

Food Safety Issues Across the Food Chain and the Contaminants Involved

Joyce Wangeci Wanjiru and Lucy Gichuku Njue

Abstract
Variety of food contaminants, toxicants and adulterants have been found to be responsible for certain health challenges such as poor utilization of nutrients upon consuming contaminated foods which ultimately results in the deficiency of essential nutrients required by the body. Sequel to this, several food borne disease outbreaks and problems of ill health in humans and animals have gained wide international recognition. Majority of food contamination occurs through naturally occurring toxins and environmental pollutants or during processing, packaging, preparing, storage, and transportation of food. At normal levels of food consumption, there is little potential for toxicity from natural food toxins. Nevertheless, there is always the possibility of an idiosyncratic response of undetected contamination. As technology advances, the detection of such contaminants becomes easier. However, there are several contaminants that are still unknown. This review provides current insight on the effects elicited by food contaminants on the body's ability to utilize nutrients upon consuming contaminated foods.
Keywords: Contaminants, Nutrients, Health Hazards, Food, Toxicants, Health hazards.
DOI: 10.7176/FSQM/118-04
Publication date: August 31st 2022

1. INTRODUCTION

Food is classified as a very crucial contributor to well-being and health where it contain compounds known as nutrients, which are essential to life and health, providing us with energy, the building blocks for repair and growth and substances necessary to regulate chemical processes [1]. Generally, nutrients are classified as either macro or micronutrients, based on the amounts we require from the diet [2]. Some nutrients can be stored (e.g., glucose as glycogen in the liver, fat-soluble vitamins in fat reserves) while others are required more or less continuously [3]. In recent decades, our need for a broad spectrum of non-nutrients, phytochemicals, has also been recognized [3]. These non-nutrients (bioactives) are not essential for life in ways that macro or micronutrients are, but nonetheless have putative health benefits and, whether acting directly or indirectly, diets rich in these compounds significantly reduce our risk of chronic disease, including cancer and cardiovascular disease. We also require dietary fiber, non-digestible materials, such as cellulose, to support gut function (mechanical) and a healthy microbial population (prebiotics) [4].

Intricate biochemical processes extract the energy and other useful components from food that enable us to grow and function, and many compounds that were seemingly unimportant in the past are now accepted as being fundamental for health [5]. There are three macronutrients – carbohydrates, fats, and proteins [2]. They provide 'structural materials' (e.g., amino acids, lipids) and energy (joules or kilocalories). When necessary, or as a result of disease, proteins can be broken down to generate energy, but carbohydrates and fats are used preferentially for energy [3]. Virtually all nutrients from the diet are absorbed into blood across the highly polarized epithelial cell layer forming the small and large intestinal mucosa before they metabolized [4].

Food contamination has become as a serious challenge in our society today as it has been associated with numerous diseases that lay threat to human health. Majority of the food contamination occurs through naturally occurring toxins and environmental pollutants or during the processing, packaging, preparing, storage, and transportation of food [4]. Food preparation undergoes a long chain of processing, where each stage is a potential source of chemical contaminants invasion of the food [5]. Transportation of food can also lay the foundation for contamination of food, specifically under poor sanitary conditions [6]. Likewise, some chemicals are mixed deliberately during the food preparation process to improve the shelf life of a food product. The contaminants may include food impurities that come in contact with foods when cooked in the kitchen; nevertheless, the transmission is mainly dependent on the effectiveness of the kitchen hygiene though [7]. Contaminants enter the food chain naturally as well with pathogens that are present in the environment and show high bacterial numbers on some key raw foods such as poultry meat [8]. Packaging materials can lead to chemical contamination due to the migration of some harmful substances into foods. Furthermore, use of unapproved or erroneous additives may result in food contamination [5].

