Chemical Contaminates of Meat and Meat Products which Threaten Human Health

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ABSTRACT

The priorities, which concern meat and meat products consumption today, are food safety issues and meat quality. Humans around the world are exposed to chemical contaminants during their life time. Among the thousands of existing contaminates, some are persistent and remain in the environment for years. The variation in measurable levels depends mainly on the fact that some are synthesized as industrial products, whereas others are released accidentally, as by-products, or given to animals as growth promoters or as prophylactic or therapeutic agents. The measurement of these contaminants requires a complex procedure including sample extraction, sample clean-up, and physico-chemical analysis after chromatographic separation. Contaminants such as organochlorine pesticides, heavy metals, microbes, melamine, hormones, antibiotic, and other feed additives are often measured in various types of matrices during food safety programs, environmental monitoring, and epidemiological studies. Serious health problems including cancer, kidney diseases, disarray and other diseases in humans might be related to food contaminates. According to the World Health Organization (WHO), 1.8 million people died from diarrhea related diseases in 2005. Children and developing fetuses are generally at greater risk from exposure to different chemicals. A great number of these cases might be attributed to contaminate found on food. More than 90% of human exposure to harmful materials is due to consumption of contaminated food items such as meat, milk and dairy products, as well as fish and derived products. The overwhelming majority of food poisoning in the world might originate from contaminated animal products and there are millions of cases, and hundreds of deaths, caused by contaminated animal products every year. This paper will discuss and highlight the most common chemical and biological contaminates in meat and meat products from various species which threaten human health.

Key words: Meat; meat products; contaminants; human health

INTRODUCTION

The principle contaminants of food-stuff in the world include microorganisms and their metabolites, mycotoxins, heavy metals, nitrates, nitrites, hormones, pesticide residues, antibiotics, dioxins, polychlorinated biphenyls, genetically modified organisms, toxic pigments, and melamine. Meat and meat products are integral parts of the daily diet for many people due to tradition, variety, reasonable prices, versatility, satiety value and taste. It is the nutritional value of meat, however, which distinguishes it as a beneficial component in a balanced diet. Meat provides a ready source of protein, minerals and some vitamins (B_6 and B_{12}). Meat is a rich source of many nutrients per unit energy; therefore, emphasis should be placed on the importance of meat safety for human consumption. Traditional meat inspection systems are to a large extent based on the concept of inspecting live animals (ante-mortem) and carcasses (post-mortem) to ascertain the presence of items hazardous to human health. Judgment of gross findings relative to the suitability of the product for human consumption is made according to standardized criteria. However, traditional methods of meat and fish inspection do not determine contaminants, such as antibiotics, anabolic agents, melamine, and heavy metals.

The objective was to review the current situation of meat and meat products contaminants with residues of hormones, antibiotics, pesticides, melamine, and heavy metals in meat and fish products. Moreover, pilot studies were carried out to detect hormones, antibiotics, heavy metals and melamine in meat and fish collected from local market. Samples were collected from the major supermarket outlets and butcher shops and evaluated ELISA.

1. Pesticides

More than 100 pesticides are known, but it is unlikely to find all of them in one food-stuff. They are mainly used in agriculture (68%), commercial and industrial activities (17%), domestic settings (8%) and in governmental applications (7%) (Cantoni and Comi, 1997). The widespread presence of organochlorine pesticide residues (OCPs) in food has arisen due to their extensive agricultural application and industrial emissions in the environment. A large number of pesticides may potentially be used in the production of agricultural crop commodities, leading to indirect exposure of animals through feed and the potential for residues in animal products (MacLachlan and Bhula, 2008). Exposure to pesticides can occur through ingestion of crops or crop by-products that are used as animal feed. Significant animal exposure to pesticides usually occurs through the intake of grain, fodder and forage, as well as feeding on processed by-products, meals and waste. Animals may also be exposed to pesticides by ingestion of contaminated soil while grazing. Less frequent sources of livestock exposure to pesticides include accidental spills, improper waste disposal and contaminated areas from past use of products that are persistent in the environment (Robertson *et al*., 1990). Many pesticides tend to accumulate in animal tissues and are a function of the physicochemical properties of the pesticides (Addison *et al*., 1984). The lipophilic compounds have a great tendency to accumulate in animal tissues and products (MacLachlan and Bhula, 2008). One reason for the environmental persistence of these compounds is that microorganisms are either unable to degrade them or do so at a very slow rate (Alexander, 1981). Persistent organic chlorine compounds such as dichlorodiphenyltrichloroethane (DDT) play an important role in chronic poisoning and contribute to a number of pathological processes (Lembowicz *et al*., 1991; Sitarska *et al*., 1991). Fat solubility of these compounds is responsible for their varied concentrations in tissues and their accumulation in the lipoproteins of the cell membranes, thus changing their structure and permeability (Chowdhury *et al*., 1990; Antunes-Madeira *et al*., 1993). However, compounds that are water-soluble or can be readily metabolized to water-soluble products are rapidly excreted in the urine and do not give rise to significant residues in meat.

