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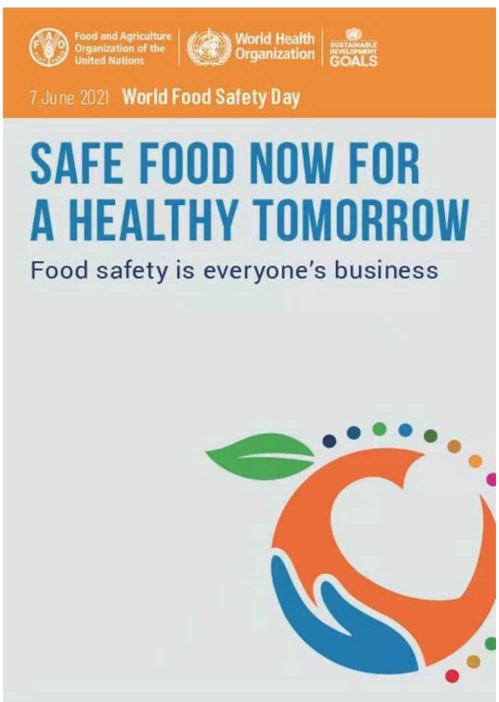

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This week's issue was organized by Guest Editor Yongning Wu.

Foreword

Food Safety Strategies: The One Health Approach to Global Challenges and China's Actions

Di Wu[1]; Christopher Elliott[1,#]; Yongning Wu[2,#]

WORLD FOOD SAFETY DAY

World Food Safety Day (WFSD) (*1*) celebrated on 7 June 2021 aims to draw attention and inspire action to help prevent, detect and manage foodborne risks, contributing to food security, human health, economic prosperity, agriculture, market access, tourism and sustainable development.

The theme of 2021, "Safe food today for a healthy tomorrow", stresses that production and consumption of safe food has immediate and long-term benefits for people, the planet and the economy. Recognizing the systemic connections between the health of people, animals, plants, the environment and the economy will help us meet the needs of the future.

Recognizing the global burden of foodborne diseases, which affect individuals of all ages, in particular children under-5 and persons living in low-income countries, the United Nations General Assembly proclaimed in 2018 that every 7 June would be World Food Safety Day. In 2020, the World Health Assembly (WHA) further adopted a decision on strengthening efforts on food safety to reduce the burden of foodborne disease. The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) jointly facilitate the observance of World Food Safety Day, in collaboration with Member States and other relevant organizations.

Food safety is a shared responsibility between governments, producers and consumers. Everyone has a role to play from farm to table to ensure the food we consume is safe and healthy. Through the World Food Safety Day, WHO works to mainstream food safety in the public agenda and reduce the burden of foodborne diseases globally. Food safety is everyone's business.

WHY AN UPDATED GLOBAL FOOD SAFETY STRATEGY?

At the 73rd WHA forum held in May 2020, WHO called for experts to advise the body's work to update its global strategy for food safety (*2*) and aimed to deliver a new plan by 2022. Thus, to address the most emerging challenges tout de suite and to strengthen and harmonize international food safety systems. The incorporation of innovative technologies and approaches is required to tackle existing and new threats to the safety of the food supply and to public health. As recorded in the Resolution WHA73.5, "Strengthening Efforts on Food Safety" (*3*), reaffirmed that food safety remains an essential element of public health, with the highest political level priority, and is a means to implement the 2030 Agenda for Sustainable Development. The resolution further recognized the need of collective action throughout all stages of the supply chain at the local, national, regional, and global levels. It also called on Member States to develop food safety policies that take into consideration all stages of the supply chain, the best available scientific evidence, advice, and innovations; to provide adequate resources to improve national food safety systems; to recognize consumer interests; and to integrate food safety into national and regional policies on health, agriculture, trade, environment, and development.

In many jurisdictions, oversight of the food chain is fragmented with different ministries and professionals responsible for different segments and often there are gaps and inconsistencies in the continuum of oversight from farm to fork. The multidisciplinary and multiagency One Health holistic approach must be adopted if existing and emerging problems are to be tackled effectively.

The WHO has outlined five strategic priorities to develop this Global Strategy for Food Safety based on situational assessment and multiple consultations with its Member States, subject matter experts, regional advisers in food safety, intergovernmental, non-governmental organizations, private sector, and in addition, the Regional Framework for Action on Food Safety in the WHO Regional Office (Figure 1).

WHO has established the Technical Advisory Group (TAG) on food safety to draft this strategy in order to adds value by providing an overall vision and strategic priorities for concerted global action and by underlining the importance of food safety as a public health priority and the need for enhancing global cooperation across the whole food and feed chain. The strategy also reflects, and is complementary to, existing WHO health programs, such as nutrition and non-communicable diseases, antimicrobial resistance, public health emergency and emerging diseases, climate change, environmental health, water and sanitation, and neglected tropical diseases.

THE AIM AND VISION OF THE FOOD SAFETY STRATEGY

The Global Food Safety Strategy (*4*) has been developed to guide and support Member States to prioritize, plan, implement, monitor, and regularly evaluate actions towards the reduction of the incidence of foodborne diseases by continuously strengthening food safety systems and promoting global cooperation.

The vision of the strategy is to provide safe and healthy food for all. All countries are essential stakeholders in food safety to promote, support and protect public health and reduce the burden of foodborne diseases.

FOOD SAFETY: A PUBLIC HEALTH PRIORITY

Foodborne diseases have enormous impacts on public health. Unsafe food, containing harmful levels of bacteria, viruses, parasites, or chemical or physical substances, contribute to acute or chronic illnesses, with more than 200 consequential diseases and conditions — ranging from diarrhea to cancers to permanent disability or death. An estimated 600 million, almost 1 in 10 people in the world, fall ill after eating contaminated food, resulting in a global annual burden of 33 million disability-adjusted life years (DALYs) and 420,000 premature deaths (*5*). Unsafe food disproportionately affects vulnerable groups in society, particularly infants, young children, the elderly, and the sick. Low- and middle-income countries are the most affected, with an annual estimated cost of 110 billion USD in productivity losses, trade-related losses, and medical treatment costs due to the consumption of unsafe foods (*6*). Moreover, the globalization of the food supply means that populations worldwide are increasingly exposed to new and emerging risks, such as emerging pathogens, existing pathogens with new virulence traits and the development of antimicrobial resistance (AMR) in foodborne pathogens. It was estimated that by 2050, 10 million lives will be at

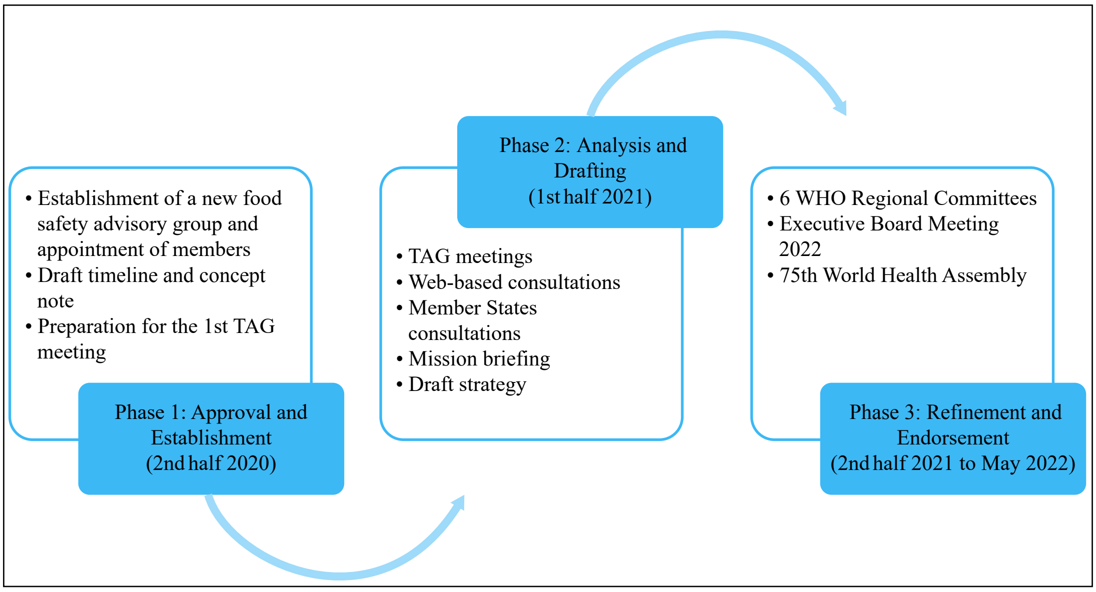

FIGURE 1. The overall process for the update of the WHO Global Strategy for Food Safety.
Abbreviation: TAG=Technical Advisory Group.

