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Integrated risk to food safety and halal using a Bayesian Network model

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ABSTRACT

This study aims to comprehensively identify risks to food safety and halal status in food manufacturing processes. The research was conducted through risk identification, data collection, Bayesian Network (BN) structure, decision analysis, and mitigation programs. The results showed that there were 19 integrated risks to food safety and halal. Twelve risks were due to food safety and seven risks were due to halal status. Overall, risks identified were described through the BN structure, which consists of four levels, as a basis for determining risk opportunity values. The results of BN decision analysis show that the highest integrated risk to food safety and halal each level. The risk of chickens dying when stunning is the highest risks in level 1 and cleaning and chilling department in level 2. The partially integrated risks for level 3 and total integrated risks in level 4 has a chance of contamination. Due is the results, the analysis and decision analysis is to reject or rework.

KEYWORDS

Food safety; halal; Bayesian Network; risk assessment

Introduction

Food safety and halal are essential aspects for consumers to choose food to be consumed because of health and religious beliefs. Food safety is critical for human because it relates to human physical health, while halal is crucial because it relates to a Muslim's adherence to the provisions of the Islamic religion. Besides, halal for non-Muslims is a guarantee of quality food that is safe for consumption. Food safety is in line with the concept of halal. Therefore, the concept of food safety must be adopted so that the availability of halal food can be realised (Raheem and Demirci; Krishnan et al. 2017). Foods that meet the elements of food safety are free from biological, chemical and physical dangers. Microbiological hazards are sourced from microorganisms such as bacteria, parasites, and viruses; chemical hazards derived from pesticides, and chemicals for food processing; and physical hazards are usually caused by fragments resulting from the food production process (Ruby et al. 2019). Halal status is mandatory in the Muslims' diet. Halal, defined as all things or actions allowed following Islamic law, is stated in the Al-Quran and Hadith (Bonne et al. 2007; Fuseini et al. 2016; Khan, Haleem, and Khan 2018). The halal concept is increasingly widespread along with the increasing Muslim population in the world, which is accompanied by the increasing demand for halal production methods both globally and in regional Europe (Verbeke et al. 2013).

In Ghana, 57-91% of consumers are concerned about hygiene issues in places to cook and sell food that pose a risk to food safety (Omari, Frempong, and Arthur 2018). Consumer's concerns in Vietnam are also severe, primarily due to pesticide residues, food preservatives, and hormones in livestock (Mai, Shakur., and Pham Do 2019). The same is true for the halal status. Consumers' concerns about halal food are high, that is whether or not food is lawful because of the process. The risk comes from several things, for example: the use of enzymes (Ermis 2017), ethanol (Alzeer and Hadeed 2016; Pauzi et al. 2019) in livestock, the distributors, the slaughter and the retailers (Wahyuni, Vanany., and Ciptomulyono 2018). Halal risk identification provides many benefits for the industry, including developing risk prevention, mitigation, and recovery measures (Tieman 2017). Due to the risk non-compliance with halal standards will have an impact on the decline in industrial economic profits (KKhan et al. 2019).

To solve the problem, food companies must guarantee food safety and halal status. To be able to provide the guarantee, companies need to identify and measure risks to eliminate changes in food status (unsafe and not halal). The integration of functions and tasks to manage risks for food safety and halal is more critical to achieving efficient and effective operations in quality and halal assurances in food companies. Integration between two or more functions is essential because it has implications for achieving high performance by utilising labour and minimal time to obtain better quality (Chen, Daugherty, and Landry 2009; Kobayashi, Tamaki, and Komoda 2003).

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Besides, integration is also needed because of the increasing complexity and competition between companies, as well as requiring integration of the flow of goods and information in order to improve operational and business performance (Mostert, Niemann, and Kotze 2017).

The integration of managing risk in food safety and halal is encouraged to conduct by food companies. Alzeer, Rieder, and Hadeed (2018) believe the primary goal of halal status is not only to meet the halal standard but also to meet food safety requirements. They also believe halal certification is also mean clean and safe food following 'Syaria' law. In the halal certification process, halal standards as main guidelines must be fulfilled by food companies to get halal certifications are now part of the requirements of food safety. (Demirci, Soon., and Wallace 2016). The identification of risk events as the first stage in risk management stages is a significant stage because the results of this stage will affect the next stage. If there are the unidentified risk events, then in the next stage, the unidentified risk events cannot be structured, assessed, analysed, and mitigated. The business process approach is often used as a basis in risk identification stages in order for all risk events from receiving raw materials as the first process until delivering finished products to customers as final process are identified. The business process approach can describe the risk events (sources) in risk identification stages and also has the ability to integrate them (Lambert, Jennings, and Joshi 2006; Berente, Vandenbosch, and Aubert 2009). Therefore, the study for integrated risk to halal and food safety needs the business process approach to find out the business process flow in the food company.

This study aims to measure integrated risk to food safety and halal. Risk measurement is done by identifying the probability of a risk event. The food safety risk is the risk of food contamination from the aspect of food safety (chemistry, physics, biology), meanwhile the halal risk is a risk that arises due to incompatibility of the process with the provisions of the Islamic religion. The risk model is built on two main phases of management, which consist of risk identification and risk assessment (Septiani, Herdiyeni., and Haditjaroko 2016). Integrated risk probability measurement is carried out using the Bayesian Network (BN) method. Sykora, Markova, and Diamantidis (2018) pointed out that BN was chosen because it was able to show the value of uncertainty statistically and was able to describe the relationship between output data and input used graphically (Kwag, Gupta, and Dinh 2018; Smid et al. 2010).

