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REVIEW ARTICLE

Toxints in modern food and thier role in cardiovascular disease

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Abstract

The modern food supply is increasingly contaminated with various toxins, including pesticides, herbicides, heavy metals, food additives, endocrine disruptors, and mycotoxins. These substances, although sometimes present in trace amounts, can have significant implications for cardiovascular health. Cardiovascular diseases (CVD) remain the leading cause of mortality worldwide, and traditional risk factors such as poor diet, physical inactivity, and smoking are well-known contributors. However, emerging evidence indicates that environmental toxins present in food also play a crucial role in the development and progression of CVD. This comprehensive review explores the types of toxins found in modern food, their sources, mechanisms of action, and the scientific evidence linking them to cardiovascular diseases. By understanding these relationships, we can appreciate the importance of mitigating exposure to these harmful substances and developing effective strategies to protect cardiovascular health. The review covers the following categories of toxins: pesticides and herbicides, heavy metals, food additives, endocrine disruptors, and mycotoxins, examining their impact on cardiovascular health and suggesting future research directions.

1. Introduction

The 21st century has witnessed significant advancements in food production and technology, leading to increased food availability and convenience. However, these advancements have also led to the introduction of various toxins into the food supply. The modern diet is characterized by a high intake of processed foods, which often contain various chemical additives, residues from agricultural practices, and contaminants from packaging materials (Weaver et al., 2014). These substances, although sometimes present in trace amounts, can have significant health implications, particularly for cardiovascular health. Cardiovascular diseases (CVD) are the leading cause of death globally, accounting for approximately 17.9 million deaths each year, according to the World Health Organization (WHO) (Dong et al., 2022). The primary risk factors for CVD include hypertension, dyslipidemia, diabetes, obesity, and lifestyle factors such as poor diet, physical inactivity, and smoking. However, emerging evidence suggests that exposure to environmental toxins present in food can also play a crucial role in the development and progression of CVD (Alissa and Ferns, 2011). The modern food industry relies heavily on pesticides, herbicides, and other agrochemicals to ensure high crop yields and protect against pests and diseases. While these chemicals have undoubtedly contributed to increased food production, their residues can remain on food products and enter the human body upon consumption. Additionally, heavy metals such as lead, mercury, arsenic, and cadmium can contaminate food through polluted water, soil, and air. These metals are known for their toxic effects on various bodily systems, including the cardiovascular system (Rehman et al., 2018).

Processed foods, which form a significant part of modern diets, often contain additives such as trans fats, artificial sweeteners, and high levels of sodium. These additives enhance the taste, appearance, and shelf life of food products but can have detrimental effects on cardiovascular health (Srour et al., 2019). For example, trans fats are well-documented for their role in increasing the risk of coronary heart disease, while excessive sodium intake is a major contributor to hypertension (Ganguly and Pierce, 2015). Furthermore, endocrine disruptors such as bisphenol A (BPA) and phthalates, commonly found in food packaging materials, can leach into food and disrupt hormonal functions in the body. These chemicals can interfere with lipid metabolism, blood pressure regulation, and glucose homeostasis, all of which are critical factors in cardiovascular health (Ong et al., 2022). Mycotoxins, toxic compounds produced by fungi that contaminate crops, are another group of food contaminants that pose significant health risks. Chronic exposure to

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mycotoxins such as aflatoxins and ochratoxin A has been linked to liver damage, oxidative stress, and inflammation, contributing to the development of cardiovascular diseases (Bhat and Reddy, 2017). This comprehensive review aims to explore the types of toxins found in modern food, their mechanisms of action, and the scientific evidence linking them to CVD. By understanding these relationships, we can better appreciate the importance of mitigating exposure to these harmful substances and developing effective strategies to protect cardiovascular health. The review will cover the following categories of toxins: pesticides and herbicides, heavy metals, food additives, endocrine disruptors, and mycotoxins. Each category will be examined in detail, including their sources, mechanisms of action, and evidence linking them to CVD.

