Chapter 9

Chemical Contaminants in Poultry Meat and Products

Ayhan Filazi, Begum Yurdakok-Dikmen,
Ozgur Kuzukiran and Ufuk Tansel Sireli

Additional information is available at the end of the chapter

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Abstract

Consumption of poultry meat and products has increased as a consequence of economic crisis, driven by several factors, while people keep away from high priced beef/lamb meat or meat products. Meanwhile, due to this increasing demand in industry resulting strict measures in disease control and environmental factors, these products may involve some chemical and natural compounds with hazardous properties at detectable or even very low concentrations. Among these compounds, residues are of concern, including veterinary drugs, environmental pollutants (such as dioxins, pesticides, and phthalates), natural contaminants (mycotoxins, etc), and/or phytosanitary substances accidentally contaminating poultry product during production or marketing stages. In order to keep the consumers safe from the harmful/undesirable effects due to these compounds, such as genotoxic, immunotoxic, carcinogenic, teratogenic, or endocrine disrupting effects, new strategies and concepts for poultry food security have been emerged and developed globally. This chapter includes detailed information on the residues of some potential chemical contaminants in poultry meat and products (eggs, etc.) along with risk analysis regarding their hazardous effects and detection in various matrices.

Keywords: contaminants, egg, meat, poultry, residues

1. Introduction

Air, water, soil, and food are vital constituents of the human environment. While these sources directly affect the quality of human life, the risk of contamination with various pollutants in this industrialized new era is unfortunately inevitable [1]. As the main source of nutrients, food itself contains chemical and natural compounds with hazardous properties. Among these hazardous contaminants, the most important ones are the chemical residues including veterinary drugs, pesticides, and dioxins. With the increased awareness of health and increasing demand on health food, food security standards were developed for the protection of consumers for their adverse health effects. In terms of a wide definition, food safety is defined as a multidisciplinary field including the production, preparation, and the conservation of food in order to protect consumer safety for foodborne diseases in accordance and guidance with the related legislations. Food security, as an evolving scientific field, is an ongoing process, starting with the production until the consumption of the final product [2].

In recent years, consumption of poultry meat and products has increased as a consequence of economic crisis, as people avoid high-priced food. Although egg consumption diminished remarkable in the last period of the twentieth century due to its cholesterol content, recent advances in research provides more evidence on the positive health effects increasing the consumption trades [3].

Residues are substances that can occur in food and feedstuffs naturally or anthropogenically as the accidental, intentional (adulteration), or environmental (persistent organic pollutants like dioxins) contamination of the food with veterinary drugs or phytosanitary products during the production or marketing stages [4]. Codex Alimentarius defines “contaminant” as “any substance not intentionally added to food, which is present in such food as a result of the production, manufacture, processing, preparation, treatment, packaging, transport, or holding of such food or as a result of environmental contamination. The term does not include insect fragments, rodent hairs, and other extraneous matter” [5]. Therefore, all food products are at risk of contamination from several resources, and poultry meat and products are no exemptions. Drug residues can be prevented by not using the substance in animal production, where legal monitoring procedures are applied; meanwhile, these contaminants can be difficult to exempt completely due to the background level of pollution in the environment [4, 6].

The development of a primary production and processing standard for poultry meat uses an approach that investigate the sources of potential chemical risks, which may be introduced at different points through the primary production and processing chain. Poultry meat and products supply chain is divided into four distinct steps: primary production, processing, retail, and consumer. At each of these steps, poultry meat and products may be directly or indirectly exposed to chemicals [3]. Direct exposure results when a compound is present in raw food materials, whereas in indirect exposure, contaminants cross into food during processing, storage, packaging, or preparation. Indirect contaminants also include substances that become toxic and harmful to people due to food-processing practices. Indirect pollution is most frequently the result of unawareness, lack of education of food handlers, insufficient and awful places, or inappropriate handling applications [7].

In all production stage, there is a risk of iatrogenic contamination of multiple substances such as antimicrobials. These substances are essential for poultry production because of their effects in support of health, welfare, and performance, as well as the reduction of manufacturing costs and final costs for the consumer. Additionally, they are substantial to decrease spread of potentially pathogenic organisms from animals to humans and to the environment [8]. Several substances among these drugs used in the treatment have the potential to constitute residues

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in edible tissues and other food products, which can potentially cause adverse health effects including allergy, pharmacological/toxicological effects, antimicrobial resistance/reduced susceptibility, change of gut microflora, and endocrine disruption in consumers. Therefore, it is substantial that manufacturers, veterinarians, and all other professionals included in food production are aware of the residues and abide by the regulations and the instructions regarding the prudent use, for protecting consumers from potentially detrimental levels of residues [3].

