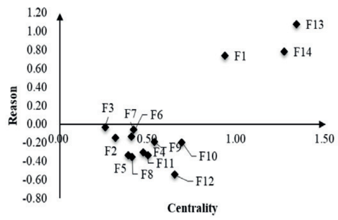
Identification of food safety risk factors based on intelligence flow and DEMATEL-ISM (DEcision-MAking Trial and Evaluation Laboratory and Interpretative Structural Modeling)



Identificación de los factores de riesgo de la seguridad alimentaria basados en el flujo de inteligencia y DEMATEL-ISM (laboratorio de toma de decisiones de prueba y ensayo - modelado estructural interpretativo)

Yu Zhang[1,2] and Yinghua Song[1,2]

[1] China Research Center for Emergency Management, Wuhan University of Technology, Wuhan, 430000, Hubei, China. Email: hbwhutzy@163.com
[2] Hubei Collaborative Innovation Center for Early Warning and Emergency Response Technology, Wuhan, 430000, Hubei, China

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RESUMEN

- En los últimos años, cada vez más países se han centrado en los posibles factores de riesgo para la seguridad alimentaria con la frecuente exposición a riesgos, como la encefalopatía espongiforme bovina, el aceite de cocina ilegal y la salubridad de la comida precocinada. Los riesgos de seguridad alimentaria son frecuentemente llevados por múltiples sujetos en la mayoría de los casos, y el flujo de inteligencia entre estos sujetos es fácilmente ignorado. Para identificar los factores de riesgo de la inocuidad de los alimentos, se analizó la relación interna entre el flujo de inteligencia y los riesgos de seguridad de los alimentos, y se estableció un sistema de índice de factores de riesgo de la inocuidad de los alimentos. Además, se construyó un modelo de reconocimiento de riesgos de inocuidad de los alimentos con el laboratorio de toma de decisiones de prueba y ensayo – modelado estructural interpretativo (DEMATEL-ISM). Los resultados demuestran que la supervisión deficiente, el grado de actividad de la información de la opinión pública y la conciencia personal de los riesgos de inocuidad son los factores clave que influyen en los riesgos de inocuidad de los alimentos bajo la perspectiva del flujo de inteligencia. Además, un ambiente de procesamiento antihigiénico y un procesamiento y alimentación inapropiados son las causas superficiales de los riesgos de seguridad alimentaria o de los incidentes de seguridad alimentaria. Las conclusiones sirven de referencia para reforzar el reconocimiento y la notificación precisos de los factores de riesgo para la inocuidad de los alimentos desde la perspectiva del flujo de información.
- **Palabras clave:** riesgo de seguridad alimentaria, flujo de inteligencia, DEMATEL-ISM, factor de riesgo.

ABSTRACT

In recent years, increasing number of countries have focused on potential food safety risk factors with the frequent exposures of food safety incidents, including "bovine spongiform encephalopathy," "illegal cooking oil," and "hygiene of take-out." Food safety risks are frequently carried by multiple subjects in most cases, and intelligence flow among these subjects is easily ignored. To identify food safety risk factors from the perspective of intelligence flow, the internal relationship between intelligence flow and food safety risks was analyzed, and an index system of food safety risk factors was established. Furthermore, a food safety risk recognition model was constructed with the DEcision-MAking Trial and Evaluation Laboratory and Interpretative Structural Modeling (DEMATEL–ISM). Results demonstrate that poor supervision, activity degree of public opinion information, and personal safety risk awareness are the key factors influencing food safety risks. In addition, unhygienic processing environment and inappropriate processing and eating are the superficial causes of food safety risks or food safety incidents. The conclusions serve as reference to strengthen accurate recognition and notification of food safety risk factors from the perspective of intelligence flow.

Keywords: food safety risk, intelligence flow, DEMATEL–ISM, risk factor.

1. INTRODUCTION

Food is a paramount necessity of the people, and its safety is the top priority. The food industry has achieved exceptional progress as well with the rapid economic and social development. On the other hand, with increasing food categories, development of new food technologies, and changes of eating modes, food safety problems have attracted much concern in the society. In particular, recently reported food safety incidents, such as "bovine spongiform encephalopathy," "lean meat powder," "illegal cooking oil," "zombie meat," and "hygiene of take-out," have not only threatened public physical health but also caused remarkable negative social impacts. Thus increasing countries have focused on potential risk factors influencing food safety and aimed to effectively recognize food safety risks and reduce the possibility of food safety incidents through monitoring and recognition [1]. However, food safety risks may frequently be carried by multiple subjects because food industrial chains involve multiple subjects, including peasant households, producers, forwarders, and consumers, and overlapping of multiple risk factors among different subjects is likely to cause food safety problems [2]. This condition requires the food supervision department to control and master food safety information of different subjects in the industrial chain, timely, completely, and accurately. But this information is only acquired through the monitoring and recognition of food safety risks. Thus, the recognition of food safety risk factors becomes an important link in notifying and managing food safety risks [3]. Therefore, monitoring and recognition of food safety risks are of great significance to food safety control as well as the key to theoretical and practical applications.

