Chapter

Health Risks Associated with the Consumption of Legumes Contaminated with Pesticides and Heavy Metals

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Abstract

Legumes have high nutritional value and they are important sources of protein, carbohydrates, fats and dietary fiber. The contamination of legumes with pesticides and heavy metals has been reported in scientific literature. Human beings are mainly exposed to the residues of pesticides and heavy metals through the dietary route. The purpose of this review chapter is to highlight the acute and chronic health risks that human beings may be exposed to as a result of the ingestion of legumes polluted with pesticides and heavy metals. Additionally, the mechanisms through which pesticides and heavy metals engender different undesirable health outcomes in human beings were stated. Scientific literature were perused and the information contained in them were collated to derive this chapter. Pesticides cause short-term health effects including hypersensitivity and mortality, while heavy metals induce acute effects like seizures and death. Some chronic untoward effects of pesticides are congenital disabilities and neurological damage. Heavy metals elicit disorders like anemia, hypertension and cancer. It is envisaged that the findings documented in this review will create awareness of the health risks posed by the contamination of legumes with the residues of pesticides and heavy metals so that food safety measures can be enforced globally.

Keywords: Legumes, Health risks, Pesticides, Heavy metals, Contamination

1. Introduction

Legumes are plants that belong to the family, *Fabaceae* or *Leguminosae*, and they include chickpeas, cowpea, lentils, soy, etc. [1]. They are highly nutritious and can be consumed as food by human beings and animals [2].

Pesticides are chemical substances that are manufactured for the control of pests in domestic, agricultural and industrial settings, among others [3]. They are classified as herbicides, fungicides, bactericides and insecticides mainly for agricultural applications [4]. Insecticides comprise carbamates, organochlorines, organophosphates, neonicotinoids, pyrethroids; herbicides include benzothiazolyl urea, carbamic and sulfanilic acids, isoxazolyl urea, phenylpyrazole and pyridinium; while fungicides contain carboxamides, carbamates, dithiocarbamates, etc. [5, 6].

Heavy metals (HMs) are a group of metals that possess high atomic weights and densities beyond 5 g/cm^3 [7]. They are usually derived from agricultural, mining and industrial activities, as well as effluents [8]. It has been observed that HMs for instance, lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni) and copper (Cu), build up in the soil and in plant uptake structures and evoke injurious effects on the environment and the health status of human beings [7, 9, 10]. Besides, HMs have the propensity to be toxic when the populace are exposed to them or when they are consumed in proportions beyond the acceptable daily limits [11].

Different food stuffs such as legumes, cereals, fruits, vegetables, etc. have been contaminated with pesticides and HMs in various parts of the world. It is noteworthy that the common environmental pollutants, pesticides and HMs, increasingly cause numerous health hazards to the populace because of their permeation and upsurge in the food chain, as well as their persistence in the bionetwork [12].

In 2020, [13] identified the organophosphate pesticides (malathion, parathion, ethion and carbophenothion) in cowpea (an African legume) from Gwagwalada market in Abuja, Nigeria, through the use of Gas Chromatography–Mass Spectrometry. The levels of the pesticides found in the cowpea samples exceeded the maximum residue limits set by the European Union and the Agency for Toxic Substances and Disease Registry. Additionally, [14] confirmed the contamination of cowpea by residues of organochlorine (endosulfan and lindane), and organophosphorus (malathion) pesticides in high levels in Northern Cameroun.

Furthermore, heavy metals including nickel, cadmium, manganese and cobalt were detected in cowpea by [15]. In the research, the concentrations of nickel, cobalt and manganese discovered in the legumes were below the acceptable limits by FAO/WHO, while the cadmium concentration was beyond the FAO/WHO limit permitted. However, in a study conducted in Saudi Arabian markets, it was discovered that kidney beans and haricots contained high levels of Mn, while peas had elevated levels of zinc beyond the standard permissible levels [16]. Hence, regular monitoring of food stuffs for HM content was advocated.

It has been observed that fertilizers and pesticides are responsible for the increased level of soil pollution by non-essential micronutrients such as arsenic, cadmium, mercury, nickel and lead [17]. These non-essential micronutrients in the soil are conveyed through various plants as they accumulate in the edible portions [18]. Subsequently, the general population and animals may be exposed to the residues of these environmental contaminants (pesticides and HMs) when they consume plants that have been polluted with them.

The aim of this review chapter is to underscore the acute and chronic health risks that human beings may be exposed to during their life time as a result of the consumption of legumes contaminated with pesticides and HMs. In addition, the mechanisms through which pesticides and HMs engender different undesirable health outcomes in biological systems were highlighted.

