Environmental Pollution 234 (2018) 667–676

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Public health risk of trace metals in fresh chicken meat products on the food markets of a major production region in southern China☆

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A R T I C L E I N F O

Article history:
Received 18 August 2017
Received in revised form
30 November 2017
Accepted 3 December 2017

Keywords:
Trace metal
Inorganic arsenic
Chicken tissue
Chronic dietary exposure
Cancer risk
Phenylarsenic feed additive

A B S T R A C T

Because most chickens are reared in intensive farms, where a range of feed additives are used routinely, concerns have been raised on the potential public health risk of chicken product consumption. This study was conducted to characterize the contents of trace metals in fresh chicken tissues (354 samples) on the food markets in Guangdong province of southern China, a major region of chicken production with heavy per capita chicken consumption, and to assess the public health risk from chronic dietary exposure to the trace metals through chicken consumption. With the exception of Cr, Ni, and Pb, the contents of trace metals were generally higher in the chicken giblets (livers, gizzards, hearts, and kidneys) compared to muscles (breasts and drumsticks). Chicken tissues from the urban markets generally contained higher levels of As, Cu, Mn, and Zn than those from the rural markets, while the contents of Pb were typically higher in the chicken muscles from the rural markets. Results of statistical analyses indicate that Cu, Zn, and As in the chicken tissues derived mainly from the feeds, which is consistent with the widespread use of Cu, Zn, and phenylarsenic compounds as feed supplements/additives in intensive poultry farming. No non-carcinogenic risk is found with the consumption of fresh chicken meat products on the food markets, while approximately 70% of the adult population in Guangzhou and 30% of those in Lianzhou have bladder and lung cancer risk above the serious or priority level (10^{-4}), which arises from the inorganic arsenic contained in the chicken tissues. These findings indicate that the occurrence of inorganic arsenic at elevated levels in chicken tissues on the food markets in Guangdong province poses a significant public health risk, thus the use of phenylarsenic feed additives in China's poultry farming should be significantly reduced and eventually phased out.

1. Introduction

According to the Food and Agriculture Organization, the global consumption of poultry meat per capita has increased by 76.6% between 1990 and 2009 (Henchion et al., 2014). Chicken meat is relatively inexpensive because chickens can be produced faster and with higher feed efficiency than other commercial meats. Poultry meat has been the second most consumed type of meat products (>20%) in China and its production has increased by 10.2 times between 1996 and 2015 (Hu et al., 2017a). Such a rapid increase was achieved primarily through the transition from family backyard and small farms to intensive farms (Hu et al., 2017a). Approximately 80% of the chickens in China were raised in intensive poultry farms (with annual production capacities of greater than 50 thousand heads) by 2012 (Liu et al., 2013b).

Besides a range of environmental pollution and public health problems associated with livestock and poultry production in intensive animal farms, food safety concerns have also been raised regarding the potential residues (e.g., antimicrobials and trace metals) of veterinary drugs and feed supplements/additives in animal food products, including meats, eggs, and milk (Hu and Cheng, 2016; Hu et al., 2017a). The use of formulated animal feeds and feed additives in intensive animal farming has turned out to be a double-edged sword: they improve the production

☆ This paper has been recommended for acceptance by Charles Wong.

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https://doi.org/10.1016/j.envpol.2017.12.006

efficiency of animal food products (Poulsen, 1998; Visek, 1978), while the occurrence of their residues at levels above the safety thresholds in foods of animal origin can pose health risks to consumers (Kan and Meijer, 2007; Nachman et al., 2013, 2017; Silbergeld and Nachman, 2008). Besides the health risks from foodborne residues, the overuse and misuse of antimicrobials in animal farms also cause selection and spread of antimicrobial resistance (AMR), which poses a significant public health risk worldwide (Marshall and Levy, 2011; Mole, 2013; Singer et al., 2016). Although heavy metals are not the main cause for the proliferation of AMR in animal farms, some of them could drive co-selection of AMR (Baker-Austin et al., 2006; Seiler and Berendonk, 2012; Singer et al., 2016), which is beyond the scope of this study.

Various trace metals, such as copper and zine, and nickel and selenium to a lesser extent, are supplemented extensively in commercial feeds for the purpose of boosting animal health and performance (Richards et al., 2010). Zinc, copper, and manganese are essential trace elements, and play multiple biological and physiological roles in the development and health of all animals (Richards et al., 2010; Underwood and Suttle, 1999). Various minerals, primarily those of iron, copper, zinc, manganese, and cobalt compounds, are allowed as feed ingredients for food-producing animals (AAFCO, 2017; MOA, 2009; 2013), even in organic livestock production (USDA, 2017), and are commonly found at elevated levels in animal feeds (e.g., Granados-Chinchilla et al., 2015; Nicholson et al., 1999; Shurson et al., 2011). In addition, phenylarsenic compounds, primarily roxarsone and *p*-arsanilic acid, used to be widely used as feed additives in intensive swine and poultry farming for the purposes of enhancing feed conversion efficiency, improving animal weight gain, and controlling intestinal parasites (Liu et al., 2013a; Mangalgiri et al., 2015).

