



# Food supply and food safety issues in China

Hon-Ming Lam, Justin Remais, Ming-Chiu Fung, Liqing Xu, Samuel Sai-Ming Sun

*Lancet* 2013; 381: 2044–53

State Key Laboratory of Agrobiotechnology, and School of Life Sciences, Chinese University of Hong Kong, Shatin, Hong Kong Special Administrative Region, China (Prof H-M Lam PhD, Prof M-C Fung PhD, Prof S S-M Sun PhD); Department of Environmental Health, Emory University, Atlanta, GA, USA (J Remais PhD); and School of Business, Jiangnan University, Jiangsu, China (Prof L Xu PhD)

Correspondence to: Prof Samuel Sai-Ming Sun, School of Life Sciences, Chinese University of Hong Kong, Shatin, Hong Kong Special Administrative Region, China [ssun@cuhk.edu.hk](mailto:ssun@cuhk.edu.hk)

Food supply and food safety are major global public health issues, and are particularly important in heavily populated countries such as China. Rapid industrialisation and modernisation in China are having profound effects on food supply and food safety. In this Review, we identified important factors limiting agricultural production in China, including conversion of agricultural land to other uses, freshwater deficits, and soil quality issues. Additionally, increased demand for some agricultural products is examined, particularly those needed to satisfy the increased consumption of animal products in the Chinese diet, which threatens to drive production towards crops used as animal feed. Major sources of food poisoning in China include pathogenic microorganisms, toxic animals and plants entering the food supply, and chemical contamination. Meanwhile, two growing food safety issues are illegal additives and contamination of the food supply by toxic industrial waste. China's connections to global agricultural markets are also having important effects on food supply and food safety within the country. Although the Chinese Government has shown determination to reform laws, establish monitoring systems, and strengthen food safety regulation, weak links in implementation remain.

## Introduction

China's population is anticipated to peak at 1.4 billion in 2025,<sup>1</sup> and the country's demographic transition is being accompanied by rapid economic growth and a nutritional transition involving increased consumption of animal products and edible oils.<sup>2</sup> The vast size of China's food production and consumption enterprises, along with the country's global economic importance, make China's food supply and food safety issues of major interest to international markets and trading partners. We review the major food supply and safety issues facing China in this context, connecting these issues with global trends and analysing key policy options available to China to stabilise food supplies and improve food safety in years to come.

Historically, food security has played a crucial role in public health in China.<sup>3,4</sup> China went through 3 years of famine in the middle of the last century, and although

data on effects of the famine are sparse, mortality attributable to starvation in that period has been estimated at tens of millions of people.<sup>5</sup> National mortality rates were 1.46% in 1959, 2.54% in 1960, and 1.43% in 1961,<sup>6</sup> and in 1960 the mortality rate exceeded the birth rate.<sup>6</sup> A legacy of this formative public health tragedy is that food supply, price, and availability continue to be high priorities on China's national agenda.

After the famine, in the decades following the late 1970s, China went through rapid economic growth, industrialisation, and modernisation, and this rapid development, as well as an increasing population, placed new strains on the national food supply. In 1995, Lester Brown published his classic text *Who Will Feed China*,<sup>7</sup> sending a wake-up call to global policy makers and warning that China's large population and the conversion of arable land for urbanisation and industrialisation might eventually lead to a large gap between food demand and production in China. Such a situation would place substantial strain on global markets for agricultural products, potentially destabilising global food security. Here, we revisit the status of China's food supply nearly two decades after this seminal publication, and examine the extent to which food security issues have coincided with trends in food supply, price, and availability. We then examine

## Key messages

- Major food supply issues in China might be exacerbated by the rapidly rising demand for animal feed, which is associated with the country's transition towards greater consumption of animal products; despite recent progress, undernutrition is still reported in children living in remote regions
- A gradual shift in focus from food supply to food safety has occurred in China, and public engagement in food issues has increased in recent years
- Although most food safety incidents are related to microorganisms, toxic plants and animals, and chemical contamination, illegal food additives and contamination with environmental hazards are growing problems in China
- The Chinese Government has shown a strong commitment to reforming food safety laws and strengthening vital surveillance and monitoring systems, yet weak links remain, particularly in implementation

## Search strategy and selection criteria

We searched published scientific literature, official websites, and news websites from international and Chinese sources (in both English and Chinese) with the key words "food security", "food safety", "foodborne disease", "food consumption", and "diet", combined with the term "China". We drew statistical data mainly from public databases hosted by Chinese Government agencies and by the UN Food and Agriculture Organization. We compared, analysed, and summarised the evidence drawn from the scientific literature, official and media sources, and related databases.

China's shifting attention from food supply issues to food safety concerns.

### Key factors that affect China's food supply: land, water, soil, and diet

Environmental factors affecting agricultural productivity are in part summarised by the Chinese character for food (panel). The country's food supply is a function of China's large population, the quantity and quality of arable lands, climatic factors, water supply and scarcity, the abundance of micronutrients in soil, and other factors. China has only 7–9% of the world's arable land, but more than 20% of the world's population,<sup>8</sup> and thus the country's arable land per person is well below the global average (figure 1A). Furthermore, the area of arable land has been decreasing for the past 50 years, due in part to soil erosion and land conversion associated with urbanisation and industrialisation. Arable land for food crops also faces competition from economic non-food crops; for instance, despite the strong demand for food crops, cotton production has occupied a stable and substantial portion of the arable land throughout the past few decades as a result of its economic value (appendix).

Of the available arable land in China, only about 40% is classified as the highest grade (most suitable for crop production), with much of the remaining area subject to environmental stresses such as drought and high salinity content.<sup>9</sup> The highest value arable land is located in three large alluvial plains: the Northeast China Plain, the North China Plain, and the Yangtze Plain.<sup>9</sup> These regions comprise the exact stretch of land along China's eastern coast that has undergone the most intensive urbanisation,<sup>10</sup> and the area represents the front line of the struggle to balance agricultural and urban land use. Meanwhile, in much of China's vast northern territories, such as in the Qinghai-Tibet Plateau and the northern part of Heilongjiang, the cumulative temperature is too low for meaningful production of major crops, and thus the region contributes minimally to the nation's total arable land.

