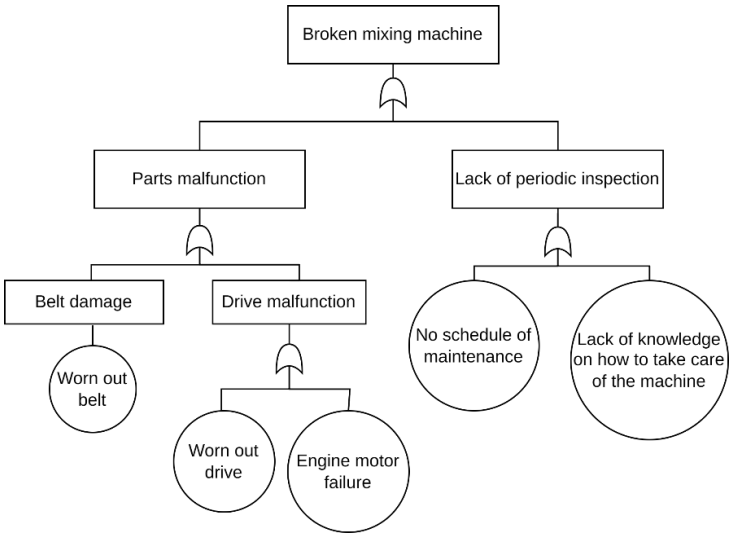

Fig 2. Fault tree of broken mixing machine (R6).

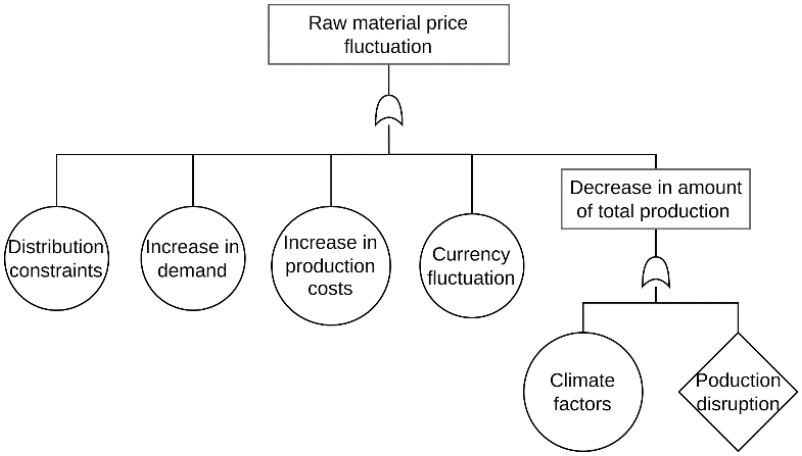

Fig 3. Fault tree of raw material price fluctuation (R3).

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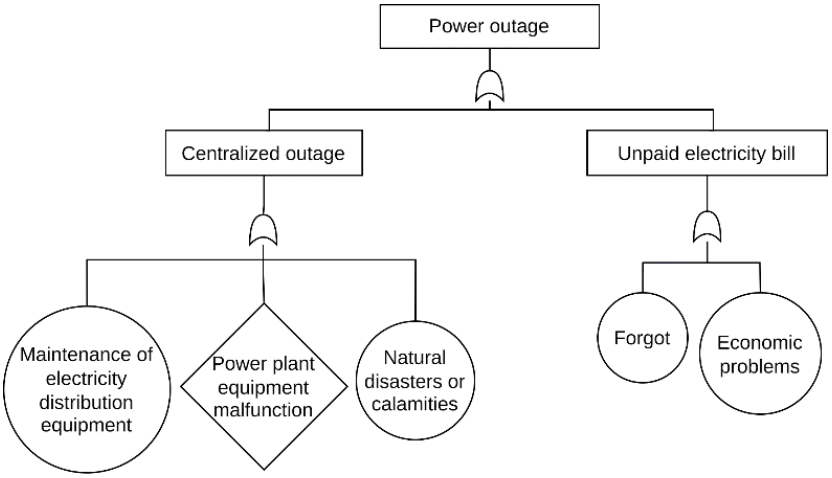

Fig 4. Fault tree of power outage (R7).

