Application of Bayesian Network for Food Safety Risk in Cattle Slaugtering Industry

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Abstracts - **The risk in food safety has become a significant research issue that has often been studied in food safety research. However, a few studies pay attention to investigate the relationships between risks event based on the processes using the bayesian network method. This study aims to apply the bayesian network method to measure and analyse the risk in food safety with a case study in the cattle slaughtering industry. Five (5) stages are used to apply the Bayesian network method including identification of risk event in case study, determination of probability of risk event, development of Bayesian network structure, calculation for condition probability table (CPT), and analysis of food safety in case study. Research data collection was conducted through observations, discussion and interviews with supervisors in case study. 50 cow's observations are used to investigate food safety risk in cattle slaughtering industry. Eight (8) risk events for food safety were founded and the results of Bayesian network based on processes is the slaughter process is the highest food safety risk in cow slaughtering industry.**

Keyword - **Food Safety, Bayesian Network, risk, and slaughtering industry**

I. INTRODUCTION

Nowadays, food safety has an important role for consumers. Food safety plays a role in maintaining the health of consumers as the end point of the food supply chain [1]. Fulfillment of the aspect of food safety is also encouraged to reduce consumer concerns about food safety, especially from the hazards of pesticide residues, preservatives, and hormones in livestock [2]. The survey results in China show that consumer concern for food safety is indicated by buying food in supermarkets, expiration dates, food color and nutritional content [3].

The inconsistency of the food industry in implementing food safety has a negative impact on consumers. Foods that are processed without regard to food safety aspects has also a negative impact on human health in the short or long term. This negative impact arises because of the contamination of physics, biology (pathogens) or chemistry. Some phenomena due to food that do not meet food safety aspects have occurred in various countries. In the UK, an estimated 500,000 congenital diseases are caused by pathogens [4]. In South Korea, it is estimated that every year 9.59 million people experience, 1.56 million are diagnosed and 140,000 people are hospitalized due to foodborne illness [5]. Whereas according to WHO, there are 600 million cases and 420,000 deaths caused by foodborne diseases, so training activities, government, and private cooperation are needed to support the implementation of food safety [6].

This phenomenon shows the risk of changing safe status into unsafe. To keep the risk can be eliminated or eliminated, it is necessary to identify risky activities in the food manufacturing process. Aspects of food safety so that a system can be formulated that is suitable for prevention. This study aims to (a) identify the risk event of food safety, (b) measure the opportunities for these risks with Bayesian Network. Therefore, this research contributes to the development of the use of the BN method to determine the risk of food contamination based on aspects of food safety

II. METHODOLOGY

This research was conducted in three phase, namely observation, data collection, risk statistical analysis. Several stages are need to complete each phase.

1. Observation

Observations were carried out at one of the Animal Slaughter Houses in East Java, Indonesia. This activity aims to observe the process of slaughtering animals (cattle) so that the risk event for food safety can be identified. In addition to observations, observations were also made through interviews with animal slaughterers. Observation activities carried out in April (first week) 2019.

2. Data collection

Data collection was carried out in the second week of April 2019. Data was collected using the checklist form which was arranged based on the observation stage. The code used on the form is Y (yes) and N (no). Code Y is be used if the observed activities identified are at risk of food safety. While the N code is used for activities that are not at risk of being contaminated with food safety.

3. Risk statistical analysis

After the data is obtained through data collection, then proceed with data processing. At this stage, data is processed by one of the statistical methods, namely the Bayesian Network (BN). The Bayesian method was developed by Thomas Bayes in the 1700s based on probability theory, which is expressed by equations [7]:

$$P(H|E,c) = \frac{P(H|c)xP(E|H,c)}{P(E|c)}$$

The P value (H|E,c) shows posterior opportunity, which describes the prediction of the chance of an event based on information from the E activity that occurred in the past (c). P(H|c) shows the chance of prior, namely the chance of an event occurring which is influenced by E events in the past (c). P(E|H,c) shows an opportunity that states the degree of influence between events. While P(E|c) shows evidence opportunities which are comparative measures with constant values based on information on the probability of an event occurring. Bayesian network is done through steps [8]: (a) compiling BN structure, (b) compiling BN node classification, (c) mapping BN causal relationship, (d) preparing conditional probability table (CPT).