risk and a cumulative 100 trillion USD will be lost due to the spread of AMR if no proactive solutions are taken (*7*). One of the main sectors of antimicrobial usage is the food system. AMR arises from the inappropriate use of antimicrobials in humans and in food producing animals, so the food production system has a role to tackle the problem.

DRIVERS OF THE CHANGE IN FOOD SAFETY

Numerous factors impact on food systems and influence the safety of the food supply. While it is not always possible for agencies of government with responsibility for food safety to control these "drivers," it is important to recognize and understand their influence on existing and emerging food safety risks. In strengthening any national food control system, the key drivers Member States need to be aware of are summarized as the following: 1) Stakeholder interests and demands for safe food; 2) Global food safety threats; 3) Global changes in the economics of the food supply, 4) Environmental and climate change challenges; 5) Shifts in consumer preferences and expectations; 6) Rise of new technologies and digital transformation; 7) Population demographics.

FOOD SAFETY DEMANDS A ONE HEALTH APPROACH

It is now widely recognized that the health of people is closely connected to the health of animals and our shared environment (Figure 2) (*8*). With rapid population growth, globalization, and environmental degradation, threats to public health have become more complex. Recent emerging diseases such as Middle East respiratory syndrome (MERS), Ebola, and H7N9, have all been linked to our food systems and the environment. The COVID-19 pandemic has shown how vulnerable the global population is to the undetected emergence of new diseases, particularly zoonoses that originate at the human-animal-environment interface. Food production, intensive agriculture, livestock systems, wildlife trade and humans encroaching on wildlife habitats and weather-related disasters all contribute to increasing the risk of emergence of new zoonotic diseases. Mitigation of these threats cannot be achieved by one sector acting alone.

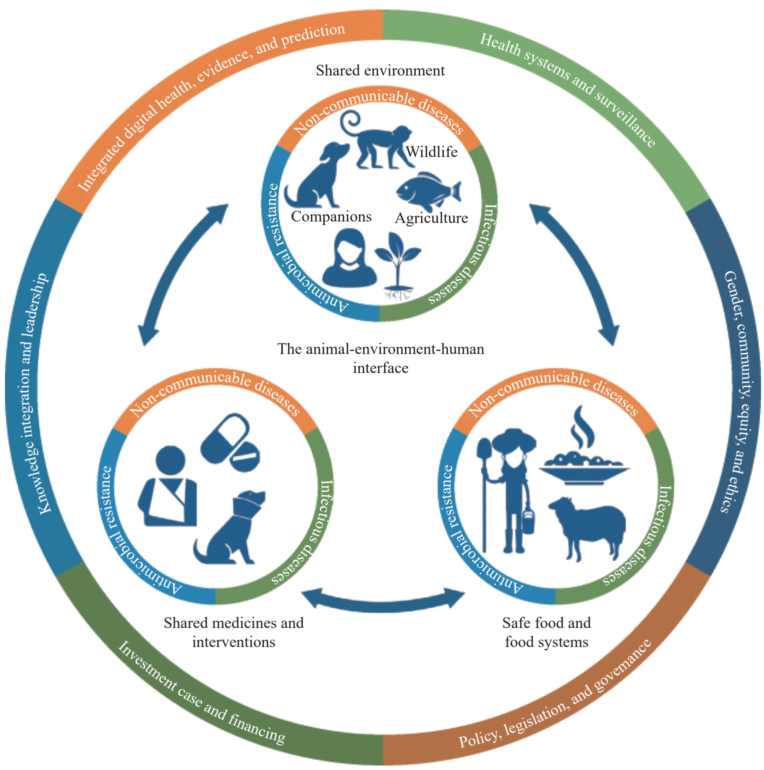

FIGURE 2. One Health approach: tackling health risks at animal-environment-human interface.

The One Health approach must be adopted if emerging diseases are to be detected and controlled at source. Whole genome sequencing is providing the ability to compare isolates from the environment, livestock, food and humans and track pathogens to where corrective actions are required. Future improvements in food safety and public health will largely depend on how well sectors manage to collaborate using the One Health approach. Data on the occurrence of and disease burden from foodborne hazards combined with knowledge of source attribution will be crucial in assessing costs and benefits of novel control measures. One Health collaboration will enable the necessary integration of data to inform preventive actions at the appropriate stages of the food chain. Without knowledge of the incidence and burden of disease, and the source of contamination, associated with hazard/food combinations, prioritization of mitigation action will be difficult and food safety improvements will be largely unsuccessful.

Many food related to chemical hazards, both from natural and manmade sources, reach consumers from or via animals or the environment and should be covered within the One Health framework. Chemical food contamination is a major cross-cutting issue with many agrochemicals and antimicrobials used in plant and animal production. In addition, the naturally occurring toxins, such as mycotoxins, present an ongoing challenge and an increasing threat due to climate change. Therefore, One Health monitoring and surveillance systems should clearly include natural and manmade chemical hazards.

Climate change is a major and growing influencing factor of food systems and is likely to have considerable negative impacts on food security, nutrition, and food safety. By modifying the persistence and transmission patterns of foodborne pathogens and contaminants, climate change leads to the escalation of foodborne risks (*9*). In this regard, food safety should also be integrated into interventions and commitments for climate change adaptation and mitigation under a One Health approach.

Adopting a One Health approach to food safety will allow Member States to detect, prevent and respond to emerging diseases at the human-animal-environment interface and to address food-related public health issues more effectively.

SCOPE OF THE STRATEGY

Strengthening national food safety systems begins with establishing or improving infrastructure and components of food control systems as described in Strategic Priority 1. For example, these may include developing framework food legislation, standards and guidelines, laboratory capacity, food control activities and programs, and emergency preparedness capacity. In addition to establishing a national food control system, four important characteristics/principles (Figure 3) (*10*) need to be considered and adopted for the system to be fully operational. The five strategic priorities are based on the fundamental components/infrastructure of the food safety systems and four additional principles.

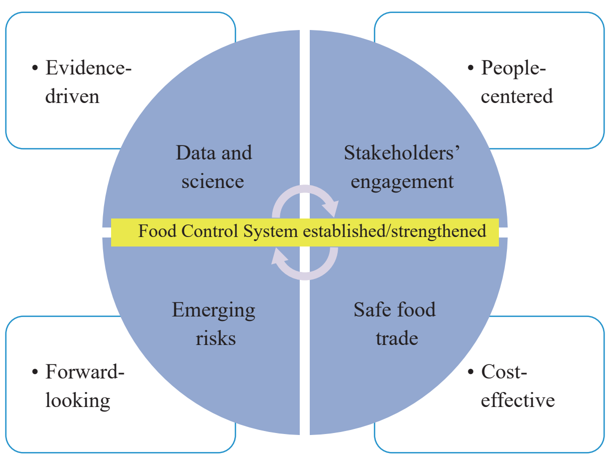

FIGURE 3. Conceptual framework for strategic priorities.

