Food Production Safety Risk Assessment Based on Game Combination Weighting AEC-VIKOR Model

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Abstract: In order to improve the scientificity and validity of food production risk assessment results, an AEC-VIKOR evaluation model based on game combination weighting was proposed. Based on the theory of total quality management and the existing food related norms, a food production risk assessment system consisting of 19 secondary indexes was constructed from five dimensions of foreign object management, equipment management, biological management, material and product management, and administrative management, and the actual calculation was carried out. The results showed that the three factors that had the greatest influence on food production safety were: key material control (0.111), cleaning and disinfection (0.096), allergen control (0.09). In the management and control of food safety risks, enterprises not only need to pay attention to the indicators with high weight, but also the indicators with low weight can not be ignored, because the indicators with low weight will also become a barrier factor affecting the level of food production safety. This study can provide reference for the production risk assessment of food production enterprises, and can reflect the production quality and safety level of food production enterprises, as well as the weak items. It plays a driving role in improving the quality and safety control of production process and improving the risk awareness and identification ability of enterprises.

Keywords: Food Production, BWM, CRITIC, Combinatorial Weighting, Adversarial Extract Champion Mothod， VIKOR

1. INTRODUCTION

The country is based on the people, and the people depend on food. Since the "13th Five-Year Plan", China's food quality and safety system has gradually improved, but with the rapid growth of the food industry, food quality and safety problems are also increasing, which seriously affects people's health and social development. In 2021, the number of complaints related to food safety reached 692,000, a year-on-year increase of 93.8 %. The 14th Five-Year Plan also puts forward new requirements for food safety. For this purpose, the National Health Commission issued the 14th Five-Year Plan for Food Safety Standards, Monitoring and Evaluation in August 2022 to protect people's food safety and health, implement the "four strictest" requirements[5], and promote the healthy development of social economy. To improve the level of food safety risk monitoring, identification and assessment is one of the main tasks in the planning, but also the hot and difficult research in the field of food safety.

For food safety risk monitoring, identification and assessment, many scholars have carried out research on this. In terms of research content, [6] believe that food quality and safety risk

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assessment should be carried out from the following five directions: relevance, effectiveness, efficiency, impact and sustainability. [10] constructed the index system of Chinese food safety evaluation from four dimensions of traceability, transparency, detection power and timeliness. [4] constructed food safety risk early warning index system from the perspective of risk management to provide a basis for improving the ability of food safety risk prevention and control. [13] built an evaluation system for the development of the food industry from three aspects: macro level, industrial level and enterprise management. In terms of research methods, [11] built a risk assessment index system of dynamic and static combination of health food production enterprises with Delphi method based on the actual food safety supervision. Based on AHP and Delphi method, [15] constructed a comprehensive evaluation index system that can effectively evaluate the level of food safety in various regions from two levels of theoretical research and practical exploration. [12] used fuzzy AHP to assign weights to indicators, considering the mutual influence among indicators, and improved the evaluation method with the four-quadrant rule to make the evaluation model more scientific and reasonable. To sum up, most domestic and foreign scholars study food safety evaluation from a macro perspective. There are few studies on the quality and safety risk system of food production process, and the evaluation index construction is general and difficult to involve the entire production process. However, food production safety issues cover all links of the food supply chain. Food production enterprises are the core of food safety in the whole supply chain [14] and need to take more responsibility for safety. Therefore, it is particularly important to monitor, identify and evaluate safety risks in the food production process. At the same time, most scholars also rely on the subjective evaluation of experts in assigning index weights, which is too subjective and affects the accuracy of evaluation results. The subjective weighting method can determine the index weight according to the actual situation and the intention of the empowerer, but the subjectivity is strong. However, the objective weighting method does not require the subjective judgment of the empowerer, but relies on specific data. However, sometimes the weights assigned to indicators differ greatly from their actual importance. However, combinatorial weighting method [16] can better combine the advantages of the two, give the results of weighting scientifically and reasonably, reduce the subjective influence and give consideration to the objectivity of data. Based on the total quality management theory of 5M1E(Cheng 2017), which affects product quality, and combined with food related norms, this paper studies all links in the production of food enterprises, and establishes an enterprise food production quality and safety risk assessment system. The food production safety risk assessment model of VIKOR method is improved by establishing the combination weighting method of BWM and CRITIC based on the combination of game theory and the adversarial selection method, which solves the problem that the traditional evaluation model is too subjective and improves the objectivity of the evaluation results. Meanwhile, adversarial extract champion method is used to improve the VIKOR method to solve the problem that the compromise value is too simple. The model was verified by an example to provide ideas and methods for food production enterprises and relevant government departments to improve food risk monitoring, identification and assessment.