2. FOOD CONTAMINANTS

Food contaminants include environmental contaminants, food processing contaminants, unapproved adulterants and food additives, and migrants from packaging materials [9]. Environmental contaminants are impurities that are either introduced by human or occurring naturally in water, air or soil. Food processing contaminants include those undesirable compounds, which are formed in the food during baking, roasting, canning, heating, fermentation, or hydrolysis [10]. With several agents like viruses, bacteria, toxins, parasites, metals, and other chemicals causing food contamination [11], the symptoms of the food borne illness due to food contamination range from mild gastroenteritis to fatal cases of hepatic, renal, and neurological syndromes. The classes of food contaminants are as follows:

2.1 Heavy Metals

Heavy metals are chemical pollutants that may have harmful effects on human health [12]. These pollutants are stable and are not decomposed by biological processes. They can find their way into the human body through inhalation, oral, and dermal routes [13]. Their multiple industrial, domestic, agricultural, medicinal and technological applications have led to their wide distribution in the environment; raising concerns over their potential effects on human health and environment [14]. Below are some examples heavy metals that pose threat to human health:

2.1.1 Selenium

Selenium (Se) enters the food chain via plant and microorganism conversion of inorganic selenium to organically bound forms [15]. Selenium toxicity (*i.e.*, selenosis), caused by excessive selenium intake, has occurred on a large scale in seleniferous regions in China as the result of increased consumption of selenium-containing foods (approximate daily intake of 3–6.5 mg Se/day) [14]. The most common symptoms of selenosis are loss of hair, deformity, and loss of nails. Other reported symptoms include increased blood selenium levels, diarrhea, fatigue, a garlic-like odor of the breath and bodily secretions, irritability, peripheral neuropathy, and skin lesions [15]. Selenium intake levels that cause selenosis have not yet been well defined. Studies in China suggest that approximately 3–5mg/day (0.05–0.08 mg/kg/day) will cause selenosis.

2.1.2 Methyl Mercury

Exposure to elemental mercury is relatively rare, although was once an occupational disease of hat manufacturers as elemental mercury was used for the curing of animal pelts. Inhalation of the mercury fumes led to mental deterioration and subsequently named ―mad hatter syndrome [13]. Of interest to food toxicology, is the methyl derivative, methyl mercury, formed by bacterial action in an aquatic environment from anthropogenic and natural sources of elemental mercury. Anthropogenic sources include burning of coal (which contains mercury), chloralkali process and other sources of elemental mercury into aquatic environments. Methyl mercury exposure may cause neurological paresthesias, ataxia, dysarthria, hearing defects and death [16].

2.1.3 Lead

Lead (Pb) since the phasing out of leaded gasoline, major sources of high Pb exposure are Pb and drinking water contaminated from Pb pipes or brass fixtures, which may contain up to 8% of this metal. However, lead also persists in the environment, including soils that food crops are grown on, and food appears to be the major source of Pb exposure. Local Pb contamination of pastures can result in considerable contamination of meat and milk, and fish generally also contain high Pb concentrations [17]. The extent of gastrointestinal Pb absorption depends on nutritional status, with iron deficiency resulting in increased and calcium supplementation in decreased Pb absorption. Age is another factor that influences Pb absorption. The primary target of lead toxicity is the central and peripheral nervous system [18]. In adults, this most commonly manifests as peripheral neuropathy involving extensor muscles, but not sensory nerves. The developing brain is much more susceptible to the neurotoxic effects of Pb than the adult brain [19].

2.2 Naturally Formed Substances

2.2.1 β–Thujone

Thujone, a monoterpene ketone, is the primary constituent of essential oils derived from a variety of plants, including sage (*Salvia officinalis*), clary (*Salvia sclarea*), tansy (*Tanacetumvulgare*), wormwood (*Artemisia* spp. and white cedar (*Thujaoccidentalis*L.) [20]. Essential oils from these plants are used in herbal medicines, as flavorings in alcoholic drinks and fragrances throughout the world. Thujone is potentially toxic and the presence of alpha- or beta-thujone in food and beverages. Both alpha- and beta-thujone act as noncompetitive blockers of the gamma-aminobutyric acid (GABA)-gated chloride channel [21]. Thujone is believed to be the toxic agent in absinthism, a syndrome produced by the chronic use of absinthe, made from the essence of wormwood. The syndrome is characterized by addiction, hyperexcitability and hallucinations [21].