2. Types of Toxins in Modern Food

2.1. Pesticides and Herbicides

2.1.1 Organophosphates (OPs)

Organophosphates are widely used pesticides known for their neurotoxic effects. Chronic exposure to OPs has been linked to cardiovascular dysfunction. Studies found that exposure to OPs is associated with an increased risk of hypertension, suggesting that OPs may interfere with the autonomic regulation of blood pressure. Additionally, OPs can cause oxidative stress and endothelial dysfunction, both of which are critical factors in the development of cardiovascular diseases (Naughton and Terry, 2018).

2.1.2. Glyphosate

Glyphosate, a common herbicide, has been scrutinized for its potential health impacts. Research indicates that glyphosate can disrupt gut microbiota, which plays a crucial role in cardiovascular health. A study reported that glyphosate-based herbicides induced gut dysbiosis in rats, which could contribute to metabolic syndrome, a precursor to CVD. Furthermore, glyphosate's potential to induce oxidative stress and inflammation further exacerbates cardiovascular risk (Maddalon et al., 2021).

2.2. Heavy Metals

2.2.1. Lead

Lead exposure, primarily from contaminated water and soil, has been linked to cardiovascular issues. A previous studies highlighted that lead exposure is correlated with hypertension, attributing this to lead-induced oxidative stress and endothelial dysfunction. Lead interferes with the renin-angiotensin system, which plays a crucial role in regulating blood pressure, thus contributing to hypertension and other CVD (Vaziri, 2008).

2.2.2. Mercury

Mercury, found predominantly in fish, is known for its cardiotoxic effects. A study showed that mercury exposure is associated with increased risks of hypertension and coronary heart disease due to its role in inducing oxidative stress and inflammation. Mercury can accumulate in the cardiovascular system, leading to endothelial dysfunction and increased arterial stiffness, which are key factors in the development of atherosclerosis (Arbi et al., 2021).

2.2.3. Arsenic

Arsenic contamination, especially from groundwater, poses significant health risks. A study found a strong association between arsenic exposure and CVD, particularly through mechanisms involving endothelial dysfunction and inflammatory responses. Chronic arsenic exposure can lead to oxidative stress, which damages endothelial cells and promotes the formation of atherosclerotic plaques (Balarastaghi et al., 2023).

2.2.4. Cadmium

Cadmium, absorbed from certain foods like grains and vegetables, has been shown to negatively impact cardiovascular health. According to Tellez-Plaza et al. (2013), chronic exposure to cadmium is associated with increased risk of cardiovascular mortality, likely due to its effects on vascular calcification and oxidative stress. Cadmium interferes with calcium metabolism, which is crucial for maintaining vascular tone and health, leading to increased arterial stiffness and hypertension (da Cunha Martins et al., 2018).

2.3. Food Additives

2.3.1. Trans Fats

Trans fats, used in processed foods for their preservative qualities, are well-documented for their adverse cardiovascular effects. The robust evidence that trans fat consumption significantly raises the risk of coronary heart disease by increasing LDL cholesterol and reducing HDL cholesterol. Trans fats promote systemic inflammation and endothelial dysfunction, both of which are critical factors in the development of atherosclerosis (Lopez-Garcia et al., 2005).

2.3.2. Sodium

Excessive sodium intake is a well-established risk factor for hypertension. The study demonstrated a clear correlation between sodium intake and elevated blood pressure, emphasizing the role of dietary sodium in cardiovascular risk. High sodium intake increases fluid retention and vascular resistance, leading to elevated blood pressure and increased workload on the heart, which can result in hypertensive heart disease (Felder et al., 2022).

2.3.3. Artificial Sweeteners

Artificial sweeteners have been linked to metabolic dysregulation. It suggested that artificial sweeteners could disrupt metabolic processes, leading to weight gain and metabolic syndrome, both of which are risk factors for CVD. Some studies have also indicated that artificial sweeteners may alter gut microbiota, leading to insulin resistance and glucose intolerance, further increasing the risk of CVD (Schiano et al., 2021).