Although most consumers are mainly worried about the residues of veterinary drugs in their food, there are many more potential contaminants in the environment, which are more likely to contaminate the product from various resources. These include phthalates, persistent organic pollutants, various emerging toxic elements, and pesticides [2]. Some of these compounds in residual amounts in poultry meat and eggs have important deleterious effects and known to have genotoxic, immunotoxic, carcinogenic, teratogenic, or endocrine disrupting effects [4].

Contaminants and residues require a comprehensive health apprehension, leading to strict regulations of their concentrations in products decided by national and internationally authorities. For this reason, analysis of relevant chemical substances is a major part of food safety programs to provide consumer safety and agreement with regulatory limits. Modern testing procedures can identify known chemical substances in complex food matrices at very low levels. Additionally, they can also help to reveal and determine new or unexpected emerging chemical substances [9]. This chapter summarizes some potential chemical contaminants and residues in poultry meat and eggs, their hazards, and analysis.

2. Veterinary drugs

Veterinary drugs are generally prescribed for the treatment and prevention of the diseases compromising mostly coccidia, ectoparasites, fungi, and bacterial infections in poultry. Nowadays, a large part of drug use in poultry farming is prophylactic, with the bulk of medications including mainly anticoccidial substances and antibacterial growth promoters [10]. Poultry production systems are closely related to animal and human health; which also has a direct effect on the environment. Therefore, critical risk assessment in the overall production and processing system has great importance [11].

Poultry feed is typically composed of corn and soybean meal mixtures, including several vitamins and minerals, and generally contains two or three medications; which comprises 68% of total production costs. For each development phase, the amounts of the content differ, where starter, grower, finisher, and layer feeds are commercially available. Among all manufacturing costs, drug application and vaccinations cover about 2% [11]. In poultry production, the use of hormones is prohibited and is not considered profitable [2].

Antimicrobials are widely used for the disease prevention and treatment, sustain the health in all poultry treated, induce growth, and enhance the quality of the meat for the purpose of reducing production costs. In European Union (EU), the usage of antimicrobials for the promotion of growth has been prohibited since 2006; whereas in United States, it is still currently been used for this purpose [12]. In addition to their specific effects, edible tissues of poultry might contain veterinary drug residues, which would cause hazardous health effects in human, such as direct toxicological/pharmacological effects, hypersensitivity, allergic reactions, change of gut microflora, and increased bacterial resistance to antibacterials [13]. Serious concerns are raised on the antibacterial resistance in zoonotic enteropathogens (*Salmonella* spp., *Campylobacter* spp.), commensal bacteria (*Escherichia coli, Enterococci*), and bacterial pathogens of animals (*Pasteurella, Actinobacillus* spp.) [4].

Nowadays, the prevention of coccidiosis has become the norm in modern farming for broilers and turkeys. Therefore, broiler producers almost constantly contain a coccidiostat in grower rations for reduced morbidity and mortality. Ionophores are the most extensive used drugs for the prevention of coccidiosis. Some drugs are not well absorbed from alimentary canal or not detrimental to require a withdrawal period, yet they can be used until slaughter legally. However, the majority of coccidiostats require withdrawal periods. Currently, vaccination is popular for the control of coccidiosis, which thereby eliminates the risk of residue transfer into poultry products [14].

Drug residues in poultry eggs are an issue of concern since only a few drugs are approved for laying hens, while a variety of drugs are approved for other production types. Residues could be accidental through mixing the feed in the same mill with the previously medicated feed or off-label treatment [12].