2.2.2 Erucic Acid in Rape

Rape (*Brassica napus*L. or *Brassica campestris* L.) is an annual herb of the mustard family native to Europe and is grown in the United States because it produces oil-rich seeds for cooking oil [22]. Rapeseed oil had been used for hundreds of years as oil for lamps and more recently as machine oil lubricant. Widespread use of rapeseed oil as a food ingredient was not considered until the late 1940s and 50s. However, early studies found that feeding high levels of rapeseed oil to rats significantly increased cholesterol levels in the adrenal glands and lipidosis in the cardiac tissue [22]. Erucic acid is a long-chain fatty acid with one unsaturated carbon-carbon bond (C22:1).

High levels of erucic acid have been liked to fatty deposit formation in heart muscle in animals [23]. Erucic acid is poorly oxidized by the mitochondrial β-oxidation system, especially by the myocardial cells, which results in an accumulation of erucic acid, producing myocardial lipidosis which has been reported to reduce the contractile force of the heart [23].

2.3 Industrial Chemicals

2.3.1 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are known carcinogens that are formed from the incomplete combustion of fossil fuels such as wood, coal and oil. PAHs can enter the food chain from environmental contamination or from food processing. Foods containing the highest concentrations of PAHs include cooked or smoked meat or fish, smoked or cured cheese, tea and roasted coffee. Grilling or broiling of meat, fish or other foods over intense heat or direct contact with flames promotes production of PAHs. In general, concentrations of PAHs in meat are highest after charcoal grilling, followed by smoking, roasting and steaming. Concentrations of PAHs in smoked foods are influenced by temperature, type of wood, oxygen concentration and type of smoker. Concentrations of PAHs in tea dried over burning wood, oil or coal are generally higher than in tea dried over air, and coffee beans that are roasted over a direct fire contain higher concentrations than beans that do not come in contact with flames [24].

2.3.2 Heterocyclic Aromatic Amines

There are two major classes of heterocyclic aromatic amines (HAAs). Pyrolytic HAAs are formed from the pyrolysis of amino acids or proteins at high temperature and aminoimidazoarenes (AIAs) are formed from creatine, free amino acids and monosaccharides, via the Maillard reaction. HAAs are present in many protein-rich foods of animal origin including cooked meat, fish, poultry and gravies and sauces derived from pan residues and scrapings of cooked meats. The formation and yield of HAAs are dependent on cooking temperature and time (concentrations increase with higher temperatures and longer cooking times), cooking technique and equipment (concentrations of HAAs in meat are generally higher after grilling and panfrying than broiling or roasting), and the ability of HAA precursors to migrate to the surface [25]. Several HAAs are carcinogenic in rodents after long-term dietary administration. The doses required to induce tumors at a 50% rate (TD50) vary for each HAA, and range from 0.1 to 64.6 mg/kg bw/day [25]. Due to the fact that exposure to HAAs in cooked meats is highly variable (concentrations in cooked meat may range from <1 to 500 ng/g), it has been estimated that the risk of developing cancer from exposure to HAAs in food is anywhere from 50 in one million to one in a thousand [25].

2.4 Pesticides

Pesticides are a numerous and diverse group of chemical compounds, which are used to eliminate pests in crop yields and households [18]. They are significantly used as an input in modern agriculture and are used for management of controlling the pests that are noxious, destructive or troublesome organisms. The Application of these pesticides to crops may leave residues in or on food, and those specified derivatives are considered to be of toxicological significance [19]. This has been a matter of serious concern as the presence of pesticides residues in fruits are consumed fresh. These bioaccumulative or Persistent chemicals can be magnified through the food chain and have been detected in products ranging from meat, poultry, and fish, to vegetable oils, nuts, and various fruits and vegetables [16]. Exposure of the general population to these residues most commonly occurs through consumption of treated food sources, or being in close contact to areas treated with pesticides such as farms or lawns around houses [26]. This exposure is strongly associated with acute and chronic health effects in humans. However, total elimination of the use of pesticides is not possible even though it would be preferable. Based on chemical classification, pesticides are classified into four main groups namely; organochlorines, organophosphorus, carbamates and synthetic pyrethriods [27].