2. CONSTRUCTION OF FOOD PRODUCTION SAFETY RISK EVALUATION INDEX SYSTEM

Based on 5ME1 and food production related norms in the comprehensive quality management theory, this paper confirms the influencing factors of food quality and safety in food production through field research and questionnaire survey, and establishes a food production risk evaluation system. The risk control of food production process is mainly reflected in the following five aspects.

Management of foreign materials: control the pollution of Chinese and foreign products in the process of food production, which has a serious impact on food appearance, nutritional value and consumer psychology. For the graded food production areas, some items in the low-risk areas are foreign to the high-risk areas, which will bring risks to the production operations in the high-risk areas.

Equipment management: equipment is the material basis of food production, inspection, maintenance and calibration are the necessary measures to ensure the stable and safe operation of equipment, but also to control the control of food quality and safety risks.

Biological management: food is contaminated by microorganisms or insect pests, which seriously affects the quality and safety of food and poses a threat to the health of consumers. Through management to prevent biological food contamination through air, water, operators and appliances.

Material and product management: material and product acceptance, storage, processing and site control, from material acceptance to the production of finished products.

Administrative management: administrative management through the formulation of personnel management and related systems on food quality and safety can not be ignored, also belongs to an important link in food production.

In this paper in the index system construction, follow the principle of scientific, typical, comprehensiveness, operability, around the food production related each link, from the external management, equipment management, biological management, material management and product management, administrative management five dimensions, built 19 secondary indicators of food production risk evaluation system, and the secondary index, see Table 1.

Table 1: Food production safety risk evaluation index system.

First-order Index	Secondary Index
Foreign Matter Management	Fragile Product Control（X1）
	Item Control in Risk Area （X2）
Equipment Management	Maintenance Management （X3）
	Online Product Protection（X4）
	Building and Equipment Maintenance Control（X5）
	Calibration Control（X6）
Wildlife Management	Pest Control（X7）
	Cleaning and Disinfection （X8）

	Environmental Monitoring （X9）
Materials and Product Management	Allergen Control （X10）
	Critical Material Control （X11）
	Identification （X12）
	Product Appearance/Sensory Inspection （X13）
	Incoming Material Inspection （X14）
	Waste Control （X15）
Public Administration	Staff Training （X16）
	Document Record Control （X17）
	Alien Control （X18）
	Change Control （X19）

3 FOOD PRODUCTION SAFETY RISK ASSESSMENT MODEL

3.1 Weight of security risk assessment indicators

After the establishment of the food production safety risk index system, the weight of each index needs to be discussed due to the different importance of different indicators. In the evaluation model, the weight of the index directly affects the accuracy of the evaluation model. Therefore, this paper will adopt a combination of subjective and objective methods to weight indicators. First, the Best and worst method (BMW) will be used to calculate the subjective weight of indicators, then the CRITIC method will be used to calculate the objective weight of indicators. Finally, with the goal of minimum difference between the subjective weight and objective weight, a solution model of combined weight will be established by game theory. Find the optimal combination weight.

3.1.1 Subjective weighting method of base weight BWM

The best-worst method proposed by the Dutch scholar [9] is one of the latest weighting methods, which determines the weight of indicators through pairwise comparison. Compared with the commonly used AHP, which only has reference comparison, it means that the advantages of the optimal index over all other indexes and the advantages of these other indexes over the worst indexes are defined, which reduces the number of comparisons. The optimal value of the weight coefficient can be obtained only by 2n-3 comparisons. A small number of paired comparisons can reduce errors and eliminate inconsistencies in the standard comparison process.

The steps of BWM method to determine the weight index are as follows:

Step 1) Determine a set of evaluation indicators C = {C1, C2... Cn}, where n represents the total number of indicators.

Step 2) Determine the optimal index and the worst index, Cb and Cw respectively represent the optimal index and the worst index in the model.