The intelligence flow proposed in this study comprises the process of analyzing, transmitting, sharing and utilizing knowledge, as a means of transmission between knowledge sources and decision makers. The acquisition of food safety information mainly comes from two aspects. One is that, government supervision department gains information, which is valuable to notifying subsequent food safety risks through post analysis of food safety incidents, thereby enabling to determine the key control point of food safety risks in the industrial food chain [4]. The other is that valuable information resources are formed based on regulatory means in the food safety monitoring system by combining regular or random examination of the supervision department on the subjects of industrial chain [5], and positive disclosure of food safety information by subjects in the industrial chain [6]. Comprehensive judgment of this information can guide decision making and prevent the occurrence of food safety incidents. Existing studies have ignored the intelligence flow of food safety between the two acquisition means and cut the correlations of information resources, thereby resulting in information distortion and misjudgment during information analysis. These conditions may influence the accurate recognition of food safety risks. This study monitored and recognized food safety risks from the perspective of intelligence flow. An index system of food safety risk factors based on intelligence flow was proposed, and a risk factor recognition model was constructed on the basis of the international relationship between intelligence flow and food safety risks. Moreover, key causation factors were determined through decision making trial and evaluation laboratory and interpretive structural modeling (DEMATEL-ISM) by thoroughly discussing the mutual interaction of food safety risk factors.

The remaining structure of this study is as follows: Section 2 reviews relevant studies on intelligence flow and food safety risk recognition. Section 3 presents the methodology, which discusses index system of food safety risk factors based on intelligence flow constructed by discussing the internal relationship between intelligence flow and food safety risks. Besides, a risk factor recognition model is constructed using DEMATEL-ISM. Section 4 analyzes and discusses the results, in which interaction of different food safety risk factors is thoroughly discussed, and key causation factors are determined. Section 5 summarizes the research conclusions.

2. LITERATURE REVIEW

The academic community has increasingly focused on food safety problems and relevant scholars have conducted research on food safety risk perception and identification at a certain scale of food safety incidents. Risk perception refers to the possibility that consumers perceive that the product cannot achieve the expected performance during the product purchase decision process [7]. When consumers feel that there is a security risk in the food purchase process, their purchasing behavior will change accordingly [8].The associated research results indicate that artificial factors, such as the abuse of additives or nonedible substances, the use of unqualified raw materials, and the improper application of ingredients, are the key risks of causing food safety problems in China. Production and processing are the weak links in the supply chain with high risk occurrences. Food enterprises, especially small enterprises and individual workshops, are the major subjects to liability in food safety incidents. For example, Tompkin [9] pointed out that food safety is the common goal of the government and enterprises. Thus, enterprises assume the main responsibility in ensuring food safety and can produce food by implementing policies and programs that assure their product safety. Charlotte [10] investigated small and medium-sized food enterprises and found that the lack of trust to staff in environmental health and to food safety act, the lack of legal consciousness on handling food safety problems, and lack of knowledge and understanding are internally correlated. Also, small and medium-sized enterprises lack demands for food safety and have no knowledge on food safety principles. In other words, policies are viewed to be unrelated with food safety and are unacceptable. Gailliot [11] studied the public's perception of the risks of food additives. When the public believes that the government's safety regulation of additives is more ineffective, the higher its level of risk awareness of additives, the greater the possibility of refusal to purchase. Lam [12] analyzed the status of food safety quality in China. He pointed out that the abuse of additives and their environmental pollution are the key causes of food safety risks by discussing multiple key food safety accidents exposed by the media. Tang [13] discovered that the abuse of chemical substances and the use of unqualified raw materials and unqualified products during food processing are the key causes of food safety accidents through textual analysis of the news report of pork safety.

On the other hand, control theories and intelligence flow technologies have achieved outstanding progresses. Rafiq [14] analyzed that the data in current business intelligence analysis are mainly obtained from business systems. However, few data are oriented to decision-making and knowledge management. Many data in practical business intelligence analysis have poor accuracy and high ambiguity. Experiences and lessons can be smoothly shared by integrating a general analysis framework of nonbusiness intelligence factors, such as empirical knowledge and cultural background. Xu [15] believed that the process of a competition information system is equal to a cyclic process of information planning, information acquisition/organizing, information analysis, information communication, and information assessment/management. On this basis, they discussed the influences of Internet technology on different links of intelligence flow competition. Balazs [16] applied information integration into opinion mining, as well as transformed multisource information into uniform expression, and guided the integration of opinion mining. They analyzed the application of information fusion in opinion mining through a survey.

Associated studies mainly recognize food safety risks through systematic analysis on existing food safety incidents. On one hand, Because of limited research samples and the independence of food safety incidents, risk factors, which are recognized from post analysis, are frequently one-sided. On the other hand, the important role of food safety information in food safety management is ignored. Therefore, this study built an index system of food safety risk factors based on intelligence flow and constructed a risk factor recognition model to clearly reflect the evolution of food safety risks. The constructed model can improve consumers' behavior giving a quick and effective response to emergencies [17]. Research conclusions can contribute to the notification of food risks by government officials, the positive disclosure of food safety information by subjects in the industrial chain and the assurance for consumers to receive, communicate and feedback authentic food safety information.

