Study on Evaluation Index Model and Hierarchical Management of Food Safety

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Abstract

Food safety is closely related to the health of people. It also affects national stability and continuous development of economy and society. It is not an easy task to accurately measure and evaluate food safety because food production processes may be affected by multiple and complicated factors. This paper proposes an index model and a hierarchical management method to serve as a reference for food companies in their operation and for government in its safety inspection by considering various possible influential factors on food safety.

1. Introduction

Food safety is a one of the foundations of sustaining the economic development of China. Chinese government has worked hard on ensuring the foods produced in China are safe to eat. It has established a food safety monitoring and management system to monitor the food safety from Farm to Table and that system has steadily improved the food safety in China. In the first half year of 2008, food produced in China passed the safety standards was 98.4% based on a study conducted by the national quality's

examination & supervision agency.

Along with the fast development of national economy, people have higher demand on food safety. With the increasing demand for more food varieties, the uncertainty and risk of food safety is also increasing at the same time. The discovery of poly-Sudan，melamine and the powdered milk contamination incident had greatly endangered people's health. Although a number of food companies have controlled some potential hazards in the food chain by implementing GAP and HACCP, there is still lack of accurate evaluation system for food safety in measuring the work effectiveness and level of customer satisfaction on food safety.

By the year of 2008, the sales revenue of food industry in China reached 4000 billion RMB and with the fast growth of food industry, food safety improvement has aroused a wide concern. To analyze the new characteristics of food safety problems, search for a rational and scientific evaluation system and improve food safety level in China becomes a pressing issue.

In recent years, food safety problems have drawn great attentions of governments and scholars in the world. In January 2001, the Council of the European Union issued a White Paper on Food Safety and decided to strengthen the control of food safety from farm to fork and gradually set up a traceable system of food production. This system traces and inspects food products on all processes from production to sales. In 1996, United States issued the Food Quality Protection Act (FQPA 1996) and emphasized that evaluating the harm of pesticide residues to people's heath is no longer based on the quantity of single residue in a single food, rather on the total intakes of residues. Some Chinese scholars have made researches on food safety issues from the perspective of economics. Zhou Yingheng, Huo Liyue (2003) considered that, the problems of food Safety occurred due to the following reasons: poor government regulations, the immoral behaviors of some food products providers, and the uncertainty of new technologies. In fact, at the temporal level of technical development, factors of enhancing food production in early periods, such as chemical fertilizers, pesticides, and feed additives, had risks of uncertainty caused by new technological development (Zhang Lei, 2007). Some scholars, from the aspects of

food quantity security, food safety and food sustainable safety, established the evaluation model to comprehensively assess China's food Safety profile, which includes three-levels and sixteen indicators. The above-mentioned study has not made deep analysis of food safety characteristics, and indicator selection, however, this paper provides a certain foundation.

2. Characteristics of Food Safety

"Safety" is an integrated concept, which comprises both quality factors, namely the extent to which it meets the needs of the people, and safety factors, the extent to which it may do harm to people's health. Therefore, food Safety is a complex system engineering, which involves raw materials, activities of production, product test, and so on. Food in the transferring processes of these activities might be affected by number of factors and has the following characteristics.

(1) Hidden hazards. If the raw material is contaminated, the contamination would hide in following processes. Thus it would be difficult to estimate the food Safety situation in a timely manner. So it has a characteristic of hidden hazards.

(2) Direct hazards. Some of the food does not need to be cooked and can be served directly, such as milk powder. If this kind of food is contaminated, it would cause direct harm to people's health and life.

(3) Additive hazards. Food might be affected by a variety of factors at every step in the "food chain". If the affection cannot be eliminated in time, hazards will be cumulated in sequential process transfer and through biochemical reactions.

(4) Wide range hazards. Food processing cycle is relatively short, usually in large and continuous production, and the sales and circulation radius of food is very big. Thus the hazards of Safety would involve a wide range and the effect is great

Because of the above characteristics, it is difficult to identify food safety situation at different steps by traditional methods of evaluation or with general inspection equipment. Furthermore, once the inspection of food is not carried out timely, accurate evaluation would be more difficult.

