

Research Article

Study on Food Safety Risk Pre-warning Based on Set-valued Statistics

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Abstract: Food safety problem happens frequently in recent years, it is necessary to pre-warning the food safety risk, therefore the set-valued statistics model is applied in it. Firstly, research progress of food safety pre-warning system at home and abroad is summarized. Secondly, the theory model of set-valued Statistics is studied; thirdly, the structure of food safety risk pre-warning system is designed; then the corresponding pre-warning analysis steps of food safety risk based on set-valued statistics. Finally, the application of set-valued statistics model on food safety pre-warning is carried out, results show that the set-valued statistics method is an effective for analyzing the food safety problem.

Keywords: Food safety, pre-warning, set-valued statistics

INTRODUCTION

In recent years, the food safety problem raises red flags constantly, the occurrence with high frequency and fatalness of it make strategic decision makers concern the early pre-warning of food safety problem based on prediction technology. The research on the food safety mainly concerned on monitoring technology and supervision system of food safety and ignored the early pre-warning of food safety risk (Wang and Chen, 2014). Therefore it is necessary to carry out effective monitoring. An advanced pre-warning technology should be found out for innovating the working mechanism of food safety risk monitoring and improving the level of food safety risk monitoring. In order to reduce and prevent the occurrence of food safety risk, the pre-warning model of food safety risk should be constructed, the probability and seriousness of food safety risk can be measured, the probability and degree of occurrence of food safety problem can be evaluated, the hidden danger can be find out, the effective measurement can be put forward, the early pre-warning mechanism of food safety risk can be established.

The set-valued statistics method is put forward by Prof. Wang Pei-Zhuang, in classic Probability and statistics, every test can only get a certain point in phase space, if this condition is relaxed, then every test can get a fuzzy sub set in phase, this kind of test is set-valued statistics test (Li and Fan, 2013). The set-valued statistics is the extension of classic and fuzzy statistics and that is expert gives a interval evaluating value for a evaluating index, this statistics method offers a new quantitative method for evaluating food safety problem.

RESEARCH PROGRESS OF FOOD SAFETY PRE-WARNING SYSTEM AT HOME AND ABROAD

In recent years, many countries have carried out food safety pre-warning research and some excellent achievements have been obtained. European Union established the rapid alert system for food and feed, this system connected with food and feed safety administrator of every country, European Commission health and consumer protection Administration, European Free Trade Union and European Food Safety Authority, the members of the system has contacting point and can contact each other, then a smooth network system is formed. When food and feed with risk appears on the market, the corresponding action should be taken. The member country issued pre-warning that monitored the relating situations and took measurements. This problem can be informed to other countries and then they inspected the same problem in their jurisdictional limits. American food safety supervision is responsible by United States Department of Agriculture and FDA, the Department of Agriculture is responsible for meat, poultry and eggs and FDA monitored the other food. FDA can collect food safety information based on many Multi group channels, FDA can issue safety alerts and advisories, publish recall information and send out warning letters and untitled letters. At same time, in China the food safety pre-warning researches haven carried out, but the corresponding work is limited, China can put the effective food safety pre-warning measurement drawing on the experience of European Union and America. Scientific risk evaluation of food safety is the main basis for risk pre-warning, the pre-warning work of European Union and America reflected the everywhere

scientific risk evaluation. According to degree of potential risk, the different pre-warning information is published and different measurement is taken. America recalled all food that the content of pollution is over the standard and the limit standard is established based scientific evaluation mechanism. The set-valued statistic is a scientific evaluation method, which can be applied in the food safety pre-warning model.

Theory model of set-valued statistics: The interval evaluation for j^{th} index of project x_i by k^{th} expert is defined as $[x_{ij}^{(k)}(1), x_{ij}^{(k)}(2)]$, then the interval evaluation samples of L experts is defined as a set-valued statistics series, which is expressed as follows (Tian *et al.*, 2013):

$$\{ [x_{ij}^{(1)}(1), x_{ij}^{(1)}(2)], [x_{ij}^{(2)}(1), x_{ij}^{(2)}(2)], \dots, [x_{ij}^{(k)}(1), x_{ij}^{(k)}(2)], \dots, [x_{ij}^{(L)}(1), x_{ij}^{(L)}(2)] \} \quad (1)$$

The L intervals can be superposed as a kind of distribution, the fuzzy coverage rate of a point x_{ij} in the interval is expressed as follows:

$$f(x_{ij}) = \frac{1}{L} \sum_{i=1}^L F(x_{ij})_{[x_{ij}^{(k)}(1), x_{ij}^{(k)}(2)]} \quad (2)$$

where, $F(x_{ij})_{[x_{ij}^{(k)}(1), x_{ij}^{(k)}(2)]} = \begin{cases} 1, & x_{ij} \in [x_{ij}^{(k)}(1), x_{ij}^{(k)}(2)] \\ 0, & \text{other} \end{cases}$ denotes drop shadow function, denotes evaluation value of index j of project x_{ij} can be taken as expert proportion of x_{ij} .