FIVE STRATEGIC PRIORITIES

It is intended that the new global strategy will provide an overall vision and strategic priorities for concerted global action that will underline both the importance of food safety as a public health priority and the need to enhance its critical role as a public health component in food systems. In discussing the strategic priorities, some participants suggested that the broad focus should be on national food safety systems rather than on national food control systems. Food systems encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption, and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal, and natural environments in which they are embedded. In the context of a food systems approach, the national food safety system would be the combination of activities of all stakeholders in the food chain to safeguard the health and wellbeing of people, while fostering economic development and improving livelihoods by promoting access to domestic, regional, and international markets.

The different components of the national food safety system would include, but would not be limited to, the national food control system (official food controls conducted by government agencies); food safety management systems (risk-based systems based on Hazard Analysis and Critical Control Point (HACCP) principles conducted by food business); foodborne disease surveillance systems (responsibility of the health sector); national food monitoring system for pesticide/residues/mycotoxin contaminants (part of official controls conducted by government agencies); animal disease surveillance systems (part of official controls conducted by veterinary agencies). Animal disease surveillance is important both for zoonotic pathogens and for animal specific disease. Many animal specific diseases can disrupt supply changes, e.g. Foot and Mouth Disease and African Swine fever and sick animals require antimicrobial treatment which can trigger the development of AMR in non-target microbes.

For the purposes of this strategy and to ensure alignment with the standards, guidelines, and codes of practice of the Codex Alimentarius, the WHO, in consultation with the FAO, has proposed that the term national food control system will be used where referring to the national food safety system. A national food control system of policies, procedures, and plans, includes a mandatory regulatory approach together with scientific information and preventative educational strategies that protect the whole food chain. This includes effective enforcement of food legislation, along with training and education, community outreach programs, and promotion. TAG members noted the importance of aligning with the Codex Alimentarius on the usage of terminology. However, concerns were also expressed as "food safety systems" is the terminology used in the WHA73.5 and the usage of "food control systems" can create an impression with those who are not familiar with the Codex standards, that the strategy only focuses on the control functions carried out by governments while excluding the activities of other relevant stakeholders in food safety. The 5 Strategic Priorities agreed by participants are:

- Strategic Priority 1: Strengthening national food control systems.
- Strategic Priority 2: Identifying and responding to food safety challenges resulting from the transformation and global changes in food systems.
- Strategic Priority 3: Increasing the use of food chain information, scientific evidence, and risk assessment in making risk management decisions.
- Strategic Priority 4: Strengthening stakeholder engagement and risk communication.
- Strategic Priority 5: Promoting food safety as an essential component in domestic and international trade.

An additional strategic priority was proposed to include technical cooperation to enhance the food safety situation in developing countries. Fostering regional and global cooperation and international connectivity should be a key theme for the strategy.

Countries have flexibility to determine how best to design their food control system and implement a wide range of control measures. The Codex Alimentarius Principles and Guidelines for National Food Control Systems will assist Member States in reviewing and strengthening their national systems (*11*). While recognizing the diversity of national food control systems at different levels of development and the wide range of food safety hazards, FAO and WHO have developed a framework for developing national food safety emergency response plans to assist Member States to develop country-specific plans (*12*). Today's global challenges are transforming the way we produce, market, consume, and think about food (*13*). The provision of a long-term safe, nutritious, and affordable food supply is a global endeavor and how we grow, produce, and sell food impacts us all, either as stakeholders in national and global agri-food value chains or as consumers of the increasing variety of food that is produced domestically or imported. The complexity of global food systems, and the speed at which they can change, demands that governments and competent authorities have a clear view of the connectedness between the global and regional food systems within which food is produced, distributed, and sold, and the food control system they regulate. Food safety is a core enabling factor to successfully transform food systems and Member States need to be aware of food safety issues as the transformation of food systems accelerates.

In many countries, different government ministries have a strong interest in decisions on food control measures made by the competent authority and their inputs may need to be considered as part of the decision-making process. Competent authorities can benefit from the use of international guidelines on multi-factor decision-making to promote consistency and transparency in their choice of control measures (*14*). A One Health approach to risk management generally involves cross-disciplinary inputs when responding to new or emerging risks arising at the human-animal-plant-environmental interfaces. As health threats become more complex, mitigation cannot be achieved by one sector acting alone. Food safety authorities may have to factor in public, veterinary, and environmental health considerations in establishing control measures. As an example, use of antimicrobials of critical importance (*15*) to public health may require their partial, or even, total withdrawal from use in food animal production because of the likelihood of antimicrobial resistance.

CHINA'S NATIONAL FOOD SAFETY STRATEGY AND ITS STRATEGIC PRIORITIES

The national food safety strategy proposed by China marks the foundation of a unique Chinese framework in food safety managing system with a core goal to ensure its people "eat at ease and safely." An entire food chain approach from animal feed production right through to consumption by the final consumer will be adopted. Consistent oversight of the food chain with equal risks receiving equal amounts of attention will be adopted. There will not be degrees of safety and food for the domestic market and for export will meet the same food safety standards.

Under the state-level guiding principle of "integrated marketing, supervision, industry, and management," the strategy focuses on harmonizing the domestic food market, optimizing government supervision, promoting high-quality development, and coordinated social governance. In addition, this strategy is supported with increased financial investment, education, and related regulations. Specific measures include: 1) establishing a unified, modern, open market system with managed competition; 2) promoting optimization, collaboration, and efficiency of the supervision system; and 3) establishing a social governance model based on collaboration, participation, and common interests. Therefore, as a concrete application of the WHO strategy, the Chinese government has proposed its own timetable and roadmap for its domestic food safety strategy: 1) zero tolerance of systemic food safety risks by 2020 and constantly improving the level of food safety assurance; 2) establishing a strict, highly efficient, and socially-governed food safety governance system by 2027; 3) achieving the modernization of food safety governance by 2035; and 4) achieving universal modernization of food safety governance and approaching world's top food safety level ranking by 2050.

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Preplanned Studies

Prevalence of *Salmonella* and Antimicrobial Resistance in Isolates from Food Animals — Six PLADs, China, 2019

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Summary

What is already known about this topic?

Salmonella causes acute and chronic diseases in food animals, and infected food animals are one of the most important source of human infection.

What does this report contribute?

The prevalence of *Salmonella* was 10.5% in chicken samples, 24.4% in pig, 23.3% in duck, and 29.4% in milk. *Salmonella* isolates were highly resistant to ampicillin (59.60%).

What are the implications for public health practices?

Data on *Salmonella* infections among food animals in China could help identify sources and factors related to the spread of *Salmonella* in food animals and food production chains.

Salmonella bacterial infections have become a major public health issue, causing a wide range of clinical manifestations, including acute gastroenteritis and bacteremia. Antibiotics are commonly used to treat and control salmonellosis in food animals, contributing to the increasing prevalence of antibiotic-resistant *Salmonella* that has been attracting worldwide attention (*1*). Thus, investigating the prevalence of resistance-related genes in *Salmonella* could enhance the understanding of drug impacts on epidemiology. The study mainly followed the 2019 National Surveillance Program of Antibiotic Resistance in Bacteria of Food Animal Origins to conduct animal-food sampling in 6 provincial-level administrative divisions (PLADs) in China: Hebei, Shanxi, Shandong, Sichuan, Inner Mongolia, and Beijing. In addition to a minor decline in prevalence of *Salmonella* in chicken, results showed an increase in prevalence of *Salmonella* in pigs, ducks, and milk. *Salmonella* contamination of food animals has become a serious public health threat in China. Through antimicrobial susceptibility testing, *Salmonella* of animal origin was found to have multiple drug resistance and a high rate to ampicillin (59.6%). Therefore, in the animal breeding environment, public health practitioners should pay attention to the disinfection of the breeding farm environment and reduce the overuse of therapeutic drugs, promote the scientific use of drugs in the breeding process, and ensure the safety of public health.