3. Quantitative Evaluation Model for Food Safety

From the analysis of the characteristics of food Safety, we can see that the food hazards and quality loss may occur at any step along the food chain. Therefore, planned control and prevention are necessary along the food chain to provide food Safety.

3.1 Evaluation System for Food Safety

3.1.1 Analysis of influential factors to food safety

Food is a kind of special goods, directly relating to people's health and safety. At present, food production and marketing mainly covers requirements of three aspects(Figure 1) :

- Market access of food Safety, which are the basic requirements of Chinese food production and marketing. These requirements are also called imperative requirements.
- Supervision and sampling inspection of food quality, which is regularly or irregularly carried out by the government in accordance with the relative technical standards. The government implements corrective and condemnatory conventional actions to unqualified food. The requirements of this aspect are called normal requirements.
- Requirements of HACCP, ISO9001 and ISO22000 standards, which fully reflect food Safety control in all the production processes of the "food chain" .These requirements are also called voluntary standard requirements. Enterprises implementing these standards could obtain higher level of food Safety, and get more benefit than those who did not implement these standards.

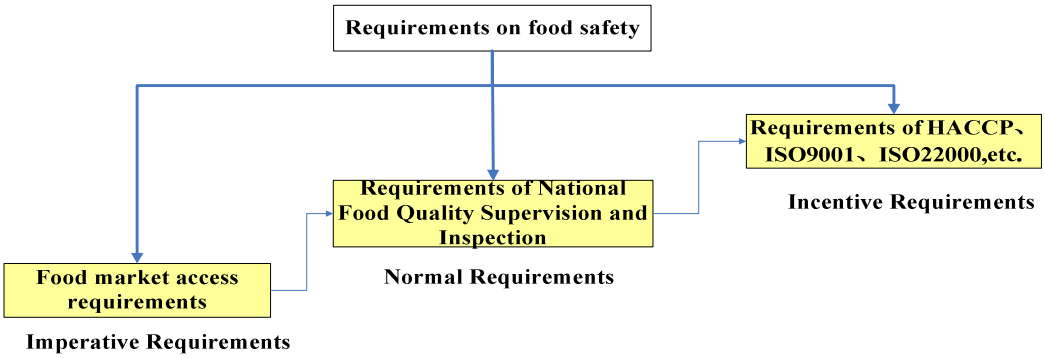

Figure 1 Requirements on Food Safety

(1) Imperative requirements: market access of food safety

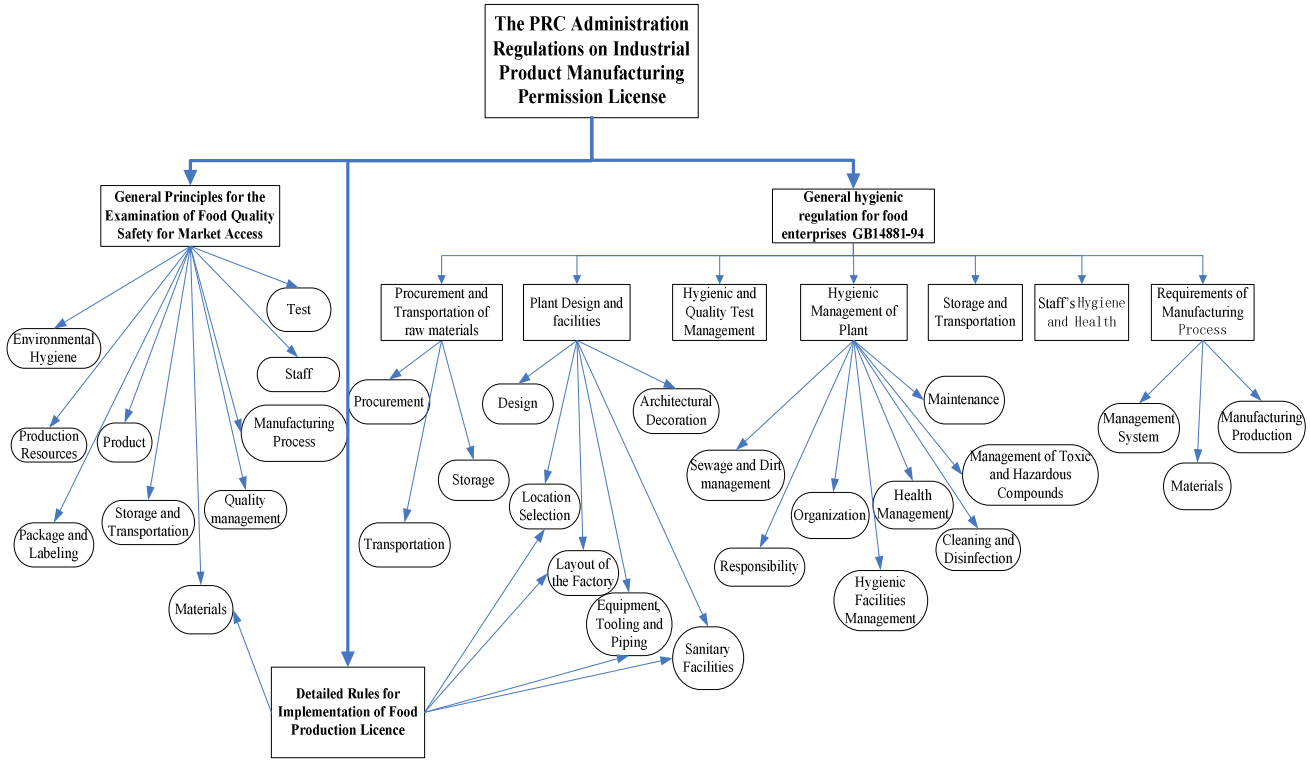

Figure 2 Factors Relating to Market Access of Food Safety

China General Administration of Quality Supervision, Inspection and Quarantine started to implement the system of market access of food Safety July 2002, which is for food production and marketing enterprises having fixed production sites, corresponding processing equipment and technical procedures. Implementing the system of market access of food Safety is the basic condition of food production and marketing