Step 3) Compare the optimal index with all other indexes using the 1-9 score system to determine the importance, and construct the comparison vector between the optimal index and other indexes:

$$\boldsymbol{A}_B = (a_{B1}, a_{B2}, \dots, a_{Bn}) \qquad (1)$$

Step 4) Compare all other indicators with the worst indicators to determine their importance using the 1-9 score system, and construct the comparison vector between the worst indicators and other indicators:

$$\mathrm{A_W} = (\mathrm{a_{1W}}, \mathrm{a_{2W}}, \dots, \mathrm{a_{nW}})^{\mathrm{T}} \qquad (2)$$

Step 5) Calculate the optimal weight of attributes. For each pair of W_B/W_j and W_j/W_w, there are $W_B/W_j=a_{Bj}$ and $W_j/W_w=a_{wj}$. In order to meet these conditions of all n attributes, the optimization model of $W_B/W_j=a_{Bj}$ and $W_j/W_w=a_{wj}$ is established to minimize the maximum absolute difference of the objective function.

$$min\ max_j\{|\frac{\omega_B}{w_j} - a_{Bj}|, |\frac{w_j}{w_W} - a_{jW}|\}$$

$$s.t.\begin{cases} \sum_{j=1}^{n} w_j' = 1 \\ w_j' \geq 0 \end{cases} (j = 1,2,\dots,n) \qquad (3)$$

The above model can be converted to the following;

$$\min \xi$$

$$s.t.\begin{cases} |\frac{\omega_B}{\omega_j} - \alpha_{Bj}| \leq \xi, \\ |\frac{\omega_j}{\omega_W} - \alpha_{jw}| \leq \xi, \\ \sum_{j=1}^{n} \omega_j = 1, \\ \omega_j \geq 0, \end{cases} (j = 1,2,\dots,n) \qquad (4)$$

The final weight can be obtained by solving the program. One of the key features of BWM method is that it can determine the consistency ratio. In order to meet the consistency, formula (5) needs to be verified.

$$\mathrm{CR} = \frac{\xi}{\mathrm{CI}} \qquad (5)$$

The smaller CR is, the higher the consistency is.

3.1.2 Objective weight method based on CRITIC

CRITIC method is an objective weight method proposed by Athens scholar Diakoulaki (1995), which has certain advantages compared with other common objective weight methods. Its principle is to use the contrast intensity and conflict between indicators to consider the objective weight of indicators. In addition to considering the variability of indicators, the correlation between indicators is also considered. Scientific evaluation is carried out according to the objective attributes of the data itself.

The steps of determining the weight indicator by CRITIC method are as follows:

Step 1) Suppose that there are p research objects and n evaluation indexes, and form the original index data matrix (X) :

$$X = \begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{p1} & \cdots & X_{pn} \end{bmatrix} \quad (6)$$

Where X_{ij} is the original data value of the JTH index of the ith analysis object.

Step 2) In order to eliminate the impact of dimension on evaluation results, dimensionless processing is required for each indicator, as follows:

Positive indicators (the larger the value of the indicator used, the better):

$$X'_{ij} = \frac{X_{ij} - X_{min}}{X_{max} - X_{min}} \quad (7)$$

Inverse index (the smaller the value of the index used, the better) :

$$X'_{ij} = \frac{X_{max} - X_{ij}}{X_{max} - X_{min}} \quad (8)$$

Step 3) Show index variability in the form of standard deviation:

$$\begin{cases} \bar{x}_j = \frac{1}{p} \sum_{i=1}^{p} x_{ij} \\ S_j = \sqrt{\frac{\sum_{i=1}^{p} (x_{ij} - \bar{x}_j)^2}{p-1}} \end{cases} \quad (9)$$

Step 4) Use correlation coefficient to represent index conflict:

$$R_j = \sum_{i=1}^{n} (1 - r_{ij}) \quad (10)$$

Among them, r_{ij} represents the correlation coefficient between evaluation indicator i and j. In the CRITIC method, the correlation coefficient is used to represent the correlation between indicators. When an indicator has a strong correlation with other indicators, the conflict between the indicator and other indicators will be smaller, and the evaluation content it reflects will be repeated more, which will weaken the evaluation strength of the indicator to a certain extent. Reduce the weight assigned to this indicator.

