Review

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Food traceability systems in China: The current status of and future perspectives on food supply chain databases, legal support, and technological research and support for food safety regulation

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Summary **Over the past few decades, the field of food security has witnessed numerous problems and incidents that have garnered public attention. Given this serious situation, the food traceability system (FTS) has become part of the expanding food safety continuum to reduce the risk of food safety problems. This article reviews a great deal of the related literature and results from previous studies of FTS to corroborate this contention. This article describes the development and benefits of FTS in developed countries like the United States of America (USA), Japan, and some European countries. Problems with existing FTS in China are noted, including a lack of a complete database, inadequate laws and regulations, and lagging technological research into FTS. This article puts forward several suggestions for the future, including improvement of information websites, clarification of regulatory responsibilities, and promotion of technological research.**

Keywords: Food safety, sharing information, quality control, recall

1. Introduction

With the rapid development of China's economy, the food safety problem has garnered public attention since the 1990s. This problem harms public health and causes a wide range of diseases (*1*). As a result of the outbreak of bovine spongiform encephalopathy (BSE), commonly known as "mad-cow disease," in 1986, a food traceability system (FTS) was established to manage food safety (*2*). An FTS is an information-based proactive strategy to manage food safety that facilitates the identification of food risks and orderly recalls in the event of an incident to prevent food safety hazards. The roles of an FTS are to *i*) improve food supply management; *ii*) facilitate traceback for food safety and quality; *iii*) market foods with subtle quality attributes; *iv*) better use resources such as flora and fauna for food production, and *v*) establish long-term relationships in the food chain (*3,4*).

Since FTS was first used to control BSE, FTS has successively been used to manage food safety in the United States of America (USA) and many European countries, and structure of FTS has improved over the past decade. In 2002, the European Commission defined "traceability" as the ability to trace and follow a food, feed, food-producing animal, or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing, and distribution (*5,6*). In 2004, the 27th Session of the Codex Alimentarius Commission of the United Nations defined the general principles of an FTS: "Traceability/ product tracing: the ability to follow the movement of a food through specified stage(s) of production, processing, and distribution" (*7*). In 2005, Section 7.9 of International Standardization Organization (ISO) 22000:2005 (food safety management system) clearly indicated that an FTS should be able to identify a direct supplier of materials and the distribution of the end product and that records of traceability should be maintained for a defined period to allow system evaluation to enable handling of unsafe products and product withdrawal (*8*). In 2007, ISO 22005:2007 Food

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Table 1. Major food safety incidents in China from 2003 to 2014

Year	Incident	Content	Consequence
2003	Jinhua ham dichlorvos incident	Ham producers added the highly toxic pesticide dichlorvos when making ham.	Companies in Jinhua suffered huge economic losses.
2004	Fuyang, Anhui substandard infant milk powder incident	More than 100 babies suffer from severe malnutrition after eating substandard infant milk powder.	60 infants were injured, and at least eight babies died.
2005	"Sudan 1" at KFC fast food outlets in Shanghai	Sudan 1 was found in condiments of the New Orleans-style roasted wings at KFC.	The company suffers economic losses.
2006	Shanghai clenbuterol food poisoning incident	Clenbuterol in pork and viscera exceeded limits.	336 people suffered food poisoning in nine districts of Shanghai
2006	"Red-yolk salted duck eggs" incident	The eggs contained the industrial dye Sudan IV.	Harmed consumer health.
2008	"Melamine" incident	The chemical melamine was found in infant milk powder.	39,965 infants and toddlers were treated on an outpatient basis after consuming the infant formula.
2011	"Dyed" steamed bun incident in Shanghai	The sweetener sodium cyclamate and preservative potassium sorbate were added to steamed buns that were expired and then the buns were repackaged.	334,864 "dyed" steamed buns were resold, harming public health.
2012	Lipton "poisoned tea" incident	The tea contained a variety of harmful pesticides.	Harmed consumer health.
2013	Kung Fu Restaurant ice cube incident	The microbial colony count on ice cubes at the Kung Fu Restaurant exceeded the limit.	Loss of consumer trust.
2014	Hui Yuan "Rotten Fruit" incident	The factory bought rotten fruit to make juice	Massive drop in company stock.

Traceability Standard states that: "food safety is the joint responsibility of all the actors involved" (*9*).