enterprises, and it is the necessity of enforcing legal management of food production. This system is based on Product Quality Law of the P.R.C, Food Hygiene Law of the P.R.C and the PRC Administration Regulations on Industrial Product Manufacturing Permission License. And General Principles for the Examination of Food Quality Safety for Market Access, Detailed Rules for Implementation of Food Production License and General Hygienic Regulation for Food Enterprises GB14881-94 are the operating documents of the system. According to the requirements of the system food production enterprises have to meet the requirements relating to environmental conditions, production equipment, raw

material, processing techniques and procedures, product standard, staff, inspection equipment, packaging and labeling, storage and transportation, quality management. Food products must be inspected and proved to be qualified, granted "food production license", and labeled the food market access mark（QS）before being released to the market.

(2) Normal requirements: food supervision and sampling inspection

In 1985, State Council of China determined to implement the system of national supervision and sampling inspection of product quality. The system requires the Product Quality Supervision Division of State Council of China to act according to relative legal regulations, such as Product Quality Law of the P.R.C, Standardization Law of the P.R.C and Metrology Law of the P.R.C, and organize provincial technical supervision divisions and quality and inspection agencies to implement sampling inspection against the products being produced or sold by enterprises, make announcement of the results and take necessary follow up actions. It is one of the effective measures and main style of food quality supervision and macro management by Chinese government. National sampling inspection of food products is mainly to determine whether products are qualified or not according to relative food technical standards.

(3) Incentive requirements: management system of ISO9001, HACCP, ISO22000 and etc.