While most of the trace metals ingested by animals are excreted via urine and feces, small fractions (e.g., approximately 10–20% for Cu and Zn) are absorbed by the bodies of animals to meet their nutritional requirements (Carlson et al., 2004; Veum et al., 2004). The absorption rates of trace metals are influenced by a range of factors, including species and chemical forms of the metal, its reactions with other metals and other dietary components in the feed, its supplementation dose, and the growth stages of the animals (Ashmead and Graff, 1985; Creech et al., 2004; Vieira, 2008). As a potential public health concern, residues of trace metals in chicken meat products have been studied in various countries and regions (Demirbaş, 1999; Iwegbue et al., 2008; Liu et al., 2016; Oforka et al., 2012; Sinkakarimi et al., 2017; Tahvonen and Kumpulainen, 1994; Uluozlu et al., 2009). In particular, the use of phenylarsenic feed additives could result in elevated residues of arsenic in chicken tissues. Results of a 35-day feeding experiment showed that the breast of chickens fed with roxarsone had higher concentrations of arsenic species, with <10% of the total arsenic occurred in inorganic form, compared to those in the breast of controls fed with a roxarsone-free diet, even after a 7-day withdrawal period (Liu et al., 2016). A market basket study in the U.S. conducted between 2010 and 2011 showed that the meat of chickens produced by conventional farms without policies prohibiting the use of roxarsone had higher contents of inorganic arsenic (*i*-As) compared to that of chickens raised by antibiotic-free producers, which had mixed policies on roxarsone use, and the organic chicken meat (produced without using roxarsone) (Nachman et al., 2013). As a result of the additional *i*-As ingested, lifetime consumption of conventional chicken would bring 37 additional cases of bladder and lung cancer per 1 million persons compared to organic chicken (Nachman et al., 2013). Similarly, due to the significantly elevated residues of *i*-As, lifetime consumption of the turkey meat produced by conventional farms not prohibiting the use of nitarsone, another important phenylarsenic feed additive that was allowed in the U.S. until 2014, would result in 3.1 additional bladder and lung cancer cases per 1 million persons compared to the meat of turkey raised without using nitarsone (Nachman et al., 2017). Although already phased out in many developed countries, including the E.U. member states and the U.S. (EC, 1999; FDA, 2009), the use of phenylarsenic feed additives is still allowed in many countries, including China.

Exposures (through ingestion, inhalation, and injection) to non-essential trace metals, such as As, Cd, and Pb, can cause carcinogenic and non-carcinogenic adverse effects to human beings, even at low concentrations, while the essential ones, including Co, Cr, Cu, Mn, Se, and Zn, can also be toxic when occurring at concentrations above the safety thresholds in food products (CAC, 2016; NHFPC and SFDA, 2017). Concerns have been raised on the potential accumulation of trace metals in chicken meat products due to the use of formulated animal feeds and feed additives in intensive farming. Despite of few investigations on exposure to trace metals based on the total dietary study (TDS) approach (Wu et al., 2016; Zheng et al., 2007), assessment of the public health risk of dietary exposure to trace metals in chicken meat products is lacking in China. This study was conducted to evaluate systematically the contents of trace metals in fresh chicken meat products on the food markets in Guangdong province, a major chicken production and consumption region in southern China, and assess the potential health risk associated with dietary intake of chicken meat products for the local populations.

2. Materials and methods

2.1. Study area and sample collection

Guangdong province, which is one of the most economically developed regions in southern China, ranks among the top in both chicken production and per capita consumption of chicken meat products in the country (NBS, 2017). As the largest city in Guangdong, Guangzhou has a total official population of approximately 14 million and a gross domestic product (GDP) per capita of 1.39×10^5 Yuan RMB in 2016 (Statistical Office of Guangzhou, 2017). Lianzhou, which is located in the northern part of Guangdong and is dominated by rural areas, has a total official population of approximately 0.55 million and a GDP per capita of 2.52×10^4 Yuan RMB in 2016 (Statistical Office of Lianzhou, 2017). Consumers in Guangdong are well known for their love for chicken, and they prefer live poultry sold in wet markets over frozen meat in grocery stores as the former is much more flavorful. A total of 9 wet markets in Guangzhou and 5 wet markets in Lianzhou, which were selected to represent the developed urban centers and the developing rural areas of Guangdong province, respectively, were visited multiple times over the period of January 2013 through October 2014. Multiple samples of whole chickens (slaughtered on site by the vendors) and/or pieces of freshly slaughtered chickens, which were generally representative of those sold in the markets, were purchased during each visit. Although no specific labels existed for chickens sold in wet markets, information on their breeds and locations of production (when known) was collected through interviewing the vendors. A total of 354 chicken tissue samples, which could well represent the chicken meat products consumed by local populations, were obtained. According to the poultry vendors, chickens sold in Guangzhou markets were mostly supplied by intensive farms, while a large portion of those on Lianzhou markets still came from family backyards or small farms. Details on sample collection and transfer have been described in our previous work (Hu et al., 2017b). Once received in the laboratory, all chicken samples were carefully rinsed with distilled water and sliced into