As an agricultural country, China has witnessed numerous problems and incidents related to food safety (Table 1) that have captured public attention both nationally and internationally (*10,11*). During the Fuyang inferior infant milk powder incident, 229 Chinese babies suffered from severe malnutrition after eating inferior infant milk powder (*12*). During the "melamine" incident, 39,965 infants and toddlers received outpatient treatment as of September 2008 after eating infant formula (*13*). In the face of those incidents, China has realized the importance of the FTS and started to use an FTS to facilitate meat traceability in 2004 (*14*). This marked the creation of China's FTS. Overall, however, FTS databases, laws, and technological research in China need to be improved further.

The FTS has been established around the world to reduce the risk of food safety problems and ensure quality and supply-chain integrity (*15,16*). The current paper reviews the use of FTS in the USA, Europe, Japan, Australia, and other countries. This paper discusses the current state of the FTS in China, its achievements, its existing problems, and prospects for the future.

2. FTS around the world

2.1. *The characteristics of foreign FTS*

FTS has been established in many countries as a method of managing food quality and safety risks in order to improve the system for supervision and management of food safety (*17,18*).

Based on the FTS established in the Netherlands, United Kingdom (UK), European Union (EU), Japan, Australia, USA, Canada, India, South Korea, and Norway (Table 2) (*3,19-35*), the current FTS has the following characteristics:

Establishment of a database for the FTS. A complete database of the food supply chain has been created in some countries to facilitate a website providing information on food traceability (*36*), such as the Cattle Tracking System (CTS) established in the UK that stipulates all livestock born after July 1, 1996 have identification documents (*20*).

Legal support for the FTS. With the support of government, food safety laws and regulations have been enacted in many countries to promote clearly assigned responsibilities. For example, the Food Safety Modernization Act, the Food Safety Enhancement Act, and other comprehensive laws have been enacted in the USA to promote multi-sector management by the Food and Drug Administration (FDA) with the support of the Department of Agriculture, the Department of Health, and the Environmental Protection Agency (*24*). In the USA, a regulatory body has legal authority to oversee a specific product or resource with additional levels of supervision. This means that the Department of Agriculture is mainly responsible for the regulation of livestock and poultry products, the Department of Health is responsible for the regulation of the vast majority of food (in addition to the scope of the jurisdiction of the Department of Agriculture), and the Environmental Protection Agency is responsible for water quality security and pesticide registration and management (*36*).