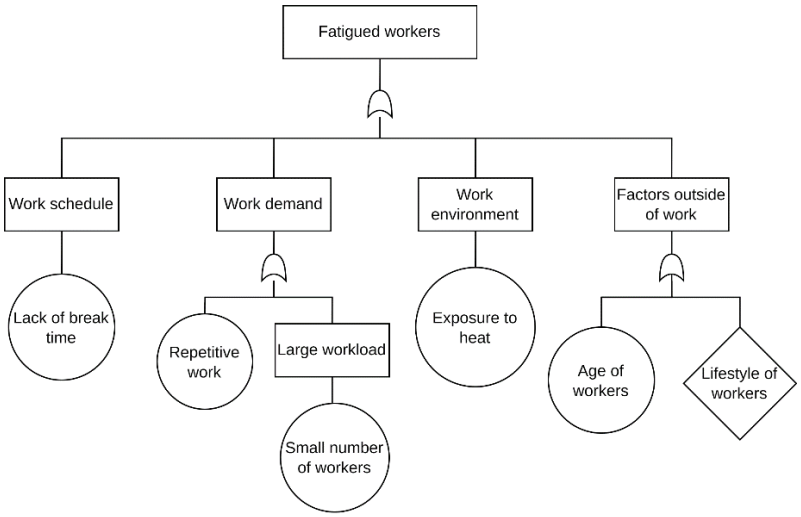

Fig 5. Fault tree of fatigued workers (R12).

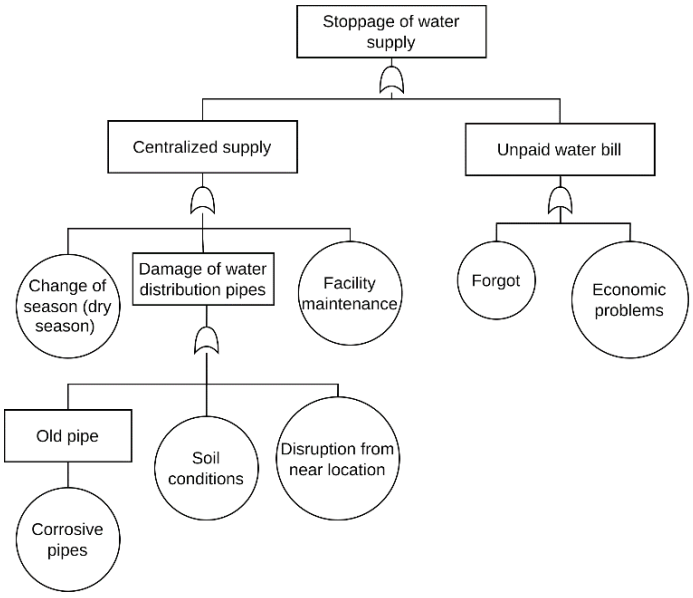

Fig 6. Fault tree of stoppage of water supply (R19).

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Proposed improvement is a proposed response that can be done to eliminate or improve the risks that occur in the stage under study. This proposal can be done by the business if the risk occurs during the production process. There are several strategies that can be applied in dealing with risks such as avoidance, reduction of the impact, sharing or transferring, or to retain the risk. Stakeholder may choose to accept and budget for risk when the resources required to address the risk are greater than the total loss experienced (Stamatis, 2019). Based on the results of the identification and assessment of risks and analysis of their causes, an improvement proposal can be prepared that can be applied by the business to handle risks. The improvement strategy can be seen in Table 6.