2.5 Pharmaceuticals and Personal Care Products

The term pharmaceuticals and personal care products (PPCPs) includes a wide range of substances that may enter the environment and thence food or water sources. Antimicrobials and other drugs may originate from use in both humans and animals. For example, swine waste containing antimicrobials may contaminate both water and food [29]. Aside from the very real threat of increased antimicrobial resistance through exposure to extraneous sources of these chemicals, it has also been shown that many drugs have other side effects including endocrine disruption [30]. In some circumstances, the medicinal products themselves may be contaminated, for example, in many herbal products [31].

2.6 Electronic Waste

Modern society has become encumbered with many electrical devices, and electronic waste (or e-waste) has become a major problem. Inappropriate processing, for example, incomplete combustion, of such products releases a variety of pollutants covered above, including PBDEs, dioxins/furans (PCDD/Fs), PAHs, PCBs, and metals/metalloids [32]. In addition, contamination from such devices can enter drinking water and food.

2.7 Plastics

In recent times, we rely more and more on packaging materials—in particular plastics—to transport and help preserve food. These materials are not inert and may themselves contaminate food and drinks as multiple chemicals are released into foods and beverages from food contact materials. These are termed "migrants" and include such chemicals as phthalate plasticizers which have been detected in bottled water [33]. Factors such as higher storage temperatures and prolonged contact time with the packaging were linked to higher levels of contamination, but a health risk assessment showed that the risk for consumers was low [33].

2.8 Nanoparticles

Another recent development is that of nanoparticles. These have one dimension less than 1 x 10−7m, and engineered nanoparticles have been used in a wide range of products, such as paints, cosmetics, and pesticides [34]. Pathways and effects of these in biota are as yet unclear, but they have been shown to travel in the food chain [35]. Nanosized materials have been detected in foods such as wheat-based products [36].

2.9 Radioactive Elements

Most radioactive elements did not exist naturally, and soil contamination with such material has only become a problem since nuclear weapons and reactor shave been developed (Walker and Don, 2013). After tsunami damage affected the Fukushima nuclear plant in Japan in 2011, monitoring of food and water samples detected contamination above provisional regulation values and restrictions were put in place [37]. Radionucleotides have also been detected in seafood in India, various foods in the Balkans, and food and drinking water in Switzerland [38]. Risk assessments are conducted to ensure that levels remain within acceptable limits. Furthermore, experimental models are undertaken to assess safety in ingestion pathways, considering several different food intakes [39]. In the US, there is an FDA rule pertaining to uranium, radium, alpha particle, beta particle, and photon radioactivity in bottled water [40].

3.0 BIOCHEMICAL MECHANISMS WHICH CERTAIN FOOD CONTAMINANTS AFFECT NUTRIENT UTILIZATION BY THE BODY

The physico-chemical properties and structures of food contaminants determine their interactions with biomolecular targets. Partitioning into non-aqueous phases, e.g., membranes, occurs with almost any chemical in all organisms and it is the predominant process causing non-specifictoxicity. Additional interactions with specific targets, e.g., enzymes, may produce increased toxicity. Mode of action is, however, not a constant property of a compound but it varies between species and may change with concentration and duration of exposure. Chemicals may act by the same mode in some organisms but by dissimilar modes in others, depending on the abundance of specific targets and the particular end point measured by experiment.

3.1 Lectins

Lectins are a group of glycoproteins that are present in high levels in legumes (e.g., black beans, soybeans, lima beans, kidney beans and lentils) and grain products (Fig 2) [43]. Lectins can reversibly bind to carbohydrates without altering their covalent structure (Fig 1) [43]. The ability of lectins to bind and agglutinate red blood cells is well known and used for blood typing hence, the lectins are commonly called hemagglutinins. Lectins also can bind avidly to mucosal cells and interfere with nutrient absorption from the intestine [41].

Because the ability of the lectins to cause intestinal malabsorption is dependent on the presence of enteric bacteria, it has been hypothesized that lectins may also produce toxicity by facilitating bacterial growth in the GI tract [43]. Lectins isolated from black beans can produce growth retardation when fed to rats at 0.5% of the diet, and lectin from kidney beans causes death within two weeks when fed to rats at 0.5% of the diet. Soybean lectin produces growth retardation when fed to rats at 1% of the diet. The castor bean lectin ricin (one of the most toxic natural substances known) is notorious for causing deaths of children, and has been used as an instrument of bioterrorism (Fig 2) [41].