Scientific research to provide technical support to

Table 2. National regulations regarding FTS

Region (Date)	Content	*Ref.*
Netherland (1992)	• In the early 1990s, Holland's Animal Husbandry Department implemented the Integrated Chain Control system (initials in Dutch: IKB) for "the overall control of the food chain" including food, meat, and egg products. The IKB requires controlled production, processing, and sales of meat and eggs. • In 1992, the IKB began with pork as a pilot product. In 1995, it expanded to beef production. So far, more than three-quarters of the pork and most beef are controlled in the IKB system. An identification and registration (I&R) system is also a part of the IKB system. The IKB system can quickly trace the source of animal products through the recognition and registration system. • In order to ensure the quality of dairy products and implement traceability based on the food chain, the Dutch implemented a Dairy Quality Control (KKM) system based on GMP and the dairy industry chain.	(*19*)
UK (1996)	• The UK established CTS which operates online. The system is one of the four core elements of an FTS. Livestock breeding records are recorded in the CTS system in order to facilitate positioning and tracking. The four elements of the livestock identification and registration system are identification, farm records, id cards, and a livestock tracking system.	(*20*)
EU (2000)	• On January 12, 2000, the European Commission formally issued the "White Paper on Food Safety" to introduce the concept of traceability "from farm to table" and to define the tasks and responsibilities of each participant in the food chain. • On January 28, 2002, the EU's 178th Council Regulation (2002) specified that sales of all food must be traceable.	(*21-23*)
Japan (2001)	• In 2001, a Japanese beef traceability system was established in order to deal with mad cow disease. • In May 2002, the Japanese Government formulated a "beef id card" system. Consumers can obtain information on the cattle breed, breeding, slaughtering, and distribution process information. • In June 2002, the Japanese FTS expanded to rice and oysters. Via an electronic tag on rice packaging, consumers can learn the rice's origin, producers, the pesticides and fertilizers used in the production process, and specific processing information. • In June 2003, the Japanese Diet passed a special act to identify cattle. This act has regulated beef sales and required all beef packing to identify the beef containing since December 1, 2003. • The Japan Agricultural Co-operatives decide to implement an "identity code recognition system" for vegetables, meat, and other agricultural products by the end of 2006. The system requires detailed information such as product origin, producers, and fertilizers and pesticides used to facilitate consumer queries.	(*24-26*)
Australia (2001)	• Australia began a National Livestock Identification Scheme (NLIS) in 2001.	(*27,28*)
USA (2002)	• The Bioterrorism Preparedness Act, *i.e.* the Public Health Security and Bioterrorism Preparedness and Response Act of 2002, designated food safety as a priority of national security and put forward traceability "from farm to table" for food risk management. • In May 2003, the FDA announced food safety regulations requiring that all food transportation, distribution, and import companies keep records of the food distribution process. • From 2005 to 2009, the USA gradually instituted nationwide animal breeding, processing, transportation, and traceability management through the National Animal Identification System (NAIS). The NAIS includes three key links: registered farms, animal identification, and information tracking.	(*3,29*)
Canada (2002)	• In 2002, Canada instituted a beef cattle identification system in order to facilitate the traceability. Live cattle are given an ear tag or brand for identification after NIXS certification. When cattle are moved to a new location, a radio frequency identification reader at the farm or abattoir will read and record that information in the NLIS database.	(*30-32*)
India (2006)	• In 2006, India enacted the Food Safety and Standards Act. This Act has defined the FTS, it requires that food producers provide information on the food production process, it requires that information on companies providing raw materials be indicated, and it requires that food on the market be labeled in order to ensure the traceability of food.	(*33*)
South Korea (2007)	• On December 21, 2007, South Korea's Parliament announced the Cattle and Beef Traceability Act. The act applies to cattle raised in South Korea and mainly specifies that the owner of the cow must report the cow's birth or death, import or export, transfer or processing (including slaughter) to the Food and Agriculture Forestry and Fisheries Department (MIFAFF). Owners must assign identification numbers to each head of cattle and report incidents. Meat processing plants and sellers must display the ID number on meat and beef products so that their source can be traced.	(*34*)
Norway (2010)	• In 2010, the Norwegian Seafood Export Council required that producers of marine products mark the country of origin on packaging and implement marine product traceability to promote global sales of marine products from Norway.	(*35*)

the FTS. The scientific research providing technical support to FTS is relatively advanced (*37*). Japan, as an example, has been attempting to use the latest scientific research to enhance the reliability of its FTS (*38*). One of Japan's approaches is to use DNA markers to trace animal products (*3*).

2.2. *The role of the FTS*

The series of food scandals around the world has resulted in reduced consumer confidence and has highlighted the lack of an integrated approach of the food chain. A traceability system emphasizing comprehensive control and continuous management of food production needs to be established, and legislation that covers all aspects of food production and distribution needs to be passed (*4*). In response to this situation, the EU's General Food Law came into effect in 2002; this law mandates traceability for all food and feed businesses. Traceability allows targeted product withdrawal and recall when necessary and the provision of accurate information to the public.

The benefits of FTS are numerous and diverse and they affect the whole supply chain. The role of an FTS is mainly reflected in the following aspects (Table 3):

Table 3. Benefits of traceability systems

Items	Qualitative benefits	Quantitative benefits
Supply	Food safety; Establishes long-term relationships.	Improves techniques; Allows selection of varieties.
Production	Better use of resources; Improves operational procedures.	Increased production; Increased productivity of employees; Efficient production process.
Distribution	Increases the trust of customers; Increases the breadth of customers.	Lower compensation fees.

i) establishing long-term relationships in supply; *ii*) promoting the efficiency of production processes; and *iii*) increasing the breadth of customers (*39*). Before the implementation of an FTS, suppliers were commonly chosen based only on price. With the traceability system, however, each supplier must be monitored in a way that allows a price-quality ratio to be calculated. In this sense, the FTS has helped suppliers to reduce their costs.

3. FTS in China

3.1. *Policy support for FTS*

In 2004, the creation of China's FTS began with a project to create a meat FTS proposed by the State Food and Drug Administration (SFDA) (*40*). In September 2004, the State Council published its "Decision on Further Enhancing Food Safety" that proposed a system of quality and safety standards for agricultural product and that established a routine monitoring and traceability system for the quality and safety of agricultural products (*41*).