Pesticides can be taken up by livestock in their feed or water and may be incompletely eliminated at the time of slaughter (Abou-Arab, 2002, MacLachlan and Bhula, 2008). These compounds tend to accumulate in body tissues. They are resistant to chemical or biological degradation and persist in the environment for a considerable period of time. They can be absorbed by all routes, including inhalation, ingestion and dermal absorption. The awareness that OPPs may also concentrate along the food chain has led to the establishment of low maximum residue limits (MRLs) in meat and fish. Consequently, this requires the control of this type of compound in fatty matrices (Frenich *et al*., 2006). Pesticides may induce or aggravate certain health problems in humans such as cancer, immune system disturbances and disruption of hormonal functions (Vincenzo *et al*., 2002). Residues of OCPs were found in meat and meat products (Cantoni *et al*., 1991; Arino *et al*., 1992, 1993, 1995: Hernandez *et al*., 1994; Herrera *et al*., 1994; Gallo *et al*., 1996) at different levels depending on the type of pesticide and meat.

Although DDT had been banned, however, it is a widely used insecticide that persists in animal tissues. Other cyclodiene groups also tend to accumulate in body fat (Ruiter, 1985). The accumulation of pesticides in the liver may be as much as 100 times higher (Ruiter, 1985). Lactating cows excrete a considerable amount of these compounds in the milk, and residues are also found in eggs of laying hens. The intermuscular and intramuscular fat determines to a great extent the amount of these compounds ingested by the consumer. Polychlorinated biophenyls (PCBs) are synthetic compounds with high chemical and thermal stability. PCBs are extremely persistent and soluble in body tissues and have tumor-promoting effects (Ruiter, 1985).

2. Heavy metals

Anthropogenic activities may have an adverse impact on human health due to the discharge of industrial waste and domestic sewage (Gulf Research Center, 2006).

These effluents usually contain elevated levels of heavy metals that accumulate in macro-particles which form the basis of many food chains (Alloway and Ayres, 1997).

The non-essential elements such as lead, cadmium and mercury, have toxic properties and a tendency to accumulate in meat and fish products. Significant concentrations of these elements were found in edible animal tissue such as muscle, liver and kidney. Eight per cent of the lead in food is taken up from the human gastrointestinal tract. Lead interferes with haemoglobin synthesis and is able to inhibit several enzymes (Ruiter, 1985). Cadmium accumulates in the kidneys and it has an extremely long biological half-life in humans in the order of 20-30 years (WHO, 2009). Five to ten per cent of cadmium is absorbed and bound in the liver with metallothionein and stored in the kidney as Cd-thionein. Kidneys which contain more than 200 mg Cadmium per kg may exhibit morphological abnormalities in the tissue structure and increase excretion of proteins, amino acids, glucose and calcium (Fassett, 1975). Other symptoms of cadmium poisoning are emphysema of the lungs, anaemia and insufficient bone mineralization as a result of increased calcium excretion. Cadmium concentrations in old animal tissues are sometimes extremely high. Mercury levels above 0.05 mg/kg in meat and fish products should be considered harmful or hazardous. Copper and thallium are also elements that warrant concern (Ruiter, 1985).

3. Veterinary drugs

Veterinary drugs are generally used in farm animals for therapeutic and prophylactic purposes. They include a large number of different types of compounds which can be administrated in the feed or in the drinking water. The residues may also originate from contaminated animal feedstuffs (McEvoy, 2002). The presence of residues and its associated harmful health effects on humans makes the control of veterinary drug residues an important measure in ensuring consumer protection. Residues include anabolic compounds and hormones in animal products.

4. Antibiotics

Antibiotics contaminating livestock products (milk, eggs and meat) are dangerous because they can induce allergic reactions, disturb the gastrointestinal microflora. Previous studies at Sultan Qaboos University demonstrated that various types of antibiotic residues were found in meat samples of poultry, sheep and goats (Kadim *et al*., 2009; Mahgoub *et al*., 2006). Anti-microbial activity has also been found in all commercial milk products sold in Oman (Srikandakumar *et al*., 2004).