Research design

Two main stages of research are used to developing and testing the applicability of an integrated risk to food safety and halal using Bayesian Network Model. A case study research is generally used to test the proposed model based on Bayesian Network model such as Sharma and Sharma (2015), Qazi et al. (2018), and Hosseini, Ivanov, and Dolgui (2019). In the first stages, the development of integrated risk to food safety and halal was carried out based on the Bayesian Network model. The second stage used a case study to test the applicability of the proposed model in chicken processing companies.

Development of an integrated risk to food safety and halal model

The proposed model used 5 (five) stages to manage the integrated risks among food safety and halal using Bayesian Network. The objectives, factors, and formula are also described in each stage.

Stage 1: risk identification

The goal to be achieved at this stage is to obtain integrated types of food safety and halal risks. Risk identification can be done based on the scope of the research In this study, risks were identified in two (2) categories, namely:

a. Food safety risk

In this study, the risk of food safety is based on aspects of risk expressed in ISO 22,000 on food safety, namely the risk of food contamination originating from physical, chemical and biological contamination. Physical risks in the food industry often occur due to the mixing of food products with foreign objects such as stones, gravel, rubber, broken glass, etc. Chemical risks occur due to contamination from organic chemical compounds such as antimony, mercury, lead, etc. While biological risks are caused by contamination from the presence of parasites, viruses or bacterial pathogens that cause poisoning and infection in humans. Besides based on chemical, physical and biological risk classification, basically, food safety risks can be classified based on other risk elements such as food chemical safety, food allergens, raw materials, pathogenic microorganisms (Barlow et al. 2015), risks based on heavy metal contamination, bacteria and pesticides (Mai, Shakur., and Pham Do 2019), fat, protein, non-fat stable milk, acidity, lead, mercury, arsenic, chromium, aflatoxin (Han et al. 2019).

b. Halal Risk

Halal risk is the risk of food contamination from non-halal factors, such as equipment, location, facilities, labour (Demirci, Soon., and Wallace 2016). In addition, the source of halal risk can also come from the retailer's misunderstanding, distributors of the concept of halal, the implementation of halal status, the absence of halal requirements in work contracts, and cargo status that does not distinguish between halal and non-halal goods (Tieman 2017). Besides, halal risk can also occur due to lack of information about the production process, animal feed, animal medicine, proximity of the animal enclosure (cattle) to the pigpen (Maman, Mahmubi, and Jie 2018).

The integration process is carried out by identifying risks throughout the process based on food safety and halal. This stage identifies risks to food safety and halal status that will cause food contamination. Rns deals with food safety (physics, chemistry, biology) and the risk to halal status with n = 1, 2, ... n. In the observation, each Rns and Rnh answered by the code Y or N.

The Y and N listed in Table 1 show the contamination (Y/yes) and non-contaminated (N/no). Codification of contamination can be done with several other terms to indicate contaminated or not, including: affected/non affected (Liu et al. 2019; Bouzembrak and Marvin 2019; Sharma and Sharma 2015), low, medium, or high (Marvin et al. 2016) or short, medium, long (Chan et al. 2018).

Stage 2: data collection

This step aims to develop a research plan, including the observation sheets, time, and data processing and literature review. This plan is prepared according to the stages of the research that have been determined. Furthermore, the research plan, especially the observation sheets that have been prepared, are disseminated to surveyors who will assist the observation process. At this stage, communication is also carried out with all parties who will be the object of observation/interview. The data collection stage was conducted through observation and interview method.

Table 1. Risk identification.

No	R_1	R_2	R_3	R_4	......	Rn
1	Y	N	N	N	...	N
2	Y	Y	N	N	...	N
3	Y	Y	Y	N	...	N
....	....	....	....	....	....	....
n	Y	Y	Y	Y	Y	Y

Stage 3: Bayesian Network Structures

Bayesian Network structures are described in nodes, arcs, and probabilities. The node value can be discrete or continuous, but most of the values are discrete (Bouzembrak and Marvin 2019). The Bayesian Network Structure for Integrated Risk to Food Safety and Halal Risk integrated is shown in Figure 1.

Figure 1 consists of three nodes: food safety risk, halal risk, and integrated risk. Food safety risk and halal risk is called parent nodes and integrated risk is called a child node. The parent nodes and child node is connected to an arc. Two types of events in each node are Yes (Y) for occurrence of risk when observed and No (N) for no-occurrence of risk when observed. For example, the value of the possibility of a risk to food safety is 0.05, halal status is 0.02, and while the N (no) values in food safety risk is 0.95 and in halal risk is 0.98 based on data collection (see Figure 1). The calculation for P (Risk integrated) is shown in Figure 1. P (integrated risk) shows the probability of the occurrence of integrated risk to food safety and halal status. Furthermore, this data is used to calculate the value of conditional probability assessment (CPA)

The next step is to arrange CPA, which is a level of quantitative confidence that describes an event's uncertainty. CPA is a tabulation form that contains the probability of each possible risk event that might occur. For the risk integrated node, there are four combinations of probabilities. The value of CPA is calculated by using Bayes theory, which is based on

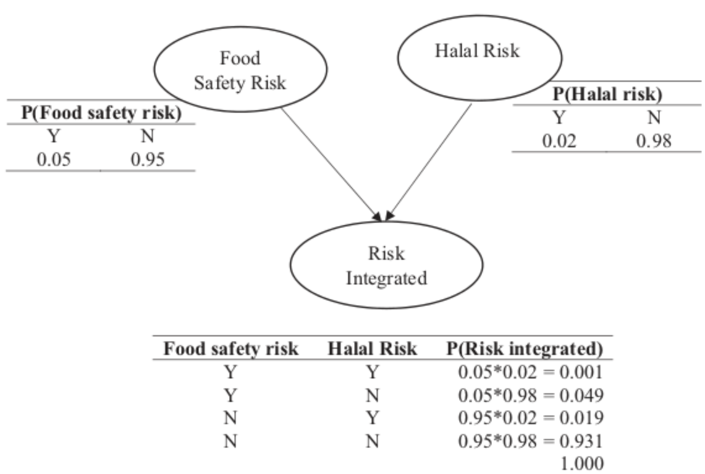

Figure 1. Bayesian Network Structure for integrated risk to food safety and halal risk integrated.