III. RESULTS

A. Case Study

The research was carried out in a cow slaughterhouse company that conducts cutting process 4-6 cows per day. Time of production in case study is at night in order to make fresh the meat of cows. The cattle slaughtering production process is as follows:

a. Cows are slaughtered by officers determined by the management of the slaughterhouse.
b. Cutting and separating body parts: meat, innards, and skin.
c. Delivery of meat, offal and skin to traditional markets by truck.

The average time required by each officer to process cows is about 30 minutes per cow. The speed of the process depends on the skill level of the slaughterer. Furthermore, based on observations of the process, the identification of risk events for safety was arranged.

B. Stages 1: Identification of Risk Event

This stage aims to identify risk events in cattle slaughtering industry which can lead to food safety contamination.

TABLE 1.
RISK EVENT DESCRIPTION

No	Code	Description	Process
1	Fs1	The risk of animals is not healthy	Pre-slaughter (P1)
2	Fs2	Animal risk is stress and pain	
3	Fs3	The risk of the knife used to slaughter is not hygienic	Slaughter (P2)
4	Fs4	The risk of cow body parts is not safe because they contain bacteria	
5	Fs5	The risk of a knife used to cut unhygienic (rusty) parts of an animal	
6	Fs6	The location of cutting animal parts is not hygienic	
7	Fs7	Transportation equipment for meat distribution is not hygienic	Post-slaughter
8	Fs8	Meat distribution equipment is not equipped with refrigerators	

Table 1 shows that there are 8 risk events that are at risk for food safety. Furthermore, based on the results of risk identification, observations were made on the process of slaughtering animals. This observation aims to find out activities that are risky and not risky.

C. Stages 2: Determination of Probability of Risk Event

This stage aims to determine the opportunities for food safety contamination for each risk event that has been identified. Calculation of opportunities is done by observing. Observations were carried out on 50 cows. Y indicates the risk event is potentially contaminated, while N is not contaminated. The results of these observations are as follows:

TABLE 2
NUMBER OF RISK EVENT

Code	Number of risk event		Total
	Y	N	
Fs1	2	48	50
Fs2	2	48	50
Fs3	3	47	50
Fs4	3	47	50
Fs5	2	48	50
Fs6	2	48	50
Fs7	2	48	50
Fs8	4	46	50

Table 2 is a risk recapitulation for each risk event that has been identified. Based on these results, the probability of each risk event is calculated.

TABLE 3
RISK EVENT PROBABILITY

Code	Risk event probability	
	Y	N
Fs1	0,04	0,96
Fs2	0,04	0,96
Fs3	0,06	0,94
Fs4	0,06	0,94
Fs5	0,04	0,96
Fs6	0,04	0,96
Fs7	0,04	0,96
Fs8	0,08	0,92

D. Stages 3: Development of Bayesian network structure

This stage aims to develop the Bayesian Network structure. Furthermore, the structure will be used to show the relationship between risk events that occur in the cattle slaughtering industry.