2.4. Endocrine Disruptors

2.4.1. Bisphenol A (BPA)

BPA, commonly found in plastics and food can linings, has been shown to interfere with hormonal functions. A study linked BPA exposure to an increased risk of hypertension, suggesting that BPA's estrogenic activity may play a role in vascular health. BPA can induce oxidative stress and inflammation in endothelial cells, leading to endothelial

dysfunction and increased risk of atherosclerosis and hypertension (Zhang et al., 2020).

2.4.2. Phthalates

Phthalates, used in food packaging, are associated with adverse cardiovascular outcomes. It was found that higher urinary levels of phthalates were correlated with increased blood pressure in children and adolescents, highlighting the potential for long-term cardiovascular risks. Phthalates can disrupt lipid metabolism and hormone regulation, leading to dyslipidemia and increased cardiovascular risk (Gao et al., 2022).

2.5. Mycotoxins

2.5.1. Aflatoxins

Aflatoxins, produced by Aspergillus fungi, contaminate various crops. A study indicated that chronic aflatoxin exposure is associated with increased oxidative stress and inflammation, contributing to cardiovascular diseases. Aflatoxins can induce liver damage, leading to metabolic disruptions that increase cardiovascular risk (Rotimi et al., 2017).

2.5.2. Ochratoxin A

Ochratoxin A, found in cereals and dried fruits, has been implicated in cardiovascular toxicity. Research suggested that ochratoxin A can induce oxidative damage and endothelial dysfunction, leading to hypertension and heart failure. Chronic exposure to ochratoxin A can lead to kidney damage, further exacerbating cardiovascular risk through the development of hypertension and chronic kidney disease (Chen and Wu, 2017).

3. Mechanisms of Action

3.1. Oxidative Stress and Inflammation

Oxidative stress and inflammation are critical pathways through which food toxins contribute to CVD. Many toxins induce the production of reactive oxygen species (ROS), leading to oxidative damage (Sharma et al., 2012). For instance, heavy metals such as mercury and lead generate ROS, which in turn cause lipid peroxidation and damage to endothelial cells. Inflammatory responses triggered by these toxins further exacerbate endothelial dysfunction, promoting plaque formation and arterial stiffness (Jourde-Chiche et al., 2011). Oxidative stress results from an imbalance between the production of ROS and the body's antioxidant defenses. Excessive ROS can damage cellular components, including lipids, proteins, and DNA. This damage can lead to the activation of inflammatory pathways, further contributing to the development of CVD. Inflammation plays a key role in the initiation and progression of atherosclerosis, as it promotes the recruitment of immune cells to the vascular wall and the formation of atherosclerotic plaques (Zhu et al., 2018).

3.2. Endothelial Dysfunction

The endothelium regulates vascular tone and maintains blood fluidity. Toxins like arsenic and BPA impair endothelial function by reducing nitric oxide (NO) bioavailability, a crucial molecule for vasodilation. For example, arsenic exposure has been shown to reduce NO production, leading to vasoconstriction and hypertension (Balakumar and Kaur, 2009). Similarly, BPA's estrogen-mimicking effects can disrupt endothelial cell function, contributing to vascular diseases (Andersson and Brittebo, 2012).

Endothelial dysfunction is a critical early event in the development of atherosclerosis. It was characterized by a reduced ability of the endothelium to produce NO and maintain vascular homeostasis (Sitia et al., 2010). This dysfunction can result in increased vascular permeability, promoting the infiltration of lipids and immune cells into the arterial wall. The subsequent inflammatory response leads to the formation of atherosclerotic plaques, which can eventually rupture and cause cardiovascular events such as heart attacks and strokes (Rosenfeld, 2013).

3.3. Dyslipidemia

Food toxins can disrupt lipid metabolism, leading to dyslipidemia, a major risk factor for atherosclerosis. Trans fats, for example, increase low-density lipoprotein (LDL) cholesterol and decrease high-density lipoprotein (HDL) cholesterol, promoting plaque formation within arteries. Endocrine disruptors like phthalates have also been linked to altered lipid profiles, exacerbating cardiovascular risk (Kirkley and Sargis, 2014).

