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Evaluation of Influencing Factors of Food Safety in Cold Chain Logistics Based on Improved AHP

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Abstract: With the continuous increase of global trade and the increasing demand of consumers for high-quality food, people pay more and more attention to how to ensure food quality and safety in cold chain logistics. The research of cold chain logistics has also become the focus of the food industry, relevant government agencies and academia. In order to study the influence of various common factors in cold chain logistics on food safety, this paper introduces the application steps of improved analytic hierarchy process in detail, and uses this method to establish a hierarchical structure model, uses the three-scale method to establish the comparison matrix of influencing factors, and obtains the weight ranking of each factor by quantitative analysis. The calculation results show that: among the 13 factors affecting food safety, the main factors are packaging, equipment failure rate, wet temperature and inspection and testing, whose weights are 0.160, 0.133, 0.118 and 0.116, respectively, which are the focus of attention in the process of cold chain logistics. The evaluation results make the influence degree of various factors affecting food safety more clear, and can also provide a reference for improving the safety of cold chain logistics and adopting effective measures and means to do a good job in safe operation management.

Keywords: Cold chain logistics; Food safety; Improve the analytic hierarchy process; Triple scale.

1. Introduction

The traditional normal temperature logistics transportation system is difficult to meet the special requirements of food transportation, such as temperature control, monitoring and preservation, etc., while the temperature fluctuation of food during transportation, storage and distribution may lead to food corruption, reduced nutritional value, and even bring potential risks to consumers' health[1]. Therefore, cold chain logistics becomes crucial in maintaining food freshness, extending the shelf life of goods and ensuring product safety. At present, the study of cold chain logistics at home and abroad has become an active field, and scholars are paying more and more attention to all aspects of cold chain logistics.

2. Improve the Analytic Hierarchy Process

2.1. Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a multi-objective decision-making analysis method that combines qualitative analysis and quantitative analysis, and is used to deal with the relationship between multiple factors and multiple levels in complex problems[2]. The basic principle of AHP is to decompose the problem, divide it into several levels, and establish a hierarchical structure, including goals, criteria, sub-criteria, etc. Within each level, a judgment matrix is established by comparing the relative importance between different elements in pairs. The scale of comparison is usually 1 to 9. Using mathematical methods, the weight of each element is calculated, which usually involves calculating the eigenvectors and eigenvalues of the judgment matrix. Checking the consistency of each judgment matrix is the key to ensure the consistency of the judgment matrix. Finally, the calculated weights are integrated to get the final evaluation result. According to the obtained weights and evaluation results, the corresponding decision is made.

2.2. Improve Analytic Hierarchy Process (AHP) and procedures

The improved analytic hierarchy process (AHP) is based on the analytic hierarchy process (AHP), which adopts "three-scale method" instead of the original "nine-scale method" to construct a comparison matrix[3], and adopts three-scale method (0,1,2) to construct a pair-to-pair comparison matrix of influencing factors, which greatly reduces the number of comparisons between indicators, and greatly reduces the fuzziness in judging the importance of indicators, and greatly simplifies the operation process[4]. The quasi-optimal consistent matrix is obtained through step by step calculation, and finally the feature vector is calculated and sorted according to the number size from high to low, that is, the influence degree of each factor on the target layer is obtained. The result does not require consistency test, which reduces the trouble of adjusting the judgment matrix several times, simplifies the calculation and improves the calculation accuracy[5]. The specific steps to improve AHP are as follows[6].

(1) Build a hierarchical model. The hierarchical model of the system is established based on the traditional analytic hierarchy process (AHP) principle, which mainly includes the target layer, criterion layer and element layer.

(2) Construct a comparison matrix, and make pairwise comparison according to the importance of each layer factor to the upper layer factor, and adopt the "three-scale method" to establish the corresponding comparison matrix Aij, as shown below.