Antibacterial drugs are usually used in animals for therapeutic, preventative and nutritive purposes (McEwen and Fedorka-Cray, 2002). If proper withdrawal times are not adhered to, residues may be present in the animal tissues at slaughter. The use of antibiotics for growth promotion or prevention and treatment of infectious diseases, can result in resistance among both resident bacterial pathogens and commensal organism (Harbottle *et al*., 2006), which can cause allergic reactions and transfer of resistance to humans (Butaye *et al*., 2001).

Antibiotic resistance is most clearly a problem when it leads to therapeutic failure or the need to use more costly, toxic, or expensive drugs (McEwen, 2006) and it can also be a problem when it increases the frequency, duration or severity of infection (Barza, 2002). In humans, microbial resistance is an important problem in a wide variety of infections of the skin, respiratory, genito-urinary and gastrointestinal tract (McEwen, 2006). There is considerable evidence that antibiotic used in animals, caused the selection of resistant strains that can then spread to humans (McEwen, 2006).

5. Anabolic compounds

Anabolic agents influence the metabolic functions of animals resulting in an increased growth rate and also an increased deposition of proteins in the muscle mass. A primary effect is an increase in the protein deposition, usually linked to fat utilization that decreases the fat content in the carcass and increases meat leanness (Lone, 1997). Many of the anabolic compounds have oestrogenic or androgenic properties. The residues of anabolic agents or their metabolites in fish, meat and other foods of animal origin may cause adverse toxic effects on consumers' health. It has been shown that there was an association between some forms of hormone-dependent cancers and red meat consumption (EFSA, 2007). Barbosa *et al*. (2005) reported that consumption of lamb and beef meat containing residues of clenbuterol was associated with symptoms in humans characterized by gross tremors of the extremities, tachycardia, nausea, headaches and dizziness.

The implantation of 17β-estradiol in meat animals results in high concentrations in edible tissue. Estradiol is carcinogenic in reproductive, bone, pituitary and lymphoid tumors. Thyreostats, which have been prohibited in many countries, are inhibiting the thyroid function which allows a significant increase in the live weight of animals due to water retention in muscle mass. Residuals of this hormone may be found in muscle tissues and can interfere with normal hormonal action (Ruiter, 1985).

It has been reported that high doses of progesterone administered over a long period of time are correlated with an increase in the rate of tumor growth (Lone, 1997). It stimulates cell division in hormonally sensitive tissues, thereby increasing the possibility for accumulation of random errors during DNA duplication (Doyle, 2000). This increased cell proliferation also has the effect of stimulating growth of mutant cells (Henderson and Feigelson, 2000). Some women taking estrogen supplements develop breast or uterine cancer, indicating that estradiol may be one of several factors important in the development of these cancers (Doyle, 2000). Two outbreaks, one of breast enlargement in young school children (Fara *et al*., 1979) and another of precocious sexual development (Saenz de Rodriguez *et al*., 1985) were suggestive of exposure to environmental estrogenic compounds, possibly Zeranol. The researchers suspected that one consignment of meat might have contained residues of some estrogenic compounds and reported that symptoms gradually disappeared after the children stopped consuming meat. Carcinogenicity studies of trenbolone in rodents indicated that 10 or 100 ppm (µg/g) trenbolone in the diet was associated with an increase in liver cancer in mice and 50 ppm trenbolone may have enhanced pancreatic cancer in rats (Roe, 1983). The $ß_2$ –agonists (adrenaline) are produced by the adrenal gland and are released when an animal is under stresses. Synthetic compounds (ß-adrenergic agonists) have been shown to repartition nutrients from fat to muscle. The doses of $ß_2$–agonists necessary to cause repartitioning are 5-10 times greater than the recommended therapeutic doses. There is a potential risk to consumer's health at the high doses necessary for growth promotion. There have been documented cases of mass intoxications after consumption of liver and meat treated with Clenbuterol. Use of the highly active $ß_2$ –agonists as growth promoters is not appropriate because of the potential hazard for human and animal health.