In this study, a total of 1,493 non-duplicate samples were collected and stored in ESwabs (a swab-based collection kit) from animal farms and 85 from milk storage tanks on dairy farms. The sample collection method strictly complies with 2019 National Surveillance Program of Antibiotic Resistance in Bacteria of Food Animal Origins. *Salmonella* isolates were identified by matrix-assisted laser desorption ionization time-of-flight mass spectrometry (MALDI-TOF MS). *Salmonella* serotyping was performed using the White-Kauffmann-Le Minor scheme. Minimum inhibitory concentrations (MICs) were determined by the broth microdilution method according to the recommendations in the Clinical and Laboratory Standards Institute guidelines (CLSI, 2015: M100-S25). Whole genome sequencing was conducted using an Illumina HiSeq2500 platform (Bionova Biotech Co. Beijing, China). Multilocus sequence typing (MLST) results were analyzed using MLST Version 2 (Seemann T, mlst Github http://github.com/tseemann/mlst), and plasmid replicon typing was conducted using online tools (Center for Genomic Epidemiology, Technical University of Denmark, http://www.genomicepidemiology.org/). Resistance genes were identified using SRST2 Toolkit (version 0.2.0, The University of Melbourne, http://katholt.github.io/srst2/).

A total of 198 *Salmonella* isolates (198/1,578, 12.6%) were obtained from food animal samples from Hebei, Shanxi, Shandong, Sichuan, Inner Mongolia, and Beijing in 2019. Samples were collected from the feces, cecum, and milk of food animals. The highest rates of *Salmonella* isolates were obtained with the samples from cows. Beijing displayed the highest *Salmonella* isolation rate among the examined PLADs (23.3%), while Hebei displayed the lowest isolation rate (8.8%) (Table 1).

Salmonella serotyping divided 133 isolates into 35 serotypes, with 65 isolates being incapable of being typed (Table 2). *Salmonella* Enteritidis (*S.* Enteritidis; 37.6%, 50/133) was the predominant species, followed by *S.* Tympanum (9.0%, 12/133) and *S.* Kentucky (9.0%, 12/133). Notably, multidrug resistant (MDR) strains were widely distributed among the various *Salmonella* serotypes. Among all the serotypes, *S.* Agona (77.8%) showed the highest rates of antimicrobial resistance and MDR in the present study.

The MDR rates among *Salmonella* from animal sources were different in different PLADs. Beijing displayed the highest rate of MDR, reaching 100% (Figure 1A), followed by Shandong (52.0%), Inner Mongolia (50.0%), Sichuan (48.0%), Shanxi (45.7%), and Hebei (25.0%). *Salmonella* isolates from six different PLADs were highly resistant to ampicillin (Figure 1B and 1C). A total of 18 strains of *Salmonella* with unique drug-resistant phenotypes were selected for whole-genome sequencing. Most *Salmonella* strains were resistant to multiple drugs. These strains were derived from chickens and pigs, and the MLST type was mainly ST11. The predominant serotype among these 18 *Salmonella* strains was enteritidis.

DISCUSSION

In the present study, the prevalence of *Salmonella* was 10.5% in chicken samples, 24.4% in pig, 23.3% in duck, and 29.4% in milk. The high contamination rate of *Salmonella* in milk samples indicated that milk is an important medium for *Salmonella* transmission. These results indicated that *Salmonella* contamination of food animals in China was a serious public health problem. Better measures should thus be taken to control *Salmonella* on dairy farms. Antimicrobial susceptibility tests in this study revealed that all the 198 *Salmonella* isolates were highly resistant to at least one tested antibiotic class (penicillin, folate pathway antagonists, tetracyclines, quinolones, and fluoroquinolones). The highest rates of antimicrobial resistance were observed for ampicillin (59.6%). High prevalence of resistance to ampicillin is due to this antibiotic has been widely used in animal husbandry in China (*2*). At present, clinics have reported high resistance of *Salmonella* to ampicillin (53%) (*3*) and high resistance in food animals (68.7%) in China (*4*). We should carry out regular disinfection and sterilization of the breeding environment and avoid eating meat, eggs, and other dairy products that have not been treated with high temperatures. This research provided important guidance and reference value for animal breeding drugs, and provided data reference value for the detection, diagnosis, and treatment of *Salmonella* infection in clinic.

Compared with other research reports in China, the prevalence of *Salmonella* was 43.3% for chickens (*5*), 17.4% for pigs (*6*), 2.1% for ducks (*7*), and 1.3% for

TABLE 1. Characteristics and prevalence of *Salmonella* isolates from the 6 PLADs, China, 2019.

PLAD	Sample	Source	No. of samples	No. of isolates	Isolating rate (%)	95% CI
Shanxi	Cow	Milk	85	25	29.4	(20.0, 40.3)
	Chicken	Cecum	121	10	8.3	(4.0, 14.7)
Sichuan	Chicken	Cecum	144	14	9.7	(5.4, 15.8)
		Fecal	60	14	23.3	(13.4, 36.0)
	Pig	Fecal	90	22	24.4	(16.0, 34.6)
Beijing	Duck	Fecal	30	7	23.3	(9.9, 42.3)
Shandong	Chicken	Cecum	247	26	10.5	(7.0, 15.0)
		Fecal	712	72	10.1	(8.0, 12.6)
Inner Mongolia	Chicken	Cecum	39	4	10.3	(2.9, 24.2)
Hebei	Chicken	Fecal	50	4	8.0	(2.2, 19.2)
Total	Chicken	Cecum/fecal	1,373	144	10.5	(8.9, 12.2)
	Pig	Fecal	90	22	24.4	(16.0, 34.6)
	Duck	Fecal	30	7	23.3	(9.9, 42.3)
	Cow	Milk	85	25	29.4	(20.0, 40.3)

Note: The six PLADs inculdes Hebei, Shanxi, Shandong, Sichuan, Inner Mongolia, and Beijing. The primary objective of the present study was to investigate the Isolating Rate and corresponding 95% CIs of prevalence of *Salmonella* isolates from the 6 PLADs, China, in 2019.
Abbreviations: PLADs=provincial-level administrative divisions; CI=confidence interval.

TABLE 2. *Salmonella* serovar isolates obtained from chicken, pig, cow, and duck samples from the six PLADs, China, 2019.

Serovar	Chicken	Pig	Cow	Duck	Total
Enteritidis	44	5		1	50
Tymphimurium	1	6	5		12
Kentucky	12				12
Agona	4	2	3		9
Djugu	6				6
Corvallis	4				4
Paratyphi B	4				4
Essen	2	1			3
Koenigstuhl	1			1	2
Norwich	1	1			2
Schwarzengrund		2			2
Trachau	2				2
Meleagridis			2		2
Kedougou		2			2
Kingston	1				1
Shannon	1				1
Stuttgart	1				1
Bovismorbificans	1				1
Mbandaka	1				1
Uppsale		1			1
Eschweiler	1				1
Braenderup	1				1
Derby		1			1
Havana		1			1
Anatum		1			1
Waycross		1			1
Bareilly		1			1
Azteca		1			1
Gueuletapee	1				1
Bloomsbury	1				1
Hato				1	1
Powel 2	1				1
Rissen		1			1
Menden	1				1
Nola	1				1
Total	93	27	10	3	133

Note: The six PLADs inculdes Hebei, Shanxi, Shandong, Sichuan, Inner Mongolia, and Beijing.
Abbreviation: PLADs=provincial-level administrative divisions.

milk (*8*). In addition to the reduction in the prevalence of *Salmonella* from chickens, our results showed an increase in the prevalence of *Salmonella* in pigs, ducks, and milk. In this study, the high rate of *Salmonella* contamination in cow milk samples. Other studies have reported *Salmonella* infection in raw milk and milk-related infant foods (*9*) as well, which might threaten the health of babies. Although the milk sample sources used in this study were limited, the findings suggested that *Salmonella* poses a threat to the milk supply. The highest rates of antimicrobial resistance were observed for ampicillin (59.6%), in agreement with the results of many previous studies on *Salmonella* isolates from food animals (*10*).