ISO 9000 series quality management system from the perspective of quality management, has active and promotive effects to food Safety and it reflects that enterprises use process management approaches to ensure food product quality. HACCP is an assurance system, which from the perspective of safety, identifies and controls potential hazards in food production, prevents unqualified products and protects food safety. ISO9001 provides holistic framework of management system while HACCP regulates procedures of implementing food safety system. In combination of ISO 9001 and HACCP, ISO 22000 (food safety management system) was formulated to provide safe end-products, which would meet both customers' requirements and food safety regulations by controlling food supply chain. ISO 22000

mainly covers requirements of management responsibilities, resource management (such as human resource, infrastructures, working environment), safe product planning and realization, validation and verification of food safety management system; improvement. Each requirement has subdivided prescriptions. These are self incentive measures implemented by enterprises to improve food production management, and enhance food safety.

3.1.2 Evaluation index framework of food safety

From the perspective of "food chain", we analyzed the above imperative, normal and incentive requirements and identified 22 influential factors in 3 areas, and based on this worked out an evaluation index framework for food Safety (see Table 1).

The index framework includes three levels. The first level is general index，second index includes enterprise design and implementation, management responsibilities of food hygiene and quality, enterprise management requirements, food hygiene quality control. Each first level index has its own next level indices and the second level has third level indices. For example, under the second level index enterprise design and implementation, there are five third level indices, such as location selection, factory layout, equipment tooling and piping, architectural decoration, sanitary facilities. Each third level index also has its detailed observational indices.

Table 1 Index Framework of Food Safety

The first level indices	The second level indices	Weight	The third level indices	Weight
Evaluation indices for food Safety	Enterprise design and implementation	0.12	1 layout of the factory	0.22
			2 equipment, tooling and piping	0.23
			3 architectural decoration	0.27
			4 sanitary facilities	0.26
	Food enterprise management requirements	0.30	5 organizational leadership	0.18
			6 management goal and objectives	0.16
			7 management responsibility	0.17
			8 production equipment	0.08
			9 staff requirements	0.13
			10 technical standards	0.10
			11 process documents	0.09
			12 document management	0.09
	Control of food hygiene and quality	0.58	13 procurement systems	0.08
			14 procurement inspection	0.13
			15 process management	0.13
			16 quality control	0.11
			17 product protection	0.07
			18 testing equipment	0.07
			19 test management	0.10
			20 process inspection	0.11
			21 normative use of food additives	0.10
			22 recent 3 years' records of sample passing rate	0.10

(1) Enterprise design and implementation

Mainly check the enterprise's environment, location and facilities, including four third level indices: layout of the factory; equipment, tooling and piping; architectural decoration; sanitary facilities. This forms the environment or conditions of food production.

(2) Food enterprise management requirements

Food enterprise management requirements have two parts, management responsibilities and enterprise management requirements.Management responsibilities

is an important requirement of food Safety, and in ISO22000, it includes management commitment, food safety policy, food safety management system planning, responsibility and authority, communication, management review. Enterprise management requirements is to fully reflect the requirements of resource management, product realization, measurement analysis and improvement in ISO9000 quality standard and the nature of using process management to insure system implementation, including production equipment, staff requirements, technical standards, process documents, document management.

(3) Food hygiene and quality control

Food hygiene and quality control is the requirement in the complete process of food production, which includes eleven third level indices: raw material procurement, production processes, product packaging, and release inspection. It relates to procurement systems, procurement inspection, process management, quality control, product protection, testing equipment, test management, process inspection, normative use of food additives, and recent three years' records of sample passing rate.

3.1.3 Determination of the weight of food safety evaluation indices

By combining food technical testing and on-spot investigations, we can determine the criteria in evaluating each index. The weight of each second level index can also be calculated by the AHP method through firstly designing the second level indices comparison matrix (Table 2), then inviting several experts of the food quality management to compare the indices with each other by using the 1 to 9 scale method (Table 3) given by the US famous operations research expert Ernesto, after that we can get the weight of the second level indices (Table 2 is the calculation results of the secondary index weight based on an expert evaluation).The weight of enterprise design and implementation is 0.12; the weight of management responsibilities of food hygiene and quality is 0.30; the weight of enterprise management requirement is 0.29 and the weight of food hygiene and quality control is 0.29.