Dyslipidemia involves abnormal levels of lipids in the blood, including elevated LDL cholesterol, low HDL cholesterol, and high triglycerides. These lipid abnormalities contribute to the development of atherosclerotic plaques, which can obstruct blood flow and lead to cardiovascular events. The consumption of trans fats and exposure to endocrine disruptors can exacerbate dyslipidemia by disrupting lipid metabolism and promoting the accumulation of lipids in the blood (Mosca et al., 2024).

3.4. Hypertension

Hypertension is a common endpoint of many toxin exposures. Sodium intake, a well-known dietary factor, directly increases blood pressure by altering fluid balance and vascular resistance (Perez and Chang, 2014). Heavy metals such as lead and cadmium induce hypertension through mechanisms involving oxidative stress and disruption of calcium signaling in vascular smooth muscle cells. Hypertension, or high blood pressure, is a major risk factor for CVD. It results from increased resistance in the blood vessels, which forces the heart to work harder to pump blood. Chronic hypertension can lead to damage to the blood vessels and the heart, increasing the risk of heart attack, stroke, and heart failure. The consumption of high levels of sodium and exposure to heavy metals can significantly contribute to the development of hypertension (Wu et al., 2018).

4. Impact of Food Toxins on Cardiovascular Health

4.1. Pesticides and Herbicides

Studies consistently show a link between pesticide exposure and cardiovascular disease. For instance, a study found that individuals exposed to pesticides had a higher prevalence of hypertension and ischemic heart disease (Zhao et al., 2023). This association is thought to be mediated by the impact of pesticides on autonomic nervous system regulation and endothelial function. Additionally, the

disruption of gut microbiota by herbicides like glyphosate may contribute to metabolic changes that increase cardiovascular risk (Rueda-Ruzafa et al., 2019). Pesticides and herbicides can enter the human body through ingestion, inhalation, or dermal absorption. Once inside, these chemicals can interfere with various physiological processes, leading to cardiovascular dysfunction. For example, organophosphates can inhibit acetylcholinesterase, an enzyme essential for nerve function, leading to autonomic dysregulation and increased blood pressure. Furthermore, the oxidative stress and inflammation induced by these chemicals can contribute to endothelial dysfunction and the development of atherosclerosis.

4.2. Heavy Metals

Heavy metals are potent cardiovascular toxins. Epidemiological studies provide robust evidence for the cardiovascular effects of lead, mercury, arsenic, and cadmium. The studies have confirmed the positive association between blood lead levels and hypertension. Similarly, mercury exposure, primarily through fish consumption, has been linked to increased risks of myocardial infarction and coronary artery disease (Virtanen et al., 2007). Arsenic exposure, often through contaminated drinking water, has been shown to significantly increase the risk of ischemic heart disease. The cardiovascular toxicity of cadmium is well-documented, with studies indicating that cadmium exposure contributes to the development of atherosclerosis and increases cardiovascular mortality (Fagerberg et al., 2012). Heavy metals can accumulate in the body over time, leading to chronic exposure and long-term health effects. These metals can induce oxidative stress by generating ROS, which can damage endothelial cells and promote the formation of atherosclerotic plaques. Additionally, heavy metals can interfere with essential physiological processes, such as calcium signaling and nitric oxide production, leading to vascular dysfunction and increased cardiovascular risk. The evidence linking heavy metal exposure to CVD underscores the importance of reducing environmental contamination and limiting dietary exposure (Li et al., 2022).

4.3. Food Additives

The detrimental cardiovascular effects of trans fats are well-established. The multiple studies confirming that trans fat consumption increases the risk of coronary heart disease. This is supported by biological evidence showing that trans fats adversely affect lipid profiles and promote systemic inflammation (Mozaffarian et al., 2007). Excessive sodium intake is another significant concern, with large-scale studies demonstrating a direct link between sodium consumption and elevated blood pressure. Artificial sweeteners have also come under scrutiny; It was found that these substances might contribute to metabolic syndrome, thus indirectly increasing cardiovascular risk. Food additives are used to enhance the flavor, appearance, and shelf life of processed foods. However, many of these additives have been linked to adverse health effects. Trans fats, for example, are created through the hydrogenation of vegetable oils and are commonly found in processed and fried foods. These fats increase LDL cholesterol and decrease HDL cholesterol, promoting the development of atherosclerosis. Similarly, high sodium intake is linked to increased blood pressure and cardiovascular risk, as excessive sodium can lead to fluid retention and increased vascular resistance. Artificial sweeteners, while marketed as a healthier alternative to sugar, have been implicated in metabolic dysregulation and increased cardiovascular risk (Pereira and Odegaard, 2013).