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

In order to realize the quantization of the elements of the comparison matrix, the three-scale method is:

$$a_{ij}=\begin{cases} 0 & Factor\ j\ are\ more\ impor\tan t\ than\ factor\ i \\ 1 & Factor\ i\ and\ factor\ j\ are\ equally\ impor\tan t \\ 2 & Factor\ i\ are\ more\ impor\tan t\ than\ factor\ j \end{cases} \quad (2)$$

(3) Construct the judgment matrix. Construct the judgment matrix according to the comparison matrix. The elements of the judgment matrix follow the following formula:

$$b_{ij}=\begin{cases} \dfrac{r_i-r_j}{r_{\max}-r_{\min}}(b_m-1)+1 & r_i \geqslant r_j \\ \left[\dfrac{r_j-r_i}{r_{\max}-r_{\min}}(b_m-1)+1\right]^{-1} & r_i < r_j \end{cases} \quad (3)$$

Where r_i is the sum of factors in row i of the comparison matrix, r_{min} and r_{max} are shown as follows.

$$\begin{cases} r_{\min}=\min\{r_i\} \\ r_{\max}=\max\{r_i\} \end{cases}$$

To compare the scale bm, the formula is as follows:

$$b_m=\frac{r_{\max}}{r_{\min}} \quad (4)$$

(4) Find the transfer matrix of the constructed judgment matrix, and the elements of the transfer matrix follow the following formula:

$$C_{ij}=\lg b_{ij},(i,j=1,2,\cdots n) \quad (5)$$

(5) Find the optimal transfer matrix of the transfer matrix, and the elements of the optimal transfer matrix follow the following formula:

$$d_{ij}=\frac{1}{n}\sum_{k=1}^{n}(c_{ik}-c_{jk}) \quad (6)$$

(6) Find the quasi-optimal consistent matrix of the judgment matrix, and the elements of the quasi-optimal consistent matrix follow the following formula:

$$b_{ij}'=10^{d_{ij}} \quad (7)$$

(7) To find the eigenvector of the quasi-optimal uniform matrix: the sum method is used to calculate, the elements of the quasi-optimal uniform matrix are normalized according to the column, and then $b_{ij}' / \sum_{k=1}^{n} b_{kj}'$, and then the columns after normalization are added, and the added vector is divided by n to obtain the eigenvector, that is, the required weight vector.

(8) Total sort. Using the above single-level sorting results, the final total sorting is carried out, and the main factors affecting the target layer are obtained.

3. Analysis of Influencing Factors of Food Safety

3.1. Principles of system construction

When constructing the index system of influencing factors of cold chain logistics food safety, the following principles can be considered[7] :

1. Comprehensive principle: The evaluation system should comprehensively consider all aspects and factors of cold chain logistics, including the whole process from supplier selection to distribution to consumers. This ensures the comprehensiveness and accuracy of the evaluation in order to fully assess the impact of cold chain logistics on food safety.

2. Risk-oriented principle: The evaluation system should be risk management-oriented, that is, to evaluate and control various potential risks of food safety. Considering the possible problems such as temperature fluctuations, cross-contamination and food breakage in cold chain logistics, the evaluation system should emphasize the identification, evaluation and effectiveness of control measures for these risks.

3. Standard consistency principle: The evaluation system should be based on national, industry or international standards and norms to ensure the comparability and consistency of the evaluation process. For example, you can refer to food safety management system standards (such as ISO22000) or cold chain logistics industry standards, according to these standards to develop the corresponding evaluation indicators and evaluation methods.

4. Operability principle: The evaluation system should have practical operability, that is, it can be practically applied to the management and operation of cold chain logistics enterprises or organizations. Evaluation indicators and methods should be simple and clear, easy to understand and implement. At the same time, the suggested evaluation system can provide practical suggestions and improvement suggestions to help enterprises improve and enhance the level of food safety management.

5. Principle of continuous Improvement: The evaluation system should encourage continuous improvement and learning. Through regular evaluation and monitoring, identify problems and deficiencies, and take appropriate corrective actions and improvement measures. The evaluation system should have a feedback mechanism in order to timely adjust and improve the evaluation indicators and methods, as well as the management system of cold chain logistics.

When constructing the cold chain logistics food safety evaluation system, it can refer to relevant standards, norms and best practices according to the above principles, and formulate evaluation indicators and evaluation methods suitable for enterprises in combination with specific business needs and food safety risks, so as to ensure the effective control and guarantee of cold chain logistics for food safety.

