

Research Article

Formulation and Implementation of Meat Product HACCP Plan Based on FMEA

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Abstract: Dedicated to preventing and reducing safety problems of meat products, we integrate Failure Mode and Effect Analysis (FMEA) method into Hazard Analysis Critical Control Point (HACCP) system and through analyzing the potential failure mode and the risk priority number of meat products, we determine the critical control points in the whole supply chain so that we formulate HACCP plan of meat products that has provided a method or basis and ideological references to other food safety problems.

Keywords: Failure Modes and Effect Analysis (FMEA), Hazard Analysis Critical Control Point (HACCP), meat products

INTRODUCTION

With rich nutrition and delicious taste, meat products are a kind of people's most important and favorite food (Stamatis, 2003). Meat food safety is a global problem, but it is prominent in China particularly, where it is hard to prohibit inferior meat and disease meat, it is frequent for the outbreaks of avian influenza, aphtha and animal epidemics and there are various outbreaks of food additives and a series of food safety events, which have sounded the alarm of quality safety of meat products for us. Therefore, our country should keep establishing and perfecting a safety supervision and management of meat products as well as preventing and controlling each link in the supply chain of meat products with the advanced modern quality management principles and quality control technologies. HACCP (Hazard Analysis Critical Control Point) is a kind of systematic method (Mortimore and Wallace, 2013) used to identify, evaluate and control the whole food chain and the formulation and implementation of meet product HACCP plan based on FMEA (Failure Modes and Effect Analysis) can promote the scientific and effective operation of the safety supervision and management system of meat products so as to improve the level of the safety quality of China's meat products essentially (Cormier *et al.*, 2007).

In this study, we determine the critical control points in the whole supply chain so that we formulate HACCP plan of meat products that has provided a method or basis and ideological references to other food safety problems.

MATERIALS AND METHODS

HACCP system is a preventive system to control food safety hazards based on the effective

implementation with GMP (Good Manufacturing Practice) and SSOP (Sanitation Standard Operation Procedure), whose purpose is to determine the possible hazards in any link of the food chain and take preventive measures (Paiva, 2013). The general steps for the implementation of HACPP are as follows:

- Carry out the hazard analysis, list all possible hazards and put forward prevention and control measures.
- Determine the critical control points.
- Establish the critical limit according to each critical control point.
- Monitor all the critical control points.
- Establish the corrective actions when the monitoring displays that a critical control point is out of control.
- Set up a verification procedure for the effective operation of HACCP.
- Establish the above steps and all the applicable procedures and record keeping.

FMEA method: FMEA is a basic tool in the field of reliability engineering and through the identification of each potential failure mode, it can confirm and analyze the influences and the consequences of the failure, find out the mechanism of production and the fundamental cause of the failure mode and then sort out the weak link of the system and formulate improvement and control measures (Teixeira, 2005). First of all, FMEA can identify the potential failure modes in the design and process control of products or the system on the basis of the existing information, analyze the influences and find out the failure causes and the failure mechanism and then through certain statistical methods, determine S (Severity), O (Occurrence) and D

(Detection) of the failure and according to formula 1, calculate the risk priority number of all failure modes namely RPN value (Risk Priority Number) (Wang, 2013). Finally, according to the size of RPN, identify the influence degree of the failure modes and enhance the reliability of products or the system by formulating improvement and optimization measures:

$$RPN = S \times O \times D \quad (1)$$

Among them, severity S is the influence degree to the system, the next procedure, or the product, or the customers when potential failure modes happen, usually, it only applies to the consequences of failures and it is generally divided into such levels as mild, moderate, heavy, very heavy, etc. and the value is from 1 to 10; O is the possibility or frequency of the cause or mechanism of the failure and is generally divided into such levels as very low, low, medium, high, very high, etc. and the value is from 1 to 10; D refers to the Non-detectable degree and non-detection of the cause or mechanism that causes a failure mode (Li and Han, 2009), it is generally divided into such levels as easy, general, difficult, very difficult etc. and the value is from 1 to 10 (Wang, 2014).

RESULTS AND DISCUSSION

FMEA analysis of meat products: First of all, FMEA analysis of meat products should follow the basic

principle of FMEA design, combine the characteristics of meat products and design FMEA forms of meat products, which mainly include functional requirements of meat products, potential function failure modes, consequences of potential failures, causes and mechanisms of potential failures, risk priority numbers, improvement measures and other elements, as shown in Table 1.