3. METHODOLOGY

3.1. EXTRACTION OF RISK FACTOR INDEX BASED ON INTELLIGENCE FLOW

Young [18] indicated that the food industrial chain includes many links, such as raw material production, food processing, food circulation, food consumption, and food supervision. Different sources of food safety information are implied in different links. The flow of food safety information in different links forms the intelligence flow of food safety. Therefore, with the needs of the five links of raw material production, food processing, food circulation, food consumption and food supervision, an index system of food safety risk factors, which could be independent and representative of the evaluation target, was developed from the perspective of intelligence flow (Table I), mainly followed the principles of scientificity, reliability, representativeness, comprehensiveness, practicability, dynamicity, operability and systemicity.

During raw material production, information about food safety risks are mainly obtained from personalized perception of safety risks, natural environmental monitoring report, and inspection report of accessories. First, strong personalized consciousness on the responsibility of safety production is conducive to ensure the safety of raw materials during production [19]. Second, planting of crops, which are the raw materials of food, is significantly influenced by the natural environment [20]. Natural environmental monitoring reports can help to control quality safety during planting and lower food safety risks. Finally, the production of food raw materials cannot be realized without chemical fertilizers, pesticides, fodders, and other accessories, and problems of which may influence the food safety of raw materials in the final products [21].

In food processing, food safety information is mainly obtained from the reports of the food safety incidents, production environmental inspection, production accessory inspection, and production inspection. Quality safety of food raw materials should be controlled for unsafe raw materials are forbidden to enter during processing to prevent food safety risks. Inspection information of production accessories shall be acquired, and manufacturers should be assisted in acquiring relevant information to control production accessories. In addition, the processing environment shall be inspected in accordance with relevant hygiene standards to inspect whether the processing environment meets the hygiene standards. Production programs shall be strictly observed during process. Meanwhile, whether the processing program and package are qualified can be determined through intelligence analysis of production inspection reports.

In food circulation, any problem during warehousing and transportation will certainly cause significant potential hazards and risks to food safety [22]. Information sources include food safety event report, warehousing information, and waste inspection information. Among them, potential risk information of food warehousing environment can be acquired from the warehousing information. Improper disposal of food wastes may significantly increase food safety risks [23]. Besides, food safety event reports can be used to avoid food safety risks by learning from the experiences of existing food safety incidents.

Food consumption is an important node of outburst of food safety incidents. Because, consumers can relatively acquire much information about food safety risks from food safety event investigation and hygiene inspection reports published by government supervision departments and from supervision reports of network and news media. Thus, they can avoid to buy products with food safety risks [24]. In particular, food safety risks mainly include two types in terms of source, where the first type is the nonstandard safety of dining places, and the second is improper eating process that mainly refers to substandard edible value eating of food in the marketing link.

Symbol	Indexes	Explanation
F_1	Weak personal safety consciousness	Weak personal safety consciousness lowers the subjective control over quality of the process of raw material production and restricts peasant household to accept and follow the standardized production of food raw materials to some extent.
F_2	Natural environmental pollution	Unqualified foods caused by natural resource pollutions, such as soil and water pollutions.
F_3	Pesticide and veterinary drug residues	Unqualified foods caused by excessive use or abuse of pesticides or veterinary drugs.
F_4	Use of unsafe raw materials	Poor quality or nonedible materials are used as raw materials in food production and processing.
F_5	Unhygienic processing environment	Environment and hygienic conditions for food production and processing are unqualified.
F_6	Use of unsafe accessories	Additives, preservatives, and other accessories are illegally applied during food production and processing.
F_7	Unqualified package	Toxic and harmful substances are used as package materials of edible goods or substandard food package, resulting in food expiration and deterioration.
F_8	Unqualified processing	Unqualified food are caused by food processing programs that fail to conform to standards.
F_9	Unqualified warehousing and transportation	Warehousing environment or transport tools of food fail to meet the standards
F_{10}	Improper disposal of waste foods	Food wastes are disposed during warehousing and transport
F_{11}	Unqualified dining places	Food supply and hygiene of dining places are unqualified
F_{12}	Improper eating	Edible standards of food are unqualified for eating, resulting in food poisoning and expiration.
F_{13}	Inadequate supervision strength	Government food safety monitoring department poorly conducted food safety supervision, resulting in poor food safety quality control throughout production, processing, circulation, and consumption.
F_{14}	Activity degree of public opinion information	Whether the news media and We-media network frequently and actively report food safety problems or not.

Table I. Index system of food safety risk factors based on intelligence flow
Source: organized by the author.

Food supervision information is mainly acquired from two aspects. The first aspect is the supervision behavior of government food supervision departments, including the investigation report of existing food safety incidents and daily food safety inspection of the government [25]. The second is the social public concerns and online public opinions, including news and online We-media reports of food safety incidents [26]. Besides, government supervision shortage should be balanced with participation of social public. Activity level of public opinion information may also influence food safety risks.

3.2. MODELING

The specific modeling steps of the design idea of DEMATEL-ISM are introduced as follows:

Step 1: Risk factors are determined on the basis of the index system of food safety risk factors based on intelligence flow. They are denoted as F_1, F_2, ..., F_n .