As in much of the world, China's agricultural production is closely linked to available water: irrigated land accounts for 75% of the country's grain production,<sup>11</sup> and irrigation accounts for more than 60% of the country's total water consumption.<sup>12</sup> Water supply is one of the major factors limiting the extent of arable land, and yearly agricultural production, in China.<sup>9</sup> In 2008, for example, drought stress affected nearly 10% of China's arable land (a total of 12 million hectares), with 812 000 hectares undergoing total crop failure.<sup>13</sup> Regionally, water scarcity is especially severe in northwest China, which comprises more than 40% of China's total land area. This area has undergone widespread desertification and thus contributes minimally to the country's overall agricultural output.<sup>14</sup> Nationally, per-person freshwater resources in China

are far below the global average (figure 1B), and supplies are further diminished by widespread water pollution.<sup>15</sup>

Compounding the productivity limits imposed by insufficient land and inadequate water supplies, intensive farming of productive land has led to deficiencies in soil micronutrients that impede agricultural productivity in China.<sup>16</sup> The distribution of micronutrients in soil differs substantially by region,<sup>16</sup> and for zinc and iron, for instance, the bioavailable quantity rather than the absolute quantity defines the micronutrient quality of the soil. In acid soils found in southern China, iron and zinc are more chemically available for uptake by plants than in calcareous soils typically found in northern China.<sup>16</sup>

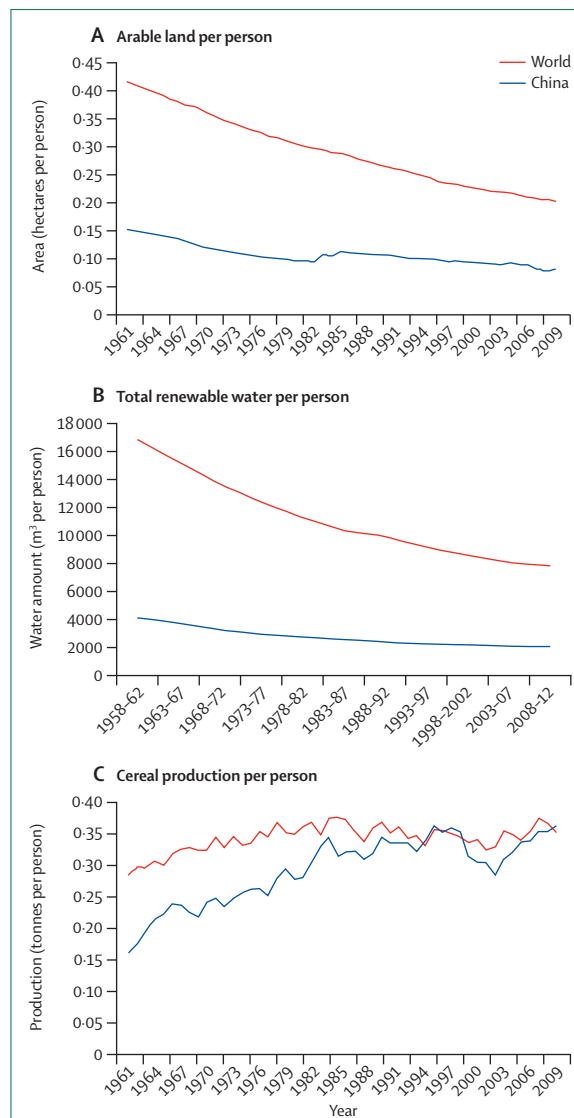
Deficiencies of some micronutrients in soil can be passed along to crops, contributing in some cases to dietary micronutrient deficits.<sup>17</sup> Such a pathway from soil micronutrient deficiency to malnutrition from food micronutrient deficiency is rare, although evidence from China of such a pathway for iodine has been reported.<sup>17</sup> Much more often, human populations, such as those living in remote regions and with low incomes, cannot readily access diverse food types, leading to dietary micronutrient deficiency, which poses major threats to public health<sup>18</sup> and the economy<sup>19</sup> in China. In a 2002 survey, an estimated 208 million Chinese people, mainly in rural areas, had iron-deficiency anaemia and 86 million had zinc-deficiency stunting.<sup>18</sup> The problem of malnutrition still persists in some very poor populations,<sup>19</sup> despite the rapid overall economic growth in China. Diversification of diets, and when appropriate, fortification of food products, are important to address this serious issue.<sup>18</sup> Additional research on biofortification, which aims to help the accumulation of micronutrients inside edible plant parts with classic breeding and transgenic technologies, might constitute new directions in this arena.<sup>20</sup>

Despite the many challenges that have faced agricultural productivity in China, particularly those from

See Online for appendix

#### Panel: The etymology of the Chinese character for food

The traditional understanding of food in Chinese culture is embedded in a composite character, 糧, meaning food in Chinese. This Chinese character summarises the environmental factors that help or limit agricultural productivity in China. The subpart 米, means rice or is a collective term for cereal, which is the staple crop for Chinese people. To grow crops, 日, the sun, is needed to provide photosynthetic energy and warm temperatures, but appropriate climatic conditions (eg, rainfall) are also needed and thus depend on 一, a simplistic representation of the sky. Labour and agricultural inputs are added to 田, the field, but ultimately the field is composed of 土, earth, which controls agricultural productivity via constituents of the soil, its structure, and other properties.



**Figure 1: Temporal trends in land use, water resources, and cereal production, worldwide and in China**

Total arable land (A), renewable water resources (B), and cereal production (C) were divided by the total populations of the world and China, respectively. Data are from the UN Food and Agricultural Organization.<sup>8</sup>

the late 1950s to the late 1960s (appendix), the gap has closed between the global average and Chinese average per-person production of cereals—the major source of calories in the Chinese diet (figure 1C). Many factors have contributed to rising per-person production, including successful breeding programmes of high-yield varieties of cereal, heterotic grains (eg, hybrid rice), and increasing agricultural inputs (eg, with agrochemicals and energy for farm machinery and production of agrochemicals).<sup>21–23</sup> Sustaining these gains while limiting environmental degradation from overuse of agrochemicals and other inputs is a major challenge facing China, particularly as the Chinese diet shifts towards

greater consumption of animal products, edible oils, and processed foods.

China has seen dramatic dietary shifts throughout the past five decades, including a rapid increase in the consumption of animal products such as meat, milk, and eggs (figure 2A). Indeed, the nutritional transition has been well documented in China,<sup>24</sup> involving a switch from a semivegetarian diet to an animal-product-dominant diet. A coincident rapid increase in the overweight population, particularly in Chinese cities, threatens to impose major public health effects from associated metabolic syndromes and diet-related diseases,<sup>24,25</sup> following trends in other industrialised countries.

Furthermore, rising demand for animal products increases the need for animal feed, potentially requiring China to import food crops to supply its massive domestic animal agriculture sector.<sup>26</sup> Such an effect has already been noted within China's domestic agricultural market: acreage of maize production has increased rapidly when compared with the relatively steady acreage devoted to rice and wheat (appendix). The largest use of China's maize crop is as animal feed, and consumption has doubled since the 1980s.<sup>27</sup> To protect its supply of animal feed, the Chinese Government is contemplating measures to restrict the industrial use of maize—eg, for the production of starch, sweeteners, and ethyl alcohol.<sup>28</sup>

The country's rapid increase in its production of fishery products has eased the pressures on China's land-based animal agriculture somewhat (figure 2B). Most of the increase throughout the past decade is a result of the expansion of freshwater fish farming, which is expected to continue despite the serious environmental effects on freshwater resources.<sup>29,30</sup> Since China has an extensive coastline, increases are also expected in the catch from marine fisheries. Sustainable fish farming and marine fish harvesting, along with the protection of endangered marine species, will be key issues for these industries in the future.