China has implemented at least 52 laws and regulations on FTS, indicating that China has gradually enhanced the role of the system for tracing food products (Table S1, *http://www.biosciencetrends.com/docindex.php?year=2015&kanno=1*). The "State Council's Decision on Further Enhancing Food Safety" issued in 2004 proposed a system of quality and safety standards for agricultural products and suggested the establishment of a routine monitoring and traceability system for the quality and safety of agricultural products. In the aspect regulation of distribution/sales companies, the "Notice of the Ministry of Finance on printing and distribution of documents on the management of special funds for development of rural logistics systems" provides support to upgrade and transform facilities for the wholesale marketing of fresh agricultural products. The Food Safety Law of the People's Republic of China requires records that cover all of the links in the food supply chain to facilitate traceability and product recall in the future.

China also has issued 118 local regulations governing FTS that increase government inspections and financial investment. These regulations stipulate traceability technology, material support, pilot projects, and inspection results in detail (*42-48*).

3.2. *Use of FTS in practice in China*

In 2004, the "Pilot Project for a System to Trace the Quality of Beijing Vegetable Products" was launched by the Beijing Municipal Agriculture Bureau and the Department of Agriculture of Hebei Province. The earliest project to create an FTS in China, the project selected 6 counties in Hebei as a base of vegetable production at which to implement unified packaging and product traceability labels.

In 2007, Beijing Jinweifuren Halal Food Co., Ltd. developed software for a traceability system with the technical support of the Beef Cattle Research Center of China Agricultural University (CAU). The system covers abattoirs and fattening farms in Jinwei. With increasing government regulations on beef quality and safety, traceability is becoming an imperative requirement in the cattle industry (*49*).

In 2008, an FTS was created to uniformly track all food for the Olympic Games in Beijing. This system featured the integrated use of numerous technologies – radio frequency identification device (RFID), global positioning system (GPS), automatic temperature recording and control, humidity control, and encrypted communication – to track and record a host of information on food, including its production, processing, transportation, and storage (*50*). In addition, quality monitoring stations were established at key sites to inspect and record information on food quality and implementing complete monitoring from the site of food production to processing companies and distribution centers up to the final consumer. This allowed food to be tracked during the Olympics.

Since 2010, the Ministry of Commerce (MOC) and Ministry of Finance (MOF) have supported a pilot program to create a meat and vegetable distribution traceability system (MVDTS) in 50 cities in four batches (Figure 1) (*51*). In order to promote the MVDTS, the central government spent 1.86 billion yuan. This amount covered major municipalities, cities with independent planning, and provincial capitals. The MOC program seeks to have the MVDTS cover all cities with a population of more than million, and the MVDTS should cover meat, vegetables, livestock, marine products, fruit, edible fungi, soy products, and other types of food by the end of the ‘12th Five-Year Plan' (52)."