conditional probability. Bayes theory was put forward by Thomas Bayes in the 1700's and subsequently combines subjective beliefs with evidence known as the Bayesian Network, with a basic formula (Lockamy 2017):

$$P(H|E,c) = \frac{P(H|c)P(E|H,c)}{P(E|c)} \quad (1)$$

Equation [P (H | E, c)] represents the probability of the hypothesis H by considering the occurrence of activity E in the past c. Whereas P (H | c) is an a priori probability of H given by c. For this reason, a-priori probability is a subjective belief in the occurrence of hypothesis H based on past experience. P (E | H, c) is the probability of the occurrence of the hypothesis H based on background information c in the past is true. The Bayesian Network value is determined by combining the probability of all variables by using the following formula:

$$P(X) = \prod_{i=1}^{n} P(Yi|pa(Yi)) \quad (2)$$

X is a combination of all the variables (risks) consisting of Yi … Yn. The pa (Yi) is defined as the parent variable of Yi. BN illustrates the combined probability distribution of all probability with formula P (X) = Yi … Yn. The CPA value is described in $P(Yi|pa(Yi))$.

Stage 4: decision analysis

Decision analysis is an important aspect of determining a solution to a problem. Before making a decision, every alternative problem solving needs to be analysed related to the impact, effectiveness and efficiency in solving the problem that occurred at that time. Alternatives that can be used as options include discarded or reprocessed products if contaminated with food safety and halal. Bystrzanowska and Tobiszewski (2018) states that decision analysis can be carried out mainly related to complex decision-making processes, there are a number of alternative decisions, multistage decision making, decision issues are very important, decisions taken are associated with very high profits.

One method that can be used as a tool in decision analysis is BN. BN is an effective tool for providing decision support based on expert knowledge in an uncertain and complex environment. In a study conducted by Pant et al. (2019) using the BN model with the Bayesian Belief Network (BBN) specification to estimate population parameters for stakeholder groups, based on a sample assessment of individual values. This approach allows the quantification and visualisation of variability in views between and within stakeholder groups.

In this study, decision analysis is based on the results obtained at the CPA stage. In this section, we will discuss the impact of each risk based on the probability value and the follow-up actions from this impact, which will be reprocessed or discarded. The results of calculations with BN obtained are then used to set risk priorities. Determination of risk priorities is based on the highest probability value to the lowest probability.

Stage 5: mitigation programs

As a form of anticipation so that opportunities for risk occurrence do not occur, it is necessary to determine mitigation programs. This is important to do, because the mitigation programs are expected to be able to produce strategic steps in reducing food and halal security risks. Although, currently there are a number of activities that have been carried out by the food industry related to risk mitigation and require high investment funds, but have not provided maximum results (Schmid 2019). For this reason, the determining for mitigation programs must be based on existing real conditions and on the priority of risks that will occur in the process in the food industry.

The analysis shows that the safety risks of contaminated food and halal status can stem from both, and the consequence is that the product must be rejected or reprocessed. Rejection or reprocessing of products is one of the actions that require operational costs, so it needs to be reduced. Reduction of this process is necessary because these costs are a form of waste, so they need to be eliminated. In addition, mitigation programs can be implemented by carrying out a variety of activities that are based on the priority occurrence of the risk.

Case study

The application of the proposed Bayesian network for integrated risks to halal and food safety is carried out on chicken processing company that have implemented certification for food safety and halal. The company is also supported by a subsidiary of chicken farms. Processing capacity of ± 8,000 chickens per day. Facilities owned by the company to support its products such as cold storage with a capacity of ± 1,000 tons, Air Blast Freezer (ABF) room and chilling room. Figure 2 shows the chicken processing flows that begins with the inspection of raw materials (chickens) from various regions in East Java, Indonesia.

Risks identification

Risks identification is carried out, starting from the process of procuring raw materials to the delivery of fresh chickens to consumers. Table 2 shows the types of risk found in the chicken meat supply chain, especially in the manufacturing process. Nineteen risks are consisting of 12 risks to food safety and seven risks to halal status. When further analysis, risks originating

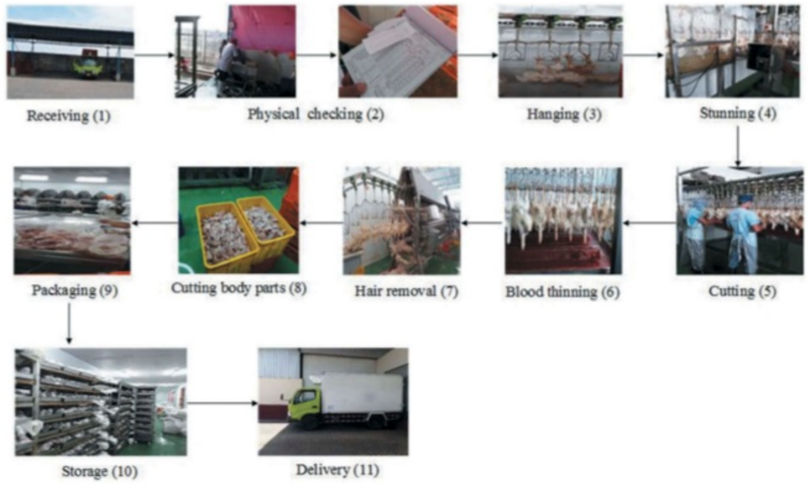

Figure 2. Chicken processing flows.

from food safety can be grouped into three main groups, namely biology (4 types of risk), chemistry (0 types of risk) and physics (8 types of risk). This food safety risk arises because the washing process is not clean enough to allow the growth of bacteria (biology), mixed with foreign objects such as rubber, gravel, etc. Meanwhile, halal sources can be classified into three main groups, namely material (1 risk), equipment/work methods (4 risks) and actors (1 risk). One of the causes of halal risk is a knife that is not sharp enough so that the chicken does not die in a short time.