A large part of integrated poultry breeders monitor potential residues in meat or eggs routinely. This practice decreases possibility of drug residues in tissues, while the variation in cost among withdrawal feed and grower feed is significant. Some businesses do further monitoring in tissue before slaughter [9]. Fat and other tissues are analyzed for residues of contaminants such as pesticides, toxic elements, or persistent organic pollutants. Compared to fruit and vegetables, residues of pesticides such as organophosphorus, fungicides, herbicides, and carbamate compounds in poultry meat and products are negligible due to the elimination of these compounds to certain extent [12, 15]. Therefore, the risk of adverse health effects on human is assumed to be relatively low. In order to reduce adverse health risks arising from residues, Food and Agriculture Organization (FAO) and World Health Organization (WHO) expressed the mandate regarding the legal withdrawal periods for each drug [16, 17].

Fast and successful treatment of poultry infectious diseases is essential since it might lead important economical losses [18]. Therefore, selective, fast-acting, and potent drugs are selected [10]. So the drug selection at treatment of poultry infectious diseases, arrangement of treatment programs, determination of application ways, determination of individual or collective treatment doses and periods, and finally treatment of clinic efficiency of the drug are very different compared to the treatment options specific to the animal species [19].

Veterinary drugs are generally added to the feed as “feed additive” in the feed factories [20]. For the proper dosage, homogeneity of the active compound in the feed has great importance. Homogeneity of the medicated feed is standardized using specialized mixing equipments, yet these devices are expected to be cleaned each and after the preparation of the medicated feed. Documentation of procedures and relevant records are essential for each feed lot for legal requirements and external inspections. In order to prevent cross contamination, medicated feed should be stored in separate and not in the poultry house; where the bins or silos in the storage areas should also be cleaned properly [9].

3. Toxic elements

Entry of undesirable substances into the food chain is mainly due to environmental pollution. Fortunately, eggs are not a significant source of toxic elements, since only negligible amounts of these are able to penetrate the egg. Poultry meat may be contaminated with toxic elements such as arsenic, cadmium, or lead as a result of coming into contact with the materials on the farm or factory or while moving through marketing channels. These three toxic elements are known to induce more/widespread adverse health effects, which would be emphasized [21, 22].

3.1. Arsenic (As)

Organic arsenic compounds (roxarsone, arsanilic acid, nitarsone, and carbarsone) have been widely used in the poultry sector for long years as they prevent the diseases, accelerate growth, increase feed efficiency, and increase pigmentation of the meat. More than 90% of these organic arsenic compounds that are given to the chicken as feed additive are excreted with the feces as unchanged. The manures prepared from chicken feces including arsenic are applied to the croplands in order to increase efficiency of the soil; which would eventually lead environmental pollution [23]. Along with that, organic arsenic compounds available at the chicken manure were found to transform into dimethyl arsenic acid, monomethyl arsenic acid, and inorganic arsenic compounds; which are even more toxic than the ones available in the environment. Also, residuals of arsenic compounds were seen at body fat, liver, egg, and feather of the chicken fed with organic arsenic compounds [24]. Therewith, the use of organic arsenic compounds in 1998 was forbidden in EU countries. USA Food and Drug Administration (FDA) forbids the arsanilic acid, carbarsone, and roxarsone use in 2012 and nitarsone in 2015 [25].

3.2. Lead (Pb)

Due to pressure of the concerns in public health along with the regulations, a decrease in Pb emission along with the developments in the quality of chemical production in the recent years significantly decreased the Pb content in the environment. Even though this decrease, Pb, was still found in many food products such as giblets and offal at low concentrations [26]. Processing or production of foods in the fields contaminated with Pb was found to increase Pb level at the foods. Recent researches reveal that chronic Pb intoxication with low concentrations were found to cause pain, constipation, anemia, and an increase in hypertension and cardiovascular diseases in adults, while neuropathological disorders and even learning capacities are affected in children [27]. It was defined in Codex Alimantarius that Pb levels at a maximum of 0.1 mg/kg in the poultry meat and 0.5 mg/kg in edible offal were found to cause no adverse health effects [28].

3.3. Cadmium (Cd)

It is a metal that come to forefront as an environmental contaminant resulted from both natural and industrial and agricultural sources. The individuals who do not smoke are exposed to Cd through foodstuffs [29]. Absorption of Cd through digestive canal is very low in the humans (3–5%); while they are able to accumulate in liver and kidney at significant amounts in human. Its biological half-life is very long (10–30 years). Cd mainly leads to damage of kidney functions by damaging proximal tubular of the kidneys [30]. Also it leads to bone damage both directly and indirectly. The tubular damage is seen as a result of exposure to Cd at low dose for a long period or at high dose for a short period. As a result, glomerular filtration speed is decreased and finally renal impairment is seen [31]. International Agency on Cancer Research (IARC) classifies Cd as human carcinogenic (Group 1) [32]; while European Union Food Safety Authority (EFSA) also underlined this fact stating, and exposure of Cd would lead increased risk for lung, endometrium, urinary bladder, and breast cancer [33].