Step 5) Calculation of the amount of information C_j:

$$C_j = S_j \sum_{i=1}^{n} (1 - r_{ij}) = S_j \times R_j \quad (11)$$

When the amount of information C_j is larger, the JTH index plays a greater role in the whole index system, that is, it should be given a greater weight.

Step 6) Calculation of objective weight. The objective weight W^*_j of the JTH index is:

$$W_j^* = \frac{c_j}{\sum_{j=1}^{p} c_j} \tag{12}$$

3.1.3 Combinatorial weight solution based on game theory

Game theory is used to find the equilibrium point between the subjective weighting method and the objective weighting method[1], that is, the target weight with the lowest deviation between each weight. It takes into account the interrelationship between each index, reduces the imbalance of subjective and objective combination, and increases the scientific nature of combination empowerment.

The steps to solve the combination weight based on game theory are as follows:

Step 1) Calculate the subjective weight W and objective weight W^* of food production safety and quality risk evaluation indexes by using BWM method and CRITIC method respectively, and form a weight vector set $W_2=\{W,W^*\}^T$. The linear combination coefficient of BWM method is u1, and the linear combination coefficient of CRITIC method is u_2. Then the comprehensive weight after group sum is:

$$W_z = \mu_1 W^T + \mu_2 W^{*T} \tag{13}$$

Step 2) The optimal linear combination of the above two weights is carried out in combination with game theory. The minimum deviation is set as the target, the linear combination coefficient is optimized, and the optimal weight combination is obtained. Then the objective function is:

$$min||W_z - W_2||^2 \tag{14}$$

Step 3) Because of the differentiability of matrix, Equation (14) is transformed into a system of linear equations with the best first-order derivative conditions:

$$\begin{pmatrix} WW^T & WW^{*T} \\ W^*W^T & W^*W^{*T} \end{pmatrix} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} = \begin{bmatrix} WW^T \\ W^*W^{*T} \end{bmatrix} \tag{15}$$

Step 4) According to Equation (15), the optimal linear combination coefficient of subjective and objective weighting method is obtained, and it is normalized to obtain the optimal comprehensive weight based on the combination weight of game theory:

$$W_z = \overline{u_1}\mathrm{W} + \overline{u_2} W^{*T} \tag{16}$$

$$\left(\overline{u_1} = \frac{\mu_1}{\mu_1+\mu_2}; \overline{u_2} = \frac{\mu_2}{\mu_1+\mu_2} \right)$$

3.2Adversarial Extract Champion Mothod

Based on the common principle of minority obedience to majority in decision-making process, this paper proposes the Adversarial Extract Champion Mothod（AEC）.

The steps are as follows:

Step 1) Suppose there are 3 schemes A, B and C, and 10 experts have voted on their rankings, as shown in Table 2:

Table 2: Voting results

	A	B	C
First	2	3	5
Second	4	5	1
Third	4	2	4

Step 2) Plan C has the largest number of votes in the first-place voting result, and C is selected as the first place

Step 3) Sink the elements of Plan A and B in the first place to the second place: A=2+4=6, B=3+5=8, as shown in Table 3:

Table 3: Voting results after extraction.

	A	B
Second	6	8
Third	4	2

Step 4) In the second place voting result, plan B has the largest number of votes, which is selected as the second place, and the remaining plan C is the third place. (C > B > A)

When there are more schemes, repeat the above operation to get its ranking in the winning scenario.

3.3 Improved VIKOR modeling

VIKOR method is a compromise ranking method (He 2022), whose principle is to maximize the group utility value and minimize the individual regret value, and then conduct compromise ranking of the scheme.

However, in the compromise solution of VIKOR's method, most coefficients are taken as 0.5 or the cases greater than 0.5 and less than 0.5 are discussed. The number of sorting, that is, the number of clustering, can be solved by the adversarial preference rule. The essence of compromise solution is that Manhattan distance can be used to construct countless ways of compromise solution. Unless multiple inflection points overlap, the clustering characteristics of any compromise solution are completely consistent, and all that changes is the K-value interval. The adversarial preference method can further point out that the optimal compromise solution does not necessarily fall on the compromise value of k=0.5. Therefore, this paper uses adversarial selection method to improve VIKOR method.