It is envisaged that the information in this review chapter will stimulate and enhance concerted efforts towards the regular monitoring of legumes and other foodstuffs for pollutants in order to attain food safety.

2. Mechanisms through which pesticides induce adverse health effects

When human beings consume pesticides in legumes and other food sources through the dietary route, the pesticides may cause acute and chronic health risks through diverse mechanisms. For instance, organophosphate pesticides (chlorpyrifos, diazinon, dichlorvos, fenitrothion, malathion, parathion, etc.) bring about deleterious health effects by inhibiting the function of acetylcholinesterase, reducing the secretion of insulin, and perturbation of the metabolism of nutrients in living systems [19–21].

Moreover, organophosphate pesticides stimulate the release of reactive oxygen species and this phenomenon might cause oxidative stress [22, 23]. Oxidative stress refers to a disparity between the levels of prooxidants and antioxidants thereby culminating in damage to vital molecules including DNA, RNA, lipids and proteins in biological systems [24]. Oxidative stress has been identified as an important mechanism through which different kinds of pesticides cause biological injuries to human beings and animals.

The organochlorine pesticides are chlorinated hydrocarbons that persist in the environment and they include methoxychlor, dieldrin, chlordane, mirex and lindane, among others [25]. They cause the stimulation of the nervous system through the perturbation of action potentials, thereby leading to paralysis and death [26]. Dietary exposure brings about the bioaccumulation of organochlorine pesticides in the body, and this may terminate in derangements in human health [27].

Carbamates such as methiocarb, carbaryl, aldicarb, propoxur and carbofuran reversibly inhibit acetylcholinesterase in mammals and humans [19]. This group of pesticides are capable of causing apoptosis and necrotic changes in the cells of the immune system [28]. Consequently, the immune system becomes compromised and affected individuals become susceptible to various diseases when they are exposed to these pollutants in food and other sources.

Pyrethroids (e.g. allethrin, permethrin, cypermethrin and deltamethrin) are neurotoxicants and they disrupt the muscular structures and modify voltage-dependent sodium channels in the body [29]. They exhibit low acute toxicity to mammals and avian species. Conversely, at low levels, pyrethroids elicit acute toxicity to diverse aquatic species and arthropods [30].

3. Acute health risks associated with dietary exposure to pesticides

Acute health risks may become visible instantaneously or within 24 hours sequel to exposure to a pesticide [31]. Pesticides can have access to human bodies through the dermal [32], ocular [33], oral and respiratory [34] routes. According to [35], the exposure of the populace to pesticide residues through the oral route is about five orders of enormity compared to the other routes. It has been affirmed that pesticides can produce acute health disorders such as hypersensitivity, asthma and mortality in people [8, 36–38].

4. Chronic health risks related to dietary exposure to pesticides

It has been reported that chronic detrimental health risks do not manifest in human beings even within a day subsequent to pesticide exposure [31]. Chronic health risks evoked by exposure to pesticides in food such as legumes include congenital disabilities and decreased birth weight [36, 37]. Additionally, many organophosphate insecticides bring about declines in sperm counts, viability, density and motility; inhibition of spermatogenesis, reductions in testes weights, and sperm DNA damage in males [38]. Other chronic adverse effects of pesticides entail hindering the activities of hormones, their time of release, or mimicking these hormones, thereby culminating in reduced fertility and deformities in the male and female reproductive tracts [39]. These harmful effects may result in declines in the population of human beings affected. Also, pesticides perturb the immune system function and elicit carcinogenicity [40, 41].

Some investigators have asserted that organochlorine pesticides and their active metabolites are linked to neurological aberrations, cancers, hypertension, cardiovascular and dermatological disorders in humans [42–44]. Besides, the exposure of the populace to organophosphate, organochlorine and carbamate pesticides may evoke chronic neurological disorders such as Alzheimer's and Parkinson's disease [45]. According to [46], pesticides affect neuronal function negatively by hyperphosphorylation and the disruption of microtubules thereby ultimately causing Alzheimer's disease.

5. Mechanisms by which heavy metals induce health risks in the human population

Heavy metals can accumulate in the bones or adipose tissues of human beings through dietary intake (for example, the consumption of legumes and other crops), thereby leading to the diminution of critical nutrients and undermined immune defenses [8].

Lead induces oxidative stress in tissues and it is plausible that it brings about deleterious effects in humans that consume legumes and other plants contaminated with it through this mechanism [47]. Also, lead, a ubiquitous lethal HM, may activate the development of tumors through the production of reactive oxygen species, as well as the promotion of damage to DNA and its repair mechanisms in living organisms [48].