6. Melamine

Melamine (2,4,6-triamino-1,3,5-triazine) is an organic compound commonly used to produce various products, including dishes, plastic resins, in fertilizer, as a flame retardant, manufacture of wrinkle-free textiles and components of paper and paperboard that may come into contact with meat (Garber, 2008). Newton and Utely (1978) used melamine as a non-protein nitrogen source for feeding animals and concluded that the melamine was digested but most of it was eliminated because micro flora in the rumen was not able to assimilate. As a result, trace amounts of melamine and its three analogues, cyanuric acid, ammelide and ammeline, referred to as melamine compounds may be present in animal tissue. The average concentration of melamine in food from approved industrial uses is estimated to be less than 0.015 parts per million (USDA, 2009). These levels of melamine in food are extremely minute and do not pose a public health concern. Intentional addition of melamine to food, however, does pose a significant risk. These levels of melamine and related analogues in food from accepted uses that do not result from adulteration or misuse. This includes expected levels from the environment, food processing, packaging materials, residues from the legitimate use of triazine pesticides or veterinary drugs, and legitimate use of melamine in fertilizers or cyanuric acid in feed additives. However, the intentional addition of melamine and/or analogues directly to food, food ingredients, animal feed, feed ingredients or pelletizing agents is not acceptable. It may also be present indirectly in foods of animal origin as a result of carryover from the intentional addition to animal feed, therefore, there is an urgent need to detect melamine in foods (Sivaraman, 2007; Varelis, 2008). In particular, it was discovered that melamine-contaminated ingredients had been used to prepare feed for chickens and fish. A preliminary study at Sultan Qaboos University demonstrated that various levels of melamine were found in poultry meat (Unpublished data).

7. Mycotoxins

One of the most dangerous pollutants of food-stuff is fungi and their metabolites – mycotoxins, which can cause myocotoxicosis. Myoctoxins are found on many plant products, particularly oilseeds and cereals. These substances are characterized by acute and chronic toxic properties, while some of them are potent carcinogens. Although animals are an effective toxin eliminator (Stoloff, 1979), residues of mycotoxin can still be present in animal tissue. The carcinogenic potential of aflatoxins B1 is the highest. Aflatoxins are stable, heat resistant compounds and can be found in animal tissue.

8. Genetically modified products

Plant food produced through genetic engineering, in an aim to produce desirable traits, have reached the consumer markets. After 12 years of commercialization of biotech crops, the global area of planted biotech crops has increased more than 80-fold, from 1.7 million hectares in 6 countries in 1996, to 143 million hectares in 23 countries in 2007 (Magana and Calderon, 2008). The most cultivated genetically modified plant is the soybean, which represents the staple constituent of many processed meat and fish products. Soybean meal is also the main source of protein in livestock diets. In meat and fish products, soy proteins are widely used in emulsified products due to their unique functional properties such as water binding, fat binding, texture and emulsifying capability and organoleptic features such as appearance, firmness and slicing characteristics (Belloque *et al*., 2002). For a successful solution for the problem of quality and safety of genetically modified products in the Sultanate, there needs to be methods in place to detect components in products.

Detection, evaluation and determination techniques and equipment

Rapid, sophisticated, reliable and versatile screening methodologies are critical to detect contaminants in various meat and fish products, but current detection methods may require several days to produce results. The most reliable and accurate procedures will be recommended to set up a national monitoring program and sampling. This will contribute to a sensible reduction in the number of contaminates in meat and fish products. The availability of simple and useful screening techniques is invaluable for effective control. The following techniques will be used:

1. Immunological Techniques

These methods are based on the interaction antigen-antibody which is very specific for a particular residue. The most common technique is enzyme-linked immunosorbent assay (ELISA). ELISA kits are available for a specific residue such as sulpametazine or a group of related compounds such as sulphonamides. ELISA kits have shown good performance for the analysis of antibiotic residues in meat (de Wasch *et al*., 2001; Lee *et al*., 2001; Gaudin *et al*., 2003; Cooper *et al*., 2004; Huet *et al*., 2005; Wang *et al*., 2006; Mahgoub *et al*., 2006; Kadim *et al*., 2009).

2. Biosensors

Different types of biosensors have been developed in recent years as an alternative approach to screen residues in animal products (Akkoyum *et al*., 2000; Grundig and Renneberg, 2002; Franek and Hruska, 2005; Haughey and Baxter, 2006; Reig and Toldra, 2008).

3. High Performance Liquid Chromatography (HPLC)

HPLC allows the qualitative and quantitative detection of multi-residues in meat and fish products (Haagsma, 1985; De Bukanski *et al*., 1988; Degroodt *et al*., 1989, 1991; Van Poucke *et al*., 1991; De Brabender *et al*., 1992; Gaugain and Abjean, 1996).

4. Charm II Technology

Charm II technology is a new technique which is rapid, comprehensive and semi-quantitative testing system capable of detecting residual compounds. This technology can provide the desired selectivity and sensitivity. The use of Charm II along with HPLC separation provides an excellent method for the detection and identification of individual chemical and biological residues in animal tissue.

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