Table 6 RPN of top priority risks and recommendation plan

Failure Mode	*Failure Effect*	S	*Cause*	O	D	RPN	*Recommendation*
Broken mixing machine	- Damage the quality of the dough - Production delays	8	- Worn out belt - Worn out drive - Engine motor failure - No schedule of maintenance - Lack of knowledge to take care of the machine	5	9	360	Conduct proper maintenance and inspection of the machine on a regular basis
Raw material price fluctuation	- Decreased profit margins - Increase in the selling price of products - Production delays	8	- Distribution constraints - Increase in demand - Increase in production cost - Currency fluctuation - Climate factors - Production disruption	4	10	320	Improve product quality to maintain competitiveness
Power outage	- Production delays	8	- Maintenance of electricity distribution equipment - Power plant equipment malfunction - Natural disasters or calamities - Unpaid electricity bill	3	10	240	Provide generator set as a substitute of electrical power sources
Fatigued workers	- Declining levels of worker health and safety	9	- Lack of break time - Repetitive work - Small number of workers - Exposure to heat - Age of workers - Lifestyle of workers	8	2	144	Reconceive the works in the production process
Stoppage of water supply	- Production delays - Disrupts the sanitization stage	3	- Change of season - Corrosive pipes - Damaged distribution pipe because of soil conditions - Damaged distribution pipe because of other disruptions - Facility maintenance - Unpaid water bill	2	10	60	Make a purchase of backup supply of water

The recommended improvement plans are adjusted to the resources owned and the ability of stakeholders to handle risks. Regular maintenance of mixing machine is recommended to reduce the damage perceived. It is recommended to change the maintenance pattern from breakdown maintenance into condition-based maintenance or predictive maintenance which is done by monitoring the behavior of the machine. The benefits are it can increase the machine life and reduce the cost of maintenance (Mishra & Mahapatra, 2015). Treatment efforts that can be applied for the machine are putting oil into the machine, cleaning the bowl after executing production activities, cleaning the tool body and cavities engine, and replacing components deemed to be unfit (Hermawan & Sitepu, 2018).

Fluctuation of raw material prices is the risk that cannot be controlled so the plan is to accept and budget the risk by improving the quality of the product to ensure the business can survive in

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the competitive market. Although it comes at the expense of increased costs, this strategy can maintain competition by eliciting customer satisfaction about the quality the product offers. The quality of the product is one of the basic decision factors to stimulate customer decisions in making purchases (Magdalena & Winardi, 2020). Provide several flavors and new shapes to increase purchasing interest from potential customers. Innovation that can be initiated is to try to develop a selection of bun flavors and provide various sizes (Al Togar & Al Hakim, 2022).

The effect of power outage risk can be reduced by providing other alternative for electrical power source such as a generator set. This portable equipment provides backup power to help maintain the stability of electricity supply in the production process. Providing generators for businesses in the food industry is considered helpful in productivity and maintaining the stability of electricity supply in the production process (Mulasiwi et al., 2022).

Fatigue experienced by workers can be reduced by reconceiving how tasks are done in the production process. For instance, the business can reduce the excess workload on worker by recruiting new workers, reorganize the working hours and adding break time in it. Time off ensures that workers have time to recover from previous session before they go back to their shift. Reducing fatigue can also done by investing on tools that support work comfort such as anti-fatigue mat (Safe Work Australia, 2013).

Water is one of the most important resources used in production. But the supply of it can sometimes stop without notice, which can be an obstacle. The step that businesses can take to overcome the shortage of water supply is to buy clean water from other sources. Even though the business has to incur unexpected costs, this step can be carried out to maintain production continuity given that water supply plays a vital role as a raw material for products or as a means for steaming products and sanitation stages.

4. Conclusion and Suggestion

The results of risk identification showed that there were 20 risks that are found in the XX Bakery production process with a total RPN value of 360. There are 5 risks that made 80% of total RPN values that were prioritized for improvisations such as broken mixing machine, raw material price fluctuation, power outage, fatigued workers, and stoppage of water supplies. These risks are then further identified using fault tree to find the root events that causes them to occurs. This knowledge then serves as a basis for consideration in determining the response advice that should be given to deal with the risk. Suggestions for improvements that can be made by businesses to handle these risks are to conduct proper maintenance and inspection for mixing machine on regular basis, improve the product quality to maintain competitiveness, provide generator set as a substitute of electrical power sources, reconceive the works in the production process, and make a purchase of backup supply of water. By analyzing the risks that occur in the food production process, a business can implement preventive actions to reduce the losses incurred.

In this study there are limitations where the costs required for risk improvement are not taken into account and the research does not reach the stage of implementation, monitoring, and review of improvements. It is expected that similar research in the future can consider doing these stages.

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