The evaluation value of set-valued statistics is expressed as follows (Gil, 2014):

$$\hat{x}_{ij} = \int_{x_{\min}}^{x_{\max}} f(x_{ij}) x_{ij} dx_{ij} / \int_{x_{\min}}^{x_{\max}} f(x_{ij}) dx_{ij} \quad (3)$$

where x_{\min} and x_{\max} denote possible minimum and maximum value of index.

According to the expressions (1) and (3), the following expressions can be obtained:

$$\int_{x_{\min}}^{x_{\max}} f(x_{ij}) dx_{ij} = \frac{1}{L} \sum_{k=1}^L [x_{ij}^{(k)}(2) - x_{ij}^{(k)}(1)] \quad (4)$$

$$\int_{x_{\min}}^{x_{\max}} f(x_{ij}) x_{ij} dx_{ij} = \frac{1}{2L} \sum_{k=1}^L \{ [x_{ij}^{(k)}(2)]^2 - [x_{ij}^{(k)}(1)]^2 \} \quad (5)$$

The group information value is synthesized from using L decision intervals, which is a evaluation value, the level of its reliability can affect the final decision results directly, it is necessary to analyze the reliability of set-valued of group decision information, which can be described by variance of $f(x_{ij})$ distribution, the

variance of set-valued Statistics samples is calculated by the following expression:

$$D(x_{ij}) = \int_{x_{\min}}^{x_{\max}} (x_{ij} - \hat{x}_{ij})^2 f(x_{ij}) dx_{ij} / \int_{x_{\min}}^{x_{\max}} f(x_{ij}) dx_{ij} \quad (6)$$

$D(x_{ij})$ reflects discrete degree of evaluation value, the less the $D(x_{ij})$ is, the more uniform the advances of the experts, the grasping degree of the index is good. The expert evaluation confidence of j^{th} index of project x_i is calculated by the following expression (Li *et al.*, 2012):

$$\theta_{ij} = \frac{1}{1 + D_{ij}} \quad (7)$$

METHODOLOGY

Structure of food safety risk pre-warning system:

The food safety risk pre-warning system concludes three sub systems, which are pre-warning information management sub system, pre-warning analysis sub system and pre-warring reflecting sub system. The pre-warning information management sub system is responsible for managing pre-warning condition and alarm information published and pre-warning object information and gives priority to guaranteeing real-time. The pre-warning analysis sub system can analyze the inspected information of food and obtains the results whether the food is safe or not, which can be used by pre-warning reflecting sub system. The pre-warning reflecting sub system can publish the alarm information from pre-warning analysis sub system to public and law enforcement personnel, then the corresponding measurements can be taken early, then the loss can be reduced. The framework of food safety risk pre-warning system is shown in Fig. 1.

Pre-warning information management sub system:

This sub system is the basic data sources of food safety risk pre-warning system, the input end is the monitoring data published by every monitoring point collected by the supervision department and the output end is the available data information, which concludes import module, index standard module and data information module (Lü, 2013).

Index standard module concludes standard database of fourteen kinds of food. This module can displays national standard of every kind of food monitoring indexes through choosing the classification of food, food microorganisms standard and food additive using standard. The adding and updating function of national standard by supervision department is provided. Data information module can set displaying function of sampling time, sampling position, sample