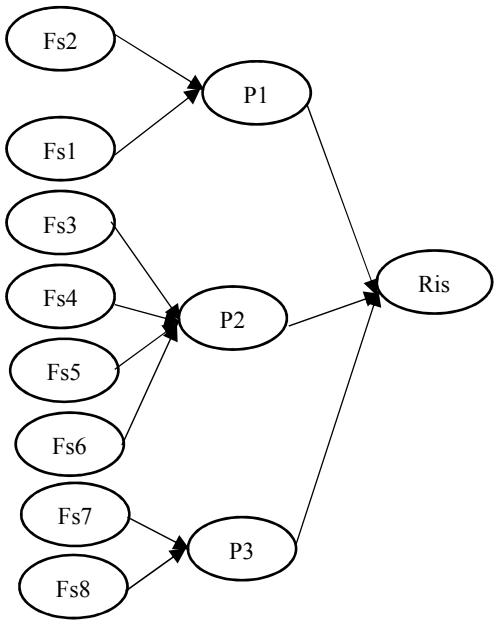

Fig 1. Structure of Bayesian Network of risk in food safety

E. Stages 4: Calculation for Condition Probability Table (CPT)

Risk event probability is used as the basis for calculations in the Bayesian Network. As a first step in the Bayesian Network, a Bayesian Network structure should be arranged. The structure of Bayesian network illustrates the relationship between food safety risks that have been identified.

The Bayesian Network structure is used as the basis for preparing the CPT. In this study, there are 3 CPTs that is calculated based on figure 1, namely P1, P2, and P3.

TABLE 4
CPT FOR P1

Fs1	Fs2	P(Fs1)	P(Fs2)	P(P1)
Y	Y	0,04	0,04	0,00
Y	N	0,04	0,96	0,00
N	Y	0,96	0,04	0,00
N	N	0,96	0,96	0,84
				0,84

TABLE 5
CPT FOR P2

Fs 3	Fs 4	Fs 5	Fs 6	P (Fs3)	P (Fs4)	P (Fs5)	P (Fs6)	P (P2)
Y	Y	Y	Y	0,06	0,06	0,04	0,04	0,00
N	Y	Y	Y	0,94	0,06	0,04	0,04	0,00
Y	N	Y	Y	0,06	0,94	0,04	0,04	0,00
N	N	Y	Y	0,94	0,94	0,04	0,04	0,00
Y	Y	N	Y	0,06	0,06	0,96	0,04	0,00
N	Y	N	Y	0,94	0,06	0,96	0,04	0,00
Y	N	N	Y	0,06	0,94	0,96	0,04	0,00
N	N	N	Y	0,94	0,94	0,96	0,04	0,00
Y	Y	Y	N	0,06	0,06	0,04	0,96	0,00
N	Y	Y	N	0,94	0,06	0,04	0,96	0,00
Y	N	Y	N	0,06	0,94	0,04	0,96	0,00
N	N	Y	N	0,94	0,94	0,04	0,96	0,00
Y	Y	N	N	0,06	0,06	0,96	0,96	0,00
N	Y	N	N	0,94	0,06	0,96	0,96	0,00
Y	N	N	N	0,06	0,94	0,96	0,96	0,00
N	N	N	N	0,94	0,94	0,96	0,96	0,69
								0,69

TABLE 6
CPT FOR P3

Fs7	Fs8	P(Fs7)	P(Fs8)	P(P3)
Y	Y	0,04	0,08	0,00
Y	N	0,04	0,92	0,00
N	Y	0,96	0,08	0,00
N	N	0,96	0,92	0,81
				0,81

TABLE 7
CPT FOR RISK

P1	P2	P3	P(P1)	P(P2)	P(P3)	P(Risk)
Y	Y	Y	0,04	0,04	0,08	0,00
N	Y	Y	0,96	0,04	0,08	0,00
Y	N	Y	0,04	0,96	0,08	0,00
N	N	Y	0,96	0,96	0,08	0,00
Y	Y	N	0,04	0,04	0,92	0,00
N	Y	N	0,96	0,04	0,92	0,00
Y	N	N	0,04	0,96	0,92	0,00
N	N	N	0,96	0,96	0,92	0,74
						0,74

TABLE 8
CPT RECAPITULATION

	Probability	
	N	Y
P1	0,84	0,16
P2	0,69	0,31
P3	0,81	0,19
Risk	0,74	0,24

Table 8 shows the results of CPT calculations for P1, P2, P3, and Risk. Based on the table, it is identified that the probability of food safety risks in the process of providing in cattle slaughtering industry is 24%. The probability shows that the opportunity for food safety contamination is 24%.