In addition, websites with information on food

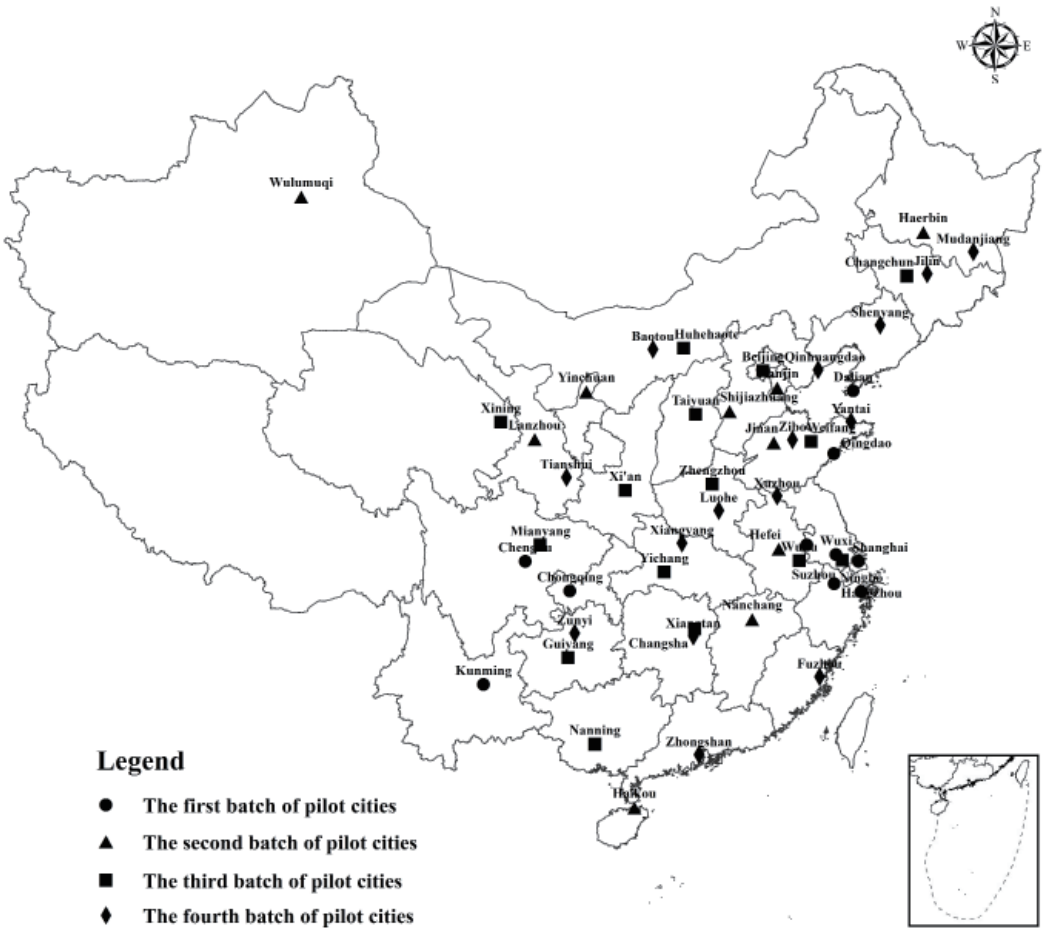

Figure 1. The pilot cites for creation of a Meat and Vegetable Distribution Traceability System in China since 2010

traceability have gradually been created. These include the National Platform for Tracking Food Safety (*http://www.chinatrace.org*), the Product Identification, Authentication, and Tracking System (*http://www.95001111.com*), and the Agricultural Product Quality and Safety Network (*http://www.safetyfood.gov.cn*). By November 2014, the National Platform for Tracking Food Safety will be able to track 34,364,423 items. This indicates that more manufacturers are aware of and participating in the system and that basic data are gradually being collected.

3.3. *Challenges facing FTS in China*

Although China's FTS has made some progress, including policy support, project implementation, and website design, these are still many challenges that need to be overcome.

3.3.1. *Lack of a complete database of the food supply chain*

The implementation of food traceability requires a substantial amount of valid information (*53*). The Japanese beef traceability system, as an example, was established in 2001 in response to mad cow disease. In May 2002, the Japanese government developed the "Beef ID Card" system. Consumers can use this card to learn information about the cattle breed, breeding, slaughtering, and distribution process online. In June 2002, the Japanese FTS extended to the rice and oyster industries. Consumers can learn specific information on a product's origin, producers, the pesticides and fertilizers used in the production process, and processing (*54*).

In contrast, data collection for an FTS in China faces several challenges: *i*) The supply chain is mainly based in small workshops, and numerous participants are widely distributed and highly mobility, so summarizing required information is very difficult; *ii*) The types of foods consumed and frequency with which they are consumed vary widely, and companies shift between upstream and downstream so each link is not closed, resulting in a lack of data on food raw materials, the production process, and storage and transportation; *iii*) Logistics information services and technology are lagging and there is a lack of a specialized platform on which to exchange food technology and no mechanism by which to exchange information technology, so establishing a complete database of the supply chain will be difficult. Given the severe shortage of basic data, a website providing information on food traceability cannot be created (*55*).

3.3.2. *An incomplete system of laws and regulations fails to clearly define responsibilities*

Laws must be improved and responsibilities for regulating food safety must be clarified to create an FTS. The EU implemented centralized management of food safety with separate decision-making sections, administrative departments, and departments for risk analysis. The Consumers, Health, and Food Executive Agency of the European Commission is a decision-making body that oversees food safety, and the Food and Veterinary Office (FVO) is a major driver of policies on food safety. In order to provide scientific support to the decision-making body, the EU set up the Food Safety Authority as an independent organization to transparently manage food safety and provide related technical support. The EU issued the White Paper on Food Safety and enacted food hygiene legislation, the General Food Law, as well as a variety of laws and regulations related to food and feed.