Phytohaemagglutinin (PHA) is a lectin found in significant quantities (as much as 2.4–5% of total protein) in legumes such as red or white kidney beans, green beans and fava beans (Fig 2). PHA has a number of different properties, including the ability to induce mitosis, affect membrane transport and permeability to proteins, and agglutinate red blood cells. Rats fed a diet containing 6% PHA exhibit weight loss, associated with malabsorption of lipid, nitrogen and vitamin B12 [42]. PHA from red kidney beans inhibits sodium and chloride absorption in the rabbit ileum, indicating that PHA can affect electrolyte transport in the gut [42]. Symptoms of toxicity to PHA in humans such as nausea, vomiting, or diarrhea occur within three hours of ingestion. Recovery generally occurs within four or five hours of onset [40].

3.2 Rhubarb and Oxalic Acid

Oxalic acid (oxalate) is generally found in rhubarb (0.2–1.3%), tea (0.3–2.0%), spinach (0.3–1.3%), parsley (1.7%) and purslane (1.3%), but may also be found in asparagus, broccoli, Brussels sprouts, collards, lettuce, celery, cabbage, cauliflower, turnips, beets, peas, coffee, cocoa, beans, potatoes, berries, and carrots [42]. Oxalic acid is an organic acid that can bind calcium and other minerals, making them insoluble and decreasing their bioavailability. Ingestion of foods containing high concentrations of oxalates may cause decreased bone growth, kidney stones, renal toxicity, vomiting, diarrhea, convulsions, coma and impaired blood clotting [43]. Because cooking does not remove oxalate, and mineral complexes with oxalate are insoluble in water, oxalates are somewhat difficult to remove from foods. Therefore, diets rich in oxalate-containing foods should be supplemented with minerals such as calcium or potassium to prevent deficiencies. Limits on oxalic acid have been cited in ferric ammonium ferrocyanide and ferric ferrocyanide when used as color additives (21 CFR 73.1298 and 21 CFR 73.1299) with oxalic acid or its salts at not more than 0.1% of the colorant [44].

3.3 Phytates and Phytic Acid

Phytic acid (also referred to as phytate) is found in bran and germ of many plant seeds and in grains, legumes and nuts. Phytic acid is a simple sugar (myo-inositol) containing six phosphate side chains, and as such, is a dietary source of phosphorus and an effective chelator of divalent cations such as zinc, copper, iron, magnesium and calcium [45]. Studies indicate that phytate-mineral complexes are insoluble in the intestinal tract, reducing mineral bioavailability [43]. Phytate also has been shown to inhibit digestive enzymes such as trypsin, pepsin, α-amylase and ß-glucosidase. Therefore, ingestion of foods containing high amounts of phytate could theoretically cause mineral deficiencies or decreased protein and starch digestibility [45]. Vegetarians that consume large amounts of tofu and bean curd are particularly at risk of mineral deficiencies due to phytate consumption. Because phytate-rich foods are digested at a slower rate and produce lower blood glucose responses than foods that do not contain phytate, it has been hypothesized that phytate could have a therapeutic role in management of diabetes [42]. It also may have utility as an antioxidant [46]. However, because the beneficial effects of phytate are outweighed by its ability to cause essential mineral deficiencies, consumption of a diet containing high amounts of phytate is not recommended (Fig 1). Food manufacturers are developing methods to reduce phytate in foods, such as addition of the microbial phytase, which releases phosphates from the inositol backbone of phytate [47].