4.4. Endocrine Disruptors

Endocrine disruptors such as BPA and phthalates are linked to adverse cardiovascular outcomes. BPA's role in hypertension and endothelial dysfunction is supported by several studies, which found a significant association between BPA exposure and higher blood pressure (Han and Hong, 2016). Phthalates, commonly used in food packaging, have been associated with increased blood pressure and insulin resistance, which are critical risk factors for CVD. Endocrine disruptors are chemicals that interfere with hormone function, leading to various health issues. BPA, for example, mimics estrogen and can bind to estrogen receptors, disrupting normal hormonal signaling. This disruption can lead to increased oxidative stress and inflammation in endothelial cells, contributing to endothelial dysfunction and cardiovascular disease. Phthalates, used in food packaging and processing, can leach into food and be ingested, leading to chronic exposure. These chemicals can disrupt lipid metabolism and hormone regulation, contributing to dyslipidemia and increased cardiovascular risk. The evidence linking endocrine disruptors to CVD highlights the need for stricter regulations and safer alternatives in food packaging and processing (Tumu et al., 2023).

4.5. Mycotoxins

Mycotoxins such as aflatoxins and ochratoxin A are emerging concerns in cardiovascular health. Chronic exposure to aflatoxins has been associated with increased oxidative stress and inflammation, pathways that are critical in the development of CVD (Dai et al., 2024). Ochratoxin A, known for its nephrotoxic effects, also poses risks to cardiovascular health by inducing oxidative damage and endothelial dysfunction. Mycotoxins are toxic compounds produced by fungi that can contaminate food crops. Aflatoxins, produced by Aspergillus species, are commonly found in nuts, seeds, and grains. Chronic exposure to aflatoxins can lead to liver damage, increasing the risk of metabolic disorders and cardiovascular disease. Ochratoxin A, produced by Aspergillus and Penicillium species, can contaminate cereals, coffee, and dried fruits. This mycotoxin can cause kidney damage, leading to hypertension and increased cardiovascular risk. The oxidative stress and endothelial dysfunction induced by mycotoxins further contribute to their cardiovascular toxicity (Wang et al., 2023). The presence of mycotoxins in the food supply underscores the importance of monitoring and controlling fungal contamination to protect public health (Figure 1).

5. Conclusion

The presence of toxins in modern food is a significant public health concern, particularly regarding their role in CVD. Pesticides, heavy metals, food additives, endocrine disruptors, and mycotoxins each contribute to cardiovascular risk through various mechanisms, including oxidative stress, inflammation, endothelial dysfunction, and dyslipidemia. Reducing exposure to these toxins through improved agricultural practices, stricter regulations, and increased public awareness is crucial for mitigating their impact on cardiovascular health. Future research should focus on further elucidating the mechanisms of action of these toxins

Table 1: List of Toxins in Modern Food and Their Sources

Toxin	Source	Common Food Items Contaminated
Pesticides and Herbicides		
Organophosphates	Agricultural pesticide residues	Fruits, vegetables, grains
Glyphosate	Herbicide residues	Soybeans, corn, wheat, oats
Heavy Metals		
Lead	Contaminated soil, water	Leafy vegetables, root vegetables, grains
Mercury	Industrial pollution, contaminated water	Fish (especially large predatory species), seafood
Arsenic	Contaminated groundwater, soil	Rice, grains, vegetables
Cadmium	Industrial pollution, fertilizers	Grains, leafy vegetables, seafood
Food Additives		
Trans Fats	Partially hydrogenated oils	Processed foods, baked goods, margarine
Sodium	Preservatives, flavor enhancers	Processed foods, canned soups, snacks
Artificial Sweeteners	Sugar substitutes	Diet sodas, sugar-free products, processed foods
Endocrine Disruptors		
Bisphenol A (BPA)	Plastic containers, canned food linings	Canned foods, plastic-packaged foods
Phthalates	Plastic packaging, food processing equipment	Processed foods, fast foods
Mycotoxins		
Aflatoxins	Fungal contamination	Nuts (especially peanuts), corn, grains
Ochratoxin A	Fungal contamination	Cereals, dried fruits, coffee, wine