Step 2: The corresponding judgment criteria shall be set to determine the mutual influencing relations among food safety risk factors. The judgment criteria in accordance with the direct influence degree of F_i on F_j are divided into five levels, namely, strong, relatively strong, moderate, weak, and none, which correspond to 4, 3, 2, 1, and 0, respectively. The direct influence degree among different food safety risk factors in accordance with this scale is determined through expert scoring, thereby obtaining direct influencing matrix $F(F=[F_{ij}]_{n\times n})$, which can be expressed as:

$$F=\begin{bmatrix} 0 & F_{12} & \dots & F_{1n} \\ F_{21} & 0 & \dots & F_{2n} \\ \vdots & \vdots & & \vdots \\ F_{n1} & F_{n2} & \dots & 0 \end{bmatrix} \tag{1}$$

where F_{ij} (i=1, 2, ..., n; j=1, 2, ..., n; $i \neq j$) refers to the direct influence degree of F_i on F_j. $F_{ij}=0$ when $i=j$.

Step 3: Direct influencing matrix F is normalized. The normalized direct influencing matrix G $(G=[g_{ij}]_{n\times n})$ is calculated using Eq. (1).

$$G=\frac{1}{\max\limits_{1\le i\le n}\sum_{j=1}^{n}F_{ij}}F \tag{2}$$

Eq. (2) shows that $0\le g_{ij}\le 1$ and $\max\limits_{1\le i\le n}\sum_{j=1}^{n} g_{ij}=1$.

Step 4: The comprehensive influencing matrix $X(X=[x_{ij}]_{n\times n})$ among the risk factors can be calculated using Eq. (3):

$$X=G(I-G)^{-1} \tag{3}$$

where matrix I is a unit matrix.

Step 5: The influencing and influenced degrees among risk factors are analyzed and calculated. In particular, all elements in the same row of comprehensive influencing matrix X are added, thereby obtaining the influencing degree of different factors. All elements in the same column are added, thereby obtaining the influenced degree of factors. The calculation formulas are expressed as follows:

$$a_i=\sum_{j=1}^{n}x_{ij},\quad (i=1,\cdots,n) \tag{4}$$

$$b_i=\sum_{j=1}^{n}x_{ji},\quad (i=1,\cdots,n) \tag{5}$$

where the influencing and influenced degrees of risk factors F_n (i=1, 2, ... ,n) are a_i and b_i, respectively.

Step 6: The centrality and reason degree of each risk factor are calculated. In particular, centrality can be calculated by adding influencing and influenced degrees. In the process the reason degree is calculated by subtracting the influencing degree with the influenced degree. The calculation formulas of centrality (m_i) and reason degree (n_i) of each risk factor are expressed as follows:

$$m_i=a_i+b_i,\quad (i=1,\cdots,n) \tag{6}$$

$$n_i=a_i-b_i,\quad (i=1,\cdots,n) \tag{7}$$

Step 7: A Cartesian coordinate system was constructed using m_i and n_i of risk factors F_n (i=1, 2, ..., n) in Step 6. The positions of different risk factors in the coordinate system were marked to determine and analyze the importance of different risk factors.

Step 8: Risk factors were divided into several levels. The overall influence matrix H $(H=[H_{ij}]_{n\times n})$ of the risk factor set was calculated on the basis of comprehensive matrix X $(X=[X_{ij}]_{n\times n})$, which can be expressed as:

$$H=X+I \tag{8}$$

where I is the unit matrix.

Step 9: Reachable matrix K $(K=[k_{ij}]_{n\times n})$ can be determined on the basis of ISM and H $(H=[h_{ij}]_{n\times n})$. The calculation formulas are expressed as follows:

$$k_{ij}=\{1|h_{ij}\ge\lambda\},\quad (i=1,\cdots,n;\quad j=1,\cdots,n) \tag{9}$$

$$k_{ij}=\{0|h_{ij}<\lambda\},\quad (i=1,\cdots,n;\quad j=1,\cdots,n) \tag{10}$$

where λ is the threshold, which is set in accordance with the practical situations of an actual problem. It is used to determine the values of elements in K $(K=[k_{ij}]_{n\times n})$. Scientifically and reasonably setting threshold λ is the key of Eqs. (9) and (10). λ is generally set by decision makers depending on practical problems. Relations with small mutual influence degree of risk factors can be deleted on the basis of λ, thereby simplifying the system. This approach is convenient for the hierarchical division of risk factors. λ=0 indicates the risk factor set with small values of n.

Step 10: Reachable and antecedent sets are determined. Reachable set R_i and antecedent set S_i of risk factors F_n (i=1, 2, ..., n) can be calculated using the following equations:

$$R_i=\{a_j|a_j\in A,k_{ij}\neq 0\},\quad (i=1,\cdots,n) \tag{11}$$

$$S_i=\{a_j|a_j\in A,k_{ji}\neq 0\},\quad (i=1,\cdots,n) \tag{12}$$

Step 11: Whether Eq. (13) is true is further verified. If yes, then all risk factors F_i are low-level factors, and row i and column i in reachable matrix K can be deleted. Steps 10 and 11 are repeated until all risk factors are deleted.

$$R_i = R_i \cap S_i, \quad (i = 1, \cdots, n) \tag{13}$$

Step 12: All risk factors were divided into different levels on the basis of the deletion sequence of risk factors.