In order to avoid the bioaccumulation and for the sake of public health, authorities are obliged to conduct surveillance and monitoring analysis for metal contamination in poultry. It has been understood from the studies and assessments concerning to the metal pollution at the poultry meats that metal pollution that may be available at the poultry meats do not lead to a significant public health concern but it is required to be avoided from the offal of elder animals as a precaution [21, 34].

4. Radioactive substances

Ionizing radiation is a natural source of energy as people are exposed through soil, water, and vegetation. The radio waves that allow for radio and television communication, X-rays used in the medicine and industry, and solar rays are the radiation types that we are accustomed in our daily life. Humans and animals are exposed to the radioactive substances through various sources mainly through air, water, and alimentary by food feed. Nuclear trials, nuclear power plants, effluents, and residuals of the nuclear researches, nuclear accidents, mine pits including radioactive substances, facilities producing radioisotope, radioisotopes used in the scientific researches, electron microscopes, and radioactive rays used in the medicine and industry are the main sources of contamination for environment as well as food [35].

There are so many disasters in the history regarding nuclear accidents, nuclear trials, and nuclear leakages. These substances may be carried to far away from the places that they are located through air and water. As they are resistant physically, chemically, and biologically, most of them enter into food chain, leading long-term permanent undesirable effects [36]. These radioactive compounds taken through inhalation, dermal, and alimentary routes are found to accumulate at the tissues and organs, which would cause to damages to the surrounding cells, tissues, and organs by their particle composition or by emitting rays (internal ray) [37]. Intoxication with radiation with these internal radiation emitting substances may progress as acute or chronic. Chronic effects of the radiation, available at the water and foodstuffs at low amounts, are more important in the living creature in terms of food toxicology [38].

The nuclear trials, nuclear accidents, nuclear leakages, and nuclear contaminations as a result of use of nuclear weapons are the most significant sources of radioactive substance contamination in the foodstuffs. With the help of various air movements, the substances emitted to the places close to or far away from these sources contaminate plants, agricultural products, fruits, or waters; they enter into the bodies of animals that crop or the humans live in these places as well as various food sources. Also, they are transferred into the consumers through the foodstuffs obtained from these animals [39].

The researches concerning to the radioactive substances at the animals of food origin started in 1950–1960s with the tests of atomic bombs. The Chernobyl accident carried out a better warning duty in terms of understanding the factors that lead to transfer of radioactive substances to the animals and allowed for development of more appropriate precautions. International Atomic Energy Agency published a booklet including the precautions to be taken concerning to the radioactive substances available at the foods of animal origin [40]. Iodine-131 and cesium-137 were found as radioactive residues in food following Chernobyl, the biggest nuclear accident in Pripyat, Ukrainian SSR. Even after 30 years, current researches still emphasis the remedies of the residues of Chernobyl along with the recent nuclear disaster Fukushima, Japan, which is the second biggest nuclear accident.

4.1. Iodine-131 (^{131}I).

Iodine-131 is available at the herbs in the meadows and forages and transferred to the animals through the feed that were cropped in these areas. It is fully absorbed from the digestive canal and concentrates on the thyroid gland. It is transferred to animal products at differing rates, such as for milk at 6% [41] and for egg 15% [42]. It was reported that ^{131}I is still found in chicken eggs after single exposure for 20 days; while in case of a longer exposure such as exposure longer than 1 week, residues may still be found up until 30 days. Therefore, the withdrawal period for eggs exposed to ^{131}I contaminated chicken feed was defined as 30 days [42].