### Strategies to safeguard food supply in China

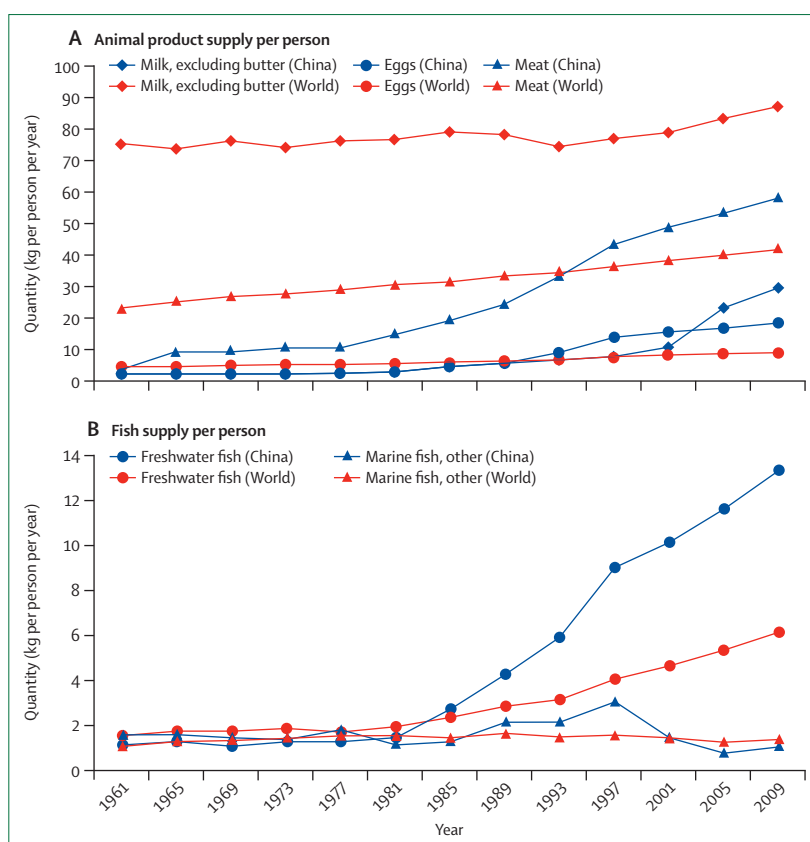
Food is an integral part of Chinese culture (appendix), and as suggested by the Chinese saying “To people, food is heaven”, food supply issues have been at the foundation of social stability in China. The challenges to food supply in China discussed so far are compounded not only by China's exceptionally large population, but also by rising inequalities. More than 13% of the Chinese population lives below the poverty line (yearly income below US\$363), with most of the poor residing in rural areas.<sup>31</sup> Undernutrition, particularly in children in underdeveloped remote regions, is estimated to cost China 4% of its gross domestic product (GDP) every year.<sup>19</sup> And although the Chinese Government has for decades focused on keeping the price of agricultural products low,<sup>32</sup> these policies have particularly benefited populations in cities

while limiting economic incentives for farming in rural areas and thus imposing negative feedbacks with respect to agricultural productivity.

These trends will be partly mitigated by China's unprecedented population migration, a continuing process that is fundamentally reshaping rural and urban populations alike.<sup>10</sup> More than half of the population now resides in urban areas—compared with less than 20% in 1980<sup>33</sup>—and the population remaining in rural areas has tended to have more land per person since 1980 onwards. The mechanisation and industrialisation of agriculture, which have accompanied larger farm sizes, can push up rural incomes and agricultural productivity,<sup>34</sup> and can also have unique effects on public health by, for instance, modifying transmission pathways of environmental pathogens such as the parasitic helminth that causes schistosomiasis.<sup>35</sup> At the same time, rapid urbanisation has several public health effects that have been comprehensively reviewed elsewhere,<sup>10</sup> including important effects of changing diet that accompany rural-to-urban migration and put pressure on food supplies as consumption of animal products increases.

In view of the importance of freshwater resources to Chinese agricultural productivity, described above, water conservation and engineering projects clearly have a part to play in addressing food supply issues, particularly in water-scarce northern China. The massive South–North Water Transfer Project<sup>36</sup> aims to redistribute freshwater resources to alleviate regional disparities in supply, but projects like this one should be accompanied by increased efficiency measures, including water-saving agricultural practices such as drip irrigation and cover crops, which have been implemented in several regions in northwest China.

China is making other major investments in agricultural technologies aimed at key products, such as the substantial US\$3.5 billion set aside to support research on transgenic varieties of rice, wheat, maize, soybean, cotton and three important domestic animals (pigs, cows, and sheep).<sup>37</sup> Use of genetically-modified (GM) technologies, and GM food and non-food agricultural products, are regarded as important means to provide for the country's future food demand. The Chinese Ministry of Agriculture has adopted guidelines based on the concept of substantial equivalence, which limits testing requirements to key product characteristics.<sup>38,39</sup> A case-by-case approach is used to assess GM food safety with the non-GM counterpart as the reference, examining the toxicology of, and allergenic response to, new proteins, key component analysis, animal feeding tests, nutrition assessments, and the effects of processing of the GM product.<sup>38,39</sup> The future market of GM products in China will depend on maintenance of Chinese consumers' confidence, which in turn will rely on enforcement of appropriate regulatory measures put in place by the government.