Data collections

Data collection is carried out through an observation method that aims to observe all processes in order to identify risks in each section/department. Observations in each department were made by 1–2 observers by filling out the form prepared earlier. Observations were made on 2,000 chickens for 2 weeks. In addition, Table 2 also shows the results of observations on the number of observations that are at risk of contamination (Y) and non-contamination (N) of food safety or halal. The number of chickens identified as being contaminated with food safety and halal is shown in Table 2. For example, for the risk of bruising chicken (R1), there were eight chickens contaminated, and 1,992 chickens were not contaminated, similar things can be seen for the risk of physical disability of chickens(R2) through the contaminated products that are not halal (R19).

Bayesian Network Structure

Based on the results of risk identification in Table 2, the BN structure is constructed. In Figure 3, the probability of integrated risks to food safety and halal status is calculated from 4 levels of risk, namely:

- *Level 1: Process risk*: in this level, risks are identified based on each activity carried out in the production process. The identification process starts from the arrival of raw materials (chickens) until the product (chicken meat) is ready to be sent to consumers. In this section, the identified risks are symbolised by R, and overall in this case there are 19 risks.
- Level 2: *Department risk*: this risk are accumulated risks from several process risks in the department. Level 2 is indicated by the symbol P1 (receiving) through P8 (delivery). In the concept of parent-children that are often used in the BN, the risk of bruising chicken (R1) through contaminated products that are not halal(R19) are children and receiving (P1) to delivery (P8) process are parents.
- *Level 3: Business risk*: this risk shows the risk probability integrated in each business process in the poultry farming company. This research uses 3 types of business processes, namely: Raw material process (BP1), Manufacturing process (BP2) and Storaging process (BP 3).
- *Level 4: Integrated risk*: this is risk probability of food safety and halal status. At this level, integrated risk parents, while 3 types of business risks as children of integrated risk level.

Level 2

The calculation on level 2, CPA begins with calculating the probability value of each P based on the risk of its formation (see Figure 3).

CPA at level 2 consists of the receiving (P1), stunning (P2), chicken slaughter (P3), blood draining (P4), cleaning chicken (P5), plucking a chicken feather (P6) and packing (P7) process. Specifically for CPA in stunning (P2), blood draining (P4), and plucking a chicken feather (P6) the value is equal to the risk value of the

Table 2. Risk identification in the chicken meat supply chain (level 1).

					Observation		Decision	
Process	Department	Risk Code	Type of Risk*	Description	Y(chickens)	N (chickens)	Reject	Rework
Raw material process	Receiving P1)	R1	Fs-p	The risk of bruising chicken	8	1,992		v
		R2	Fs-p	The risk of physical disability of chickens	19	1,981		v
		R3	Fs-p	Risk of weak chicken physical condition	6	1,994	v	
Manufactur process	Stunning(P2)	R4	H-e	The risk of chickens dying when stunning	32	1,968	v	
	Chicken slaughter (P3)	R5	H-e	The risk of slaughter process is less than perfect (2 slaughter times)	22	1,978	v	
		R6	Fs-b	Risk of imperfections in the copying process	3	1,997		v
		R7	H-a	The risk of the slaughterer does not understand the slaughter process so that there are unbroken nerves	9	1,991	v	
		R8	H-e	The risk of cutting tools (knives) is less sharp	8	1,992	v	
	Blood draining (P4)	R9	Fs-p	Risk of residual blood in chickens	27	1,973		v
	Cleaning chicken (P5)	R10	H-e	The risk is that chickens are still alive when boiled	18	1,982	v	
		R11	Fs-p	Removal of chicken feathers is not clean	22	1,978		v
		R12	Fs-b	Damage to chicken meat because it contains microbes due to boiling is not according to the standard	31	1,969		v
		R13	H-e	Halal defect due to boiling imperfection	11	1,989	v	
	Plucking a chicken feather (P6)	R14	Fs-p	Damaged chicken products because they contain small remaining chicken feathers	13	1,087		v
	Packing (P7)	R15	Fs-p	Damage to chicken products due to imperfect packaging etc.	26	1,974		v
		R16	Fs-b	Broken chicken due to temperature instability	3	1,997		v
Storage process	Delivery (P8)	R17	Fs-p	Risk of foreign objects in transportation	17	1,983		v
		R18	Fs-b	Broken chicken due to temperature instability in cold storage cars	10	1,990		v
		R19	H-r	Contaminated products that are not halal	9	1,991	v	

*Fs-p: Food safety-physics
Fs-b: Food safety-biology
H-e: Halal-equipment
H-a: Halal-actor
H-r: Halal- raw material

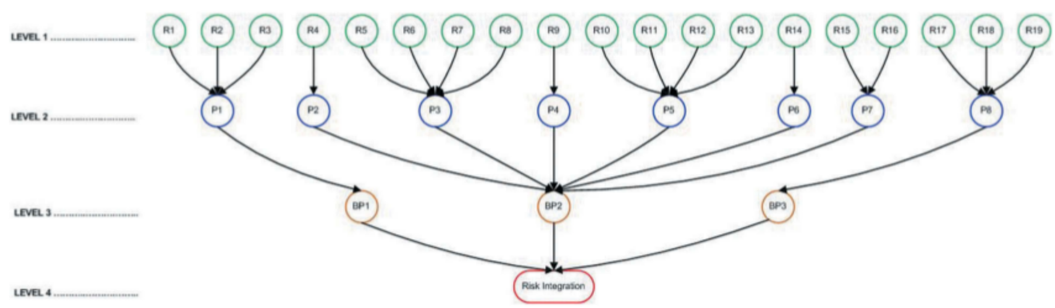

Figure 3. Bayesian Network Structure in case study.

risk of chickens dying of stunning (R4) for stunning (P2) process, risk of residual blood in chickens (R9) for blood draining (P4) and damaged chicken products because the contain small remaining chickens feathers (R14) for plucking a chicken feather (P6) process. The results shown in Table 3 represent opportunities for non-contaminated (N) food safety and halal risks. While the risk of contamination at level 2 is shown in Figure 4.