Table 2 The Comparison Matrix of Second Level Indices

Evaluation indices	Enterprise design and implementation	Management responsibilities of food hygiene and quality	Enterprise management requirements	Food hygiene and quality control	Multiplying	Square root	Weight
Enterprise design and implementation	1.00	1/3	1/3	1/2	0.056	0.49	0.11
Management responsibilities of food hygiene and quality	3	1	1/2	3	4.500	1.46	0.34
Enterprise management requirements	3	2	1	1/2	3.000	1.32	0.30
Food hygiene and quality control	2	1/3	2	1	1.333	1.07	0.25
Total						4.33	1.00

Table3 Ernesto 1 to 9 Scale Method

Definition	Intensity of Importance	Explanation
Equal importance	1	Two elements have equal importance regarding the element in higher level
Moderate importance	3	One is slightly in favor over another
Strong Importance	5	One is strongly in favor over another
Very Strong Importance	7	One is very strongly in favor over another
Extreme Importance	9	The highest order dominance of one element over another
For compromises between the above	2,4,6,8	Compromise is needed

In accordance with this method, we established in sequence the comparison matrices respectively for enterprise design and implementation, management responsibilities of food hygiene and quality; enterprise management requirements food hygiene and quality control, and then got the weight of the third level indices (See Table 1).

3.2 Food Safety Index Model

Feature analysis of food Safety tells that food quality is determined by its intrinsic features formed in the course of production. These features make the hazards of hidden, direct and additive characteristics. In the paper, we take the intrinsic features as the level of food Safety. Besides, the hazard affect should also be considered, which we call market influence coverage and it relates to factors of company size, annual output, average annual consumption, market share, etc. The market share comprehensively reflects the market influence coverage of food products. Be easy to analyses, we chose market share as the main evaluation index for influence coverage

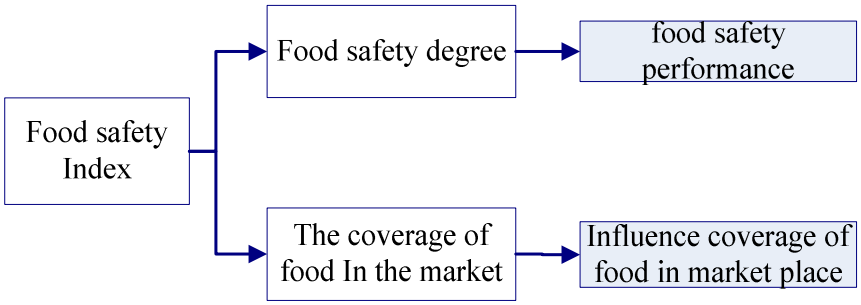

Figure 3 Framework of Food Safety Index Model

It is shown in Figure 3, that food safety level has positive effect to food safety index, which means larger value, larger food safety index. Market share reflects the influence coverage or affect of the food in market place. The larger the value, the greater potential hazards to customers and larger risk to the company, so market share is a negative index. In common, market share is defined as the ratio of certain food product sales to the total sales of similar products.

According to the opinion above, we may build the food safety model:

$$\textbf{Food Safety index} = \frac{Y_i}{1+Q_i} \qquad \textbf{(1)}$$

While Y_i **denotes to the score of i-th food product, which ranges from 0 to 100;**

Q_i **denotes to the ratio of certain i-th food product sales to the total sales of similar products.**

$$Y_i = w_{i1}\sum_{m=1}^{4} w_{im} y_{im} + w_{i2}\sum_{m=5}^{12} w_{im} y_{im} + w_{i3}\sum_{m=13}^{22} w_{im} y_{im} \qquad \textbf{(2)}$$

w_{ik} denotes to the weight of 2nd level index of i-th food product, $k = 1,\cdots,4$;

w_{im} denotes to the weight of 3rd level index , $m = 1,\cdots,22$.

y_{im} denotes to the score of m-th 3rd level index of i-th food product.

