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Review Paper

Cookware as source of toxic metals: An overview

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Abstract

Cookware assumes a pivotal function in cooking, however, there are concerns about potential health hazards associated with releasing toxic metals from cookware into food. This review investigates the importance of cookware as a source of exposure to toxic metals, focusing on the health consequences of lead, cadmium and aluminum contamination. Certain materials used in cookware, especially metals, have been identified as potential origins of toxic elements. Lead, a well-known neurotoxin, can be released from cookware, presenting a risk when ingested. Cadmium in certain metal alloys and enamels is another concern due to its toxicity, which affects various organs. Aluminum used in cookware, has raised health concerns because of its possible associations with neurodegenerative diseases. Various factors, including acidity, cooking duration, and temperature influence metal leaching. Acidic foods, such as tomatoes or citrus fruits, can facilitate the release of metals into the food during the cooking process. Extended cooking times and high temperatures also increase the probability of metals migrating from the cookware into the food. Consumers need to make well-informed decisions when selecting cookware to mitigate these risks. Selecting materials with a lower potential for metal leaching, such as stainless steel or cast iron, can significantly reduce exposure.

Cookware as source of toxic metals: An overview

Introduction

Humans rely heavily on cooking because it improves the physical and chemical properties of food, making it easier to chew, making it more palatable, and raising the net energy value of the plant and animal products that people frequently eat. Cooking enables humans to eat a larger variety of foods, including tough raw meat that would be difficult to chew otherwise (Carmody & Wrangham, 2009). Cooking is thought to have played a vital role in humans' adaptation to a high-quality diet. Additionally, it makes it possible to eat plant foods high in fiber, which in their raw form would be less appetizing and supply insufficient calories (Wrangham & Conklin-Brittain, 2003). Cooking has had a profound impact on human biology, perhaps affecting life history, social behaviour, and evolutionary psychology in addition to digestive adaptations (Wrangham & Conklin-Brittain, 2003).

From the accidental discovery of roasting food over fire, cooking methods have developed over time. Cooking is essential because it makes food easier to digest and improves its texture, colour, flavour, and appearance. When compared to more modern ways such as cooking in a microwave, traditional cooking procedures are thought to be healthier and superior. Cooking methods that have been used since ancient times include boiling and steaming. These methods have withstood the test of time and are still often employed in cooking. In addition to ensuring that food stays fresher and lasts longer, the progress of cooking techniques has allowed for the creation of a wide variety of tasty meals (Harold, 2004).

The term "cookware" describes a variety of culinary appliances used in professional kitchens, industrial food manufacturing facilities, and mass catering businesses. These appliances fall into two categories: continuous systems are utilized for large-scale manufacturing, while batch equipment is utilized for smaller production volumes. Cooking appliances can run on electricity or fossil fuels and function in vacuum, atmospheric, or high-pressure environments (Sara et al., 2023). A pot with a liquid phase-changing working medium, porous foam metal components, and a vacuum cavity is one kind of cookware. Li et al. (2016) stated that this cookware guarantees a non-adhesive cooking surface and temperature uniformity. For outdoor cooking, another kind of cookware is frequently utilized. It is made of a metal tread plate made of stainless steel, aluminum, or carbon steel. Cookware may also be made of composites and polymer materials that are heat resistant and/or nonstick, and that include an integrated or attached food support surface. These materials can be utilized to make different ovens, cooking appliances, and car parts (Williams et al., 2020a: Williams et al., 2020b).

Cookware is a vital component of daily life because it enhances safety, convenience, and aesthetics when cooking. It is used to prepare, serve, and store food. In India, traditional soapstone cookware, like *rathi chippa* and *kal chatti*, has been valued for generations because of its special qualities (Aruna, 2020). These handcrafted cookware pieces preserve food's flavour and aroma, keep it hot for longer periods, and inhibit the growth of bacteria, thereby extending the shelf life of cooked food (Rami & Bessam, 2018). Cookware affects several cooking-related variables, including temperature distribution, power distribution, and cooking outcomes (Emilio et al., 2022). The interesting design of kitchenware also adds aesthetic value to the cooking experience, making it more enjoyable for users (Pen, 2007). Cookware is manufactured using composite materials.

According to a report released by The National Kitchen & Bath Association (NKBA) in 2021, rising homeowner expenditure on kitchen refurbishing projects would improve the demand for kitchenware and cookware products. High standards of living, supported by rising disposable income levels, influence the demand for high-end and exquisite cookware products across the globe. The size of the world market for cookware was estimated at USD 30.60 billion in 2023, and it is projected to increase at a compound annual growth rate (CAGR) of 6.2% between 2024 and 2030 (NKBA Research Reports).