F. Stages 5: Analysis of Food Safety Risk in Cattle Slaughtering Industry

This stage is carried out to analyze the probability of the occurrence of food safety risks with the Bayesian Network. At this stage, a risk event ranking will be conducted as a basis for formulating preventive actions.

For this reason, so that the probability of contamination can be eliminated, strategic action is needed. The identification of strategic actions that need to be done is based on the risk event that has the highest chance. From the process side, the priority for eliminating contamination is based on the risk priority on the CPT for the P value.

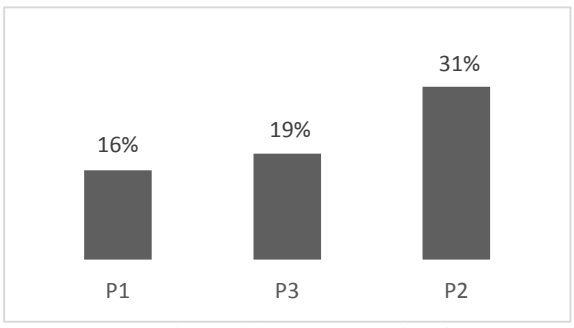

Fig 2. Priority arrangement based on CPT

Figure 2 shows that the top priority of the process that needs to be corrected immediately to eliminate contamination is P2 (slaughtering process). This process has the highest risk of contamination with food safety. For this reason, the improvement process is focused on improving the slaughter process. In more detail, the slaughter process has 4 risk events that need attention (Fs3, Fs4, Fs5, Fs6).

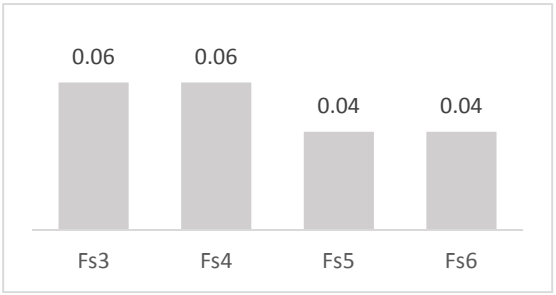

Fig 3. Risk event improvement priorities in the slaughter process

Based on Figure 3, the priority of improvements to reduce the risk of contaminated food safety is at the risk event Fs3 (not sharp knife) and Fs4 (risk of cow body parts is not safe).
For this reason, several corrective steps that need to be taken immediately are:

1. Providing equipment for sharpening knives so that the sharpness of the knife is maintained.
2. It provides a replacement knife (backup knife) that is ready for use when needed.
3. Optimize post mortem checks on animals that have been slaughtered.

IV. DISCUSSION

The results showed that there were several food safety risks that must be considered by companies in producing food. The slaughter process is a process that has the highest food safety risk. This finding of risk event is relatively the same with the findings of previous research [9,10], which states that the impact of the slaughter process on the risk of food safety is very high. Moreover, food safety risks can come from many factors, such as raw materials, distribution, marketing, and others. To reduce this risk, it is necessary to collaborate between food supply chain actors (consumers and authorities) [11]. In addition, specific strategies with location specifications can be applied to maintain food safety [12].

This research shows different results from previous studies. In China, 98.25% of food shows that it has met food quality and safety standards [13]. In the study, it was stated that dairy products and food additives had the lowest food safety risk compared to alcoholic beverages, processed fruit/vegetable products. and catering foods. For this reason, in order for food security to be guaranteed, food producers, distributors, sellers, and governments must collaborate to ensure food security, especially towards the 21st century [14].

V. CONCLUSION

Food safety is an important aspect for consumers in choosing food. This is encouraged because there is a sense of worry about the existence of food that is not safe to consume, resulting in a loss to health. For this reason, risk identification in the supply process is an important aspect of avoiding foods that are not safe for consumption.

