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Review article

Environmental and human health challenges of industrial livestock and poultry farming in China and their mitigation

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ABSTRACT

Driven by the growing demand for food products of animal origin, industrial livestock and poultry production has become increasingly popular and is on the track of becoming an important source of environmental pollution in China. Although concentrated animal feeding operations (CAFOs) have higher production efficiency and profitability with less resource consumption compared to the traditional family-based and "free range" farming, they bring significant environmental pollution concerns and pose public health risks. Gaseous pollutants and bioaerosols are emitted directly from CAFOs, which have health implications on animal producers and neighboring communities. A range of pollutants are excreted with the animal waste, including nutrients, pathogens, natural and synthetic hormones, veterinary antimicrobials, and heavy metals, which can enter local farmland soils, surface water, and groundwater, during the storage and disposal of animal waste, and pose direct and indirect human health risks. The extensive use of antimicrobials in CAFOs also contributes to the global public health concern of antimicrobial resistance (AMR). Efforts on treating the large volumes of manure generated in CAFOs should be enhanced (e.g., by biogas digesters and integrated farm systems) to minimize their impacts on the environment and human health. Furthermore, the use of veterinary drugs and feed additives in industrial livestock and poultry farming should be controlled, which will not only make the animal food products much safer to the consumers, but also render the manure more benign for treatment and disposal on farmlands. While improving the sustainability of animal farming, China also needs to promote healthy food consumption, which not only improves public health from avoiding high-meat diets, but also slows down the expansion of industrial animal farming, and thus reduces the associated environmental and public health risks.

1. Introduction

Important changes in the food consumption of over 1.3 billion people in China have taken place over the past three decades, and the demands for foods of animal origin, including milk and dairy products, aquatic products, and poultry eggs and meats, have experienced high rates of growth. As shown on Fig. S1, the per capita consumption of meat (pork, beef, and mutton) and poultry increased from 22.5 and 12.0 kg/year to 34.7 and 19.6 kg/year for urban and rural populations, respectively, while that of aquatic products, eggs, milk, and dairy products had more than tripled over the period of 1985 to 2009 (Zhou et al., 2012). The fast growth in consumption of dietary animal protein has been driven by the sustained urbanization and rising disposal income in China, and similar shift from plant- to animal-based foods with socioeconomic development has been well observed globally (FAO, 2012).

Driven by the growing demands, production of foods of animal origin in China has been expanding significantly over the past several decades. Fig. 1 depicts the growth in the country's production of major animal food products between 1980 and 2015. The production of pork, poultry meat, beef, mutton, milk, and poultry eggs increased by 3.1, 10.2, 11.9, 7.1, 13.0, and 5.4 times over the period of 1996 and 2015. Pork is the most important type of meat products consumed in China (> 60%), followed by poultry meat (> 20%). Along with the fast increase in the supply of animal food products, the production model of livestock and poultry has undergone significant changes to increase the capacity and efficiency of production. Livestock and poultry used to be produced predominantly in backyard farms and small-scale, "free range" farms in China. However, such production model was incapable of multiplying the production capacity. Instead, a steady shift from family farms and "free range" farms to more specialized and much larger concentrated animal feeding operations (CAFOs) has occurred since the late 1970s. Industrial livestock and poultry production achieves high output of meat, milk, and eggs by confining thousands or

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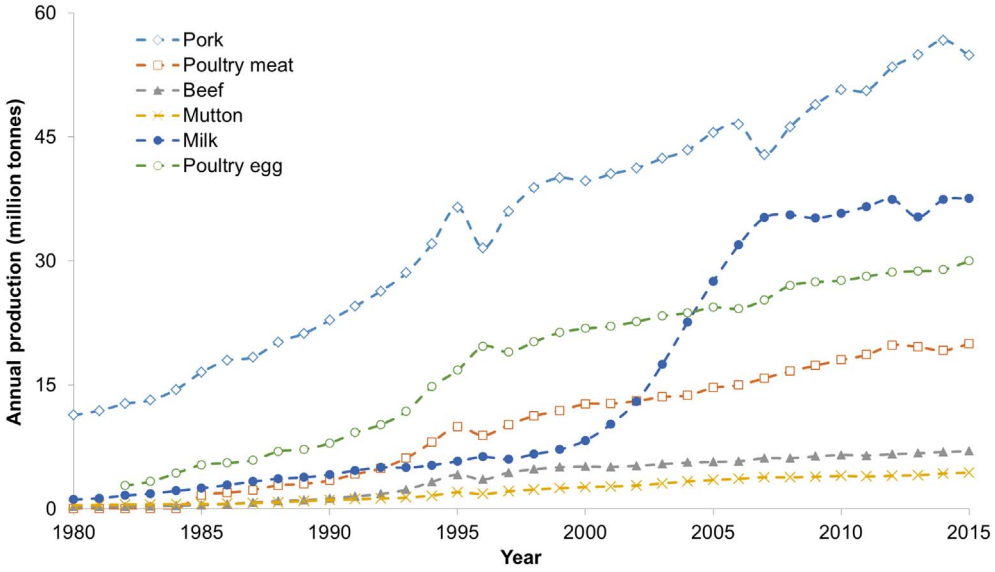