This study was subject to several limitations. First, the geographically concentrated nature of the samples in the present study does not represent China as a whole. Second, the types of the samples collected from each of the six PLADs and cities were not uniform, leading to sample biases as the collected samples could not represent the overall circumstances.

This was a survey of the prevalence of *Salmonella* in samples obtained from food animals from six PLADs in China. The isolates showed high antimicrobial resistance, with resistance to ampicillin being the most common. It is worth noting that in this study, *S.* Enteritidis displayed the most prevalent drug resistance and MDR. MDR *Salmonella* isolates from humans have a common ancestor with the isolates from food animals, increasing the difficulty of curing human infections and increasing healthcare costs. A nationally coordinated intervention strategy for drug use in farmed animals is needed to limit the spread of MDR *Salmonella*. Better methods for monitoring the emergence and spread of MDR *Salmonella* would facilitate disease control and treatment. To prevent these strains from becoming a worldwide pandemic, internationally coordinated intervention strategies to limit further dissemination of MDR *Salmonella* are required.

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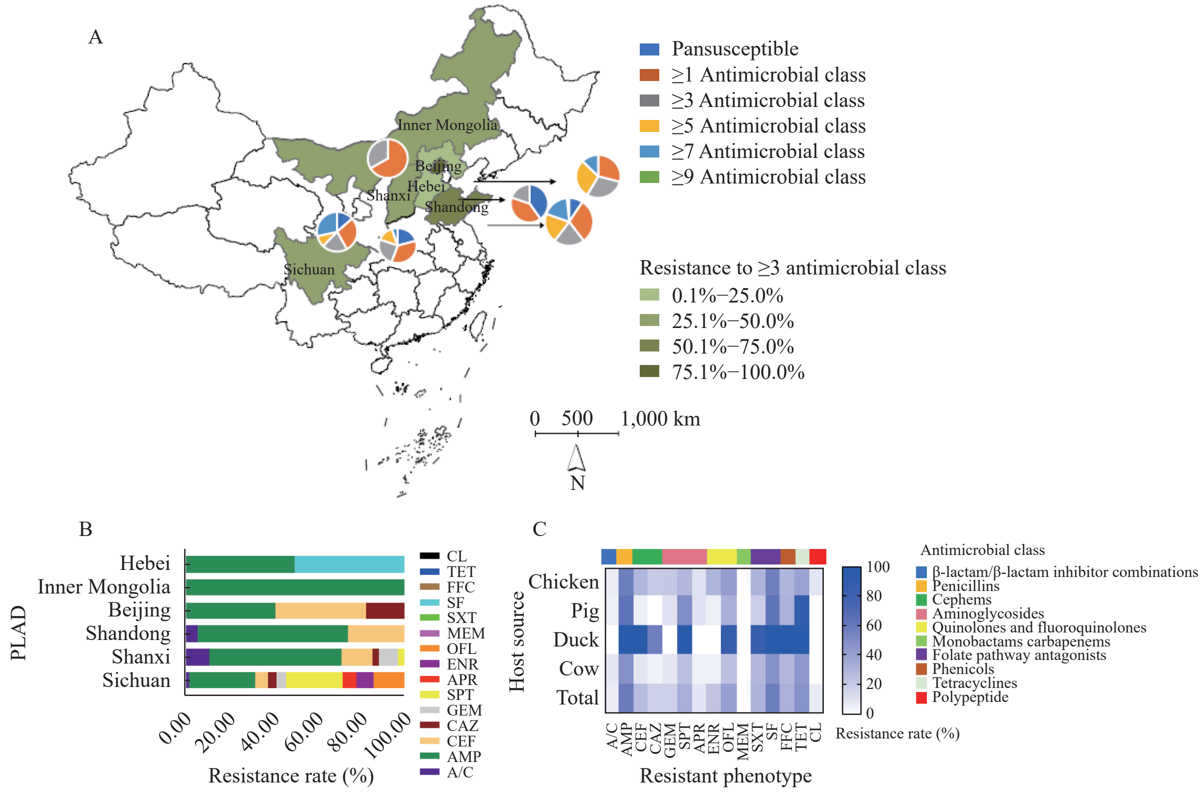

FIGURE 1. Multidrug resistance and distribution of *Salmonella* from the six PLADs, China, 2019. (A) The proportion of different antibiotic resistant types. (B) Distribution of *Salmonella* resistance phenotypes from different PLADs and cities in China. (C) Resistant phenotypes of *Salmonella* from different host sources.

Note: The six PLADs include Hebei, Shanxi, Shandong, Sichuan, Inner Mongolia, and Beijing.

Abbreviations: PLADs=provincial-level administrative divisions; A/C=amoxicilin-clavulanic acid; AMP=ampicillin; CEF=ceftiofur; CAZ=ceftazidime; GEM=gentamicin; SPT=spectinomycin; APR=apramycin; ENR=enrofloxacin; OFL=ofloxacin; MEM=meropenem; SXT=trimethoprim-sulfamethoxazole; SF=sulfamethoxazole; FFC=florfenicol; TET=tetracycline; CL=colistin.

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Vital Surveillances

Mushroom Poisoning Outbreaks — China, 2010–2020

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ABSTRACT

Introduction: Mushroom poisoning was the leading cause of foodborne disease outbreaks and outbreak-associated deaths in China. Mushroom poisoning outbreak surveillance can provide insight into the epidemiological characteristics of mushroom poisonings and guide policymaking and health education to reduce illnesses and deaths.

Methods: Foodborne Disease Outbreak Surveillance System was upgraded in 2011 to collect foodborne disease outbreaks in China. Mushroom poisoning outbreaks during 2010–2020 were selected to analyze geographical distribution, seasonal distribution, and setting of food preparation.

Results: A total of 10,036 outbreaks, which resulted in 38,676 illnesses and 788 deaths, were reported in this period. Mushroom poisonings occurred all over the country, but with highest incidence in the southwest and central China. Overall, 84.6% outbreaks were associated with food prepared in households, followed by 8.7% in street stalls, and 2.5% in canteens. Mushroom poisoning outbreaks clearly exhibited seasonality, and the peak season was summer through autumn. Outbreaks occurring between May and October accounted for 94.1% of total outbreaks, 92.4% illnesses, and 97.2% deaths.

Conclusions: Mushroom poisoning is a food safety issue of higher concern in China. Targeted health education is essential to reduce mushroom poisoning, especially in southwest China. Citizens are advised to not collect or eat wild mushrooms.

INTRODUCTION

Wild mushroom consumption is widespread throughout the world, due to the nutritional value and medicinal properties (*1*–*2*). However, mushroom poisoning is a cause of major mortality and morbidity throughout the world (*3*–*4*). Toxic mushrooms are distributed across the globe with over 5,000 species. Among them, 100 species are responsible for most of the cases of mushroom poisoning (*5*). A total of 1,020 edible, 692 medicinal, and 480 poisonous species have been identified in China (*6*). Mushrooms are more abundant in warm and rainy summer and autumn, and mushroom pickers, especially if inexperienced, may not fully perceive the risks associated with ingesting potentially toxic mushroom species. Most mushroom poisonings reported were accidental oral ingestion of poisonous mushrooms misidentified for edible species. Morphological characteristics and appearance of many edible species were like those of poisonous mushrooms. Poisonous mushrooms cause the most deaths in remote districts in southwest regions in China (*7*). Mushroom poisonings often occur in other countries (*8*–*9*), but outbreaks were rarely reported (*10*).