Types of Cookware

There are various types of Cookware which serve various functions, some of which are discussed below:

Roasting and Braising Pans are wide and shallow cookware used to cook chicken, beef, or pork. Specifically, they have two loops or handles with or without a cover. They are often made of heavy-gauge metal to ensure safe usage on a stovetop after roasting in an oven. Roasters are often shaped like an oval or rectangle, with no clear distinction between them and braisers.

Casserole Pots are similar to Dutch ovens and roasters, and many recipes work well with either. Casseroles are also used in ovens and on stovetops, depending on the material. Although they are frequently composed of metal, casseroles are also common in glazed ceramic and other vitreous materials.

A Wonder Pot is made of aluminum, this idea originated in Israel and can be used as a Dutch oven. It is composed of three parts, i.e., a round metal disk with a central hole to distribute heat; an aluminum pot, and a hooded cover with venting holes.

Frying Pans or Skillets offer a sizable, even heating surface with edges that slope and are shallow. Omelet pans are another name for these kinds of cookware. Ribbed frying pans, or grill pans, allow fat to escape from the food while it cooks. Grill pans and frying pans typically have a diameter of 20 to 30 cm.

Spiders are skillets that are supported above an open flame by three slender legs. Though the name has recently become less common, regular flat-bottomed skillets are also occasionally referred to as "spiders" (Ross, 2001).

Griddles are metal flat plates that are used for grilling, frying, and creating pan breads including tortillas, pancakes, chapatis, and crepes. Conventional iron griddles are round, with a semicircular hoop that is raised above the plate and attached to its opposing edges to create a central handle. Nowadays, it's also typical to find rectangular griddles that accommodate two stove burners and griddles with a ribbed section that functions similarly to a grill pan. Some, like waffle makers, contain several square metal slots that allow the contents to be arranged in a specific configuration. Similar to frying pans, round griddles typically have a diameter of 20 to 30 cm. Similar to griddles, but often smaller and composed of a thinner metal, are crepe pans.

Saucepans are round vessels with vertical walls, typically used for boiling or simmering. They usually have one long handle. Larger pans with a similar shape but two short handles are often called "saucepots" or "soup pots," with capacities ranging from 3 to 12 liters. Saucepans usually hold between 1 to 8 liters. While saucepots resemble Dutch ovens in shape, they are generally lighter. Smaller saucepans designed for heating milk are known as "milk pans" and often feature a spout for easy pouring. A variation of the saucepan with sloping sides is called a "Windsor," "evasee," or "fait-tout," which is ideal for evaporative reduction. Saucepans with rounded sides are called "sauciers," which provide better evaporation and create a return wave when shaken.

Stockpots are large pots with sides that are at least as tall as their diameter, allowing stock to simmer for long periods without significant reduction. They typically range in volume from 6 to 36 liters and come in various sizes, suitable for anything from cooking for a family to preparing meals for a large gathering.

Woks are wide with roughly bowl-shaped vessels having one or two handles at or near the rim. Their design allows a small amount of cooking oil to be concentrated in the center, where it can be heated to a high temperature with minimal fuel, while the outer areas of the wok keep food warm after frying. In the Western world, woks are primarily used for stir-frying, but they are versatile enough for steaming, deep frying, and other cooking methods.

Manufacturing of Cookwares

Consumers with a high level of affordability spend make informed choices to improve their quality of life, leading to the acquisition of practical and versatile household products like cookware. This trend is expected to positively impact the growth of the cookware market in the foreseeable future. Rising homeowner expenditure on kitchen refurbishing projects would improve the demand for kitchenware and cookware products.

Giovanna et al. (2016) and Louisa (2022) discussed the usage of several materials for cookware, including cast iron, aluminum, steel, Teflon, ceramic, enameled iron, wood, glass, and soapstone. Regarding cooking equipment, stainless steel is thought to be the most hygienic and sanitary option (Louisa, 2022). Aluminum, enameled iron, and stainless-steel cookware are examples of induction cookware configurations (Martinez et al., 2015). Stainless steel and enameled cast iron are the best materials for induction cookware in terms of performance and energy efficiency (Villacis et al., 2015). Southern Indian states employ traditional soapstone cookware, which offers advantages including low dielectric, high-temperature resistance, high density, and great mechanical strength (Aruna, 2020).