The AEC to improve VIKOR method are as follows:

Step 1) To construct the original decision matrix, see Equation (6), and standardize it, see Equation (7) and (8). The normalized matrix is obtained $X' = [X'_{ij}]_{n \times p}$.

Step 2) Determine the positive and negative ideal solutions of each index:

$$S_j^+ = max\{x_{ij}\}, j = 1,2,\cdots,n \tag{17}$$

$$S_j^- = min\{x_{ij}\}, j = 1,2,\cdots,n \tag{18}$$

Step 3) Calculate group utility value and individual regret value respectively:

$$S_i = \sum_{j=1}^{p} W_{zj}(\frac{S_j^+ - x_{ij}}{S_j^+ - S_j^-}) \tag{19}$$

$$R_i = max(W_{zj}(\frac{S_j^+ - x_{ij}}{S_j^+ - S_j^-})) \tag{20}$$

Step 4) Calculate the compromise solution of each evaluation object Qi：

$$Q_i = (1-k)\left(\frac{S_i - Min(S_i)}{Max(S_i) - Min(S_i)}\right) + k(\frac{R_i - Min(R_i)}{Max(R_i) - Min(R_i)}) \tag{21}$$

Step 5) Sensitive value analysis (k value inflection point analysis)

$$a_i = \frac{S_i - Min(S_i)}{Max(S_i) - Min(S_i)}, b_i = \frac{R_i - Min(R_i}{Max(R_i) - Min(R_i)} \tag{22}$$

Then$Q_i = (1-k)a_i + kb_i$, for x and y have$\{\begin{matrix}(1-\mathrm{k})\mathrm{a_x} + \mathrm{kb_x} \\ (1-\mathrm{k})\mathrm{a_y} + \mathrm{kb_y}\end{matrix}$, the problem becomes the question of whether two segments intersect in the [0,1] domain. Solve the $\mathrm{k} = \frac{\mathrm{a_x} - \mathrm{a_y}}{(\mathrm{a_x} - \mathrm{a_y} + \mathrm{b_y} - \mathrm{b_x})}$, the inflection point K was calculated for the analysis.

Step6) Cluster feature ranking analysis

Step7) Adversarial extract champion Mothod

3.4 Obstacles degree model

In order to find the obstacle factors affecting the food production safety level of enterprises[8], the index obstacle degree, index deviation degree and index contribution are introduced to diagnose and analyze the main indicators, and the calculation formula is as follows:

$$P_i = \frac{S_i M_i}{\sum_{i=1}^{n} S_i M_i} \tag{23}$$

Among them:P_i is index obstacle degree。S_i is index contribution，refers to the weight of indicators in the evaluation system.M_i is index deviation degree,it refers to the distance between the standardized index value and 1.

4 EXAMPLE ANALYSIS

In order to verify the validity and rationality of the proposed evaluation model, five food production enterprises of the same type were selected as the research objects.

4.1 Calculation of index weight

The weights are calculated according to the above weight confirmation process. In order to ensure the reliability of weight data, this paper invited experts in the field of food production to construct the comparison vector of indicators on a scale of 1 to 9, calculate the subjective weight with formulas (1) to (5), and obtain the initial data of 5 enterprises through field investigation and questionnaire survey. Considering the sensitivity of enterprise data and the convenience of data processing, the relevant data obtained were converted and processed, and each index was scored (1-10 points) through the evaluation of the expert group. The production safety evaluation table of food enterprises was obtained, as shown in Table 4.

Table 4: Index scores of food production enterprises.

Secondary Index	Enterprise 1	Enterprise 2	Enterprise 3	Enterprise 4	Enterprise 5
X1	8	8	7	10	9
X2	6	7	8	8	7
X3	6	6	10	7	7
X4	7	9	9	8	9
X5	7	8	8	7	8
X6	9	10	8	9	10
X7	8	9	8	7	9
X8	8	9	8	8	9
X9	7	8	7	9	8
X10	8	7	10	7	9
X11	7	8	8	9	8
X12	6	9	8	9	7
X13	8	9	9	8	7
X14	8	9	8	8	7
X15	6	6	9	8	7
X16	7	10	8	9	6
X17	5	9	9	9	7
X18	5	9	8	8	6
X19	7	8	10	9	6

The objective weight was calculated according to equations (6) ~ (12), and the combination of game theory was used to get u1=0.788, u2=0.365. The linear combination coefficients u1 and u2 are normalized $\frac{u_i}{\sum_{i=1}^{2} u_i}$，u1=0.687，u2=0.313. According to the linear combination coefficient and the subjective and objective weights, the combination weight is obtained. See Table 5. See Figure 1 for the direct comparison between each evaluation index.