Figure 4 shows the CPA's values for P1 through P8 (See Table 2). The value of CPA illustrates the probability of contamination at level 2. The cleaning chicken (P5) has an integrated risk to food safety and halal status and as risk accumulated from R10, R11, R12, and R14 (see Figure 2). The results of the cleaning chicken being a critical risk point that needs to be considered more seriously by the company.

Level 3

The value of Raw material entity (BP1) is similar with receiving process (P1), and storage (BP3) is similar with delivery process (P8). Therefore, the CPA value for raw material entity (BP1) and storage entity (BP3) is the same as the receiving (P1) value for raw material (BP1), delivery process (P8) for storage entities (BP3). Whereas manufacturing entity (BP2) is influenced by six departments (stunning (P2), chicken slaughter (P3), blood draining (P4), cleaning chicken (P5), plucking a chicken feather (P6), and packing (P7) process.

Table 3. Risk probability in level 2.

P1								
R1	R2	R3	Account	Probability	P(R1)	P(R2)	P(R3)	P
N	N	N	1,964	0.9820	0.9960	0.9905	0.9970	0.9658
Y	N	N	8	0.0040	0.0040	0.9905	0.9970	0.0000
N	Y	N	22	0.0110	0.9960	0.0095	0.9970	0.0001
N	N	Y	5	0.0025	0.9960	0.9905	0.0030	0.0000
Y	Y	N	0	0.0000	0.0040	0.0095	09970	0.0000
Y	N	Y	0	0.0000	0,0040	0,9905	0.0030	0.0000
N	Y	Y	1	0.0005	0,9960	0,0095	0,0030	0,0000
Y	Y	Y	0	0.0000	0.0040	0.0095	0.0030	0.0000
								0,9659

P3										
R5	R6	R7	R8	Account	Probability	P(R5)	P(R6)	P(R7)	P(R8)	P
N	N	N	N	1962	0.9810	0.9890	0.9985	0.9955	0.9960	0.9605
Y	N	N	N	21	0.0105	0.0110	0.9985	0.9955	0.9960	0.0001
N	Y	N	N	0	0.0000	0.9890	0.0015	0.9955	0.9960	0.0000
Y	Y	N	N	0	0.0000	0.0110	0.0015	0.9955	0.9960	0.0000
N	N	Y	N	5	0.0025	0.9890	0.9985	0.0045	0.9960	0.0000
Y	N	Y	N	1	0.0005	0.0110	0.9985	0.0045	0.9960	0.0000
N	Y	Y	N	3	0.0015	0.9890	0.0015	0.0045	0.9960	0.0000
Y	Y	Y	N	0	0.0000	0.0110	0.0015	0.0045	0.9960	0.0000
N	N	N	Y	8	0.0040	0.9890	0.9985	0.9955	0.0040	0.0000
Y	N	N	Y	0	0.0000	0.0110	0.9985	0.9955	0.0040	0.0000
N	Y	N	Y	0	0.0000	0.9890	0.0015	0.9955	0.0040	0.0000
Y	Y	N	Y	0	0.0000	0.0110	0.0015	0.9955	0.0040	0.0000
N	N	Y	Y	0	0.0000	0.9890	0.9985	0.0045	0.0040	0.0000
Y	N	Y	Y	0	0.0000	0.0110	0.9985	0.0045	0.0040	0.0000
N	Y	Y	Y	0	0.0000	0.9890	0.0015	0.0045	0.0040	0.0000
Y	Y	Y	Y	0	0.0000	0.0110	0.0015	0.0045	0.0040	0.0000
										0.9606

P5										
R10	R11	R12	R13	Account	Probability	P(R10)	P(R11)	P(R12)	P(R13)	P
N	N	N	N	1919	0.9595	0.9910	0.9890	0.9845	0.9945	0.9207
Y	N	N	N	18	0.0090	0.0090	0.9890	0.9845	0.9945	0.0000
N	Y	N	N	22	0.0110	0.9910	0.0110	0.9845	0.9945	0.0001
Y	Y	N	N	0	0.0000	0.0090	0.0110	0.9845	0.9945	0.0000
N	N	Y	N	30	0.0150	0.9910	0.9890	0.0015	0.9945	0.0000
Y	N	Y	N	0	0.0000	0.0090	0.9890	0.0015	0.9945	0.0000
N	Y	Y	N	0	0.0000	0.9910	0.0110	0.0015	0.9945	0.0000
Y	Y	Y	N	0	0.0000	0.0090	0.0110	0.0015	0.9945	0.0000
N	N	N	Y	10	0,0050	0.9910	0.9890	0.9845	0.0055	0.0000
Y	N	N	Y	0	0.0000	0.0090	0.9890	0.9845	0.0055	0.0000
N	Y	N	Y	0	0.0000	0.9910	0.0110	0.9845	0.0055	0.0000
Y	Y	N	Y	0	0.0000	0.0090	0.0110	0.9845	0.0055	0.0000
N	N	Y	Y	1	0,0005	0.9910	0.9890	0.0015	0.0055	0.0000
Y	N	Y	Y	0	0.0000	0.0090	0.9890	0.0015	0.0055	0.0000
N	Y	Y	Y	0	0.0000	0.9910	0.0110	0.0015	0.0055	0.0000
Y	Y	Y	Y	0	0.0000	0.0090	0.0110	0.0015	0.0055	0.0000
										0.9209