Different levels of CDCs in China investigate and report foodborne disease outbreaks according to the requirements of the Food Safety Law. The China National Center for Food Safety Risk Assessment (CFSA) maintains and manages the Foodborne Disease Outbreaks Surveillance System for data collection and analysis. This study aimed to summarize and analyze the epidemiological characteristics of mushroom poisoning outbreaks from 2010 to 2020 in China.

METHODS

A foodborne disease outbreak is defined as an incident in which two or more cases involve a similar illness resulting from the consumption of a common food (*11*). A standard form was used to report the foodborne disease outbreaks investigated by CDCs at provincial, municipal, and county levels. All approved mushroom poisoning outbreak reports from 2010 through 2020 were collected through Foodborne Disease Outbreaks Surveillance System. Data collected in each outbreak report included the reporting CDC, the date of occurrence, the number of illnesses, hospitalizations, deaths, the etiologic agents, implicated food vehicle, setting of food preparation, and contributing factors.

All reported outbreaks were audited and checked, then stored and managed using Microsoft Excel (version 2016, Microsoft, USA). All variable values were reported as counts or proportions (%).

RESULTS

During 2010–2020, a total of 10,036 mushroom poisoning outbreaks were reported to Foodborne Disease Outbreaks Surveillance System, resulting in 38,676 illnesses, 21,967 hospitalizations, and 788 deaths. The annual number of reported outbreaks increased each year, from 37 reported in 2010 to 2,705 in 2020 (Figure 1). The average number of illnesses per outbreak was 3.9, and average hospitalization and fatality rates were 56.8% and 2.0%, respectively.

Except for Xizang (Tibet) Autonomous Region, the other 30 provincial-level administrative divisions (PLADs) in China reported outbreaks (Figure 2). Southwest China was the region with highest number of outbreaks (6,062), illnesses (24,444), and deaths (454); 1,900 outbreaks occurred in central China, leading to 6,559 illnesses and 137 deaths; 1,132 outbreaks occurred in east China, leading to 4,094 illnesses and 112 deaths; 423 outbreaks occurred in south China, leading to 1,663 illnesses and 30 deaths; and followed by northwest China (213 outbreaks, 749 illnesses, and 20 deaths), north China (153 outbreaks, 621 illnesses, and 25 deaths), and northeast China (153 outbreaks, 546 illnesses, and 10 deaths). The total number of outbreaks reported by each PLAD varied from as low as 1 in Tianjin and Shanghai to as high as 4,010 in Yunnan. The overall national reporting rate during 2010–2020 was 0.3 outbreaks/million population. The top 5 PLADs, including Yunnan, Hunan, Guizhou, Sichuan, and Jiangxi, comprised 79.7% (8,002/10,036) of total outbreaks, 80.3% (31,058/38,676) of total illnesses, and 74.6% (588/788) of total deaths. Yunnan reported the most outbreaks, illnesses, and deaths, accounting for 40.0%, 43.6%, and 41.0%, respectively.

The locations of food preparation were divided into 2 main categories: household and catering service places (Table 1). Among the 10,036 reported outbreaks, 84.7% were associated with food prepared in private homes (leading to 77.8% illnesses and 92.8% deaths), followed by 8.8% related with food prepared in street stalls (leading to 8.6% illnesses and 2.0% deaths), and 2.5% in canteens (leading to 4.6% illnesses and 1.9% deaths). The major cause of private-home outbreaks was self-harvest of wild mushrooms, which led to 98.1% of all private home outbreaks, 98.2% of illnesses, and 99.6% of deaths. Purchase of wild mushroom was the most common cause of catering service outbreaks, accounting for 63.5% of all catering service outbreaks, 49.0% illnesses, and 28.3% deaths.

From 2010 to 2020, mushroom poisoning outbreaks annually clearly exhibited seasonality (Figure 3). A large proportion of outbreaks occurred between May and October, accounting for 94.1% of total outbreaks, 92.4% of total illnesses, and 97.2% of total deaths. In Yunnan, there was a clear peak of

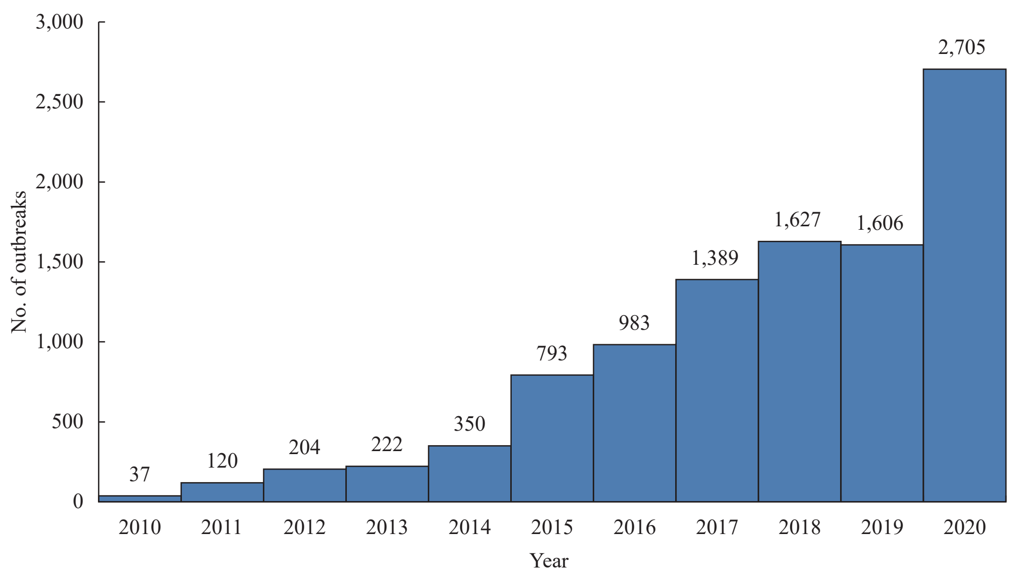

FIGURE 1. Number of reported mushroom poisoning outbreaks by year, Foodborne Disease Outbreak Surveillance System, China, 2010–2020.

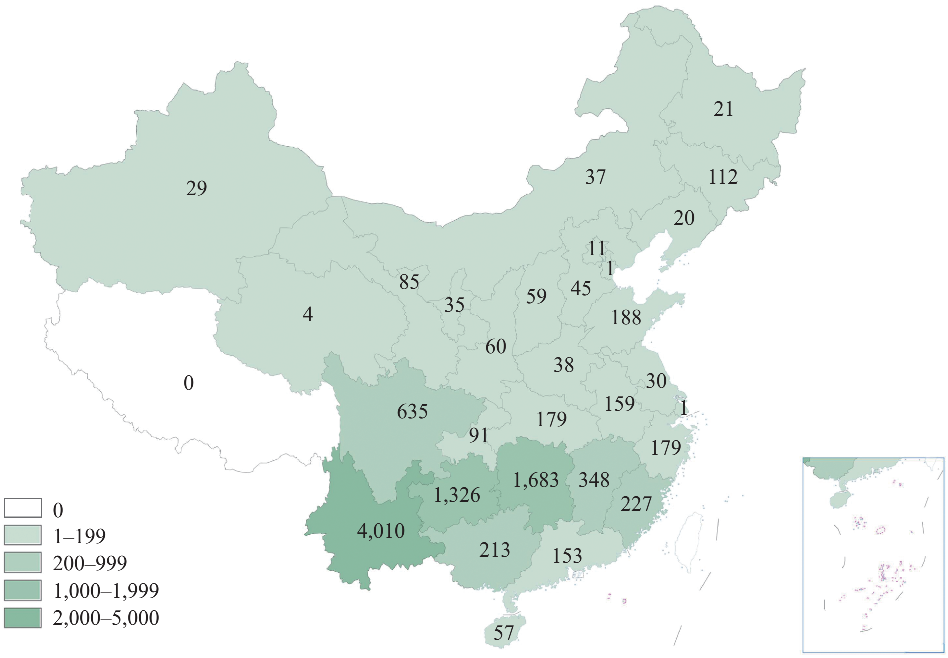

FIGURE 2. Number of reported mushroom poisoning outbreaks by PLADs in China, 2010–2020.
Abbreviation: PLADs=provincial-level administrative divisions.