Furthermore, it has been documented that arsenic sets off neoplasms through the alteration of the genome of human beings, perturbation of DNA and induction of oxidative injury [49, 50]. Another common HM, mercury, generates carcinogenesis through oxidative damage and interference with the structure, mending and preservation of DNA in living organisms [51].

These myriads of mechanisms may be responsible for the untoward acute and chronic health hazards reported in human beings who have consumed foodstuffs such as legumes, cereals, fruits, vegetables, etc. that have been tainted with HMs over a period of time.

6. Acute health risks associated with dietary exposure of individuals to heavy metals

Heavy metal contamination is a health menace to both adults and children [52]. When HMs build up in human tissues internally, for instance, when legumes polluted with HMs are eaten for some time, they may harm the central nervous system, and produce seizures, headache and coma [8].

There is scientific evidence that lead may engender neurotoxicity, nephrotoxicity and impaired haeme synthesis [53]. When children have contact with cadmium through a range of routes, for example the oral route (by feeding on legumes such as chickpeas, cowpea, etc.), they become exceedingly prone to lead intoxication and permanent neurological abnormalities may ensue [54]. Other acute impacts of lead exposure documented in children are inattention, hyperactivity, increased dullness, irritability, headache, convulsion, coma and death [55, 56].

Copper is important for the normal functioning of the brain, but it can be noxious if the cellular concentration surpasses the metabolic requirement [57]. Elevated levels of copper can cause dysfunctions in the working memory of individuals [58], while short-term exposure to copper through dietary and other routes have been linked with stomach pain, haematemesis, melena, jaundice, anorexia and vomiting [59]. Moreover, rhabdomyolysis, cardiac and renal failure, hepatic necrosis, haemolysis, methemoglobinemia, encephalopathy, as well as mortality can occur in severe copper toxicity [60]. These harmful acute impacts of high copper levels may be attributed to its induction of oxidative stress, DNA damage and lessening of cell proliferation [61].

Moreover, the distortion of the concentrations of high-density lipoproteins and impairment of the immune system have been ascribed to excessive concentrations of zinc in the bodies of human beings [62]. People are usually exposed to zinc through the ingestion of contaminated food, for instance, legumes, pulses, among others [63].

7. Chronic health risks linked with the exposure of people to heavy metals through the oral route

Chronic health effects like diabetes, neurodegenerative diseases, renal damage, bone disorders and tumors of the breast, prostate and lungs have been elicited by Cd in people [64–66].

There are existing reports that indicate that the long-term effects of lead exposure through food and other routes are manifested as anemia, abdominal colic, miscarriages, male infertility, birth defects, renal diseases and behavioral dysfunctions in children [67, 68]. It has also been observed that lead may elicit decreased circulating maternal thyroid hormone thereby influencing growth patterns adversely [67, 68].

It is known that tremendous amounts of arsenic in the soil, food crops (including legumes, cereals, vegetables, etc) and groundwater can stimulate cancer and dermal aberrations, as well as disorders in the heart, stomach, intestines, liver, kidneys and brain, among others [62, 69–73].

Furthermore, excessive copper consumption can activate hepatic damage and other gastric-related problems in people [62, 74, 75]. Wilson's disease, a form of chronic Cu toxicity in human beings, is characterized by alterations in mental states, motor disorders, dysphagia, incoordination, haemolytic anemia, renal and hepatic dysfunctions [72]. It has been shown that human beings become susceptible to chronic copper poisoning when they ingest food items (for instance, legumes, pulses, cereals, etc.) contaminated with copper probably through polluted irrigation sources [76]. Additionally, persistent bronchitis, emphysema, pulmonary disorders and fibrosis were reported in people following long-term exposure to nickel through dietary sources [77].

8. Conclusion

This review chapter highlighted the mechanisms through which the widespread pollutants, pesticides and HMs, evoke acute and chronic health disorders in human beings. Pesticides are usually applied in agricultural settings for the control of vectors and the enhancement of crop yield, while most HMs are utilized for industrial purposes.

Human beings may be susceptible to various health risks engendered by pesticides and HMs through the consumption of food crops, for example, legumes, contaminated with them. This may eventually pose serious threats to the wellbeing and survival of the populace except if regular monitoring of food items for the residues of these ubiquitous contaminants are conducted globally by the appropriate agencies.

It is envisioned that the information contained in this review chapter will provide a springboard for scientists, researchers and agriculturists, among others, to create innovative techniques for the minimization of human exposures to the residues of pesticides and HMs in order to forestall their pernicious effects in the general population.

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Conflict of interest

The author declares that there is no conflict of interest.

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