P7						
R15	R16	Account	Probability	P(R15)	P(R16)	P
N	N	1965	0.9825	0.9870	0.9985	0.9682
N	Y	9	0.0045	0.9870	0.0015	0.0000
Y	N	26	0.0130	0.0130	0.9985	0.0001
Y	Y	0	0.000	0.0130	0.0015	0.0000
						0.9683

P8								
R17	R18	R19	Account	Probability	P(R17)	P(R18)	P(R19)	P
N	N	N	1964	0.9820	0.9915	0.9950	0.9955	0,9644
Y	N	N	17	0.0085	0.0085	0.0050	0.9955	0,0000
N	Y	N	10	0.0050	0.9915	0.9950	0.9955	0,0049
N	N	Y	9	0.0045	0.9915	0.9950	0.0045	0,0000
Y	Y	N	0	0.0000	0.0085	0.0050	0.9955	0,0000
Y	N	Y	0	0.0000	0.0085	0.0050	0.0045	0,0000
N	Y	Y	0	0.0000	0.9915	0.9950	0.0045	0,0000
Y	Y	Y	0	0.0000	0.0085	0.0050	0.0045	0,0000
								0.9693

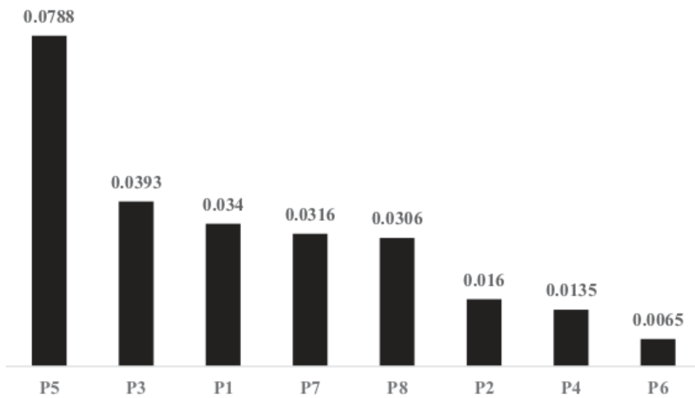

Figure 4. CPA value for level 2 (Y = Yes).

Table 4. Risk identification for P (level 3).

	Observations	
Risk event	Y (chickens)	N (chickens)
P1	11	1,989
P2	27	1,973
P3	8	1,992
P4	35	1,965
P5	23	1,987
P6	4	1,996
P7	10	1,990
P2	9	1,991

Therefore, the CPA value for manufacturing entity (BP2) in level 3 was calculated based on the results data from six departments in Table 4. The manufacturing entity (BP2) is formed from accumulated risks in level 2, such as stunning (P2), chicken slaughter (P3), blood draining (P4), cleaning chicken (P5), plucking a chicken feather (P6), and packing (P7) that consists of 64 combinations. The manufacturing entity (BP2) was calculated using Hugin software (see Figure 5).

The Bayesian network calculation shows that the probability of contamination of food safety and halal is 8.92%, while the probability of not being contaminated is 91.08%. Overall, the CPA values for level 2 that illustrate the probability value of food safety and halal contamination in Figure 4:

Figure 6 shows that the most significant risk of food safety and halal contamination at level 3 is BP2. This risk is driven because there are many activities at BP2 that are contaminated by food safety and halal.

Level 4

Level 4 is an integrated risk to food safety and halal status resulting from business risk processes such as Raw material (BP1), Manufacturing (BP2) and Storage entities (BP3). The results at level 4 illustrate the event probability of integrated risks in the whole process. The CPA was calculated based on Table 5 using Hugin Software (see Figure 7)

In Figure 8, we can see that the probability of integrated risk to food safety and halal status (Y) shows contamination at 1.7%, while the uncontaminated probability is (N) 98.30%. This value means the risk of a product being contaminated in terms of its safety, and halal status is minimal. However, even though the

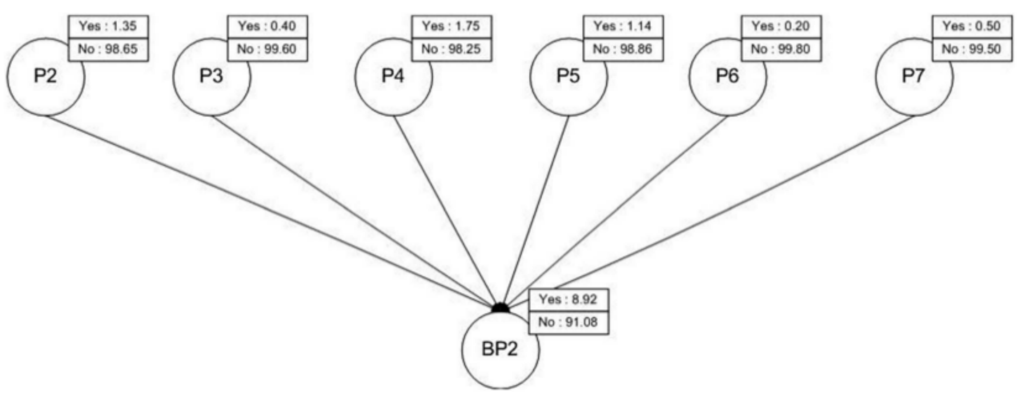

Figure 5. Bayesian Network Structure for BP2 in level 3.