4.2. Cesium-137 (^{137}Cs)

This substance is especially resulted from nuclear weapons, nuclear reactor leakages and residuals. Absorption of ^{137}Cs from the digestive canal varies between <10 and 100% in accordance with its chemical form, which is mostly distributed in the soft tissues of the body. As it is firmly bound to the soil, it may not enter into the food chain easily; but because its disengaged part at the soil is too much at the locations where it is common, it may be transferred to the plants and therefore animals and their products [43]. Its withdrawal speed from the muscle tissue is much more at the small animals compared to large animals. For example; ^{137}Cs is removed from the muscle tissue in 1–2 days at the chicken, while this period may extend up to 60 days for calves [44]. Even though the distribution of ^{137}Cs at the livestock (pig, sheep, layer hen, and broilers) varies after given orally, it was notified that the highest concentration was found at muscle and kidneys regardless the animal type. The lowest ^{137}Cs concentration was determined at the blood. The absorption through digestive canal after given orally were found to be fast in broilers; where the highest concentrations were found at chest, leg, intestine, and liver for the first day. Meanwhile, the highest accumulation was seen at the muscle tissue at the layer hens [45].

5. Persistent organic pollutants (POPs)

POPs is the general definition for the natural or synthetic organic compounds which are known to bioaccumulate in the environment without being degraded due their resistance to chemical, biological, and optical breakdown and have detrimental effects to human, animal, plant, and environment. The traces of these substances are not restricted to the areas where the production or application exists, but also with their stability which would lead long-range transport they are even found in uninhabitant areas where POPs have never been used. This issue raised a global concern and initiated global measures for the prevention of the pollution [46].

POPs have low water solubility and high lipid solubility (oil, fat) with low steam pressure, which makes their half-life in the environment long. Due to these properties, they accumulate on the fat tissues of the living creatures including human. Therefore, both acute and chronic toxic effects occur in human, wild animals, and other organisms, which are exposed to POPs for many generations creating bioaccumulation [47]. Human are also exposed to POPs by food and in utero during gestation or infant by lactation periods. Several studies proved that POPs induce endocrine disruption and effect immune, nervous and reproduction systems, even causing cancer [48].

As these compounds are used and manufactured in various sectors of the industry and agriculture; they might be formed as a consequence of by-products or even at burning procedures [49, 50]. Among these formed unintentional by-products, dioxins are the most known. The sources that lead to dioxin and other POP residuals in poultry are as follows [51]:

– Volatilization of these compounds to the air from the undefined burning procedures in industry and accumulation in the soil,

– Use of some clay minerals such as kaolin or clay ball,

– The waste disposal regions where materials including Polychlorobiphenyls (PCBs) are buried,

– The red slag (Kieselrot) formation during the copper production, polychlorobenzodioxins/furans (PCDD/Fs) used in surfacing of the road surfaces and playgrounds at significant amounts,

– Fall of the isolation material at the roof of poultry house that is decomposed in time and its intake by the animals,

– The grouting in the buildings.

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Chicken are exposed to POPs through various ways. The most important exposure route is its intake through feed. POP residuals at the feeds come from feed raw materials including fat. Along with alimental exposure, chicken are also exposed to POPs through dermal and inhalation routes Araclor 1254 (PCB mixture) given by feed at 0.5–1 ppm concentration was found to transfer the egg at 0.2–0.45 ppm levels. Meanwhile, administration of the same compound to Leghorn chicks for 8–32 weeks at 0.1–10 ppm, no toxic effect was observed including egg efficiency and hatching ratio. If Araclor 1254 and other PCB mixtures (Araclor 1248, 1242 and 1232) exceeds over 20 ppm, a decrease of the egg efficiency and hatching ratios along with teratogenic effects were observed [52, 53]. The finding in this study were found in accordance to another study where Araclor 1248 at 0.5–1 ppm given through feed, did not affect egg efficiency and hatching; while 10–20 ppm significantly decreased the egg efficiency in 8 weeks [54].

As a conclusion, chicken bred in extensive poultry production systems are more exposed to infectious agents and chemical contaminants compared to intensive systems. This susceptibility creates an increased risk of diseases and brings the fact of the increased use of veterinary drugs, which would eventually cause residues in the edible tissues and other products in poultry [51].