3.4 Hypoglycin in Ackee

Ackee is the national fruit of Jamaica and is also found in other Caribbean nations, Central America, South American and southern Florida [48]. Consumers of the unripe fruit sometimes suffer from Jamaican vomiting sickness syndrome allegedly caused by the alkaloids hypoglycin A (HGA) and B. Levels of HGA in the opened, ripe fruit are undetectable, making opened fruit safe for consumption [49]. The hypoglycin toxin (L-methylenecyclopropylalanine) inactivates several flavoprotein acyl-CoA dehydrogenases, causing disturbances of the oxidation of fatty acids and amino acids [40]. This leads to a secondary inhibition of gluconeogenesis which can precipitate an extreme, dangerous drop in blood-glucose levels (hypoglycemia) that can be fatal. Symptoms of poisoning from unripe ackee fruit occur within 6 to 48 hours of ingestion and include drowsiness, repeated vomiting, thirst, delirium, fever or loose bowels. Exhaustion of the muscular and nervous systems, collapse, coma, and death may ensue [50].

3.5 α-Amylase Inhibitors

Naturally occurring inhibitors of α-amylase are found in aqueous extracts of wheat, rye and kidney beans. The physiological role of α-amylase inhibitors in plants is not well understood, but may protect them against insect infestation. In mammals, some amylase inhibitors have been shown to attenuate the normal increase in blood glucose that occurs after ingestion of starch. However, since α-amylase inhibitors have been shown to be inactivated by gastric acid, pepsin or pancreatic proteinases, their potential as starch blockers is limited (Fig 3) [42]. α-amylase inhibitors were once added to foods as ―starch blockers to limit carbohydrate absorption for the purpose of weight loss; however, the FDA later determined that at least this use of α-amylase inhibitors was as drug, and they were consequently taken off the market [51].

4. CONCLUSION

Food contaminants have been found to be associated with inefficient absorption of nutrient molecules by the body system especially naturally formed food contaminants. They do so via different biochemical mechanisms, preventing the efficient absorption of nutrient molecules like mineral elements, vitamins, lipids, amino acids and carbohydrates by targeting and inhibiting certain digestive enzymes and/or altering some basic biochemical pathways ultimately leading to numerous health challenges. Much is yet to be uncovered regarding the mechanisms by which many food contaminants alter nutrient utilization by the body system as research in this area is still ongoing.

CONFLICTS OF INTERESTS
None of the author has the interest of conflict

REFERENCES

Wilcock A., Pun M., Khanona J, Aung M. Consumer attitudes, knowledge and behaviour: a review of food safety issues. Trends Food Sci. Technol. 2004;15:56–66.

Gibney MJ, Lanham-New SA, Cassidy A, Vorster HH. Introduction to Human Nutrition (The Nutrition Society Textbook), second ed. Wiley-Blackwell. 2009.

Halliwell B, Gutteridge J. Free Radicals in Biology and Medicine, fourth ed. OUP, Oxford, UK. 2007.\

Totelin L. When foods become remedies in ancient Greece: the curious case of garlic and other substances. J. Ethnopharmacol. 2015;167:30–37.

Ingelfinger J. Melamine and the global implications of food contamination. N. Engl. J. Med. 2008;359:2745–2748.

Unnevehr L. Food safety issues and fresh food product exports from LDCs. Agric. Econom. 2000;23:231–240.

Gorman R, Bloomfield S, Adley C. A study of cross-contamination of food-borne pathogens in the domestic kitchen in the Republic of Ireland. Int. J. Food Microbiol. 2002;76 143–150.

Humphrey T, O'Brien S, Madsen M. Campylobacters as zoonotic pathogens: a food production perspective. Int. J. Food Microbiol. 2007;117:237–257.

Mastovska K. Modern Analysis of Chemical Contaminants in Food. Food Safety Magazine. Available online at: http://www.foodsafetymagazine. com/magazine-archive1/februarymarch-2013/modern-analysis-of-chemicalcontaminants- in-food. 2013.

Schrenk D. Chemical food contaminants. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2004;47:841–877.

Callejón R, Rodríguez-Naranjo M, Ubeda C, Hornedo-Ortega R, Garcia- Parrilla M, Troncoso A. Reported foodborne outbreaks due to fresh produce in the United States and European Union: trends and causes. Foodborne Pathog. 2015;12:32–38.