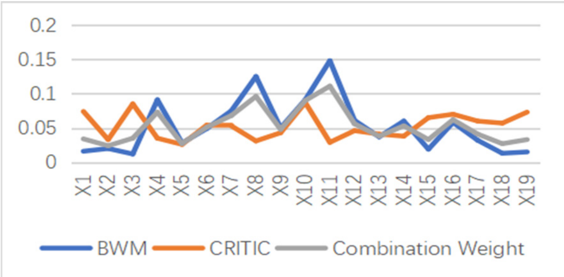

Figure 1: Weight comparison of evaluation indicators.

Table 5: Comprehensive weights of evaluation indicators.

Secondary Index	BWM	CRITIC	Combination Weight	Combination weight ranking
X1	0.016	0.074	0.034	14
X2	0.020	0.033	0.024	19
X3	0.012	0.085	0.035	13
X4	0.091	0.035	0.073	4
X5	0.028	0.026	0.027	17
X6	0.049	0.054	0.051	9
X7	0.075	0.053	0.068	5
X8	0.125	0.031	0.096	2
X9	0.050	0.043	0.048	10
X10	0.091	0.087	0.090	3
X11	0.148	0.029	0.111	1
X12	0.061	0.046	0.056	7
X13	0.037	0.041	0.038	12
X14	0.060	0.038	0.053	8
X15	0.019	0.065	0.033	15
X16	0.058	0.070	0.062	6
X17	0.032	0.060	0.041	11
X18	0.013	0.057	0.027	18
X19	0.015	0.073	0.033	15

According to the combination weight ranking, the weight of key material control (0.111), cleaning and disinfection (0.096) and allergen control (0.09) are relatively high. At the same time, combined with the comprehensive comparison chart of weight indicators, it can be seen that the indicators considered important in subjective weighting are as follows: Indicators such as cleaning, disinfection and control of key materials show a large gap with the objective weight. Combined with the data, it can be seen that food enterprises control these key factors in daily production, resulting in less objective weight of these indicators, and indicators with lower subjective weight, such as: The objective weights of maintenance management, external personnel control, change control and other indicators are relatively increased, indicating that some enterprises ignore the control of these low-weight indicators. Meanwhile, combined with the line chart, it can be concluded that the combination of subjective and objective weight can reduce the subjective influence and the fluctuation caused by data changes, so as to make the weight more stable. Embodies the necessity and rationality of combining subjective empowerment with objective empowerment.

4.2 AEC-VIIKOR sequencing analysis

Combining the combination weight and formula (19) and (20), the expectation values and regret values of 5 enterprises are obtained. Both columns are negative indicators, as shown in Table 6.

Table 6: Expected values and regret values.

Enterprise	Expectation Values S	regret values R
Enterprise 1	0.832	0.110
Enterprise 2	0.286	0.089
Enterprise 3	0.400	0.095
Enterprise 4	0.454	0.095
Enterprise 5	0.448	0.061

The table of ai and bi values obtained from formula (22) is shown in Table 7.

Table 7: ai, and bi values.

Enterprise	ai	bi
Enterprise 1	1	1
Enterprise 2	0	0.571
Enterprise 3	0.209	0.694
Enterprise 4	0.308	0.694
Enterprise 5	0.297	0

Calculate the compromise Q with formula (21) and analyze the inflection point k value in Table 8.

Table 8: Compromises at different inflection points.