Generally speaking, one enterprise will produce two or more kinds of food. Here is the food safety index for enterprises with multiple (L) products:

$$\textbf{Enterprise's food production safety index} = \sum_{j=1}^{L} Y_j \frac{p_j}{\sum_{j=1}^{L} p_j} \qquad \textbf{(3)}$$

p_j denotes to the proportion of j-th food product sale to the total sale of all food of this enterprise.

The traditional safety evaluating method is based on subjective evaluation or the sample passing rate of food products. Compared with it, this model in this paper is direct, operational and consistent.

4. Hierarchical Management of Food Safety Based on Quantitative Evaluation

By calculation of food Safety index, we can define the risk level of food enterprises and based on the risk level, conduct classified tour inspection and supervision in food enterprises in order to monitor food Safety. The relationship among food Safety index, risk level and frequency of tour inspection is shown on Table 4.

Table 4 Relationship among Food Safety Index, Food Level and Risk Level

Food safety index	Food enterprise level	Risk level	Frequency of tour inspection
[100，85]	A	**low** ↓ **high**	Once per year
（85，70]	B		Twice per year

<70	C		Three times per year

Tour inspection is carried out by the food Safety regulators, using "food Safety evaluation form" to inspect and examine food enterprises production processes. This kind of tour inspection can also be carried out by the enterprise themselves.

"Food safety evaluation form" provides enterprises with more detailed evaluation criteria. By using these criteria, enterprises can conduct self-examination, self-assessment and make improvement according to the quantitative assessment of the classified requirements so as to enhance internal management, steadily improve Safety management system and strengthen legal awareness. The quantitative evaluation and hierarchical management can fully mobilize the enthusiasm of enterprises and encourage enterprises to actively carry out upgrading activities.

Since 2007, we have been implementing the above quantitative evaluation model and hierarchical management method in assessment of food safety covering 2000 enterprises in Shanghai, such as Shanghai Xinxin Food Co., Ltd. This company locates in Pudong new area. It started to produce cakes in 2006 with an annual capacity of 510 tons and sales of 4 million RMB. In 2007, its food safety got 67.08 points evaluated according to the method shown in table 1. Considering its cakes market share of 1.2%, the food safety index of Xinxin was calculated 66.28by quantitative evaluation model. So its enterprise level is C. We helped Xinxin to apply the hierarchical management method to improve its food safety. By the end of 2008, Xinxin’s food safety index increased to 71.5, and its enterprise level was up to B.

The evaluation results of 2000 enterprises’ food safety in 2007 and the first half of 2008 are shown in Table 5. Compared with 2007, number of C level food enterprises reduced from 19.9% to 18.1%, B level increased from 59.0% to 60.8% and A level remains unchanged, which means that the situation of total food safety in Shanghai is getting better.

Table 5 Food Enterprises in Hierarchical Management

Enterprise level	Number by percentage in 2007(%)	Number by percentage in first half of 2008(%)
A	**21.1**	**21.1**
B	**59.0**	**60.8**
C	**19.9**	**18.1**

Through the quantitative hierarchical management and analysis of food Safety indices, food enterprises have been taking targeted measures to improve food production Safety control and the total quality of food production has been enhanced (See Table 6). In table 6, Average passing rate in the first half of 2008 is based on the average passing rate at all levels and enterprises to get the weighted average

Table 6 Result of Tour Inspection among Food Enterprises of Different Levels

Enterprise level	Average passing rate in 2007(%)	Average passing rate in the first half of 2008(%)
A	94.7	96.0
B	90.1	92.0
C	87.5	88.4
Total	89.8	91.5

From the above tables, we can see the improvement of food safety level in Shanghai, which testifies to the fact that the food safety index model we promote tallies with the real conditions of food quality, and can reflect the food Safety status.