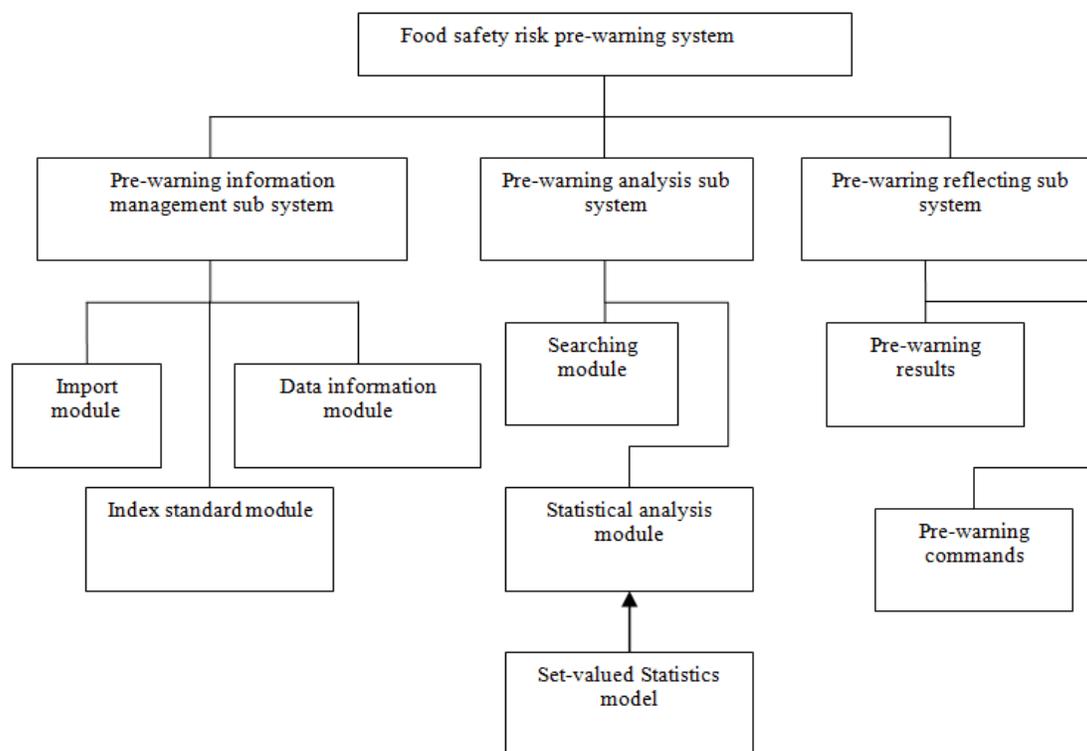


Fig. 1: Framework of food safety risk pre-warning system

classification searching, data information of every monitoring index for a year, a area, a kind of food can be displayed according to the inspecting data of every monitoring point.

Pre-warning analysis sub system: This sub system is the core part of the whole system, the input end is the available data information and the output end is all kinds of analysis information for food safety risk. Through a large number of data cleaning and data screening, the data information is given to backstage to be processed. It has strong statistics and query functions, then the pre-warning aim can be achieved.

According to the classification analysis, the statistical data concluding all monitoring indexes of chemical index, microbial index of this kind of food can be displayed through choosing the classification of sample, the corresponding statistical data concludes monitoring number, detected number, detected rate, exceeding standard number and exceeding standard rate. The trending analysis diagram of food safety risk, such as bar chart, line chart of every index can be given according to year.

Pre-warring reflecting sub system: The input end of this system is pre-warning analysis information and the output end of this system is analysis results and commands. The sub system can offer basis for

supervision personnel of food safety and the safety status warning information of food. This sub system can display the sampling total number, qualified number and rate. The food safety risk trends of year and area can be compared according to the qualified rate and then the pre-warning prompt can be obtained. This sub system has the pre-warning sub module of expert guidance, which concludes the food safety risk re-warning information, such as food source disease, food pollution, food poisoning and the corresponding pre-warning information can be published through cell phone message or network. Then the food safety risk can be monitored and pre-warned in real time (Jiang *et al.*, 2014).

PRE-WARNING ANALYSIS STEPS OF FOOD SAFETY RISK BASED ON SET-VALUED STATISTICS

The set-valued statistics can process the uncertain judgment and can collect different advises conveniently and reduce random error during the procession of judgment by expert. This evaluation method is simple, which has strong adaptability. The corresponding steps are listed as follows:

Step 1: Confirmation of index evaluation value: The number of evaluation indexes in evaluation

system is set as m , the corresponding collection is expressed as $U = \{u_1, u_2, \dots, u_m\}$. The number of experts entering into index evaluation is set as n , the corresponding collection is expressed as $P = \{p_1, p_2, \dots, p_n\}$. For index u_i , the weighted value interval confirmed by every expert is set as $[a_{i1}, b_{i1}]$, $[a_{i2}, b_{i2}]$, ..., $[a_{in}, b_{in}]$ respectively. For index u_i , the evaluation interval given by expert can form a set-valued statistics series, the sample dropping shape function can be calculated based on expression (2). The risk value of food safety pre-warning can be calculated based on expression (3).