**Figure 2: Temporal trends in supply of animal and fish products, worldwide and in China**  
Masses of yearly animal food product production (A) or fish harvest (B) were divided by the total populations of the world and China, respectively. Data are from the UN Food and Agricultural Organization.<sup>8</sup>

## Shifting concerns from food supply to food safety in China

The rapidly growing Chinese economy has led to a gradual change in focus from food supply to food safety. China's GDP reached \$7.3 trillion in 2011, accounting for 11.8% of the global economy. Living standards have thus risen across the Chinese population—per-person income has increased by nine times from 1990 to 2008<sup>40</sup>—with important effects on food and diet. China's Engel's coefficient, which measures the proportion of income spent on food, has improved from 57.5% (urban) and 67.7% (rural) in 1978 to 36.3% (urban) and 40.4% (rural) in 2011 (appendix).<sup>41</sup> However, this value is still behind industrialised countries such as South Korea—eg, in 2012, South Korea's Engel's coefficient of the high-income and low-income quintiles were 11.6% and 20.8%, respectively.<sup>42</sup> Accordingly, perception of food in China has undergone a fundamental change. In addition to fulfilling basic survival needs, food is now widely perceived as an ordinary commercial commodity for profit making, and thus several incidents of illegal activities have occurred, in pursuit of increased margins, by food producers and manufacturers that have jeopardised the public's trust in food safety. In a

2011 survey, food safety was ranked first in the top five safety issues that worried the Chinese population, surpassing public safety, traffic safety, health safety, and environmental safety.<sup>43</sup>

### Foodborne disease and food safety issues in China

Food safety—the assurance that food will not cause harm to the consumer when it is prepared and consumed according to its intended use<sup>44</sup>—is a global issue that affects the health of populations in both industrialised and developing countries.<sup>45</sup> In fact, in some industrialised countries, the proportion of the population with foodborne diseases is estimated to be up to 30% every year,<sup>46</sup> and major outbreaks of food safety problems persist—eg, the contamination of ground turkey by *Salmonella enterica* serotype Heidelberg in the USA<sup>47</sup> and the contamination of sprouts by *Escherichia coli* O104 in Europe.<sup>48</sup>

In China, fewer than 20 000 major food poisoning incidents a year were officially reported in the past ten years.<sup>49</sup> In 2012, for example, 6685 incidents were reported, with most attributable to microbial agents (56·1%), followed by toxic animals or plants (14·8%), and chemical contamination (5·9%).<sup>50</sup> As with reporting of most food safety issues globally, under-reporting is common and the number of incidents is surely much higher,<sup>51,52</sup> especially since the reported number of incidents is fewer than that reported in highly industrialised countries such as the USA.<sup>53</sup> Some civilian efforts to establish databases for food-safety-related news exist,<sup>54</sup> in part in response to the rising visibility of food safety issues in China. Contributing to this rise is the concern about the public health effects associated with food safety incidents in China's very large domestic population, and the nation's emergence as a major exporter to global food markets.

The food production process provides many opportunities for contamination at various stages (figure 3). During primary production, improper use of agrochemicals, fertilisers, and pesticides in the field, and antibiotics and antiparasitic agents in animal agriculture, might lead to the presence of unsafe compounds in food products. Meanwhile, suboptimal storage and transportation might lead to contamination

by harmful microorganisms and associated toxins. Use of unlawful additives in food processing can further contaminate food products.<sup>55,56</sup> Since water is essential to food production, preparation, and processing, a major source of foodborne disease in China stems from the shortage of clean water and poor sanitation. In 1988, 292 301 cases of hepatitis A were reported in Shanghai, due to the consumption of raw clams harvested from areas contaminated with untreated sewage.<sup>57</sup> China is not alone in having outbreaks associated with contaminated water used in food production—outbreaks of *E coli* O157 in Sweden in 2005 linked to contaminated irrigation water,<sup>58</sup> and a viral gastroenteritis outbreak in the UK in 1994 associated with contaminated water used in food processing, are important examples from industrialised countries.<sup>59</sup> However, China's water and sanitation infrastructure is at a much earlier stage of development,<sup>60</sup> and thus the risks to the food supply are much greater. In rural areas—the setting where most food production occurs—an estimated third of the population does not have access to improved sanitation, contributing, for instance, to the continuing transmission of important foodborne diseases such as trematodiasis.<sup>60–62</sup>

Meanwhile, chemical pollution is a major threat to both agricultural land and freshwater supplies.<sup>15</sup> The rapid development of industrial facilities in rural areas, often immediately adjacent to agricultural land, is an escalating food safety problem because fields are being contaminated by industrial wastes such as heavy metals. For instance, soil and water contamination with the heavy metal cadmium can lead to the presence of this toxicant in agricultural products that, when consumed, poses a range of health risks, from renal failure to osteoporosis to increased risk of some cancers.<sup>63</sup> Fatal cases of cadmium exposure, through food and environmental routes, have been reported in China,<sup>64</sup> and in 2007, results of a survey by Nanjing Agricultural University showed that 10% of rice samples collected from six agricultural regions were tainted with the metal.<sup>65</sup> A follow-up investigation in 2008 of rice samples collected from markets in southern China showed that the level of cadmium exceeded the state food security standards in 70% of the samples tested.<sup>66</sup> Another investigation in the coastal region of the Fujian province showed that more than 16% of rice samples exceeded the safety levels for lead, and more than 11% exceeded the levels for cadmium.<sup>67</sup>

Such focused investigations might not be representative, however, and severe heavy metal contamination might be restricted to some key industrial regions in the country.<sup>68</sup> Consistent with this possibility, an analysis of lead exposure, using data from the latest China Total Diet Study done by the Chinese Centre for Disease Control,<sup>69</sup> revealed that although the median values of dietary lead exposure—mainly from cereals and vegetables—was lower in 2007 than in 2000, the

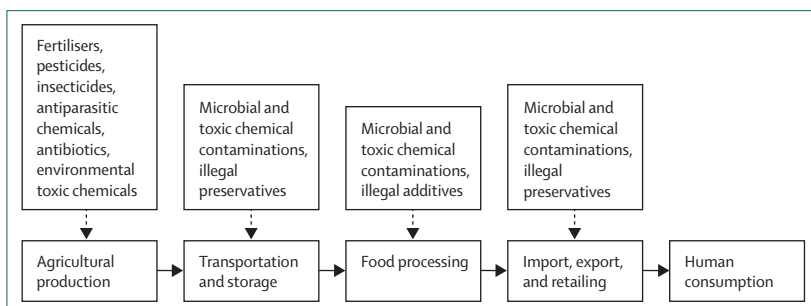


Figure 3: Possible sources of contamination in the food supply chain



level of dietary lead exposure in the highest group (97·5 percentile) in 2007 had increased tremendously,<sup>69</sup> suggesting that particular regions might be heavily contaminated. A comparison of the margin of exposure values suggests that people in China have a significantly higher risk of dietary lead exposure than do those in Australia, with children aged 2–7 years comprising the highest-risk group.<sup>69</sup> These reports call for greater attention to, and better monitoring of, the potential food safety hazards brought forth by industrial wastes.