Zhema PA, Abah MA, Emochone RY, Okoli EC, Saaku SA, Habibu B. Investigation of Trace Metal Contamination In Bread Baked and Sold In Wukari.Global Scientific Journals; 2022;10(2):2076-2084.doi: 10.11216/gsj.2022.02.60325

Gürbay A., Charehsaz M., Eken A., Sayal A., Girgin G., Yurdakök M., Yiğit Ş., Erol D.D., Şahin G., & Aydın A (2012). Toxic metals in breast milk samples from Ankara, Turkey: assessment of lead, cadmium, nickel, and arsenic levels. Biol Trace Elem Res. 2012;149(1):117–122.

Pashmi K, Pourkhabbaz A. Accumulation of toxic metals of cadmium and lead in the deciduous teeth of children. J Birjand Univ Med Sci. 2012;19:96–105.

Sors TG, Ellis DR, Salt DE. Selenium uptake, translocation, assimilation and metabolic fate in plants. Photosynth. Res. 2005;86:373–389.

Okoli, EC, Otitoju O, Abah, MA, Ozioma, PE, Bando, DC, Zephaniah, HS. Ecological risk assessment of pesticide residues in fish samples from river donga in Donga, Taraba state, nigeria. International Journal of Biochemistry, Bioinformatics and Biotechnology Studies. 2021;6(2):1-8. https://doi.org/10.37745/ijbbbs.15

Llobet JM, Falcó G, Casas C, Teixidó A, Domingo JL. Concentrations of arsenic, cadmium, mercury, and lead in common foods and estimated daily intake by children, adolescents, adults, and seniors of Catalonia, Spain. J Agric Food Chem. 2003;51:838–842.

Abah MA., Otitoju O, Okoli EC, Ozioma PE, Bando DC, Zephaniah HS. Determination of selected pesticide residues in leafy vegetables (Amaranthus spinosus) consumed in Donga, Taraba state. International Journal of Biochemistry, Bioinformatics and Biotechnology Studies. 2021;6 (2):9-16. https://doi.org/10.37745/ijbbbs.15

Otitoju O, Lewis CC. Health risk assessment of pesticide residues in bean samples from Wukari, Taraba State, Nigeria. Journal of Environmental Chemistry and Ecotoxicology. 2012; 13(1):1-13.

European Commission Scientific Committee on Food. Opinion of the scientific committee on food on thujone. 2003.

Patocka J, Plucar B. Pharmacology and toxicology of absinthe. J. Appl. Biomed. 2003;199–205.

United States Department of Agriculture (USDA). Plants Profile: *Brassica napus* L. 2010; Available online: http://plants.usda.gov/java/profile?symbol=BRNA.

International Agency for Research on Cancer (IARC). Summaries & Evaluations, 8-Methoxypsoralen (Methoxsalen) plus ultraviolet radiation. 2010.

Park JH, Penning TM. Polyaromatic Hydrocarbons (Part 2.8). In *Process-Induced Food* Toxicants. Occurrence, Formation, Mitigation, and Health Risks; 2009.

Turesky RJ (2009). Heterocyclic Aromatic Amines (Part 2.3). In Process-Induced Food
Toxicants. Occurrence, Formation, Mitigation, and Health Risks; 2009.
Stadler, R.H., Lineback, D.R., Eds.; John Wiley & Sons: Hoboken, NJ, USA. pp. 75–115.

Otitoju O, Abah MA, Otitoju GT, Okoli EC, Habibu B, Omajali PU. Risk Assessment of Pesticide Residues in Water Samples from river Gongola, Adamawa State. World Journal of Advanced Research and Reviews. 2022;13(01):424-432.

Stephen W.C., Chung., Benedict L.S., & Chen (2011). "Determination of organochlorine pesticide residues in fatty foods: A critical review on the analytical methods and their testing capabilities". Journal of Chromatography A. 2011; 1218 (33): 5555–5567.

Otitoju O, Abah MA, Otitoju GT, Yale FB, Okoli EC, Habibu B. Risk Assessment of Pesticide Residues in Soil Samples along River Gongola, Adamawa State. International Journal of Research Publication and Reviews. 2022;3(1):214-218.

He LY, Ying GG, Liu YS. "Discharge of swine wastes risks water quality and food safety: Antibiotics and antibiotic resistance genes from swine sources to the receiving environments," Environment International. 2016;92-93:210– 219.

