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Toxic Elements in Animal Products and Environmental Health

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ABSTRACT

In the higher organisms, the intake of trace elements occurs mainly through the respiratory system or through the food chain. Particularly, many dangerous elements or compounds, such as metals accumulate along the food chain. In this way, the food chain becomes the main gateway for persistent toxicants to enter higher organisms. Furthermore, these toxic elements generally have an anthropogenic origin and thus their concentrations in the environment grow with the increase of urban, agricultural and industrial emissions. With increasing environmental pollution, a toxic metal exposure assessment study is necessary. Toxic elements are not metabolized at all. Some metals irreversibly are bound to body tissues, e.g., lead to bone or cadmium to kidneys. This review updates the information on carry-over of toxic substances from feed to food of animal origin (meat, organs, milk and eggs). The control of environmental contaminants that may cause residues in food of animal origin is sometimes quite difficult and expensive and is addressed with special attention in this review.

Key words: Animal products, toxic elements, environmental health

INTRODUCTION

During recent years, there has been considerable concern over the extent of contamination of the environment with toxic elements and their relationship to health of the public. The toxic elements such as, arsenic (As), cadmium (Cd), lead (Pb) and mercury (Hg) are generally regarded as accidental contaminants although, they are frequently found in minute amounts in the newborn (Underwood, 1977) and these elements have a significant threat to people's health. They can produce neurotoxic, nephrotoxic, carcinogenic effects, they impair the functioning of cardiovascular system, bone structure, they penetrate the blood placenta barrier. They accumulate in the organism-lead mainly in bone tissue, cadmium-in the cortical tissues of kidneys and in the liver, methyl-mercury compounds-in the cerebral tissue. The noticeable symptoms of their toxic effect at little exposure do not appear at once, but after many months or even years (e.g., carcinogenic effect) or generations (mutagenic effect). However, the early changes can be observed only at the physiological or biochemical levels (Wojciechowska-Mazurek *et al.*, 2003).

An important feature of toxic elements is that the chemical form in which they are present may change during passage through the intestine or storage in animal tissue, but they are not metabolized (Kan and Meijer, 2007). These elements are translocated through the food chain to man and animals. Their toxicity depends on the chemical form of the element administered to the animal, the dosage, the route of administration and the frequency and duration of administering the element to the animal (Gough and Shacldette, 1976). Michael and Buck (1987) indicated that excessive amounts of elements in animal feed and feedstuffs are often due to human actions. They result from either agricultural or industrial production or through accidental or deliberate misuse.

The concentration of these toxic elements in animal tissues depends mainly on the dietary concentration of the element, absorption of the element, concentration of other tissue elements, homeostatic control mechanism of the body for the element and the species of animal involved (Underwood, 1977).

TOXIC ELEMENTS AND ENVIRONMENTAL HEALTH

In general, potential food exposure routes of toxic elements include ingestion of fish and shellfish, meat and game, dairy, eggs and vegetables (USEPA, 1989). Studies by Vreman *et al.* (1986) and Kreuzer *et al.* (1981) showed clearly that muscle and milk are not likely to show high levels of toxic elements when animals are exposed via the diet. Liver and kidney, on the other hand, often show a clear dose-response related increase in toxic elements concentration after dietary exposure. Muscles, liver and kidneys of farm animals and milk, eggs and honey show big diversity of the content of Cd, Hg, Pb and other toxic elements, from trace amounts to quantities exceeding several times the physiological values (Krelowska-Kula, 1993). Exposure of livestock to either high levels of toxic elements or less than optimal levels of the essential microelements can engender adverse effects such as reproductive impairment, physiological abnormalities, behavioral modifications or even death. Toxic elements accumulated in livestock can be passed on to people who consume the meat and can become a health hazard to the public. Kidney and liver constitute a special dilemma in that they have a propinquity to bioaccumulate toxic elements such as Pb, Cd, Hg and As but can also serve as a rich source of essential microelements (notably Fe, Cu, Zn and Se) in human diet (Nriagu *et al.*, 2009).

Heavy metals, such as mercury, cadmium and lead, as they represent a group of highly toxic substances accumulating in the tissues of marine organisms and being conveyed through the food chain to human. Reports from literature suggest that these toxicants are responsible of hazardous effects on human health (Aschner, 2002).