In the context of agricultural production itself, overuse and misuse of certain agrochemicals pose another set of major concerns for public health and food safety in China. Fertiliser overuse, for instance, is widely acknowledged in China<sup>21</sup> and is associated with algal blooms in lakes and reservoirs that contaminate drinking water with toxic microcystins, leading to diarrhoea, liver cancers, and other outcomes.<sup>15</sup> Meanwhile, China has now become the largest pesticide producer and exporter in the world,<sup>23</sup> and excessive application of pesticides can lead to unsafe residues in food products; indeed, severe poisoning incidents have been reported in China.<sup>23</sup> Similarly, veterinary drug residues in animal products are a major concern in China,<sup>70</sup> as is overuse of antibiotics added to animal feeds,<sup>71</sup> which poses hazards to global health far beyond China's borders.<sup>72</sup>

Finally, the addition of illegal additives is a prominent food safety problem with a particularly difficult recent history in China's food sector. Incidents of illegal chemical additives in foodstuffs have occurred recurrently (table 1), leading to public health hazards, social distrust of the food industry, and loss of public confidence in the regulatory system. In view of the many threats to food safety in the country, the Chinese Government is rapidly implementing plans to monitor food safety. Several systems have come online, including the Animal Labelling and Disease Traceability System, the National Monitoring and Control Plan on Animal Drug Residues in Animals and Animal Products, and the Surveillance Plan on Drug Resistance of Animal-Origin Bacteria.<sup>70</sup>

### Legislation versus implementation

Safeguarding global food safety requires the establishment of international laws on food safety according to a set of mutually agreed principles, which should then be actualised via country-specific legislation. The Chinese Government has made tremendous efforts to reform food safety laws as part of a long evolving process.<sup>77</sup> The milestones of China's legislation related to food safety in China are summarised in table 2. In brief, food safety in China was first conceptualised, and legislated, as a food hygiene issue. To provide clearer guidelines for compliance, laws seeking standardisation were introduced, and these guidelines were more recently harmonised with international standards to better link

compliance in China to the needs of global food product markets. This process culminated in the comprehensive Food Safety Law of the People's Republic of China, adopted in 2009, but even before this act, the Chinese Government had established many standards for the food industry, including those that involved the inspection of imported and exported food products.<sup>77</sup> China has also adopted the Agreement on the Application of Sanitary and Phytosanitary Measures (also known as the SPS Agreement), a treaty of the World Trade Organisation that is based on recommendations of the Codex Alimentarius Commission (Codex).<sup>44</sup>

Yet although food safety legislation is far reaching in China, the implementation of food safety laws is very difficult. One key challenge is that China has a broad administrative structure, and the regulatory control of food safety is a shared responsibility among national, provincial, and local government authorities. A clear chain of command and responsibilities, a set of common and consistent standards, and a well coordinated central steering committee would strengthen China's implementation of existing food safety statutes.<sup>55</sup> To improve coordination among different regulatory bodies, China established the State Council Leading Group on Product Quality and Food Safety in 2007, and following the 2009 Food Safety Law, the State Council Food Security Committee was established, composed of several high-ranking officials, and the roles of different ministries and administrations were specified. In 2013, at the first meeting of the

	Year	Details
Ractopamine	2011	Ractopamine is a $\beta$ -adrenoceptor agonist. Although it is allowed to be used to promote leanness of meat in some countries, such as the USA, high doses of ractopamine might have harmful side-effects. Ractopamine was reported to have caused an outbreak of food poisoning in 2001, and was subsequently prohibited in animal husbandry in 2002 and stopped from being imported into China in 2009. After discovering the use of ractopamine in pig rearing in Henan province in 2009, the government launched an extensive investigation to remove ractopamine from animal feed. In 2011, a new law was passed to ban the sale and manufacturing of ractopamine in China. <sup>73</sup>
Ditch oil	2011	Ditch oil is produced by recycling waste oil from hotel and restaurant drainage pipes for human consumption, which is believed to be a widespread illegal activity. For example, in 2011, joint action by detectives from Zhejiang, Shandong, and Henan provinces successfully tracked down a criminal network that sold ditch oil to restaurants. 60 000 tons of ditch oil were recovered. <sup>74</sup>
Melamine	2008	In 2004, a severe incident involving fake formula milk that did not contain sufficient amounts of protein was reported in China. Babies affected by malnutrition as a result of consuming the milk were noted as having abnormally large heads in comparison with their malnourished bodies, and some sustained permanent damage. Since then, the government has implemented a stringent standard for the protein content of milk (by measuring total nitrogen content). In 2008, criminals invented a new way to fake the detection of protein by adding melamine to milk and infant formula. Melamine caused the formation of kidney stones in babies, resulting in several hundreds of hospital admissions and a few fatalities. <sup>75</sup>
Sudan IV	2006	Due to its potential carcinogenic effects, the dye Sudan IV has been banned from use in food colouring. In 2006, the Chinese General Administration of Quality Supervision, Inspection and Quarantine announced that Sudan IV had been detected in the eggs of poultry. Some farms had illegally added Sudan IV to poultry feed to stain the egg yolk with an attractive red colour. <sup>76</sup>

**Table 1:** Selected incidents of illegal chemical food additives in China that were extensively covered by the media

Major content	
1965	The overall concept of food safety was first raised in the Provisional Food Hygiene Ordinance
1979	The 1965 regulation was formalised as the Food Hygiene Ordinance of the People's Republic of China, a first attempt to introduce the concept of standardisation of food hygiene
1988	The Standardisation Law of the People's Republic of China was implemented
1995	A comprehensive revision of the Food Hygiene Ordinance led to the announcement of the Food Hygiene Law of the People's Republic of China
2006	The new Agricultural Product Quality Safety Law of the People's Republic of China was issued to specifically regulate agricultural products
2009	To harmonise Chinese law with international standards, the comprehensive Food Safety Law of the People's Republic of China was adopted, and was accompanied by the Implementation Rules of Food Safety Law

**Table 2: Milestones of legislation related to food safety in China**

12th National People's Congress, lawmakers established a new China Food and Drug Administration, which will serve as a centralised authority, replacing the functions of other regulatory bodies. This major overhaul signifies China's determination to build a high-level, unified system to handle food safety issues.

Recent progress on food safety legislation and regulation, however, has been limited by the huge scale of China's food industry, which makes it difficult to uphold high safety standards across the vast diversity of food products. As is the case with other large developing countries such as India,<sup>56</sup> China's regulatory approaches are complicated by the sheer size of the food sector: more than 450 000 food production and processing companies are active in China, 350 000 of which are small enterprises with fewer than ten employees.<sup>55</sup> For these small food companies, the wide array of required safety tests can be a significant burden, particularly in the absence of inexpensive and standardised testing protocols. One important way forward is to provide assistance and training to these small enterprises, particularly by teaming them with private sector developers of standardised food safety tests. With support from regulators, these developers might play a part in training food industry personnel to comply with government standards, while providing safety tests and certifications for the wide range of food products covered.