3.2. Identification of influencing factors of food safety

Based on the study of existing literature, combined with the evaluation results of other experts and scholars on fresh products and the industrial characteristics of fresh products, this paper mainly analyzes and studies the food quality and safety of cold chain logistics from four aspects, namely personnel, operations, information equipment and environment [8].

1.Personnel factors

Personnel factors play a crucial role in ensuring food safety in cold chain logistics. For example, if the practitioner has professional knowledge and skills, it can greatly reduce the loss and waste of food in a sense, while if the practitioner lacks professional skills, it will bring unknown risks to food safety. In addition, if the operation of employees is not standardized, or careless, professional quality is too low, it will also bring a certain degree of negative impact on food safety.

2.operational factors

In order to improve food safety, cold chain logistics should consider the following operational factors: the inspection and testing of fresh food should be conducted in accordance with the food category and its own characteristics in accordance with the standards and requirements of food safety management, to avoid unqualified food also into the sales market, bringing safety risks to the life and health of residents. The food inspection should be transferred to the packaging link, and the packaging of food should follow the requirements and norms of health standards. Proper cold storage management should be carried out before the completion of packaging and transportation, because fresh food has the characteristics of easy corruption and short shelf life, the staff should adjust the temperature and humidity of the storage environment in a timely manner to meet the requirements of food preservation. Finally, when the food is out of the warehouse, it should ensure stable loading and unloading to avoid unnecessary damage to fresh products caused by bump and collapse, resulting in accelerated corruption of food. During the transportation process, the appropriate transportation route should be selected, the transportation time should be reasonably arranged, and the temperature fluctuations of the cold chain transportation equipment should be minimized to bring unnecessary corruption to the food, and the vehicle vibration should be reduced to cause bumps to the food and affect the quality of the food.

3.Information equipment factors

The timely transfer and sharing of information between the various links can make the cold chain system operate more efficiently and transfer parameter information in a timely manner can help the staff to monitor all aspects of the cold chain logistics in real time, so as to make timely and appropriate adjustments, so that the cold chain logistics infrastructure can be more fully utilized, so as to improve the operation efficiency of the enterprise, reduce the food cargo loss rate and quality safety. Research and development of new preservation technology, such as control of gas composition, application of microbial inhibitors and antioxidants, in order to delay food spoilage and quality loss, extend the shelf life of food. In addition, if the failure rate of cold chain equipment is too high, it is also a safety hazard for cold chain food, and the higher the probability of equipment failure, the more the safety of food cannot be guaranteed.

4.environmental factors

The environment is considered from two aspects, one is the natural environment, the control of temperature and humidity has a great impact on food quality and safety, and the weather and climate will affect the traffic order and sometimes lead to traffic jams and affect the transportation efficiency and then affect the quality of food. Moreover, the social environment, the supervision of government departments, the introduction and implementation of policies, systems and laws and regulations also provide guarantees for the quality and safety of food.

3.3. Establish the hierarchical structure model of influencing factors

The evaluation index system was constructed by comprehensively considering the above influencing factors of food safety, as shown in Table 1.

Table 1. Index system of influencing factors of Cold-Chain food quality and safety

Target Layer	Guideline Layer	Element Layer
Cold-Chain food quality and safety influencing factors A	Personnel Elements *A1*	Food safety awareness *A11*
		Professional knowledge skills *A12*
		Standard and skilled operation *A13*
	Job Elements *A2*	Inspection and testing link *A21*
		Packaging link *A22*
		Warehouse link *A23*
		Transport link *A24*
	Information Equipment Elements *A3*	Development of new preservation technology *A31*
		Information timely sharing *A32*
		Cold-Chain equipment failure rate *A33*
	Environmental Elements *A4*	Weather and climate *A41*
		Wet temperature *A42*
		Laws and regulations *A43*
		Supervision and control of relevant departments*A44*

3.4. Construct a judgment matrix to calculate the weight

According to the above calculation steps of the improved analytic hierarchy process, the elements of the criterion layer are compared in pairwise to obtain the corresponding comparison matrix, judgment matrix, transfer matrix, optimal transfer matrix and quasi-optimal consistent matrix, as shown below.