In China, supervision of food quality and safety is segmented into multiple sectors because of dispersed farming (*56*). Currently, the agencies regulating food safety in China have the following main features: *i*) most regulators track food "from farm to table" (*57*); *ii*) the administrative levels managing food safety are horizontal, performing their duties within respective areas with relative independence (*58*); *iii*) the delegation of regulatory authority is left to administrative agencies (*59*). As an example, the Ministry of Agriculture (MOA), Bureau of Quality Supervision, and MOC are all involved in creating systems for tracking food quality and safety (*60*), but the lack of unified direction has resulted in different departments creating traceability systems with differing hardware and technologies and poor compatibility. This hampers the exchange and sharing of information and prevents the traceability system from operating at its true capacity.

3.3.3. *Lagging technological research into FTS*

The West has advanced technical support for traceability systems (*37*). As an example, the EU has established a special system to track genetically modified food. This system requires participants to record information on the production and processing of genetically modified food and to retain that information for at least five years (*61*).

Although bar codes and RFID have long been used in industry, these approaches are not yet widely used in the food industry in China, limiting the ability of the Safety Inspection Bureau to perform sampling inspections. Furthermore, there is a lack of a standardized network transmission protocol for communication among departments, red tape hampering the documentation of testing information among related departments, information leaks, and a lack of detailed screening (*59*).

4. Future perspectives on the FTS in China

4.1. *The systematic creation of an FTS*

In light of the theoretical basis for and practical use of FTS in the USA and Europe, the following aspects of the FTS in China need to be improved.

i) *Gradually improve websites providing information on food traceability*. In China, the responsibility for regulating food safety is shared by multiple departments, so management of food safety must be planned and coordinated to ensure that departments are connected and share resources. The Government needs to establish a website providing information on food traceability. A network of information on food traceability is the only official channel to educate the public and disseminate information on food safety regulations, and such a network is also the best way to manage and share information on food safety. Such an approach is essential to food safety (*62*).

ii) *Improve the system of laws and regulations and clarify responsibilities for regulation of food safety*. China needs a way to establish and perfect a legal framework to implement a mandatory traceability system based on administrative regulations and rules (*63*). In addition, additional laws and regulations need to be enacted, particularly with regard to information on traceability, requirements for companies, and delineation of regulatory requirements and responsibilities. China's FTS will be successful only if it is based on laws and regulations clearly stipulating legal obligations and responsibilities for production companies and regulators (*64*).

iii) *Promoting technological research related to traceability systems*. China's FTS is still in its early phase, so the Government should enhance research into tracking technology (*65*). The implementation of an FTS involves various technologies, and a traceability system is based on unified standards (*66*). The accuracy of the information communicated and the seamless connection of different databases can be achieved using unified encoding and standards on food information in order to facilitate quick traceability. Based on information standardization, the following technologies may support the sharing of information: data sharing technology (*67*), coding technology (*68,69*), RFID (*70*), network technology, GPRS and GIS technology (*71*), and bioinformatics techniques (*11*). Information can be shared using the aforementioned technologies, allowing the creation of an FTS.

4.2. *Perspectives on the development of agriculture through use of an FTS*

An FTS is a tool for quality and safety management (*72*). The advantage of an FTS is that it prevents the incidence of food safety hazards and it reduces

the impact of such incidents when they occur (*73*). Once national and local laws and regulations on food traceability have been enacted, the food industry will be left with little option but to implement a traceability system as part of its efforts to manage food safety. This covers all movement and processing in the food chain. Interest in FTS will benefit the global trade in food. The search for cost-effective technological innovations to facilitate FTS is an important challenge facing agriculture in the new globalized economy.

An FTS is also essential factor to facilitate the establishment of common standards and guidelines for management of food safety and quality (*74,75*). These standards concern the following areas: management of food quality, management of food safety, traceability of products, and data capturing technology and exchange of electronic data in commerce, industry, and administration. Standards on internal traceability refer to records kept by a business and are not specifically required. External traceability is the sharing of information among the different stakeholders of the supply chain, and standards for and methods of exchanging data are needed. Thus, growers, processors, middlemen, policymakers, stakeholders, and consumers all need to be aware of the requirements for creation of an FTS.

In conclusion, the FTS plays an important role in ensuring food safety in the face of serious challenges to food safety. China implemented a system track meat products in 2004 and China's FTS is still in the pilot stage. China's FTS has several flaws, such as the lack of a complete database of the supply chain, vague responsibilities of food safety regulators, and a lag in technology. Based on the experiences of developed regions such as the EU, the USA, and Japan, China should take the following actions in the future: i) improving websites providing information on food traceability; ii) defining the responsibilities of food safety regulators, and iii) enhancing the technological capacity to create a traceability system in order to create a complete FTS based on the sharing of information.

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