6. Polycyclic aromatic hydrocarbons (PAHs)

PAHs are the chemical compounds, which includes two or more aromatic rings and consist of carbon and hydrogen atoms which compromise pyrolysis or partial burning of the organic substances due to the industrial proceedings and human effects. The processing processes of the foods (smoking and drying) and cooking at high temperatures (grilling, frying, and roasting) creates the main source of PAHs [55]. Pyrolysis occurs due to the drip of the oil to the flame while cooking the foods at above 200°C and PAHs contaminate the foods along with the smoke that will occur [56]. PAH levels occurred as a result of applying different cooking methods to the fowl for 0.5–1.5 h were compared, where the highest PAH content was found to be formed when the meat was cooked at the coal flame (320 μg/kg). This was followed by cooking with the skin at the coal flame (300 μg/kg), smoking (210 μg/kg), frying (130 μg/kg), steaming (8.6 μg/kg), and liquid smoking (0.3 μg/kg) [57]. In the same way, PAH was found to be produced at the highest, when the meat was directly subjected to the wood fire and at the lowest level when it was cooked at the cinder. With the disintegration occurred as a result of drip of melted fats on the heat source during cooking the meats, formation of PAHs was found to increase and volatilized to the atmosphere, accumulate back again on the meat. PAHs are mainly lipophilic and mostly stored at fat tissue, where an increase of fat content of the meat, would directly lead to increase of PAH amount. PAH contents were also found to be significantly increased as a result of cooking hamburger, beef, fish, and chicken meats at the high temperature barbecue. The coal and coal dusts at the barbecue penetrates on the cooked foods and make carcinogenic effect and mainly cause to alimentary canal and large intestine cancers [58].

Smoking is one of the oldest technologies that have been used for maintaining meats and meat products and defined as penetration procedure of the steams formed with degradation of the wood with the heat to the meat products. In general, it is widely used at the processing the fishes. PAHs may occur during insufficient burning of the wood as an undesired conclusion of the smoking. There are approximately 660 different compounds within PAH group, in which some of these have carcinogenic properties [59]. Benzo[a]pyrene (BaP), which is the most known carcinogenic PAH compound, has been used as lead coating material up to date. In EU legislation, maximum residual limit of BaP is 5 μg/kg at fume (smoked) meat and meat products. Also European Commission suggests that the member countries should research not only BaP amount but also 15 other PAHs which have possible carcinogenic effects at cured meats. Dibenzo[a,i]pyrene (DiP) received attention, due to the recent toxicological studies showing its potency in carcinogenicity much greater than BaP. EFSA also suggests the analysis of benzo[c]fluorene (BcL) since The Joint FAO/WHO Expert Committee on Food Additives (JECFA) considered at particular interest; while specific scientific studies are still missing [60].

7. Phthalates

Phthalates are the chemical substances that are used for making the plastic materials softer, more elastic, lighter, and more resistant. These kinds of plastics are also used for keeping the foodstuffs fresh, maintaining curative effects of continuous release pharmaceutical substances, and preventing burning or spread of the fire of electronics and other household and cosmetic products [61]. These compounds are produced at very high amounts since 1930s and their production amount globally was found as 4.9 million tons in 2010. Therefore, residues of phthalates such as dimethyl phthalate (DMP), diethyl phthalate (DEP), di-n-propyl phthalate (DPP), diisobutyl phthalate (DiBP), di-n-butyl phthalate (DBP), butyl benzyl phthalate (BBzP), dicyclohexyl phthalate (DCHP), diisoheptyl phthalate (DHP), di(2-ethylhexyl) phthalate (DEHP), diisodecyl phthalate (DiDP), and diisononyl phthalate (DiNP) are inevitable and widely seen at the foods and food packages [62].

Phthalates are defined among the endocrine disrupting chemicals due to their effects on the reproduction system. They found to cause sperm damage, early puberty at the females, reproduction canal abnormalities, early pregnancy termination, or hepatic tumors in rodents [63]. Widely existence of plastic materials in the nature, interest to personal care products, and various food packaging shows that humans and animals are indispensably exposed to these chemicals. Phthalates are taken through mouth, breathing, injection, or dermal contact [64, 65]. According to USA Centers for Disease Control and Prevention (CDC) reports, almost all of the humans screened were found to have phthalate metabolites at detectable concentrations in their urine. The levels of phthalates metabolytes in urine were linked to the possible daily routines of the subjects, which shows that the phthalate metabolites of adult women using soaps, body washing liquids, shampoos, cosmetic, and similar products much higher compared to the men [66]. Along with the environmental cosmetic exposure, food products such as milk, butter, and meats are very common sources for some phthalates such as DEHP, DBP and DiBP due to that they have lipophilic character [67].