TABLE 1. Number and percentage of mushroom poisoning outbreaks, illnesses, hospitalizations, and deaths by settings in China, 2010–2020.

Setting	Outbreaks		Illnesses		Hospitalizations		Deaths	
	Number	%	Number	%	Number	%	Number	%
Household	8,495	84.6	30,098	77.8	17,456	79.5	731	92.8
Catering Service Places	1,463	14.6	8,083	20.9	4,196	19.1	46	5.8
Street stall	878	8.7	3,317	8.6	1,677	7.6	16	2.0
Staff canteen	249	2.5	1,783	4.6	899	4.1	15	1.9
Restaurant	175	1.7	1,107	2.9	550	2.5	0	0.0
Rural banquet	58	0.6	1,240	3.2	789	3.6	9	1.1
Cafe	50	0.5	276	0.7	131	0.6	3	0.4
Fast food store	32	0.3	144	0.4	83	0.4	3	0.4
School canteen	7	0.1	71	0.2	30	0.1	0	0.0
Home delivery of meal	5	0.0	109	0.3	12	0.1	0	0.0
Other	9	0.1	36	0.1	25	0.1	0	0.0
Campus	6	0.1	27	0.1	14	0.1	0	0.0
Other location	72	0.7	468	1.2	301	1.4	11	1.4
Total	10,036	100.0	38,676	100.0	21,967	100.0	788	100.0

outbreaks in July, while 2 peaks appearing in June and September were observed in Hunan and Guizhou.

For all the reported outbreaks, 96.8% involved fewer than 10 cases per outbreak, leading to 95.7% of the total deaths. In addition, 12 outbreaks had more than 30 cases, met the limits of the public health emergency incidents of China, and led to 943 illnesses and no reported deaths.

DISSCUSSION

Mushroom poisoning was the leading cause of foodborne disease outbreaks and outbreak-associated deaths in China. Surveillance data showed that mushroom poisonings accounted for 31.8% of the total outbreaks and 47.4% of the total associated deaths from 2003–2017 (*12*). The annual number of

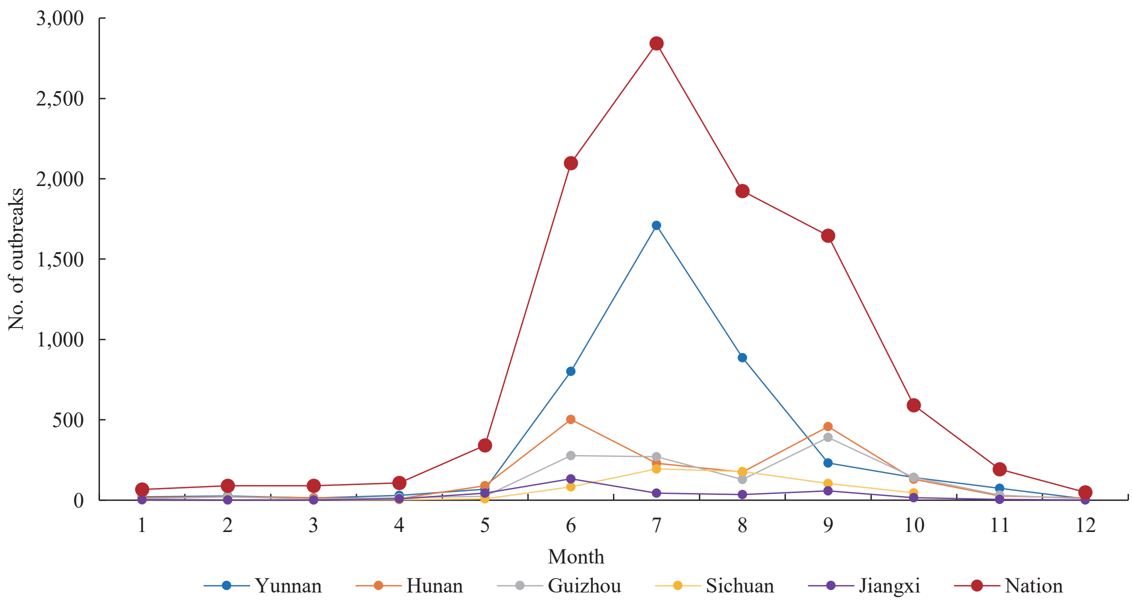

FIGURE 3. Monthly distribution of reported mushroom poisoning outbreaks in China, 2010–2020.

mushroom poisoning outbreaks reported in China gradually increased between 2010 and 2020. The increase is expected to be associated with the implementation of compulsory surveillance in 2011, increasingly strict requirements for outbreak reporting, and enhancement of reporting awareness. Therefore, the increase owed a great deal to the improvement of surveillance sensitivity. Even though 2,075 mushroom outbreaks were reported in 2020, underreporting is still likely.

Mushroom poisonings were reported throughout the country, but the incidence was highest in the southwest and central, likely due to the warm and damp climate conditions. Most outbreaks occurred in private home settings, especially in rural areas, mainly because of the self-harvesting of wild mushroom. Non-expert wild mushroom picking and consumption increases the risk of poisoning due to the difficulties of identifying poisonous mushrooms and distinguishing them from non-poisonous mushrooms. Although citizens are advised not to collect and eat wild mushrooms, mushroom poisoning continues to occur every year.

Mushroom poisoning occurred every month, with peaks in summer and autumn. The seasonality suggests that, albeit always important, health education is especially crucial in this period. Since mushroom picking is more frequent in rural environments, health education targeted for specific groups in rural areas is also essential to reduce mushroom poisonings.

Only 3,872 outbreaks (38.6%) were reported with mushroom names, involving 15,475 illnesses (40.0%) and 275 deaths (34.9%); 65.1% deaths were reported in 6,164 outbreaks involving unidentified mushrooms. Absence of relevant mushroom samples and ingestion of multiple mushrooms increased the difficulty of identifying causative species. Over 180 mushroom names were reported, but most of the outbreaks were reported with trivial, non-scientific names. Accurate and prompt species identification is crucial in the diagnosis and treatment process. More effort and cooperation is needed from administrative agencies, epidemiologists, doctors, and mycologists to increase the identification rate (*13*).

It is not possible to evaluate if the increase in reporting of mushroom poisoning outbreaks in investigations is only due to changes in surveillance practices or reflecting a true increase in incidence. Evaluating trends will be possible when surveillance and reporting practices are well-established and stable throughout the country. Currently, some degree of underreporting still exists, which is also a challenge for all foodborne illnesses globally (*14*). In addition to challenges in surveillance, underreporting is also related to failures in any other step between the occurrence of an illness and the reporting of the outbreak, i.e., patients seeking medical care, the cause of the illness being investigated, and the illness being registered (*15*).