5. Conclusion

The application of the quantitative evaluation model and hierarchical management method in Shanghai tells that the food Safety index model can better reflect the level of food Safety control in food enterprises and the hierarchical management method built on the food safety index model can serve as a guidance to supervising organizations and food enterprise in their targeted improvement for higher level food

safety assurance.

By the application of the quantitative evaluation model and hierarchical management method, we can master food safety situation in various industries, regions and enterprises, timely identify high-risk industries, regions and enterprises, find out the risk factors and the weak areas of food safety. By using the model and method, we can also make targeted measures to strengthen the management of critical control process, prevent and control food Safety risks to realize early detection, early reporting, early research, early prevention, early control and improve the effectiveness of food safety supervision.

By proposing the food Safety index model and hierarchical management method, we can help food enterprises master the condition of food safety and discover the risks and hidden danger in time, thus early warning can be set. It can also help food enterprises in their activities to reach advanced standards, promote self-discipline, and improve their ability in food safety assurance.

References

1. Saaty,T.L. Fundamentals of decision making with the analytic hierarchy process.Pittsburgh, PA:RWS Publication (1994).
2. Cho Yong-Jin, etl., Evaluation of Food Safety Using a SPR Sensor, Japan Journal of Food Engineering, Vol.6;No.1;Page.9-13,(2005).
3. Zhang Ming. The present situation and policies on food safety. The theory and practice on food safety, HeFei University of Technology Press, (12), Page. 10~12, (2005).
4. Zhao-Junqiang. Consideration to the basic frame of the law system on food safety. The theory and practice on food safety, HeFei University of Technology Press, Page. 425~428, (2005).
5. Yu-Guangyu. Study on the standard system on food safety. The theory and practice on food safety, HeFei University of Technology Press, Page. 445~447, (2005).
6. Zhang Miao, Zhang-Peidong. An analysis of food safety. The machining of agricultural produce, (2), Page. 27~29, (2005).
7. Chen-Xiwen, Deng Nan, Han Jun. Study on the strategies of the Chinese food safety. Bei Jing Chemistry Industry Press, Page. 2~40, (2004).

Biography

MR. Zhu Ming

Mr. Zhu Ming is the director of Food Production Supervision & Management Division of Shanghai Municipal Bureau of Quality and Technical Supervision. The division is responsible for food safety and quality supervision of the food production industry in Shanghai, and its main functions are as following: stipulating regulations, codes and specifications related to food manufacturing; organizing researches on food technical standards; formulating and implementing food production supervision plan in Shanghai; engaging in granting special food hygiene license; directing and examining the work of Shanghai Food Production Supervision Institute and food production supervision divisions of all districts，etc.

Mr. Zhu Ming graduated from Zhejiang University and got Bachelor degree of Engineering Science. With 20 years of working experience in product quality supervision and inspection, product quality supervision management and food Safety supervision, he holds concurrent positions of deputy secretary general of Shanghai Association of Quality Inspection and the executive member of Shanghai Association for Standardization.

Mr. Zhu Ming has taken part in writing many books, including Basic Knowledge of Food and Related Products and Cosmetics Safety Supervision & Management, A Guide to the Market Entrance Examination of Food Safety, Detailed Rules and Regulations of Production License Inspection of 13 Products including Tea and Detailed Rules and Regulations of Production License Inspection of 10 Products

including Meat.

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He got doctoral degree in business management from Shanghai Jiao Tong University in 2005 and master degree in transportation management from Shanghai Maritime University in 2002. Since September 2005, Dr. Liu has worked as a quality management consultant and a researcher in SAQM. His present research topics include food quality and safety, quality competitiveness, service encounter, quality chain management and so on. In recent years, he has authored, co-authored, and delivered more than 10 research papers on diverse aspects of quality management in the journals such as World Standardization & Quality Management. Besides papers, he is active in working on research projects founded by the Ministry of Science and Technology of P.R.C., National Natural Science Foundation of China and other organizations.