As with any commercial commodity, maximising profits and seeking quick returns might at times supersede social responsibility. In the worst scenarios, criminal acts and corruption have influenced food safety. This scenario was emphasised in the 2012 work report of China's Supreme People's Court, which documented the 320 people that were convicted for food safety crimes in 2011. The actual number of cases under investigation is expected to be much higher. Nonetheless, such prosecutions show the high priority of food-safety-related crimes in law enforcement in China.

## Moving from endpoint controls to risk-based food safety control systems

Industrialised countries faced several serious food safety crises in the 1990s, prompting their governments to undertake comprehensive reviews of their food safety policies. In brief, the laws regulating food safety before the 1990s were mainly in the form of command and control, whereas newly evolved food safety policies placed more emphases on risk analysis and cost-benefit analysis by governments, and quality management by industries.<sup>78</sup> The concepts of hazard analysis and critical control point (HACCP) have gradually gained acceptance, shifting the primary means of achieving food safety to the prevention of hazards, rather than inspection of the final products.<sup>79</sup>

Since it might be more cost effective to use auditing as an inspection method rather than placing excessive emphasis on end-product testing, the UN has recommended that China adopt the HACCP system as national food safety policy, and introduce good practices in all food sectors (eg, Good Agricultural Practices, Good Veterinary Practices, Good Aquaculture Practices, Good Manufacturing Practices, and Good Hygiene Practices).<sup>55</sup>

Substantial progress has been made along these lines. The 2009 Food Safety Law Implementation Rules provide evidence that China is adopting many of these suggestions into its national food safety laws. Rules that cover food manufacture and trade now require food manufacturers and distributors to document and arrange training for employees, establish incoming product and food shipment inspection and recording systems, and implement a range of food safety management systems. These requirements conform to HACCP, and China started to implement the global standard (GB22000-2006 or ISO 22000) in 2007, which includes standards from both HACCP and Good Manufacturing Practice.

The China National Center for Food Safety Risk Assessment was established in 2011, and will coordinate the national efforts to monitor chemical and hazard factors, foodborne pathogens, and foodborne disease according to the principles set forth in the Rules for Monitoring Food Safety Risk (Provisional) released in 2010. Implementation details and working reports are released to the public through the centre's webpage.

## The future of food safety in China: responsibility, accountability, and trackability

Although food safety in China involves a range of complicated, multidimensional issues, several high priority items were identified by this Review: establishment of a tracking system so that weak links in protection of food safety can be readily identified; building of a regulatory system with a clear chain of command and division of labour among different regulatory bodies; adoption of common safety standards for all regulatory bodies; and advancement of technologies to enable rapid and accurate measurement of food safety indicators.

The Chinese Government has committed to implementing effective and timely measures to address food safety problems, through improvements in food safety monitoring and surveillance, and by strengthening legislative mandates. During the 11th Five-Year Plan period (2006–10), the Chinese Government earmarked a total of CN¥5.51 billion (about \$88.5 million) to support the establishment of regulatory systems and strengthen enforcement of food safety monitoring. Recently, the 12th Five-Year Plan (2011–15) was issued, which included a national plan for food safety regulation systems that provides a detailed blueprint for a unified set of national food safety standards, an optimised, science-based food safety regulatory mechanism, and a plan for implementing food safety regulations.<sup>80</sup>

The 2009 Food Safety Law marked a historic turning point in food safety policy in China, with adoption of key international standards and a range of new and innovative policy mechanisms unique to China. The aforementioned China Food and Drug Administration is an essential first step to providing a centrally coordinated authority to regulate food safety. However, assurance of food safety and rebuilding of public trust will need food industries in China to recognise that they are ultimately responsible, and will be held accountable, for food safety problems, even though the government is responsible for legislation and enforcement of regulations. Technological advances such as rapid screening methods might help China's vast food industries to identify and manage risks at an early stage. But perhaps even more importantly, social responsibility should be adopted as an overarching principle governing the actions of food industries, placing food safety ahead of maximisation of profits. To raise accountability, a tracking system should be implemented to locate the origin of problems, and the strengthening of surveillance systems and improvement in enforcement of food safety laws will be the key to success. Increasing awareness of the public, and improving transparency via media reporting, should be encouraged to increase the engagement of the public in discussions about, and implementation of, food safety measures.

In view of the scale, diversity, and complexity of China's food production, processing, and distribution systems, no quick fixes exist to resolve the country's food supply and safety challenges. Through the combination of innovative legislative and regulatory actions, public engagement, and renewed commitments by industries to uphold principles of environmental sustainability and consumer protection, we cautiously anticipate gradual improvements in coming years.

#### Contributors

H-ML wrote the overall draft and created the figures and tables. JR contributed to the writing, with a special focus on the food safety, micronutrient, and water pollution sections, and improved the overall language of the manuscript. M-CF, LX, and SS-MS crosschecked and revised the contents. SS-MS coordinated the preparation of this Review.

#### Conflicts of interest

We declare that that we have no conflicts of interest.

#### Acknowledgments

We thank Fuk-Ling Wong and Hongmei Wang for collecting related scientific literature and preparing the figures, and Stephen Ng for critically reading this manuscript. This Review is supported by the Hong Kong University Grants Committee Area of Excellence scheme: Plant and Agricultural Biotechnology Project (AoE-B-07/09 to SS-MS and H-ML), the Hong Kong Research Grants Council Collaborative Research Fund (CUHK3/CRF/11G to H-ML), and funding from the Lee Hysan Foundation (to H-ML and SS-MS). JR is supported by the US National Institute of Allergy and Infectious Diseases (K01AI091864), by the US National Institutes of Health and National Science Foundation's Ecology of Infectious Disease Program (0622743), and by Emory University's Global Health Institute Faculty Distinction Fund.