Despite important improvements in surveillance of mushroom poisoning outbreaks, some of the results in the analysis were still subject to some limitations. Some of the epidemiological information is still not complete and accurate, such as mushroom species identification. Efforts should be made to improve investigative procedures, reporting practices, and data collection. Because of different surveillance systems and reporting standards, the results might be different from the other published results earlier or later (*13*).

Identifying and prioritizing interventions to reduce diseases, including mushroom poisoning, requires data on the public health impact of these diseases. The results of this study showed that targeted interventions to reduce mushroom poising in China are crucial. Policy efforts should be focused on citizen campaigns to raise awareness of the risks, and are particularly important in summer and autumn months, rural areas, and specific regions of China.

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Commentary

Upgrading from One-way Informing to Two-way Audience-oriented Health Communication: CFSA Initiations for World Food Safety Day

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Jinjun Liang[4]; Patrick Wall[5]; Yongning Wu[1,#]; Zhenyi Li[2,#]

Food safety is vital to the development of human society. On December 20, 2018, the United Nations General Assembly adopted resolution 73/250 proclaiming a World Food Safety Day. As of 2019, every June 7 is a time to increase social awareness of food safety and to encourage actions for good health promotion. The Third World Food Safety Day on June 7, 2021 aims to draw attention and inspire action to help prevent, detect, and manage foodborne risks, contributing to food security, human health, economic prosperity, agriculture, market access, tourism, and sustainable development (*1*).

Food safety risk communication shifts from the traditional approach of one-way sender-oriented to a two-way audience-oriented communication approach. International organizations have achieved consensus that recent advancement of technologies and institutions fundamentally impact how the public perceive, communicate, and react to food safety risk issues. It is crucial to conduct audience analysis to gain a comprehensive understanding of risk perception and communication. For instance, the European Food Safety Authority (EFSA) recommended an audience analysis approach for food-related risk communication practices. Data-driven insights are encouraged by EFSA's Social Science Roadmap (2019–2021) (*2*). It is key to identify and segment audiences, to measure understanding of public information, and to tailor communication methods. The importance of producing and delivering public information through partnership approach and social media integration are also emphasized (*3*).

FOOD SAFETY RESEARCH AND PRACTICE FROM CFSA

China National Center for Food Safety Risk Assessment (CFSA) has been conducting research and directing practice on risk communication, including food-borne disease and mortality caused by poisonous mushrooms and microorganisms because they are reported as high lethality in certain regions in China (*4*). For example, poisonous mushroom adds enormous burden to local health systems and causes economic loss to the families and communities (*5*). Common public health campaign attempting to dissuade mushroom picking and eating has not made very effectively changes as the cases of illness and mortality have remained high in many regions for years (*6*).

Seeing the absence of systematic examination on risk communication, the research team initiated an exploration on this issue by collecting data from the field as well as reviewing relevant literature for applicable theories since 2020. The team has collected 1,262 questionnaires from Hunan, Guizhou, Jiangxi, Chongqing, and Yunnan where mushroom poisoning cases are concentrated. The team also conducted in-depth interviews in Hunan and Yunnan for supplementary understanding of the quantitative data analysis results. Meanwhile, the team has surveyed mainstream health communication theories for a rational model that could guide our research design, data analyses, and recommendation implementation.

The major findings from empirical data identified the high-risk population as local low-income, low-education, agricultural-oriented with high-level of optimistic bias who are over-confident of their mastery of knowledge and skills to differentiate non-poisonous mushrooms from the poisonous ones based on their experiences and knowledge exchange with peers (*6*). Most of this population intend to assess risks by themselves, and they intend to interpret their own risk in a self-serving manner (*7*). This explains why common public health campaign could hardly penetrate and reach this population.

The team also found that those who received the health campaign messages were not ready to accept the message or to decide to take actions. This indicates the high-risk population is concentrated on the counterproductive side on the 5C-model (*8*) (confidence, calculation, complacency, constraints, and collective responsibility). The team also found our data and findings fit well with Massive Persuasion for Behavioral Change Model (*9*), Health Belief Model (*10*), Protection Motivation Theory (*11*), Theory of Planned Behavior (*12*), and Social Cognitive Theory (*13*). These theories all point out that the high-risk population are at the early stage of behavioral change with great probability to reject health campaign messages.

Food safety is not simply related to food consumption. For example, in our research on why people neglected risks related to poisonous mushroom, we identified 4 stumbling barriers for these population to make behavioral change based on the Health Belief Model: 1) knowledge; 2) belief; 3) habits; and 4) culture. None of these four barriers can be overcome overnight by a law or a motion. All barriers are embedded deeply in local contexts. Therefore, it is important to conduct contextual analysis on how to communicate these risks to the local people before launching any health promotion campaign. A one-for-all message can neither penetrate the population nor convince them for behavioral change. In Hunan, for example, we suggested differentiating communication strategies to regions with different risk levels. A map of poisonous mushroom risks becomes the base for selecting these strategies, from general awareness campaign in low-risk zones to specific prevention in high-risk zones. A traffic-light-like signage is now used to send clear visible messages to the public to distinguish up mushroom with high, middle, and low-poisonous-risk with red, yellow, and green colors, respectively. The team has identified that the top three information sources of high-risk population were TV, WeChat, and short videos. Based on the current findings, we recommend creating accurate messages and using diversified communication channels to target different audience groups. Instead of a traditional one-way communication method adopted by most popular science programs, we encourage creating and distributing interactive messages using Chinese social media channels, such as Kwai, to better engage different audience groups. Following the emotional appeal approach, the team produced several short videos targeting at different age groups, such as A Second Thought For Life targeting at senior groups and a rap music video targeting youth in the high-risk population. These are showcased in the 2021 World Food Safety Day exhibition.

CFSA has been collaborating with several national popular science platforms and TV programs to increase social awareness of food-borne risks such as microorganism. CFSA has designed several interactive games and WeChat mini-apps to meet different social needs, such as “Are You Ready to Cook.” Participants only need one minute to play the game from which they learn about the problems of as well as solutions to microorganism risks in food processing. CFSA has developed a popular science interactive game “Secrets Behind Foods” to guide audiences to discover illness caused by microorganisms in familiar circumstances in their daily life. CFSA also produced seven mini scientific videos on foodborne disease related topics to increase public awareness and engagement.

CFSA also assisted to promote products for different audience in 2021 World Food Safety Day including but not limited to: Healthy China Action Plan (2019–2030)” and “the National Nutrition Plan (2017–2030)” for professionals, food-borne disease and food nutrition programs with China Central TV for the public, and popular science picture books and short videos for children.

CHALLENGES AND FUTURE WORK

The media ecosystem in China has recently experienced dramatic changes due to advances in artificial intelligence (AI), Internet of things (IOT), and 5G telecommunication. Traditional media yield their influence and power to new media, which can target audiences and tailor content with greater customer stickiness. Food safety messages can take advantage of these changes as segmentation of audiences and tailor-made content become vital for communication appropriateness and efficiency. The key is how communicators respond to these changes. Here are some thoughts for future work:

First, food safety and health communication must be shifted from one-way sender orientation to two-way audience orientation. Health communication is not only for reaching the audience, but also for influencing their behavioral changes. The relationship between communicators and the audience is not superior-subordinate but mutually beneficial. Therefore, communicators must approach the audience more proactively to understand their risk perceptions before communicators send them messages.

Second, food safety and health communication must be based on valid and reliable scientific knowledge. Communicators must identify how much our audience has already grasped, wants to learn more about, and needs to know. Audience interest, trust, and receptivity are all vital for success of health communication.

Third, food safety health communication must respect audience reception rules, where listening, emotional understanding, and empathy all are vital. communicators must understand the audience before designing and delivering messages for better reception and comprehension.

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