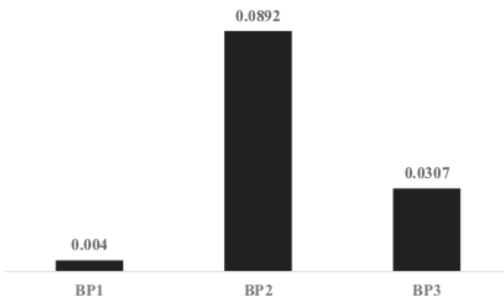

Figure 6. CPA value for level 3 (Y = Yes).

Table 5. Risk identification for BP (level 4).

	Observations	
Risk event	Y (chickens)	N (chickens)
BP1	11	1,989
BP2	27	1,973
BP3	8	1,992

probability of contamination is small, it cannot be ignored because even the slightest contamination is still harmful to physical health if consumed.

Decision analysis

Data is compiled based on the frequency of the most contaminated risk events. Risk probability is obtained by dividing the number of contaminated risk events with the entire observation data (2,000 data sets). From 2,000 data sets, the risk of chickens dying of stunning (R4) (has the most contaminated risk events. the risk of chickens dying of stunning is one of the risks to halal status. The stunning process mainly causes this. The

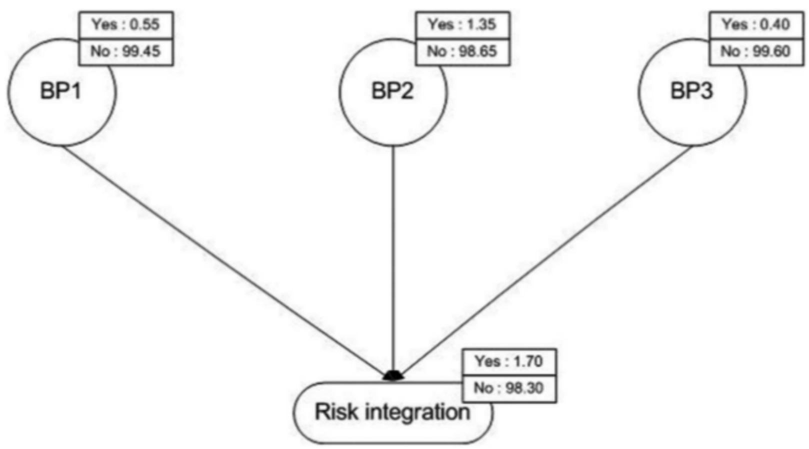

Figure 7. Bayesian Network Structure for risk integration in level 4.

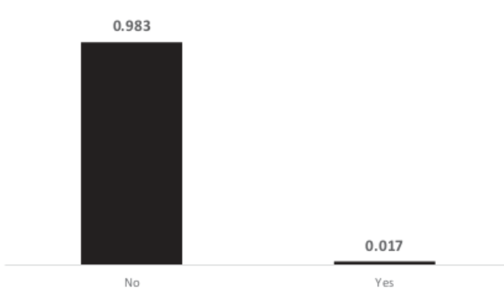

Figure 8. CPA value for level 4-risk integration.

stunning process becomes the highest risk event because chickens that die stunned are included in the non-halal category. Death from the stunning process by using electric shock on the stunning tool does not meet the Islamic standard. Meanwhile, Broken chicken due to temperature instability (R16) is a risk event that has the least amount of contamination. The broken chicken due to temperature instability (R16) is one of the risks to food safety (biology). This risk is posed by temperature instability in the storage process. The temperature in a warehouse that does not meet the standards will trigger the growth of microbes in the product. The microbe is one form of food safety contamination.

Overall, CPA for integrated food safety and halal risks is 1.7%. Even though it is small (1.7%), the results of the study indicate that there is a risk to food safety and halal status. They need special attention from the company so that the risk to food safety and halal status can be avoided. This data shows that contaminated products in terms of its halal status must be rejected and that they cannot be reprocessed, which means halal is absolute.

The risk to food safety, which results in the product being rejected, is often due to chickens' poor physical conditions due to shipments from farmers to the company. These conditions cause chickens to die before the slaughter, which means non-halal. Halal contamination can also be caused by equipment and humans (labour). For example, the equipment used is not sharp enough, so the slaughter must be done repeatedly. In the context of 'Sharia law', slaughtering must use a sharp knife, which means chickens must die quickly. The risks caused by labour are because they are in ignorance of the Islamic slaughter procedures.

Mitigation programs

Analysis results indicate that the risk of contaminated food safety and halal status may come from either of them, and the consequence is that the product must be rejected or reprocessed (rework). For this reason, companies need to prepare strategic steps to anticipate and prevent the risk from arising. Rework is a rework process because of the contamination of the product. Rework can be done if the product is contaminated with food safety, does not apply to halal contamination. Rework begins with cleaning the contaminants and is then reprocessed into new products. As an example of a rework event, if the product is physically contaminated (mixed with stones, gravel at the time of packaging), the repacking process will be carried out by removing the stones, the gravel. However, if it is not possible to do rework, then the product will reject. For example, if a chicken dies before slaughtering, then the product must be discarded because if the process is continued, the product will not be halal.

Strategic steps for improvement can be done through training, improvement of work equipment, certification, supplier selection, and collaboration with the government. The company conducts employee training to ensure that the person has the required competencies, and records of the training are documented and scheduled. Equipment repairs are carried out following the elements of food safety and halal, for example meeting the criteria of suitability and ease of access for cleaning, maintenance, and maintenance of a preventive nature and the use of equipment separately for halal and non-halal products. Food safety and halal certification can be used as a guarantee that the available food can be traced to the supply chain so that it can be used as an anticipation of the negative impacts (risks) that result (Sun and Wang 2019). For this reason, certification allows the company to choose suppliers to meet their production needs. In this selection process, companies can use several criteria to select suppliers that suit their needs, for example, based on food safety criteria, quality, delivery time, service quality, company branding (Kai-Fu 2019), price, cost, long-term cooperation projections, delivery time, supplier profile, and supply sustainability (Alikhani, Torabi, and Altay 2019) or based on economic, social and environmental dimensions (Luthra et al. 2017). Collaboration with the government is carried out through the process of coaching and mentoring – generally, policies imposed by the government.