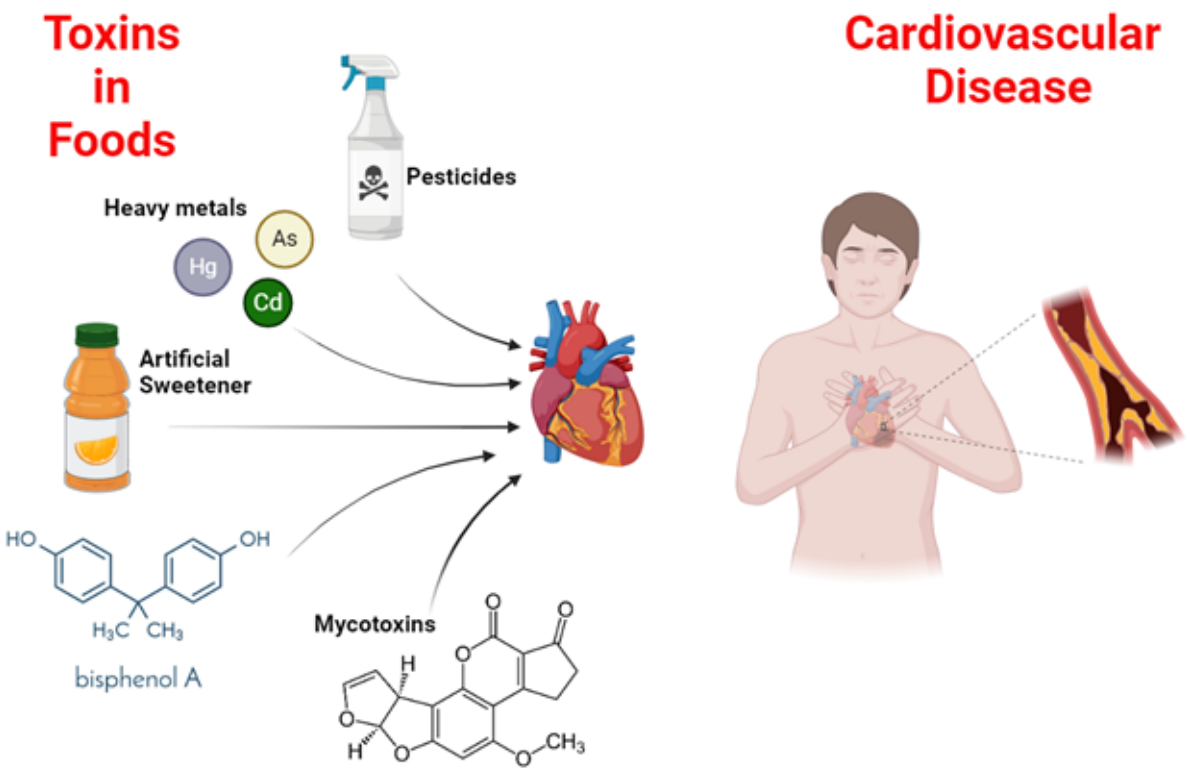

Figure 1: Effect of Toxins present in food on inducing cardiovascular disease

and developing effective strategies to minimize their presence in the food supply.

Declarations

Ethics approval statement

No ethical approval was required for the current study as it did not deal with any human or animal samples.

Consent to participate

Not applicable

Consent to publish

Not applicable

Data Availability Statement

The data are available from the corresponding author upon reasonable request

Competing Interests

The authors declare that they have no conflict of interest

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Author contribution

R.A.K.E, A.M.S.S, and A.T.F.E: investigation, formal analysis, writing original draft. D.B: conceptualization, writing original draft, and supervision.

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