Potential function failure modes: The potential failure modes of meat products refer to meat products' existing and possible problems or deviations in food quality safety (Li, 2008). Due to meat products' characteristics of particularity, inseparable and non-re-workable functions etc., we should conduct a comprehensive analysis on the whole flow of the supply chain from such main influence factors as personnel, machinery, materials, methods and environment and list the potential failure modes of meat products. Use Fault Tree Analysis to analyze faulty meat products as shown in Fig. 1, in which the main potential failure modes of meat products include pollution of sources of meat, cross contamination, pollution of packing materials, lack of cold storage protection, false label marks, bad drinking habits and so on. The occurrence of any kind of potential failure mode will affect the quality and meat products and customer satisfaction and reduce the safety level of meat products (Haioxiong and Jing, 2013).

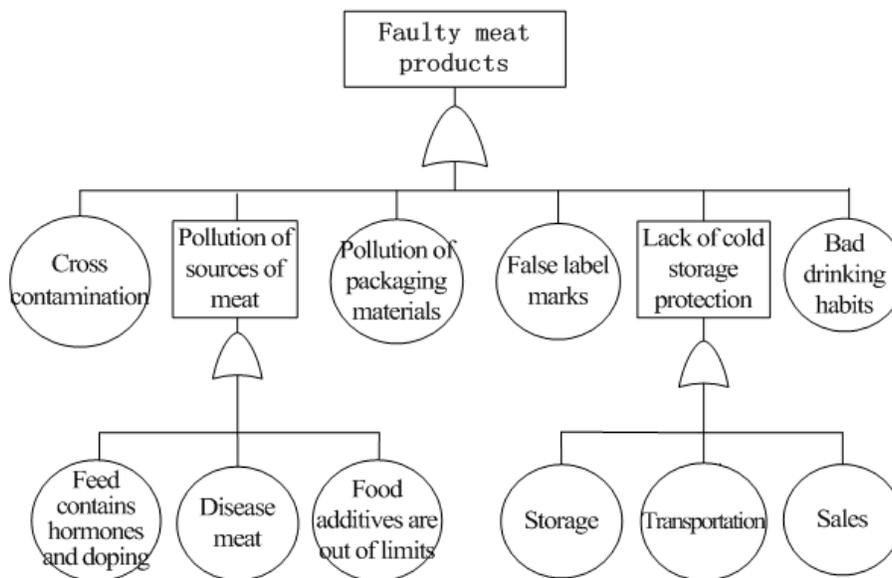


Fig. 1: Fault tree diagram of faulty meat products

Table 1: FMEA form design of meat products

Functional requirements of meat products	Potential failure modes	Consequences of potential failures	Potential failure mechanism	Current process control	D	RPN	Recommended measures	Links of responsibility supply chain	Results of measures			
									Measures taken	S	O	D

Table 2: Severity “S” assessment criteria

Severity	Grade	Value
Cause poisoning or even death incidents	Very serious	9-10
Cause injuries or diseases to eaters’ bodies or organs	Serious	7-8
This kind of failure affects eaters’ normal daily life and causes certain injuries to their bodies	Ordinary	5-6
This kind of failure causes slight discomfort on eaters	Mild	3-4
This kind of failure has little impact	Very mild	1-2

Table 3: Probability of occurrence “O” assessment criteria

Probability of occurrence or frequency	Grade	Value
The occurrence is almost inevitable	Very high	9-10
It often occurs again and again	High	7-8
It occurs occasionally	Medium	5-6
It occurs relatively rare	Low	3-4
It’s unlikely to occur	Very low	1-2

Table 4: The non-detectable degree “D” assessment criteria

Non-detectable degree	Grade	Value
It is very likely that the process control can’t detect failures	Very difficult	9-10
The probability that failures are not detected is high	Difficult	7-8
Failures are not detected occasionally	Moderate	5-6
The probability that failures are not detected is low	Easy	3-4
The process control almost surely can detect failures	Very easy	1-2

Consequences of potential failures: Consequences of potential failures are the consequences caused by the occurrence of meat products’ potential failure modes in the whole flow of the supply chain. For example, the consequence of false label marks is that the out-of-date meat products will be sold again after the date is changed and customers’ health will suffer serious damage.

Severity S: Severity S is divided according to the influence degree of meat products’ failure modes to customers’ health and the corresponding severity assessment criteria are formulated as shown in Table 2.

Causes and mechanisms of potential failures: Causes and mechanisms of potential failures refer to the reasons that cause the failure modes of meat products. There may be many kinds of causes of a failure mode, for example, the reasons of cross contamination include that the unsterilized processing or splitting tools, the cross contamination of operators, customers’ carrying of germs, etc.