Discussions

Companies need to understand how to achieve and maintain food safety and halal status in the manufacturing process to prevent these risks from occurring. Some research shows that food safety is part of the halal guarantee (Demirci, Soon., and Wallace 2016). Food contaminations, in terms of its halal status, result in product rejection. To prevent this, the production of halal food requires security, quality, and wholesomeness from farm to fork (Vanany et al., 2019a). In this study, labour also has an essential role in eliminating the risk of contamination that jeopardises the halal status, especially in early stages, i.e., the inspection of raw materials, slaughter processes, and equipment. The workers assigned to this section need to have a thorough understanding of halal concepts. The Halal Assurance System (HAS 23,000) that applies in Indonesia requires companies to conduct halal training at least once a year.

Food safety risks have an impact on human health, from food poisoning to death. Consumers are often worried about the risk of food safety to health (Mai, Shakur., and Pham Do 2019). Lack of social responsibility, low awareness of food security, and low processing technology may threaten food safety, and this should be managed by government regulation systems, and certification (Guo, Bai, and Gong 2019). Through this research, it can be seen that companies use food safety standards to increase consumers' trust so that food is safe for consumption.

The type of risk event identified in this study is a critical point in the occurrence of integrated food safety and halal contamination. With the BN model, the probability of contamination occurring at each risk event can be measured. The results showed that risk events at each level were a little bit different. For example, in the case study at level 1 (risk events), the halal risk is relatively higher (the risk of chickens dying when stunning – R4) than food safety risk (Damage to chicken meat because it contains microbes due to boiling is not according to the standard – R12). The difference also occurs in the value of the probability of contamination of each risk event at each level. Nineteen (19) identified risk events are critical points for food safety and halal contamination in a manufacturing process. Contamination at the risk event will result in contamination in the next process.

For this reason, technically, the results of the development of the BN model in this study can be utilised by companies in several aspects. First, companies can use this research methodology to monitor and control the types of risks in each process carried out. The identification of types of risk events and the development of the BN model in this study can be used as an illustration to be used in other cases. Second, this research is useful in determining the priority types of risks that companies will face. In this case, determining risk priorities is very important to be identified by the company. Risk priority is related to the impact of each risk. Third, companies can utilise research results in the preparation of mitigation programs based on the magnitude of the risk impact. Cost, time, and effort can be focused on preventing risks that have a profound impact on the company.

In managerial implication, the results of this research can be followed up by holding various activities, including training, equipment repair, certification, supplier selection, and collaboration with the government. The training is aimed at increasing the competence and insight of the workforce towards processes that meet halal food safety standards. Repairing equipment serves to maintain the hygiene of the tool, for example, to prevent the process of rusting on the blade, maintain the voltage on the stunning and others. They need to be carried out because the equipment can be a source of food safety or halal contamination. Certification is a step that companies can take to maintain quality and foster consumer confidence if the product is safe and lawful in consumption. The selection of suppliers needs to be done by the company to ensure that the raw materials used are not contaminated and meet halal requirements. For example, to ensure that chickens are healthy and alive when received. Collaboration with the government is a strategic step for companies to meet halal food safety standards. This collaboration is due to the government's is a source of information on food safety and halal policies. This collaboration is needed so that companies can optimally respect to government policies on food safety and halal. The company's strategic plan will be prepared in line with government policies for food safety and halal.

Conclusion, limitation and future scope

Integrated risks to food safety and halal status need was proposed and tested in this research. In the case study, the risk identification stage provides overviews of risk events so that companies can develop a strategy to avoid the risks. Strategic steps can be taken by considering the risk events that have the highest probability. This is because the probability value shows the possibility of the risk event occurring. The higher the probability value, the higher the risk event to occur. This study identified 19 integrated food safety and halal risk events. The link between risk events is illustrated by the BN structure consisting of 4 levels (process risk, risk department, business risk, and integrated risk). Overall, based on BN results, it is known that the risk of contamination by integrated food safety and halal is 1.7%. Although the results are considered small, they must be followed up with strategic steps to prevent this from happening. This research provides practitioners with new insights on how to integrate risk events into food and halal safety using the Bayesian Network model. The halal food industry is an essential player in maintaining the consumption of halal food (Vanany et al., 2019b) for which one of the relevant jobs is managing halal risk and food safety.

This research is limited to the identification of integrated risk to food safety and halal status in food processing. This research shows the identification of integrated food safety and halal risks in the food industry. Therefore, the results are specific to the food industry, which is used as an object of research. The analysis in this research is focused on the process of making food in the company without involving other parties, such as suppliers, distributors, and others. In terms of the model used, the limitations possessed by the BN model are the identification of risks, and the categories of risk types. The level of accuracy and knowledge of researchers on the company's business processes will determine the types and types of risk. Thus, the amount of risk identified can influence the probability value of the risk occurrence. This research on the company implies that the methodology can be useful to identify food safety and halal risks, so companies can take preventative measures to minimise the impact of losses.

In the future, research can be developed by involving players in other food supply chains, such as suppliers, distributors, sellers, etc. This future direction is based on the idea that the risks may arise from these actors. With research on actors in the food supply chain, risk events can be identified more effectively so that food safety and halal criteria are met, and consumers are not harmed. Moreover, future researchers can be developed towards determining the level of risk clustering based on the impact caused by using the BN model. Furthermore, this clustering can be used to determine company policies and strategies in minimising the impact of risk. Research development can also be directed by calculating financial losses to risks that occur in a process. The financial calculation is essential for the company because it is related to the company's capabilities and future development plans.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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