Based on these reports, continuous screening of these phthalates in foods and food products has great importance. The contamination could be from the environment as well as the plastic materials used in the production stages. Even though their usage in food packaging is decreased, many products include phthalates for softening purposes as well as various processing stages [68].

Phthalates may penetrate the foods during production, packing and preparation. Due to wide usage and availability in various products, including the laboratory materials, analysis of the food is difficult. In a study, nine phthalate esters in 72 different foods commonly consumed were screened and DEHP was found at 74% of all these products including the infant foods [69].

On the contrary to other chemical contaminants, information regarding phthalates as residue in food is very limited. Since their usage with the improved technology, lead mixed contamination at very low concentrations; previous studies do not reflect the current status. The tolerable daily intake for some phthalates was stated as 0.01, 0.5, 0.05, 0.15, and 0.15 mg/kg/day for DBP, BBzP, DEHP, DiNP, and DiDP, respectively by EFSA [68, 70].

The habitats and feeding ways of the chicken that are free-range extensive and intensive or semi-poultry houses may make difference on their exposure to the environmental pollutants such as phthalates. Information regarding the indoor-outdoor breeding on phthalate levels is missing, except one study showing only the levels of phthalates in chicken eggs in retail. This research showed that DEHP may even be found at the shell of membrane of the egg [71] and DBP and DEHP might be present at even low concentrations [72]. The same study revealed that DBP and DEHP were found only in egg white as 0–0.15 and 0.05–0.4 ppm, while no contamination was reported for egg yolk. Meanwhile another experimental study showed that DEHP may be present both at white yolk and white after it is given to the chicken orally at single and repeated dose applications (3 days). The animals are also given DEHP for 45 days at a concentration of 1/100 g feed and the results of the transfer to the egg yolk was found to be even more in these fed animals [73]

8. Other contaminants

There are many other compounds that may cause adverse health effects through poultry and poultry products. WHO and American Dietetics Association identified the potential hazards of trans-fatty acids on human health, which are formed from further-processed, deep-fried products from fast-food retails. Fatty acids in oils are generally in the cis-form, which will be transformed to the less healthy trans-form during hydrogenation and over-heating during deep frying. Compared to pesticide residues, trans-fatty acids also lead deleterious effects; which were found to be directly related to atherosclerosis, cardio-vascular diseases, cancer, ulceration, and oxidative degeneration [74].

9. Control of the contaminants at poultry meat and products

The control strategies for the pharmacological effective substances and environmental pollutants in poultry meat and products includes complex and evolving measures for defining/determination of these compounds and analysis of exposure/prevention routes.

Recent advances in analytic chemistry lead to the understanding of chemical contamination frequency/routes/prevention mechanisms in the food field more intensively. While some of these threat the health even at low concentrations at no threshold, some of them may be have legal breaching characteristic [75]. These require various risk method approaches. For appropriate control of the production procedures, biosafety, full traceability, good hygiene, and other sanitary applications are compulsory requirements [7].

As well as that the contaminants at the foodstuffs may be determined with special chromatographic methods, they may be also determined with very sensitive and cheap methods as described for antibiotics detection. The residues are found at blood, urine, sometimes gall, and mostly edible tissues. The blood, sometimes gall, muscles, liver, and egg are the target matrices that may be analyzed [76]. The amount to be analyzed is generally 1 ppm and sometimes below than 1 ppb. These analyses are based on degradation of the residuals following extraction of the residuals from poultry tissues with water or organic solvents or chromatography procedures. The disintegration is done with, immiscible liquids such as water and petroleum or two environments such as liquid and solid [7].

The analytic methods that are used for monitoring antibiotic residuals are generally classified into two groups such as "verification methods" and "screening methods." The verification methods are generally based on liquid chromatography combined with mass spectrophotometer (LC/MS) for determining the concentration of the analyte. Sometimes, the verification procedure may be carried out with the methods based on LC with ultraviolet (UV) detector or capillary electrophoresis (CE). Along with that, all of these require time-consuming, expensive and complicate laboratory equipments and trained personnel [75]. Also they are subjected to solid phase extraction (SPE) or very demanding sample preparation procedures based on multistep cleaning for extraction of the analyte. The screening methods may determine the analyte. But generally, semi-quantitative results are obtained. Ideal properties of a screen method are as follows: they give very less wrong positive results, they are efficient, their use is simple, their analyses are short, and they are selective and low priced [77].