3.3 DATA SOURCE

A questionnaire of the relation of food safety risk factors was designed on the basis of the index system of food safety risk factors under the perspective of intelligence flow in Table II and steps of DEMATEL-ISM method. The direct influencing degree of F_i on F_j in accordance with the standards of Likert five-level scale is divided into five levels, namely, strong=4, relatively strong=3, moderate=2, weak=1, and none=0. Lindstrom [27] indicated that when analyzing the causes of targeted problems, small data still dominated. Drawing on his sample selection method, 20 academic experts in food safety risk management, food safety supervision information control, and food supply chain management, as well as the middle and senior managers in food enterprises and the workers in the government food supervision department were investigated and interviewed through field survey, e-mail, and telephone interview. Twenty effective questionnaires were collected. On the basis of Shaik's [28] processing method of questionnaire data, the obtained questionnaire data were processed using mean integration rule. To protect the scale and prevent algorithm failure, the means were rounded off to determine the direct influence strength between any two risk factors, thereby constructing a direct influence matrix $F(F = [F_{ij}]_{n \times n})$of the factor set. The results are shown in Table II.

4. RESULIT ANALYSIS AND DISCUSSIONS

4.1. DEMATEL METHOD ANALYSIS

In accordance with the design steps of DEMATEL-ISM and calculation methods of Eqs. (2) and (3), comprehensive influencing matrix (*X*) of the relations among food safety risk factors from the perspective of intelligence flow was calculated on MATLAB 2015b on the basis of direct influencing matrix *F*. Furthermore, the influencing degree (D), influenced degree (R), centrality (D+R), and reason (D-R) of different food safety risk factors were calculated on the basis of the design steps of DEMATEL–ISM. The calculation results were arranged in an order. Moreover, causal relationship of

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}
F_1	0	0	3	4	4	2	3	2	2	1	2	1	0	3
F_2	0	0	0	2	0	1	0	0	0	0	0	0	0	0
F_3	0	1	0	2	0	1	0	0	0	0	0	0	0	0
F_4	0	0	0	0	0	0	0	0	0	1	0	2	0	0
F_5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
F_6	0	0	0	0	2	0	0	2	0	1	0	0	0	0
F_7	0	0	0	0	1	0	0	0	3	2	0	0	0	0
F_8	0	0	0	0	0	0	0	0	0	0	0	1	0	0
F_9	0	0	0	0	0	0	0	0	0	2	0	4	0	0
F_{10}	0	3	0	0	0	0	0	2	0	0	4	0	0	0
F_{11}	0	0	0	0	0	0	0	0	0	0	0	3	0	0
F_{12}	0	0	0	0	0	0	0	0	0	0	0	0	0	1
F_{13}	0	2	2	3	3	3	3	3	4	4	4	4	0	4
F_{14}	3	1	0	2	2	2	2	2	3	3	3	3	4	0

Table II. Direct influencing matrix of relations among food safety risk factors
Source: calculated by the author

food safety risk factors is drawn with y-axis of reason and x-axis of centrality. The results are shown in Fig. 1.

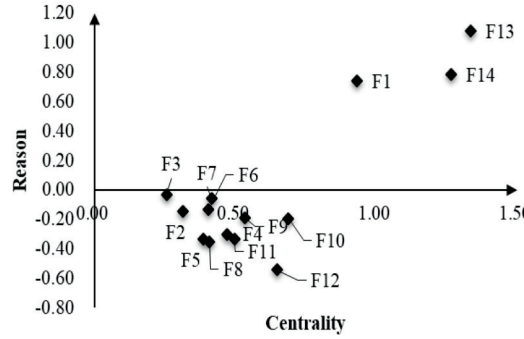

Fig. 1: Causal relationship of food safety risk factors

As shown in Fig. 1, the corresponding food safety risk factors when D-R is higher than zero are called the factors of the reason group. The corresponding food safety risk factors are called the factors of the result group when D-R is lower than zero. The analysis results were thoroughly discussed on the basis of these classification standards.

(1) Factors of the reason group.

As shown in Fig. 1, the reason degrees of F_{13}, F_{14}, and F_1 are higher than 0, indicating that the occurrence of these risk factors is extremely possible to cause food safety incidents, among which the difference between poor supervision (F_{13}) and activity level of public opinion information (F_{14}) depends on in their difference sequence in the reason group, which ranks first and second, respectively. This finding not only reflects that information is important in food safety risk control but also conforms to the characteristics of information acquisition of food safety risks [29].

(2) Factors of the result group.

As shown in Fig. 1, the reason degrees of F_3, F_7, F_6, F_2, F_9, F_{10}, F_5, F_8, F_4, F_{11}, and F_{12} are below zero, indicating that these food safety risk factors belong to the result group. Among them, F_{12}, F_{10}, and F_{11} are the top three factors in the result group. These food safety risk factors indicate that the poor supervision of food supervision department, low activity of public opinion information, and inadequate personal food safety consciousness limit the food supervision department to acquire competition information of food safety, thereby influencing the effective analysis and the use of information and reducing the notification accuracy of food safety incidents.

(3) Key risk factors.

The findings of Zhou [30] showed that D+R reflects the importance of influences of different factors on the complicated system. In particular, the factors should be evaluated during the notification process when the value of D+R is high. The results in Fig. 1 show that F_{13}, F_{14}, and F_1 are the top three food safety risk factors in terms of D+R. These factors can also significantly influence other factors, and they cannot be influenced by various risk factors. Thus, many effective decision supports are provided to notify food safety incidents.