Kabir ER, Rahman MS, Rahman I. "A review on endocrine disruptors and their possible impacts on human health," Environmental Toxicology and Pharmacology. 2015;40(1):241–258

Yakubu OE, Boyi RN, Shaibu C, Abah MA, Akighir J. Antioxidant parameters and GC-MS phytochemical analysis of Hymenocardia acida stem bark ethanolic extract. Trends Applied Sci. Res. 2019;14: 263-270.

Wong MH, Wu SC, Deng W. "Export of toxic chemicals - A review of the case of uncontrolled electronicwaste recycling," Environmental Pollution. 2007;149 (2):131– 140.

Zare M, Rastkari N, Ahmadkhaniha R, Yunesian M, Nabizadeh R, Daryabeygi R. "Amargin of exposure approach to assessment of non-cancerous risk of diethyl phthalate based on human exposure from bottled water consumption," Environmental Science and Pollution Research. 2015;22(24):19518– 19528.

Walker JS, Don GW. Mathematics and music. 2013;CRCPress, Boca Raton.

Kalman J, Paul KB, Khan FR, Stone V, Fernandes TF. Characterisation of bioaccumulation dynamics of three differently coated silver nanoparticles and aqueous silver in a simple freshwater food chain," Environmental Chemistry, 2015;12(6):662–672.

Gatti AM, Tossini D, Gambarelli A, Montanari S, Capitani F. "Investigation of the presence of inorganic micro- and nanosized contaminants in bread and biscuits by environmental scanning electron microscopy," Critical Reviews in Food Science and Nutrition. 2009;49 (3):275–282.

Hamada N. Ogino H, Fujimichi Y. "Safety regulations of food and water implemented in the first year following the Fukushima nuclear accident.," Journal of Radiation Research. 2012;53(5):641–671.

Carvalho FP, Oliveira JM. "Uranium isotopes in the Balkan's environment and foods following the use of depleted uranium in the war," Environment International. 2010;36(4):352–360.

Prohl G, Olyslaegers G, Kanyar B."Development and comparison of five site-specific biosphere models for safety assessment of radioactive waste disposal," Journal of Radiological Protection. 2005;25(4):343–373.

Food and Drug Administration. "Beverages: bottled water. Direct final rule," Federal register. 2003;68(41):9873–9882.

Omaye ST. Toxicity of Nutrients. In *Food and Nutritional Toxicology*; CRC Press: Boca Raton, FL, USA. 2004; pp. 205–213.

Deshpande SS. Food Additives. In *Handbook of Food Toxicology*; Marcel Dekker: New York, NY, USA. 2002; pp. 219–284.

Jones JM J. Food Safety; Eagan Press: St. Paul, MN, USA. 1995; pp. 71, 77, 84, 87.

Lowry N. Rhubarb and Oxalic Acid. 2010; Available online: http://helios.hampshire.edu/~nlNS/mompdfs/oxalicacid.pdf.

Fallon S, Enig MG. Cinderella's dark side. 2010; http://www.mercola.com/ article/soy/avoid_soy.htm.

Kumar V, Sinha AK, Makkar HPS, Becker K. Dietary roles of phytate and phytase in human nutrition: A review. Food Chem. 2010;120:945–959.

Baruah K, Sahu NP, Pal AK, Debnath D. Dietary phytase: An ideal approach for a cost effective and low-polluting aquafeed. NAGA, WorldFish Center Quarterly. 2004;27 (3 & 4) 15–19.

Schecter JC, Wiener SW. Plant Poisoning, Hypoglycemics. 2009;Available online: http://emedicine.medscape.com/article/817325-overvie

Lancashire R.J. Jamaican Ackee. 2008;Available online: http://wwwchem. uwimona.edu.jm/lectures/ackee.html.

Henry SH, Page SW, Bolger PM. Hazard assessment of ackee fruit (Blighia sapida). Hum. Ecol. Risk Assess. 1998;4:1175–1187.

Nutrilab I, Schweiker S. 713 F.2d 335 (7th Cir. 1983). Available online: http://openjurist.org/713/f2d/335.