Fig. 1. Growth in the supply of animal food products in China between 1980 and 2015 (data from National Bureau of Statistics, http://data.stats.gov.cn/index).

more animals, almost always a single species, at high stocking densities in localized areas. Advances in animal breeding, mechanical innovations, and the use of formulated animal feed and feed additives have helped increase the production efficiency of meat and dairy products in CAFOs, and consequently reduced their cost to the consumers (Hribar, 2010). In particular, the modernization of China's food animal industry was boosted by the Law on Animal Husbandry that took effect on July 1, 2006. This milestone legislature encourages the development of large-scale and intensive animal farms, restricts the use of veterinary drugs and feed additives to ensure the quality and safety of animal products, and requires proper disposal of waste from livestock production to protect the environment (NPCSC, 2005).

Large-scale livestock and poultry farms, i.e., CAFOs, accounted for most of the increased production capacity in China over the past decades. Fig. S2 and Tables S1–S6 of the Supplementary Data show the shift in the production scales of swine, poultry, layer chicken, dairy cattle, beef cattle, and sheep and goat in China between 2000 and 2014. Overall, the production of swine, poultry, and dairy cattle has been transitioning towards CAFOs quickly, while this occurred at much slower rates in the production of beef cattle, and sheep and goat. As of 2012, CAFOs accounted for the production of about 80% of chicken, 60% of pigs, and 40% of dairy cattle in China (Z. Liu et al., 2013). Among the food-producing animals, production of poultry is the most industrialized, and the poultry sold on the market are predominantly raised in CAFOs. Meanwhile, unlike the industrial model followed in many developed countries, beef cattle and sheep/goat farming is still based primarily on the “free range” and scattered model in China, which occurs primarily in the western provinces with low population densities and vast pasture lands.

Along with the rapid growth of industrial livestock and poultry production, the pollutants released from the multiplying CAFOs have received increasing concerns. Nonetheless, compared to the pollutant discharges from industrial sources, environmental degradation caused by agricultural sources has received relatively little attention in China, partially because their pollutant emissions are much less conspicuous and more difficult to supervise. Fig. 2 shows the contribution of various pollution source categories to water pollution in China between 2011 and 2015. Agricultural activities, including farming, aquaculture, and livestock and poultry farming, are already the largest source of chemical oxygen demand (COD) and the second largest source of ammonium nitrogen (NH_4^+-N). It was estimated that livestock and poultry farming released a total of 12.68 million tonnes of COD, 1.02 million tonnes of total nitrogen, 0.16 million tonnes of total phosphorus, 2397 tonnes of copper, and 4757 tonnes of zinc into aquatic environment in 2010 (MEP, 2010). That is, livestock and poultry farming contributed to about 41.9, 21.7, and 37.9% of the COD, total nitrogen, and total phosphorus discharged from all types of wastewaters, respectively. It is obvious that livestock and poultry farming has become a key source of environmental pollution in China.

A large number of studies have been conducted investigating various aspects of the environmental pollution and human health impacts of CAFOs, but no review has attempted to systematically explore the major pollutants emitted from CAFOs, their environmental impacts, and the potential human health risks from exposures to them. While a comprehensive review of all the environmental and public health consequences of industrial livestock and poultry farming is not possible here, it is important to identify the major impacts of CAFOs on the environment and human health. We identified studies using the most popular sources of scientific information, including PubMed, Scopus, and Web of Science, and search terms such as CAFO, public health, and environmental pollution, etc. to retrieve information on specific subjects. With a special focus on the problem in China, several Chinese papers were also identified using a major Chinese reference database, CNKI (China National Knowledge Infrastructure). In addition, limited information from conference proceedings, technical reports published by several agencies and organizations, news from an authoritative Chinese media source, statistical yearbooks, rules and technical guidelines by Chinese government was included. Although the grey literature referenced might contain biased viewpoints, the findings were consolidated with those from the peer-reviewed publications to ensure their validity as much as possible.

In this review, we summarize the major pollutants released from industrial livestock and poultry farming operations, and pollution of environmental media caused by them, focusing primarily on surface water, soil, and groundwater. The potential health risks for animal producers and neighboring communities from exposures to various pollutants emitted from the CAFOs are then discussed. We also identify key mitigation strategies to reduce the environmental pollution and human health risks brought by the multiplying CAFOs in China. Finally, we propose paradigm changes to improve the sustainability of China's animal agriculture and promotion of healthy diets to slow down the growth in consumption of animal-based foods to protect public health and reduce environmental degradation brought by industrial animal farming operations.