Enterprise	k=0	k=0.113	k=0.342	k=1
E 1	1	1	1	1
E 2	0	0.065	0.195	0.571
E3	0.209	0.264	0.375	0.694
E4	0.308	0.352	0.440	0.694
E5	0.297	0.264	0.195	0

The ranking analysis is conducted according to the compromise solution data at different k values of inflection points mentioned above, because the compromise solution is a negative index, the smaller the value, the better, and the smallest value in each column ranks first. Therefore, the ranking is shown in Table 9, and the specific changes are shown in Figure 2:

Table 9: Sort down at different inflection points

	k=0	k=0.113	k=0.342	k=1
Enterprise 1	5	5	5	5
Enterprise 2	1	1	1	2
Enterprise 3	2	2	3	3
Enterprise 4	4	4	4	3
Enterprise 5	3	2	1	1

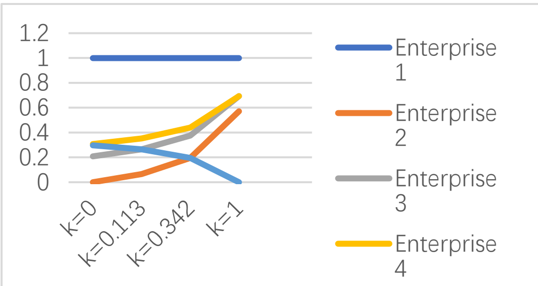

Figure 2: Cross inflection point -- polyline distribution.

The king based on k-value clustering characteristics are shown in Table Table 10.

Table 10: sorting of compromise solutions.

Rank	The Proportion of Each Enterprise
1	Enterprise 2=0.67 Enterprise 5=0.33
2	Enterprise 2=0.33 Enterprise 3=0.33 Enterprise5=0.33
3	Enterprise 3=0.67 Enterprise 5=0.33
4	Enterprise 4=1
5	Enterprise 1=1

Combined with Table Table 10, the ranking by antagonistic selection is shown in Table Table 11.

Table 11: Competitive merit sorting.

Number	K value	Compromise Solution Value Ranking
1	$0 < k < 0.113$	E 2 > E 3 > E 5 > E 4 > E 1
2	$0.113 < k < 0.342$	E 2 > E 5 > E 3 > E 4 > E 1
3	$0.342 < k < 1$	E 5 > E 2 > E 3 > E 4 > E 1

The optimal compromise solution in the winning situation is:

Enterprise 2 > Enterprise 5 > Enterprise 3 > Enterprise 4 > Enterprise 1

4.3 Obstacle degree analysis

The obstacle degree analysis can help find out the obstacle factors affecting the food production safety level of enterprises. The greater the obstacle degree of the food production safety risk index, the greater the index obstacles to the comprehensive evaluation level of the company. The combined weight was inserted into formula (23), and the top five obstacle factors and barriers affecting the food production safety level of 5 enterprises were obtained. The results are shown in Table 12.

Table 12: Order of obstacle factors of food production enterprises.

Enterprise	Index Ranking				
E 1	X11	X8	X4	X10	X12
	0.138	0.116	0.088	0.072	0.065
E2	X10	X11	X3	X15	X9
	0.312	0.192	0.121	0.114	0.083
E 3	X8	X11	X6	X9	X1
	0.239	0.138	0.127	0.120	0.085
E 4	X8	X10	X7	X5	X14
	0.210	0.197	0.149	0.059	0.058
E 5	X16	X11	X14	X13	X12
	0.139	0.125	0.119	0.085	0.084

According to Table 12, to improve the level of food production safety, we should not only pay attention to the improvement of the indicators with great weight, but also the indicators with low weight, which will become the top obstacle factor, thus affecting the level of food production safety of the company. For an enterprise to stand out in the group, it needs to maintain the indicators that have been well controlled and improve the indicators that are weaker than those of other enterprises while strengthening the control of large-weight indicators. For example, the score of Enterprise 5 in key material control, cleaning and disinfection, allergen and other indicators with high weight is not much different from that of the other 4 enterprises. Its current rectification should focus on staff training, incoming material inspection, label and other indicators with low weight. However, the maintenance management and waste management of Enterprise 2 are relatively weak, which requires the establishment of post-maintenance delivery procedures and continuous implementation, identification of key preventive maintenance related to food quality and safety and continuous improvement. The root cause of waste materials in the production process must be investigated, and corrective and preventive measures should be completed as planned.

4.4 Compared with the TOPSIS results

TOPSIS Method is also called the good and bad solution distance method, which is a kind of comprehensive evaluation method. The weights used the above combined weights, and the results are shown in Table 13.