#### References

- 1 UN Department of Economic and Social Affairs. World population prospects: the 2010 revision, highlights and advance tables. New York, NY: United Nations, 2011.
- 2 Popkin BM. Will China's nutrition transition overwhelm its health care system and slow economic growth? *Health Aff* 2008; 27: 1064–76.
- 3 Campbell TC, Campbell II TM. The China study. Dallas, TX: Benbella Books, 2006.
- 4 Kantha SS. Nutrition and health in China, 1949 to 1989. *Prog Food Nutr Sci* 1990; 14: 93–137.
- 5 Peng X. Demographic consequences of the Great Leap Forward in China's Provinces. *Popul Dev Rev* 1987; 13: 639–70.
- 6 Department of Population Statistics, National Bureau of Statistics of China. Compilation of population statistics of the People's Republic of China (1949–1985). Beijing: China Financial and Economic Publishing House, 1988 (in Chinese).
- 7 Brown L. Who will feed China? Wake-up call for a small planet. New York, NY: WW Norton & Company, 1995.
- 8 UN Food and Agricultural Organization. Statistics. <http://www.fao.org/corp/statistics/en/> (accessed March 22, 2013).
- 9 Shi YL, Yue YZ, Shi ZJ, eds. Land resources map of China. Beijing: China Land Press, 2006 (in Chinese).
- 10 Gong P, Liang S, Carlton E, et al. Urbanisation and health in China. *Lancet* 2012; 379: 843–52.
- 11 Jin L, Young W. Water use in agriculture in China: importance, challenges, and implications for policy. *Water Policy* 2001; 3: 215–28.
- 12 Ministry of Water Resources of the People's Republic of China. 2007–2008 annual report. Beijing: Ministry of Water Resources, 2008.
- 13 Ministry of Agriculture. China agriculture yearbook. Beijing: Chinese Agriculture Press, 2009: 365 (in Chinese).
- 14 UN Food and Agricultural Organization. Drylands development and combating desertification: bibliographic study of experiences in China. FAO Environment and Energy Paper 15. Rome: United Nations Food and Agricultural Organization, 1997.
- 15 Zhang J, Mauzerall DL, Zhu T, Liang S, Ezzati M, Remais JV. Environmental health in China: progress towards clean air and safe water. *Lancet* 2010; 375: 1110–19.
- 16 Zou C, Gao X, Shi R, Fan X, Zhang F. Micronutrient deficiencies in crop production in China. In: Alloway BJ, ed. Micronutrient deficiencies in global crop production. New York, NY: Springer, 2008: 127–48.
- 17 Nubé M, Voortman RL. Simultaneously addressing micronutrient deficiencies in soils, crops, animal and human nutrition: opportunities for higher yields and better health. Staff Working Paper WP-06-02. Amsterdam: Centre for World Food Studies, Department of Economics and Econometrics, Vrije Universiteit Amsterdam, 2006.
- 18 Ma G, Jin Y, Li Y, et al. Iron and zinc deficiencies in China: what is a feasible and cost-effective strategy? *Public Health Nutr* 2007; 11: 632–38.
- 19 Song X. Malnutrition, China lost 1,600 billion RMB in last year. *China Economic Weekly* (Beijing), Oct 10, 2011 (in Chinese).



- 20 Mayer JE, Pfeiffer WH, Beyer P. Biofortified crops to alleviate micronutrient malnutrition. *Curr Opin Plant Biol* 2008; **11**: 166–70.
- 21 Gong P, Liang L, Zhang Q. China must reduce fertilizer use too. *Nature* 2011; **473**: 284–85.
- 22 Li J, Xin Y, Yuan L. Hybrid rice technology development. Ensuring China's food security. Washington, DC: International Food Policy Research Institute, 2009.
- 23 Zhang WJ, Jiang FB, Ou JF. Global pesticide consumption and pollution: with China as a focus. *Proc Int Acad Ecol Environ Sci* 2011; **1**: 125–44.
- 24 Zhai F, Wang H, Du S, et al. Prospective study on nutrition transition in China. *Nutr Rev* 2009; **67** (suppl 1): S56–61.
- 25 Gu D, Reynolds K, Wu X, et al, for the InterASIA Collaborative Group. Prevalence of the metabolic syndrome and overweight among adults in China. *Lancet* 2005; **365**: 1398–405.
- 26 Niu S, Wills K. China to become world's top farm products importer. *Reuters*, Nov 6, 2011.
- 27 Gale HF, Tuan F, Wang X, Cao Z. China is using more corn for industrial products. Washington, DC: United States Department of Agriculture, 2009.
- 28 National Development and Reform Commission and the Ministry of Industry and Information Technology. Development plan for food industry during the period of the twelfth five-year plan. China: National Development and Reform Commission and the Ministry of Industry and Information Technology, 2011.
- 29 Emerson C. Aquaculture impacts on the environment, released December, 1999. <http://www.csa.com/discoveryguides/aquacult/overview.php> (accessed March 22, 2013).
- 30 Fang Y. Discussion of intensive freshwater fishery production on the influence of reservoir water. *Beijing Agric* 2011; **36**: 80–81 (in Chinese).
- 31 US Central Intelligence Agency. The world factbook: population below poverty line. <https://www.cia.gov/library/publications/the-world-factbook/fields/2046.html> (accessed March 22, 2013).
- 32 Yang DT, Li Y. Agricultural price reforms in China: experience from the past three decades. *Agroalimentaria* 2008; **14**: 13–23.
- 33 The Economist. Urbanising China: a nation of city slickers. *The Economist*, Jan 21, 2012.
- 34 Van den Berg MM, Hengsdijk H, Wolf J, Van Ittersum MK, Wang F, Roetter RP. The impact of increasing farm size and mechanization on rural income and rice production in Zhejiang province, China. *Agr Syst* 2007; **94**: 841–50.
- 35 Wang L-D, Chen H-G, Guo J-G, et al. A strategy to control transmission of *Schistosoma japonicum* in China. *N Engl J Med* 2009; **360**: 121–28.
- 36 Office of the South-to-North Water Diversion Project Commission. South-to-North Water Diversion. <http://www.nsb.gov.cn/zx/english/> (accessed March 22, 2013).
- 37 Stone R. China plans \$3.5 billion GM crops initiative. *Science* 2008; **321**: 1279.
- 38 Chinese Ministry of Agriculture. Guideline for safety assessment of food from genetically modified plant and derived products. Beijing: Chinese Ministry of Agriculture, 2006 (in Chinese).
- 39 Chinese Ministry of Agriculture. Guideline for safety assessment of genetically modified plants. Beijing: Chinese Ministry of Agriculture, 2010 (in Chinese).
- 40 EconomyWatch. China income, China national income. *Economy Watch*, June 30, 2010.
- 41 Ma MT. Rebound of Engel's coefficient in urban households in the previous year. *The Beijing News* (Beijing), June 20, 2012: section B05 (in Chinese).
- 42 Kim SA. Engel's coefficient of S. Korea's low income households jumps to 8-year high last year. *MK Business News*, Feb 26, 2013. <http://news.mk.co.kr/newsRead.php?year=2013&no=145392> (accessed April 29, 2013).
- 43 Ouyang H-Y. Five top safety issues of Chinese in 2011. *Insight China* 2011; **7**: 50–54 (in Chinese).
- 44 Codex Alimentarius Commission. Codex Alimentarius food hygiene basic texts, 1st edn. Rome: World Health Organization and Food and Agriculture Organization of the United Nations, 1997.
- 45 De Waal CS, Robert N. Global and local: food safety around the world. Washington, DC: Center for Science in the Public Interest, 2005.
- 46 WHO. WHO fact sheet: food safety and foodborne disease. Geneva: World Health Organization, 2007.
- 47 US Centers for Disease Control and Prevention. Investigation update: multistate outbreak of human *Salmonella* Heidelberg infections linked to ground turkey. Atlanta, GA: Centers for Disease Control and Prevention, 2011.
- 48 Frank C, Werber D, Cramer JP, et al. Epidemic profile of Shiga-toxin producing *Escherichia coli* O104:H4 outbreak in Germany. *N Engl J Med* 2011; **365**: 1771–80.
- 49 Xu L, Meng F. Report on China food safety studies (2011). Beijing: Science Press, 2012 (in Chinese).
- 50 Chinese Ministry of Health. 2012 report of national food poisoning incidents (in Chinese). <http://www.moh.gov.cn/mohwsyjbg/s7860/201303/b70872682e614e4189d0631ae5527625.shtml> (accessed March 22, 2013).
- 51 Mao X, Hu J, Liu X. Epidemiological burden of bacterial foodborne diseases in China—preliminary study. *Chin J Food Hyg* 2011; **23**: 132–36 (in Chinese).
- 52 Yu Y, Chen Y. Food safety in China. *J Epidemiol Community Health* 2013; **67**: 478–79.
- 53 US Centers for Disease Control and Prevention. CDC estimates of foodborne illness in the United States. <http://www.cdc.gov/foodborneburden/2011-foodborne-estimates.html> (accessed March 22, 2013).
- 54 zccw.info. Civilian database for food safety news in China (in Chinese). <http://www.zccw.info/> (accessed March 22, 2013).
- 55 Office of the United Nations Resident Coordinator in China. United Nations in China Occasional Report: advancing food safety in China. Beijing: United Nations, 2008.
- 56 Umali-Deininger D, Sur M. Food safety in a globalizing world: opportunities and challenges for India. 26th conference of the International Association of Agricultural Economists Conference; Gold Coast, QLD, Australia; Aug 12–19, 2006.
- 57 Halliday ML, Kang L-Y, Zhou T-K, et al. An epidemic of hepatitis A attributable to the ingestion of raw clams in Shanghai, China. *J Infect Dis* 1991; **164**: 852–59.
- 58 Söderström A, Osterberg P, Lindqvist A, et al. A large *Escherichia coli* O157 outbreak in Sweden associated with locally produced lettuce. *Foodborne Pathog Dis* 2008; **5**: 339–49.
- 59 Brugh R, Vipond IB, Evans MR, et al. A community outbreak of food-borne small round-structured virus gastroenteritis caused by a contaminated water supply. *Epidemiol Infect* 1999; **122**: 145–54.
- 60 Carlton E, Liang S, McDowell J, Li H, Luo W, Remais J. Regional disparities in the burden of disease attributable to unsafe water and sanitation in China. *Bull World Health Organ* 2012; **90**: 578–87.
- 61 Keiser J, Utzinger J. Food-borne trematodiasis. *Clin Microbiol Rev* 2009; **22**: 466–83.
- 62 Sripa B, Kaewkes S, Sithithaworn P, et al. Liver fluke induces cholangiocarcinoma. *PLoS Med* 2007; **4**: e201.
- 63 Bernard A. Cadmium and its adverse effects on human health. *Ind J Med Res* 2008; **128**: 557–64.
- 64 Chang Y-F, Wen J-F, Cai J-F, Wu X-Y, Yang L, Guo Y-D. An investigation and pathological analysis of two fatal cases of cadmium poisoning. *Forensic Sci Int* 2012; **220**: e5–e8.
- 65 Zhen YH, Cheng YJ, Pan GX, Li LQ, Cd, Zn and Se content of the polished rice samples from some Chinese open markets and their relevance to food safety. *J Safety Environ* 2008; **8**: 119–22 (in Chinese).
- 66 Zhang LY, Li LQ, Pan GX. Variation of Cd, Zn and Se contents of polished rice and the potential health risk for subsistence-diet farmers from typical areas of South China. *Chin J Environ Sci* 2009; **30**: 2792–97 (in Chinese).
- 67 Xie W, Yang J, Chen S, Chen D. Variation of Cd, Pb, Hg contents of rice in coastal region of Fujian province. *Ecol Environ* 2008; **17**: 206–09 (in Chinese).
- 68 Xu J, Li J. Cadmium-tainted rice only found in regions. *China Daily* (Beijing), Feb 16, 2011: sect 5.
- 69 Li X, Liu Q, Liu L, Wu Y. Application of the data from China Total Diet Study to assess the distribution of lead exposure in different age-gender population groups. *J Hyg Res* 2012; **41**: 379–84 (in Chinese).
- 70 Bureau of Veterinary Medicine. Animal health in China (2010). Beijing: Chinese Ministry of Agriculture, 2011.