In the last years, the health benefits related with seafood consumption have been extensively publicized. Seafood is rich in protein, contains low cholesterol and high percentage of (3%) polyunsaturated fatty acids, liposoluble vitamins and essential minerals (Adeyeye, 2002). Fish are the major part of the human diet because fish have low risk of coronary heart disease, hypertension and cancer. Fish also have been popular targets of toxic element monitoring programs in marine environments because sampling, sample preparation and chemical analysis are usually simpler, more rapid and less expensive than alternative choices such as water and sediments (Rayment and Borry, 2000). Fish being at the higher level of the food chain accumulate large quantities of these xenobiotics and the accumulation depends up on the intake and the elimination from the body (Karadede *et al.*, 2004). Increased industrialization and conventional agricultural activities contribute to their increased levels in the natural waters (Whalberg *et al.*, 2001). However, the accumulation of heavy metals in fish and other aquatic lives is of great importance to man as fish is consumed by a large section of the population. Toxic element accumulation in different species of fish depends on the feeding habits, size and length of the fish (Al-Yousuf *et al.*, 2000) and more particularly their habitat (Canli and Atli, 2003). Among the different aquatic lives clams and mussels accumulate large quantities of toxic elements due to their habitat and feeding habits.

THE MOST FAMILIAR TOXIC ELEMENTS

Heavy metal toxicity is one of the major current environment health problems and potentially dangerous due to bioaccumulation through the food chain (Aycicek *et al.*, 2008).

Mercury: Mercury is among the most highly bioconcentrated neurotoxicants and is ubiquitously existing in the environment. It is toxic to animals organ systems, especially the central nerve system (Lebel *et al.*, 1998). The toxicity of mercury is associated with its chemical form: elemental, inorganic and organic. The organic form, usually methylmercury (MeHg) is more hazardous than both other forms. Both forms of mercury, inorganic and organic, are found in food. The level of mercury in foods is inconsistent and reflects the level of pollution of the local environment (Dudka and Miller, 1999). Alkylmercury compounds tend to accumulate in skeletal muscles and brain, whereas aryl compounds and inorganic mercury salts accumulate in liver and kidneys (Michael and Buck, 1987).

Lead: Lead is the non-essential trace element. It has been known for a long time that lead is toxic to the brain, kidneys and reproductive system and can also cause impairment in intellectual functioning, fertility, miscarriage and hypertension. Since lead tends to accumulate in bone, teeth, hair, blood and urine, humans, particularly the unborn, newborn and children, are exposed to health risks. In children, lead toxicity causes mostly irreversible damage to the brain and hinders the body's defense mechanism. Several studies have shown that lead exposure in school-age children can significantly reduce their IQ and has been associated with aggressive behavior, delinquency and attention disorders. In adults, lead exposure has been related to increased blood pressure and hypertension, conditions known to increase the risk of cardiovascular disease (Kaplan and Yaman, 2009). Michael and Buck (1987) state that: Foods of animal origin do not usually have excessive lead concentrations. Animal tissues with the highest concentrations are liver, kidney and bone and lead concentrations in milk are usually much lower than blood levels. In the opinion of many authors (Krelowska-Kula, 1993) ruminants are the domestic animals that are most sensitive and more frequently exposed to greater doses of lead (Ministry of Health and ESR, 1995). Lead has been implicated by Boeckx (1986) in inhibiting heme synthesis and in decreasing red cell survival, in carcinogenicity (Gaffey and Cooper, 1980) and in nucleic acid destabilization by Farkas (1975).

Cadmium: Particularly, amongst the heavy metals, cadmium is caused increased international concern because its toxicity is generally considered to be much higher than those of other heavy metals (Aycicek *et al.*, 2008). Cadmium is considered potential carcinogen and is associated with etiology of a number of diseases, especially cardiovascular, kidney, nervous system, blood as well as bone diseases (Jarup, 2003). Depending on food origin, contaminants like Cd may be present in food in considerable amounts (Nriagu and Pacyna, 1988). Contaminating elements are known to interact with homeostatically regulated kinetics of essential trace metals and consequently, their absorption may increase in deficiency states for essential metals. In other cases, a contaminating element may decrease the absorption of an essential metal and be part of a vicious cycle to increase its own absorption, as can be exemplified for Cd (Flanagan *et al.*, 1978). Thus information about toxic element concentration, such as Cd, in food products and their dietary intake is very important for assessing their risk to human health (Zhuang *et al.*, 2009).

Arsenic: Arsenic occurs naturally in the earth's crust and is widely distributed in the environment. Natural mineralization and activities of microorganisms enhance arsenic mobilization in the environment but human intervention has exacerbated arsenic contamination. Although, arsenic is useful for industrial, agricultural, medicinal and other purposes, it exerts a toxic effect in a variety of organisms, including humans. Arsenic exposure may not only affect and disable organs of the body, especially the skin, but may also interfere with the proper functioning of the immune system (Duker *et al*., 2005). Arsenic (e.g., As^{3+}) can be toxic through its interaction with sulfhydryl groups of proteins and enzymes to denature the proteins and enzymes within the cells (Gebel, 2004) and through an increase of reactive oxygen species in the cells, consequently causing cell damage (Ahmad *et al*., 2000). Consequently, potential public health risks from dietary exposure to these pollutants continue to be the subject of must research, regulation and debate.

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