4.2. ISM ANALYSIS

To disclose the international structural relationship among risk factors, food safety risk factors were divided into different levels using ISM. In accordance with the processing of threshold λ proposed by Chauhan [31], the aforementioned 20 academic experts were interviewed again. In accordance with the practical situations of food safety problems and repeated discussions, the threshold was set to λ=0.05. Reachable matrix (K) can be calculated using Eqs. (8), (9), and (10). The results are shown in Table III.

Reachable set $R(F_i)$ and antecedent set $S(F_i)$ on the basis of the reachable matrix can be calculated using Eqs. (11), (12), and (13). Thus, food safety risk factors from the perspective of intelligence flow can be divided into different levels. The results are shown in Fig. 2.

Food safety risk factors from the perspective of intelligence flow are divided into seven levels and three categories in accordance with the hierarchical structure of food safety risk factors (Fig. 2). The first level covers the factors that directly influence food safety, including F_5, F_8, and F_{12}. And the seventh level covers the fundamental factors that influence food safety, including F_1, F_{13}, and F_{14}. While, the second to the sixth levels are the factors that indirectly influence food safety, including F_4, F_6, F_{11}, F_2, F_3, F_{10}, F_9, and F_7. These factors may not directly cause food safety incidents but will induce food safety incidents indirectly through