In the current literature, the most widely used techniques in the analysis of the antibiotics are LC/MS (at the rate of 38%) and LC/UV (at the rate of 18), which are the verification methods, and ELISA method (at the rate of 18), which is a screen method. Along with that, an increase of other screening methods (at the rate of 12%) and use of biosensors (at the rate of 8%) are available. As there are so many and various types of drug residuals in the animal products, many prior screening analyses are required to be completed for an effective verification; yet therefore, the use of screen tests is compulsory. Since it is cheap and does not require complicated devices and advanced trained scientists, screening methods are applied by poultry farmers extensively in the field [78].

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Microbiological methods are qualitative or semi-qualitative methods that are based on the reaction between sensitive bacteria and antibiotic at the sample. The advantages of these methods are their simplicity, reliability and their low price. Various tests are commercially available. Meanwhile microbiological methods are less sensitive, LC/MS methods may only be applied to the component to be selected as the target. In this way, any other possible antibacterial substance may not be seen. Along with that, the most important disadvantages of the microbiological methods are that they have selectivity and sometimes they need for a long incubation period. In the microbiological methods that are used for determining the residuals of the antibiotics at the solid foodstuffs, the procedures based on simple solid-liquid extraction (SLE) are the most preferred sample preparation procedure. Pollution at the processing the samples and solid phase extraction (SPE) at the degreasing or liquid-liquid extraction with hexane may be used [79].

Another most preferred screen test is the use of ELISA systems widely available for various kinds of contaminants such as hormones and drugs. This method has a very high specificity and due to use of antibodies that is specifically developed for the target molecule, it is assumed as very sensitive. Due to the specificity and reliability, analysis of different residuals at a very short time instantly is available along with relatively easy sample preparation procedures; ELISA methods are assumed as a “must” in poultry field. A typical ELISA kit is formed from 96 wells coated with the antibodies developed for target compounds, where sample and standards are added at specific amounts and other steps of reaction and washing are followed. The amount is assigned by a simple microplate reader [80].

While some liquid samples (such as urine and plasma) are directly analyzed by diluting with a buffered solution, solid samples such as meat and egg are extracted using liquid-liquid extraction by organic solvents or solid-liquid extraction using special colons followed by cleaning procedures. In some cases, chemical procedures are needed for disintegration of target molecule such like in the nitrofurans [78].

The screening tests are used for monitoring the slaughter houses, control of the import, control of the feeds, or market controls. In cases of acceptance or rejection of a feed lot, the decision may be given in accordance with ELISA results; while in the cases including legal sanctions, the positive results obtained from ELISA are required to be verified with the methods at which expensive and sophisticated laboratory equipments are used and that require difficult sample preparation stages. These analyses are carried out by the experts and strict quality control parameters are applied with the aim of achieving reliability of the results [81].

10. Conclusions

Today, the use of emerging technologies at all stages of food production, the growth of the fast-food industry, and environmental pollution lead to increase the risk of contamination of food. Home cooking and food preparation habits have been gradually decreased; while nowadays readily available convenience foods or chain restaurants are preferred. In order to serve as much people possible, companies or other food chain industries generally retail raw food as bulk from market or poultry producers with a possibility of veterinary drug residues or other environmental contaminants at very high concentrations. Even, machine washing and cleaning in restaurants may present less efficacy leading to more possible surface contaminants. Nevertheless, food manufacturers are needed to perceive HACCP training for the emerging contaminants and consider food safety regulations and follow Good Manufacturing Practices. There have to be rigorous improved quality controls by exactly implementing the HACCP program at every step of food production and processing for these contaminants.

Author details

Ayhan Filazi[1*], Begum Yurdakok-Dikmen[1], Ozgur Kuzukiran[2] and Ufuk Tansel Sireli[3]

*Address all correspondence to: filazi@veterinary.ankara.edu.tr

1 Department of Pharmacology and Toxicology, Faculty of Veterinary Medicine, Ankara University, Ankara, Turkey

2 Veterinary Control Central Research Institute, Ankara, Turkey

3 Department of Food Hygiene and Control, Faculty of Veterinary Medicine, Ankara University, Ankara, Turkey

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