Probability of occurrence or frequency O: Probability of occurrence or frequency O refers to the probability or the frequency of the occurrence of failures and it is generally assessed by the experts of meat products and the corresponding quality supervision department based on experience. The assessment criteria of the p probability of occurrence or frequency O of meat products’ failure modes are as shown in Table 3.

Current process control and the non-detectable degree D: Current process control refers to the effective monitoring modes that are taken according to the current all kinds of meat products’ failure modes,

while the non-detectable degree D refers that when each kind of failure occurs, the current process control can detect the difficulty level. The safety experts of meat products have concluded the non-detectable degree “D” assessment criteria as shown in Table 4.

Risk priority number RPN: Based on the above assessment criteria of the severity S, the probability of occurrence O and the non-detectable degree D, the severity S, the probability of occurrence O and the non-detectable degree D of the potential failure modes of meat products have been evaluated and according to formula 1, all kinds of Risk Priority Numbers RPNs have been calculated, compared and sorted so as to determine the main risks confronted by the safety of meat products. In Table 5, meat food safety experts have given the quantitative evaluation of the severity S, the probability of occurrence O and the non-detectable degree D of the above meat products’ all kinds of potential failure modes.

Formulation and implementation of meat product HACCP plan: Meat product HACCP plan, formulated based on HACCP principle and according to the above HACCP general implementation steps, is a document used to ensure that the hazards of all links of the supply chain with great significance to meat products can be controlled (Sperber, 1998). The general flow of the supply chain of meat products can be described as shown in Fig. 2, therefore, the formulation and implementation of meat product HACCP plan based on FMEA mainly includes the following five steps:

- According to the results of meat product FMEA analysis in Table 5, find out the meat products’ potential failure modes with higher RPN values or better ranks, combine meat products’ flow of supply

Table 5: FMEA analysis form of meat products

Functional requirements of meat products	Potential failure modes	Consequences of potential failures	S	Potential failure mechanism	O	Current process control	D	RPN	The link of responsibility supply chain
Meat products have fresh quality as well as their natural color and smell, and they keep the original nutrients of raw meat	Pollution of sources of meat	Meat products are polluted by hormones, diseases, veterinary drugs, etc. and food additives are out of limits	8	Feed contains hormones or illicit drugs and the breeding environment suffers contamination, animal epidemic diseases, the abuse of food additives and the abuse of slaughtering	4	Strictly implement the relevant access approval standards; check the "phytosanitary certificate" and the "official certificate of non-epizootic area"	8	256	Cultivation
	Cross contamination	Microbes and pathogenic bacteria contaminate meat products	6	Un-sterilization of the processing or splitting tools, cross contamination of operators and customers' carrying of germs	4	Avoid workers and customers to have direct contact with meat; implement operational prerequisite programs	4	96	Slaughtering, processing and sales
	Pollution of packaging materials	Meat products suffer chemical pollution	5	Packing materials contain harmful components as well as mobility and diffusivity	3	Strictly implement the national technical standards and regulations of packaging materials	3	45	Storage, distribution and transportation
	Lack of cold storage protection	Meat products suffer spoilage and are polluted by spoilage organisms and pathogenic bacteria	7	Cold storage facilities are incomplete or suffer sudden failures and no attention is paid to the cold storage protection of meat products	7	Standby application of cold storage facilities; professional distribution teams; strengthening of temperature monitoring and records	5	245	Distribution and transportation, sales
	False label marks	Expired and bad meat products	7	Use exaggerated and false packaging to change the expired meat products and sell them again	4	Authenticity test; information query; monitoring and recording of expiration dates	2	56	Processing and sales
Bad drinking habits	Parasites and living bacteria enter human body	6	Inadequate sterilization and uncooked food	2	Remind customers correct diet methods	7	84	Sales	

Table 6: Analytical table of critical control points of the supply chain of meat products

Potential failure modes	Link(s) of the occurrence of the failure	RPN	CCP
Pollution of sources of meat	Cultivation	256	Yes
Lack of cold storage protection	Distribution and transportation and sales	245	Yes
Cross contamination	Slaughtering, processing and sales	96	No
Bad drinking habits	Sales	84	No
False label marks	Processing and sales	56	No
Pollution of packaging materials	Storage and distribution and transportation	45	No

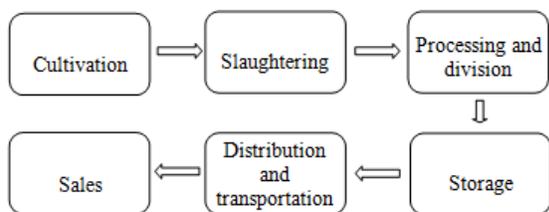


Fig. 2: The supply chain flow diagrams of meat products

chain and analyze the relationship between these failure modes and each link of the supply chain so as to determine critical control points CCP. In descending order, the meat products' potential failure modes with higher RPN values in Table 5 are respectively pollution of sources of meat and lack of cold storage protection, therefore, the main links of the supply chain where the failures occur are determined as the critical control points CCP. As shown in Table 6, the critical control points of the supply chain of meat products are cultivation, distribution and transportation and sales.