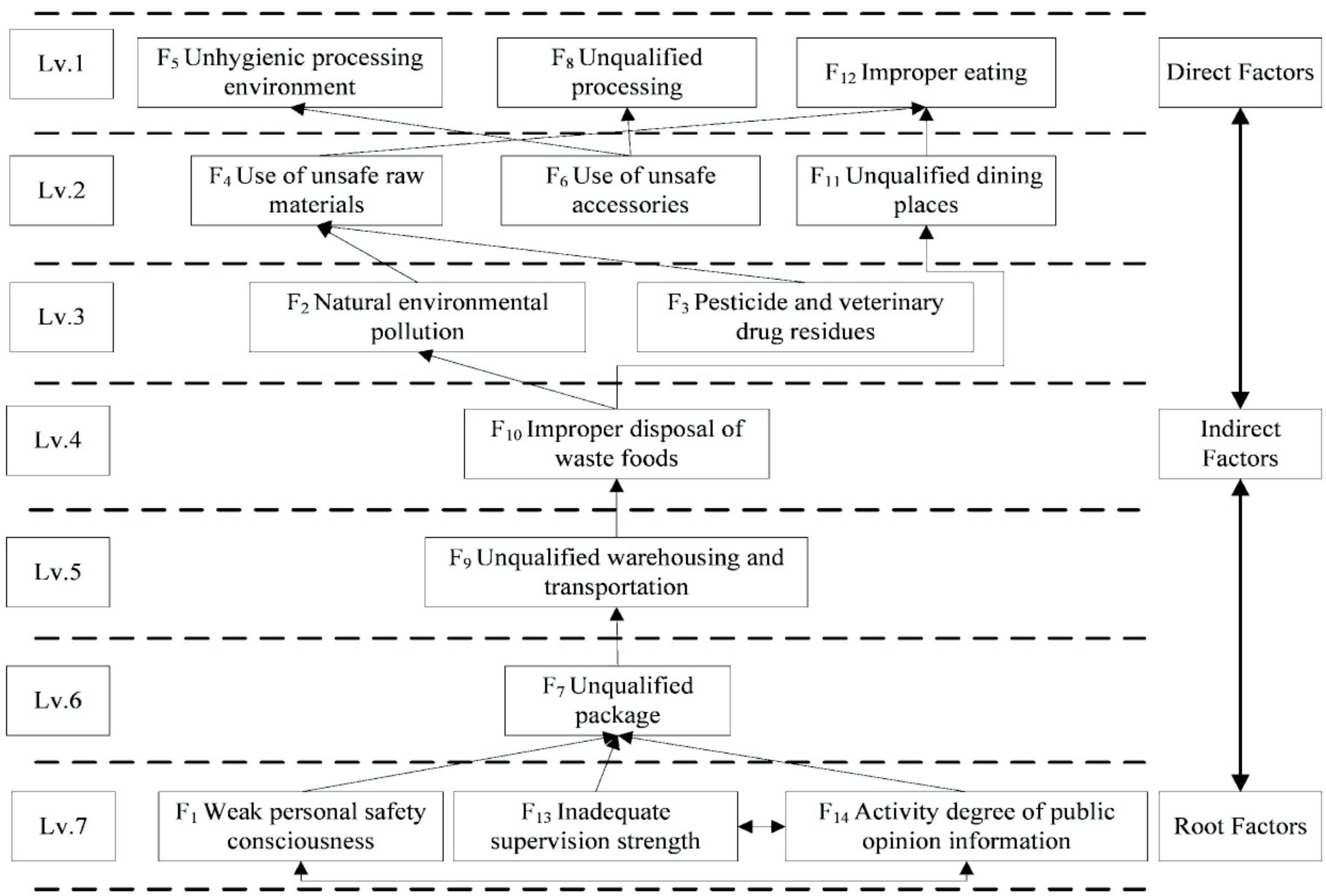

Fig. 2: Hierarchical structure of food safety risk factors

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}
F_1	1	0	1	1	1	1	1	1	1	0	1	0	0	1
F_2	0	1	0	1	0	0	0	0	0	0	0	0	0	0
F_3	0	0	1	1	0	0	0	0	0	0	0	0	0	0
F_4	0	0	0	1	0	0	0	0	0	0	0	1	0	0
F_5	0	0	0	0	1	0	0	0	0	0	0	0	0	0
F_6	0	0	0	0	1	1	0	1	0	0	0	0	0	0
F_7	0	0	0	0	0	0	1	0	1	1	0	0	0	0
F_8	0	0	0	0	0	0	0	1	0	0	0	0	0	0
F_9	0	0	0	0	0	0	0	0	1	1	0	1	0	0
F_{10}	0	1	0	0	0	0	0	1	0	1	1	0	0	0
F_{11}	0	0	0	0	0	0	0	0	0	0	1	1	0	0
F_{12}	0	0	0	0	0	0	0	0	0	0	0	1	0	0
F_{13}	0	1	1	1	1	1	1	1	1	1	1	1	1	1
F_{14}	1	0	0	1	1	1	1	1	1	1	1	1	1	1

Table III . Reachable matrix K at λ=0.05
Source: calculated by the author

F_5, F_8, and F_{12}.In particular, F_1, F_{13}, and F_{14} prove the results of DEMATEL method analyzing. In other words, these factors are the causes of food safety risks [32]. F_5, F_8, and F_{12} are three of the most superficial causes of food safety risks or food safety incidents. This finding also conforms to the occurrence characteristics of food safety incidents at present.

The analysis results of DEMATEL and ISM methods indicate that they reach equivalent results in the recognition of food safety risk factors from the perspective of intelligence flow.

5. CONCLUSIONS

This study recognizes the food safety risk factors from the perspective of intelligence flow and analyzes the internal relations between intelligence flow and food safety risk factors. Food safety risk factors are extracted from the perspective of intelligence flow, and an index system is constructed. A food safety risk recognition model is constructed on the basis of DEMATEL-ISM. Some conclusions are provided as follows: (1) poor supervision, low activity of public opinion information, and weak personal safety risk awareness are the key food safety risk factors from the perspective of intelligence flow. (2) Unhygienic processing environment, unreasonable production, and improper eating process are the most superficial causes of food safety risks or food safety incidents. (3) Notification of food safety incidents shall consider the hygiene of processing environment, the standardization of food production, and normalization of eating process.

This study recognizes the food safety risk factors from the perspective of intelligence flow. Key attention is provided to food safety risks reflected by food safety information that are carried by subjects in the industrial food chain. Recognizing different types and sources of food safety risk factors from the perspective of intelligence flow is the key research direction in future studies.

REFERENCES

[1] Wang J, Yue H. "Food safety pre-warning system based on data mining for a sustainable food supply chain". Food Control, March 2017, Vol. 73. p. 223–229. DOI: https://doi.org/10.1016/j.foodcont.2016.09.048.

[2] Cheng TJ, Feng LP. "Research on the risk warning index for food safety based on big data". Science and Technology Management Research, March 2018, Vol. 38-17. p. 175–181. DOI: https://doi.org/10.3969/j.issn.1000-7695.2018.17.027.

[3] Montet D, Al Shobaky, Barreto Crespo MT, et al. "Research on the risk warning index for food safety based on big data". Quality Assurance and Safety of Crops & Foods, 2015,Vol.7-3. p. 401-408. DOI: https://doi.org/10.3920/qas2014.0428.

[4] Li Y, An YF, Gu C. "Chinese fresh agricultural products food safety event analysis and critical control point positioning". Economy and Management, May 2013, Vol. 27-5. p. 31–35. DOI: https://doi.org/10.3969/j.issn.1003-3890.2013.05.007.

[5] Lobb AE, Mazzocchi M, Traill WB. "Modelling risk perception and trust in food safety information within the theory of planned behaviour". Food Quality and Preference, March 2007, Vol. 18-2. p. 384-395.DOI: https://doi.org/10.1016/j.foodqual.2006.04.004.

[6] Wang KS, Su X. "Study of institutional environment,benefit choice of production operators and effective transmission of food safety information". Macroeconomics, 2013, p. 84-89.DOI: https://doi.org/CNKI:SUN:JJGA.0.2013-07-015.

[7] Mitchell VW. "Consumer perceived risk: conceptualizations and models". European Journal of Marketing, 1999, Vol.33-1. p. 163-195.DOI: https://doi.org/10.1108/03090569910249229.

[8] Yeung RMW, Morris J. "Consumer perception of food risk in chicken meat". Nutrition & Food Science, 2001, Vol.31-6. p. 270-278.DOI: https://doi.org/10.1108/00346650110409092

[9] Tompkin, RB. "Interactions between government and industry food safety activities". Food control, June 2001, Vol.12. p. 203-207. DOI: https://doi.org/10.1016/S0956-7135(00)00038-4.

[10] Charlotte Y, Robyn F. "Factors affecting food safety compliance within implications for regulatory and enforcement strategies". Food Control, January 2006, Vol.17-2. p. 42-51. DOI: https://doi.org/10.1016/j.foodcont.2004.08.007.

[11] Gailliot MT, Baumeister RF, Dewall CN, et al. "Self-control relies on glucose as a limited energy source: Willpower is more than a metaphor". Journal of Personality and Social Psychology, 2007, Vol.92-2. p. 325-336. DOI: https://doi.org/10.1037/0022-3514.92.2.325.