This study identified eight risks that need to be considered in the supply of fresh meat. Of the eight risks, it can be seen that the slaughter process is the highest risk that needs attention. Therefore, the focus of attention in reducing risk is done in the slaughter process, especially the provision of tools and optimization of post-slaughter animal inspection.

The limitation of this research provides opportunities for further research. Consumers are also becoming more aware of halal food products and certification and need assessment and control models [15]. Therefore, future research should develop new framework for halal food risks using Bayesian network.

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REFERENCES

[1] J. Janjic. J.Ciric. M. Bokosvic. D. Sarccevic. M. Popovic. M.Z. Baltic. “Consumer Responsibility For Food Safety”. *Research in Agriculture*, Vol 3, No 1, pp 1-10, 2018.

[2] T. Mai Ha. S. Shakur. K.H. Pham Do. “Consumer Concern About Food Safety in Hanoi, Vietnam”. *Food Control*, Vol 98, pp 238- 244, April, 2019.

[3] A. Liu. R. Niyongira. “Chinese Consumers Food Purchasing Behaviors and Awareness on Food Safety”. *Food Control*, Vol 79, pp 185-191, September, 2017.

[4] C.C. Tam. T. Larose. S.J.O’ Brien. “ Costed extension to the Second Study of Infectious Intestinal Disease in the Community: Identifying the proportion of foodborne disease in the UK and attributing foodborne disease by food commodity”. *UK Food Standar Agency*, University of Liverpool.

[5] Y. S. Kim. S.H. Lee. S.H. Kim. Y. Joo. G.J. Bahk. “Investigation of The Experience of Foodborne Illness and Estimation of The Incidence of Foodborne Disease in South Korea”. *Food Control*, Vol 47, pp 226-230, 2015.

[6] K. Hoelzer. A.I. Moreno Switt. M. Wiedmann. K.J. Boor. “Emerging needs and opportunities in foodborne disease detection and prevention from tools to people’. *Food Microbiology*, Vol 75, pp 65- 71, October, 2018.

[7] A. Lockamy, “Benchmarking supplier risks using Bayesian network”. *Benchmarking an International Journal*, Vol 18, No 3, pp 409- 427, 2011.

[8] P. Xin., F., Khan. S., Ahmed, “Dynamic hazard identification and scenario mapping using Bayesian

network". *Process Safety and Environmental Protection*, Vol 105, pp 143- 155, 2017.

[9] H.C. Wahyuni, Vanany I., Ciptomulyono U, "*Identifying risk event in Indonesian fresh meat supply chain*". *1st International Conference on Industrial and Systems Engineering, IConISE 2017*. 2018: Institute of Physics Publishing.

[10] H.C. Wahyuni, Vanany I, Ciptomulyono U, "Food Safety and Halal Food Risk in Indonesian Chicken Meat Products: An Explonatory Study". *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, December, 2018.

[11] G. Kazsa. B.S. Bodi. Z. Lakner. T.Izso. "Balancing the desire to decrease food waste with requirements of food safety". *Trends in Food Science & Technology*, Vol 84, pp 74-76, February, 2019.

[12] E. De Boeck. L. Jacxens. P. Vanoverberghe. P. Vlerick. "Method triangulation to assess different aspects of food safety culture in food service operations". *Food Research International*, Vol 116, pp 1103- 1112, February, 2019.

[13] Y. Yang. L. Wei. J. Pei. "Application of Bayesian modelling to assess food quality & safety status and identify risky food in China market". *Food Control*, Vol 100, pp 111-116, 2019.

[14] F. Fung. H.S. Wang. S. Menon. "Food safety in the 21st century". *Biomedical Journal*, vol 41, iss 2, pp 88-95, 2018.

[15] I. Vanany, G. A. Maarif, and J. M. Soon, "Application of multi-based quality function deployment (QFD) model to improve halal meat industry," *Journal of Islamic Marketing,* vol. 10, no. 1, pp. 97-124, 2019, doi: doi:10.1108/JIMA-10-2017-0119.