- **Develop CCP monitoring procedures:** Determine the significant hazards of meat product supply chain

CCP and according to the principle of hazard control and the principle of the determination of critical limits, set up the critical limits, finally, work out the monitoring content of all the critical limits, how to monitor them, their monitoring frequency and who will monitor them.

- **Establish corrective measures:** When the monitoring displays that CCPs deviate or don't conform to critical limits CL, rectify the deviation and carry out correction and isolation to ensure that meat products in the flow of the supply chain can have effective control over CCP.
- **Set up verification procedures:** They are used to verify the effectiveness of the formulation and implementation of meat product HACCP plan and to promote the continuous improvement of meat products HACCP system.
- Form a document and establish a record keeping system. It can be the evidence of the effective operation of meat products HACCP system as well as the input information of assessment of the operation effects of meat products safety quality management system.

Table 7: Formulation and implementation table of meat product HACCP plan

Critical Control Points (CCP)	Significant hazards	Critical Limits (CL)	Monitoring				Corrective measures	Verification procedures	Record keeping
			What	How	Frequency	Who			
Cultivation	<ul style="list-style-type: none"> Feed contains hormones or illicit drugs Animal epidemics Food additives are out of limits 	<ul style="list-style-type: none"> Breeding certificate, the certificate of conditions for animal epidemic prevention and the quarantine certificate The certificate that the source of meat is from non-epizootic areas 	The certificates such as the registration certificate, the certificate of non-epizootic areas and the certificate of qualified inspection	Inspection and verification	Each batch	Acceptance inspector	<ul style="list-style-type: none"> Standardize the management of cultivation and implement immunization Strengthen the punishment of dishonesty Reject the sources of meat without the relevant certificates 	<ul style="list-style-type: none"> Ask farmers to provide conditions as well as the certificate of the test of veterinary drug residues and the heavy metal detection Check the acceptance records of each batch of source of meat that day 	<ul style="list-style-type: none"> Farmers credit records of food safety The relevant test report provided by farmers Acceptance records of sources of meat
Distribution and transportation	Growth of microbes as well as contamination of spoilage organisms and pathogenic bacteria	High temperature cold storage should be from 0-4°C and low temperature cold storage should be below -18°C	Temperature	Monitoring record	Every hour	Logistics personnel	<ul style="list-style-type: none"> Check the temperature Provide an maintenance to refrigeration equipment and provide standby facilities 	<ul style="list-style-type: none"> Transportation teams should provide professional qualifications for transportation of meat products Check the temperature records in the distribution process when receiving goods 	<ul style="list-style-type: none"> Temperature records in the distribution process Maintenance records of distribution equipment Records of isolation and assessment
Sales	Contamination of spoilage organisms and pathogenic bacteria	High temperature cold storage should be from 0-4°C and low temperature cold storage should be below -18°C	Temperature	Monitoring record	Every 2 h	Health inspector	<ul style="list-style-type: none"> Check the temperature Improve the cold storage facilities of sales market Isolate and evaluate the food with deviation 	<ul style="list-style-type: none"> Review temperature records everyday Conduct casual inspection of sample microorganisms 	<ul style="list-style-type: none"> Temperature records Equipment maintenance records Isolation and assessment records

Formulation and implementation table of meat product HACCP plan is as shown in Table 7.

CONCLUSION

The application of FMEA analysis can make a comprehensive analysis of the potential failure modes on Chinese current meat products and we can get all risk priority numbers of the failures, which have provided a basis to the identification of the critical control points in the whole supply chain of meat products and combining with HACCP principle's supervision and control to critical control points, meat product HACCP plan has been formulated. The research of the formulation and implementation of meat product HACCP plan based on FMEA is beneficial to improve the safety quality level of meat products in China and promote the sustainable and healthy development of the meat industry and at the same time, it also has provided a method or basis and an ideological reference to other food safety problems.

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