Step 2: Confirmation of index system weighted value: The weighted value of every evaluation index can be confirmed through conducting several experts. The weighted value of j^{th} expert is expressed as follows:

$$\{\lambda_{1j}, \lambda_{2j}, \dots, \lambda_{mj}\}$$

If the square sum error of it is in the permitted range, that is:

$$\max_{1 \leq j \leq n} \left[\sum_{i=1}^m \lambda_{ij} - \frac{1}{n} \sum_{j=1}^n \lambda_{ij} \right] \leq \varepsilon \tag{8}$$

Then the following expression can be obtained:

$$\bar{\lambda} = \left(\frac{1}{n} \sum_{j=1}^n \lambda_{1j}, \dots, \frac{1}{n} \sum_{j=1}^n \lambda_{mj} \right) \tag{9}$$

Expression (9) shows the optimal weighted coefficient set, otherwise, the λ_i with big error should be revised according to advices of

relating experts, this operation is over until satisfaction.

Step 3: Calculation of risk value of food safety risk:

The risk degree of food safety pre-warning is calculated based on linear weighted model, which is expressed as follows:

$$R = \sum_{i=1}^n W_i \cdot F_i \tag{10}$$

where,

R = The food safety risk of up level index

W_i = The weighted value of down level index

F_i = The evaluation score of index

Application of set-valued statistics model on food safety pre-warning: According to the real situation of food safety risk pre-warning in a province, the corresponding food safety risk pre-warning index system is established, which is shown in Table 1.

According to food safety pre-warning situation in this province, the food safety risk level is obtained, which is shown in Table 2.

According to set-valued statistics model, the calculating results of food safety risk pre-warning evaluation indexes are shown in Table 3.

As seen from Table 3, the score from quantitative analysis of food safety risk pre-warning in this province is 56.9. According to risk pre-warning level standard, the risk pre-warning level of food safety risk pre-warning in this province is III level, the food safety pre-warning level belongs to III level, the risk pre-warning level is high, the risk pre-warning is in the level that is difficult to be controlled. According to evaluation results of food safety risk pre-warning, the effective measurement can be taken, then harm of food safety problem can be reduced to a minimum.

Table 1: Food safety risk pre-warning index system

First level index	Second level index
Food raw material supplying (u1)	Qualified rate of raw material (u11) Environment quality of raw materials producing area (u12) Fertilizer standard (u13)
Food producing and processing (u2)	Standards for pesticide residues (u14) Qualified rate of producing device (u21) Environment quality of producing and processing (u22) Technical advancement of producing and processing (u23)
Food distribution processing (u3)	Product quality certification standard (u24) Transparency of food producing and processing (u25) Packaging technology standards (u31) Storage technology standard (u32)
Food sales (u4)	Transport technology standard (u33) Fresh sensory recognition degree (u41) Standard rate of food physicochemical index (u42)
Food safety supervision (u5)	Definition of food identification (u43) Construction of supervisory organization (u51) Satisfaction of food market supervision (u52) Open degree of food information (u53) Processing intensity of food safety problem (u54)

Table 2: Food safety risk pre-warning level

Risk pre-warning level	Name	Quantitative range
I	Low risk pre-warning	(90, 100)
II	Middle risk pre-warning	(70, 90)
III	High risk pre-warning	(30, 70)
IV	Extreme risk pre-warning	(0, 30)

Table 3: Calculating results of food safety risk pre-warning evaluation indexes

First level index	Weighted value	Score	Risk level	Contribution for last level
u1	0.20	52.43	High risk	10.23
u2	0.30	50.92	High risk	10.56
u3	0.15	66.32	Middle risk	11.43
u4	0.10	68.87	Middle risk	12.54
u5	0.25	57.19	High risk	14.23

CONCLUSION

The set-valued statistics model is applied in the food safety risk pre-warning, the evaluation index system of food safety risk pre-warning is established according to real situation in a province. Application analysis results show that the set-valued statistics can solve the uncertain fuzzy evaluation problem, can construct the quantity mathematical model. The set-valued statistics method can directly evaluate the extent of food safety risk pre-warning, find out the weak part of food safety and the food safety risk pre-warning level can be improved. This model has wide practicability.

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