Table 13: TOPSIS evaluation of food production enterprises.

Enterprise	D+	D-	Relative proximity	Rank
E 1	0.856	0.269	0.239	5
E 2	0.477	0.806	0.628	1
E 3	0.557	0.712	0.561	2
E 4	0.605	0.673	0.527	4
E 5	0.575	0.663	0.536	3

It is known that the evaluation results of the improved VIKOR method are as follows: Enterprise 2 > Enterprise 5 > Enterprise 3 > Enterprise 4 > Enterprise 1, the ranking results of the traditional VIKOR method (K=0.5) are enterprise 5 > Enterprise 2 > Enterprise 3 > Enterprise 4 > Enterprise 1, and the ranking results of TOPSIS method are enterprise 2 > Enterprise 3 > Enterprise 5 > Enterprise 4 > Enterprise 1. Compared with these three methods, it can be seen that the ranking results of the AEC-VIKOR method are closer to TOPSIS method, and the ranking of the first and the last two are consistent, which proves that the optimal compromise solution does not necessarily fall on the common compromise value of k=0.5, so the VIKOR improved by the adantagonistic selection method is more reasonable. However, the ranking of firm 5 and firm 3 by AEC-VIKOR method is opposite to that of TOPSIS method. This is mainly because firm 3 has a low membership degree in the index with high weight and cannot be compensated. The individual regret value of enterprise 5 is smaller than that of enterprise 3, which can balance the influence of weight on higher indicators. However, TOPSIS method only takes the close degree of each evaluation object to the positive and negative ideal solutions for ranking, and does not take the influence of distance weight on the ranking results into consideration. Compared with AEC-VIKOR, Topsis method is more one-sided.

In conclusion, the food production safety evaluation results of the improved VIKOR method based on game combination weighting are better than those of the traditional VIKOR method and TOPSIS method, which can solve the ordering quantity and use the inflection point for cluster analysis. According to the obstacle degree analysis model, the obstacle factors of each enterprise can be obtained. Enterprises can take targeted improvement measures according to the specific situation, so as to realize the efficient prevention and control of risks in the process of food production and improve the level of food production safety management.

5 CONCLUSION

This paper starts from the external material management, equipment management, biological management, material and product management, administrative management five aspects to establish the food production safety evaluation index system. Research found: first of all, this paper using BWM method and CRITIC method to calculate evaluation index subjective and objective weight, combined with game theory with the lowest deviation between the weight will both weight combination, which not only reduces the subjective influence of BWM method empowerment, also reduces the CRITIC method due to the data change weight fluctuations, make the empowerment more reasonable. Secondly, this paper proposes the adversarial merit selection method to improve VIKOR, which can clearly solve how many kinds of ranking, and also proposes to use the inflection point for cluster analysis. It can point out that sometimes the optimal compromise solution does not necessarily fall on the common compromise value of k=0.5. Compared with the traditional VIKOR and TOPSIS method, it is more reasonable and has stronger applicability. Provide reference for food production enterprises and relevant government departments to improve food quality and safety risk monitoring, identification and evaluation. Finally, through the example analysis, the three factors with the biggest impact on food production safety are: key material control (0.111), cleaning and disinfection (0.096), and allergen control (0.09). In terms of key material control, the key material control personnel should be trained and qualified before engaging in relevant operations. From accounting, weighing, to feeding, they need to have electronic inspection or double review, and timely weighing and feeding records. In terms of cleaning and disinfection, the factory shall establish the main cleaning plan and implement and record the cleaning situation according to the main cleaning plan. Before the cleaning effect is started and after cleaning and disinfection, the cleaning effect is confirmed in place, and the cleaning effect does not meet the requirements should be reported in time. In terms of allergen control, the allergens used in the factory are clearly identified at all stages of the production process, including receiving, storage, transportation, weighing and use, to prevent cross-contamination and allergen contamination, the production should be stopped first and reported to the site leader. Re-cleaning, inspection and then qualified follow-up work. Secondly, to improve food quality and safety, we should not only pay attention to the improvement of the indicators with great power, but also the indicators with small weight. Therefore, in order to stand out in the group, to pay attention to the indicators with great power, the indicators with small weight should not ignore the need for continuous improvement.

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