[12] Lam HM, Remais J, Fung MC, et al. "Food supply and food safety issues in China". The Lancet, June 2013, Vol.381-9882. p. 2044-2053. DOI: https://doi.org/10.1016/S0140-6736(13)60776-X.

[13] Tang LQ, Zhou JH, Liu Q. "The pork safety situation in China under network public opinion and policy implications: based on the statistical of 11418 pork safety news". Chinese Journal of Animal Science, 2016, Vol.52-10. p. 3-8. DOI: https://doi.org/10.3969/j.issn.0258-7033.2016.10.001.

[14] Rafiq MI, Farooq A, Mirza MU. "Business intelligence framework supporting non-BI factors". International Journal of Future Computer and Communication, January 2013, Vol.2-6. p. 608-612. DOI: https://doi.org/10.7763/IJFCC.2013.V2.237.

[15] Zhang ZZ, Xu HY. "Innovation intelligence leads development: Essays of 'Competitive intelligence'(2011-2013)". Shanghai Scientific and Technological Literature Press, 2014.

[16] Balazs JA, Velasquez JD. "Opinion mining and information fusion: A survey". Information Fusion, January 2016, Vol.27. p. 95-110. DOI: https://doi.org/10.1016/j.inffus.2015.06.002.

[17] Santacreu-Rios LJ, Talavera-Ortiz A, Aguasca-Colomo R, et al. "Expert system for making decisions about emergency and safety in case of adverse meteorological conditions". DYNA, September-October 2015, Vol. 90-5. p. 503-512. DOI: https://doi.org/10.6036/7469.

[18] Young LM, Hobbs JE. "Vertical linkages in agri-food supply chains: changing roles for producers, commodity groups, and government policy". Review of Agricultural Economics, October 2002, Vol.24-2. p. 428-441. DOI: https://doi.org/10.1111/1467-9353.00107.

[19] Wang HM, Qiao J, Yan FZ. "Analysis of factors affecting farmers' willingness to participate in the food safety traceability system: An example of vegetable farmers in Beijing". Finance and Trade Research, January 2011, Vol.22-1. p. 19-27. DOI: https://doi.org/10.3969/j.issn.1001-6260.2011.01.003.

[20] Lu Y, Song S, Wang R, et al. "Impacts of soil and water pollution on food safety and health risks in China". Environment International, April 2015, Vol.77. p. 5-15. DOI: 10.1016/j.envint.2014.12.010

[21] Geng Z, Shang D, Han Y, et al. "Early warning modeling and analysis based on a deep radial basis function neural network integrating an analytic hierarchy process: A case study for food safety". Food Control, 2019, Vol. 96. p. 329-342. DOI: https://doi.org/10.1016/j.foodcont.2018.09.027.

[22] Shim SM, Seo SH, Lee Y, et al. "Consumers' knowledge and safety perceptions of food additives: Evaluation on the effectiveness of transmitting information on preservatives". Food Control, July 2011, Vol.22-7. p. 1054-1060. DOI: https://doi.org/10.1016/j.foodcont.2011.01.001.

[23] Bai XP. "Food safety hazards and control measures".China Metrology Publishing House, 2010.

[24] Grunert KG. "Food quality and safety: consumer perception and demand". European Review of Agricultural Economics, September 2005, Vol.32-3. p. 369-391. DOI: https://doi.org/10.1093/eurrag/jbi011.

[25] Ma CG, Yuan ZL. "Investigation report of food safety supervision system, mechanism and the present problems". Food Research and Development, March 2014, Vol.35-6. p. 128-132. DOI: https://doi.org/10.3969/j.issn.1005-6521.2014.06.037.

[26] Yang G. "Contesting food safety in the Chinese media: Between hegemony and counter-hegemony". The China Quarterly, June 2013, Vol.214. p. 337-355. DOI: https://doi.org/10.1017/S0305741013000386.

[27] Lindstrom M. "Small data: The tiny clues that uncover huge trends". New York: Martins' Press, 2016.

[28] Shaik MN, Abdul-Kader W. "Comprehensive performance measurement and causal-effect decision making model for reverse logistics enterprise". Computers& Industrial Engineering, February 2014, Vol.68. p. 87-103. DOI: https://doi.org/10.1016/j.cie.2013.12.008.

[29] Gu C, An YF. "The game for food safety information disclosure". Research on Economics and Management, 2012, p. 38-45. DOI: https://doi.org/10.3969/j.issn.1000-7636.2012.01.005.

[30] Zhou DQ, Zhang L. "Establishing hierarchy structure in complex systems based on the integration of DEMATEL and ISM". Journal of Management Sciences in China, April 2008, Vol.11-2. p. 20-26. DOI: https://doi.org/10.3321/j.issn:1007-9807.2008.02.003.

[31] Chauhan A, Singh A, Jharkharia S. "An interpretive structural modeling (ISM) and decision-making trail and evaluation laboratory (DEMATEL) method approach for the analysis of barriers of waste recycling in India". Journal of the Air & Waste Management Association, January 2018, Vol.68-2. p. 100-110. DOI: https://doi.org/10.1080/10962247.2016.1249441.

[32] Shang ZQ, Chen R, Wang LX. "Research on application of competitive intelligence in food safety monitoring and early warning". Knowledge Management Forum, October 2011, p. 257-258.

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