(1) By consulting a large number of literatures, investigating and consulting cold chain logistics transportation technicians and consulting experts, the relative importance of each factor is determined. The comparison matrix *A* is constructed according to the three-scale method.

$$A=\begin{bmatrix}1&0&0&2\\2&1&1&2\\2&1&1&0\\0&0&2&1\end{bmatrix}$$

Sum the comparison matrix *A* by row, calculate the base point comparison scale,

$$r_{\min}=3,\ r_{\max}=6,\ b_m=\frac{r_{\max}}{r_{\min}}=2$$

(2) The judgment matrix *M* is obtained from the comparison matrix *A*

$$M=\begin{bmatrix}1&0.5&0.75&1\\2&1&1.667&2\\1.334&0.6&1&1.334\\1&0.5&0.75&1\end{bmatrix}$$

(3) Find the transfer matrix *Q* from the judgment matrix *M*.

$$Q=\begin{bmatrix}0&-0.301&-0.125&0\\0.301&0&0.222&0.301\\0.125&-0.222&0&0.125\\0&-0.301&-0.125&0\end{bmatrix}$$

(4) The optimal transfer matrix *P* is obtained from the transfer matrix *Q*.

$$P=\begin{bmatrix}0&-0.312&-0.113&0\\0.312&0&0.199&0.312\\0.113&-0.199&0&0.113\\0&-0.312&-0.113&0\end{bmatrix}$$

(5) The quasi-optimal uniform matrix *M* 'is obtained from the judgment matrix *M*.

$$M'=\begin{bmatrix}1&0.488&0.771&1\\2.051&1&1.581&2.051\\1.297&0.632&1&1.297\\1&0.488&0.771&1\end{bmatrix}$$

(6) Using the sum method to find the feature vector of *M* ', *W1*= (0.188, 0.385, 0.240, 0.188)^{A} can be calculated, which is the weight vector of the index layer to the target layer. The quasi-optimal uniform matrix of *B1*-*C*, *B2*-*C*, *B3*-*C*, *B4*-*C* and its eigenvector are obtained by the same method, and the result is *W2*= (0.091, 0.455, 0.455) ^{A}. *W3*= (0.300, 0.415, 0.121,0.164) ^{A}; *W4*= (0.222, 0.222, 0.556) ^{A}; *W5*= (0.376, 0.629, 0.164,0.164) ^{A}.

(7) Sort the weights in total, that is, calculate the weight coefficients of factor layer *Ci* (*i*=1, 2, 3..., 13) for target layer *A* (see Table 2).

Table 2. Weight value and ranking of influencing factors of food safety

A	*B1*	*B2*	*B3*	*B4*	$\sum_{j=1}^{4} W_{AB_j} W_{B_jC_i}$	Sort
	0.188	0.385	0.240	0.188		
C1	0.091	/	/	/	0.017	14
C2	0.455	/	/	/	0.086	5
C3	0.455	/	/	/	0.086	6
C4	/	0.300	/	/	0.116	4
C5	/	0.415	/	/	0.160	1
C6	/	0.121	/	/	0.047	11
C7	/	0.164	/	/	0.063	8
C8	/	/	0.222	/	0.053	9
C9	/	/	0.222	/	0.053	10
C10	/	/	0.556	/	0.133	2
C11	/	/	/	0.376	0.071	7
C12	/	/	/	0.629	0.118	3
C13	/	/	/	0.164	0.031	12
C14	/	/	/	0.164	0.031	13

4. Result Analysis

According to the results obtained by the improved three-scale AHP method, among the influencing factors of the criterion layer, the weight of operation factor is the largest, which is 0.385, followed by the information equipment factor, which is 0.240. From the factor layer to the target layer, the weight of the packaging link is the largest, 0.160, followed by the cold chain equipment failure rate, temperature and humidity and inspection and detection link, accounting for 0.133, 0.118, 0.116, respectively. Based on the above research results, the following countermeasures and suggestions are put forward: In order to ensure the quality and freshness of fresh products, cold chain logistics enterprises should formulate strict food processing and packaging standards, attach great importance to the cold storage and refrigerated trucks in the cold chain logistics process, regularly do the maintenance and treatment of equipment, and improve the cold chain transportation level of enterprises.

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