- 71 Ben W, Qiang Z, Adams C, Zhang H, Chen L. Simultaneous determination of sulfonamides, tetracyclines and tiamulin in swine wastewater by solid-phase extraction and liquid chromatography–mass spectrometry. *J Chromatogr A* 2008; **1202**: 173–80.
- 72 Nisha AR. Antibiotic residues—a global health hazard. *Vet World* 2008; **1**: 375–77.
- 73 Ministry of Industry and Information Technology, Ministry of Agriculture, Ministry of Commerce, Ministry of Health, State Administration for Industry and Commerce, General Administration of Quality Supervision, Inspection and Quarantine. Lock-up of ractopamine: a joint announcement, Dec 5, 2011 (in Chinese). <http://www.miit.gov.cn/n11293472/n11293832/n11293907/n11368223/14395631.html> (accessed April 29, 2013).
- 74 Xinhua News Agency. Sixty nationwide “ditch oil” crime networks were smashed, Dec 13, 2011 (in Chinese). [http://big5.gov.cn/gate/big5/www.gov.cn/jrzg/2011-12/13/content\\_2018492.htm](http://big5.gov.cn/gate/big5/www.gov.cn/jrzg/2011-12/13/content_2018492.htm) (accessed March 18, 2013).
- 75 Guan N, Fan Q, Ding J, et al. Melamine-contaminated powdered formula and urolithiasis in young children. *N Engl J Med* 2009; **360**: 1067–74.
- 76 Kwok J, Yau A. Sudan dyes in food. Food safety focus (risk communication section). Hong Kong Special Administrative Region: Centre for Food Safety, 2006.
- 77 Song H. A study on food safety standard law in China. *J Public Admin* 2011; **2**: 30–50 (in Chinese).
- 78 Hoffmann S. Food safety policy and economics: a review of the literature. Washington, DC: Resources for the Future, 2010.
- 79 Whitehead AJ, Orriss G. Food safety through HACCP—the FAO approach. Rome: Agriculture and Consumer Protection Department of the UN Food and Agriculture Organization, 1995.
- 80 General Office of the State Council. National plan for the food safety regulation system during the period of the twelfth five-year plan. Beijing: Chinese State Council, 2012 (in Chinese).