According to Ibrahim & Hajo (2020), heavy metals such as Manganese (Mn), Iron (Fe), Copper (Cu), Chromium (Cr), Arsenic (As), Zinc (Zn), Nickel (Ni), Aluminum (Al), Cadmium (Cd), and Lead (Pb) can be released via metallic cookware which are toxic metals that could be harmful to people's health. Because of their potential toxicity and detrimental effects on human health, toxic metals are a major concern. Exposure to toxic metals can arise through occupational and environmental exposures and ingesting contaminated food (Agneta & Jan, 2022). Cookware built from recycled materials, such as cans and engine parts, poses a health concern to consumers since it can leach harmful metals into food (Weidenhamer et al., 2023). Since the beginning of the aluminum industry in 1920, the utilization of scrap metal debris as a source for artisanal cookware manufacture has increased by more than 40% (Alabi & Adeoluwa, 2020). By the year 2000, 43 nations around the world were using scrap metal as their principal supply of aluminum. Of the primary aluminum recovered from scrap metal waste, around 35% came from the United States (Patricia, 2000). When compared to community individuals who were not exposed to lead, artisan cookware producers employed in unofficial foundries in South Africa had greater concentrations of lead in their blood (Renee et al., 2020). Lead, chromium, and cadmium were among the heavy metals emitted by metallic cookware bought from a local market, according to a study done in Riyadh (Ibrahim & Hajo, 2020). Food was found to contain leaching metals from tin-lined copper pots; boiling was shown to release more metals into the food than refrigeration did (Parvaneh et al., 2020). It was also discovered that traditional aluminum pots and clay utensils contributed to aluminum contamination of food (Dabonne et al., 2010). It has been reported that heavy metals included in the glazes of Nigerian ceramic cookware may seep into food (Jameson, 2008). Discoveries are available that imported ceramic dinnerware and decorative plates leak lead and cadmium at levels higher than those allowed by the US FDA, which could be harmful to human health (Aderemi et al., 2017). Furthermore, it has been recorded that locally made cookware in sub-Saharan Africa leaches significant concentrations of metals over permitted limits, including lead, aluminum, cadmium, chromium, and nickel. Nonetheless, studies on enameled cookware indicate a low and insignificant chance of toxicity when using it (Yumi et al., 2011). Glass and aluminum pans have the lowest metal migration and best oxidative stability in hot oil, according to evaluations of the propensity for different cookware materials to leak metals into food (Kesia et al., 2007). According to Gupta (2016), metals found in utensils and other products have the potential to increase environmental levels resulting in pollution leading to contamination of the public.

The level of chemical contaminants in food can also be affected by cooking methods; processes that eliminate fat tend to lower the concentrations of organic contaminants, however, the extent of release varies depending on pH, frequency of use, washing conditions, and oiling (Ye et al., 2020). Metals from tin-lined copper pots have also been observed to leach into food; acidic conditions yield the greatest amount of metal release (Parvaneh et al., 2020). Toxic metals in food, such as cadmium, lead, mercury, and arsenic, are a major source of exposure for the general public (Agneta & Jan, 2022).

Depending on the metal, toxic metals can have a variety of negative health impacts, such as cancer, osteoporosis, heart disease, neurodevelopmental toxicity, diabetes, and renal failure. Reducing environmental pollution, enforcing maximum allowable levels in food, and advising vulnerable groups on diet are some of the steps that must be taken to lessen exposure to toxic metals (Paul, 2010; Gunnar et al., 2015; Gupta, 2016; Mello & Renato, 2021). Heavy metal contamination especially that from cookware, is a concern and has been investigated in several Italian locations (Ziemacki et al., 1989). To prevent exposure and safeguard public health, regulations, and civic education must consider the effects of toxic metals from cookware.

Materials Used in Manufacturing Cookware

Gold: The material possesses a heat conductivity of 295 W/m°K and a specific weight of 1204.32 lb/ft^3. Its appearance is characterized by a bright and shiny exterior, which conveys a sense of prestige. The body of the material is composed of copper and has a thickness of 5/64 inches. The coating, on the other hand, ranges from 1.181x10 to 1.574x10-4 inches. The material is manipulated using nickel-plated cast iron. This material offers significant energy-saving capabilities due to its exceptional heat-conducting capacity. Moreover, it exhibits excellent resistance to impacts, thermal shock, scratching, and corrosion. Additionally, it possesses bacteriostatic properties. Undeniably, this exclusive material is specifically designed for individuals who appreciate luxury. Its extraordinary heat conductivity also makes it ideal for prolonged cooking at low temperatures, encompassing a wide range of dishes such as soups, braised meat, stews, and polenta. Moreover, its exceptional heat conductivity makes it incomparable for searing and grilling at high temperatures, especially when preparing specialty fillets (Guidetti & Simonetti, 2000).

Silver: The heat conductivity of this material is measured at 420 W/m°K, while its specific weight is determined to be 655.2 lb/ft^3. It possesses a luminous and distinguished aesthetic. The body of this material exhibits a range of material thickness, varying from 3/64” to 5/64”. Its manipulation is facilitated through the use of nickel-plated cast iron. This material provides notable energy preservation because of its amazing resistance to impacts, thermal shock, scratches, and corrosion. It also has an exceptional heat-transmitting ability. It also demonstrates bacteriostatic qualities. This exclusive material is also intended for those who appreciate opulence. Its ability to facilitate prolonged cooking at low temperatures, from soups to braised meats, stews to polenta, is truly exceptional (Guidetti & Simonetti, 2000).

Aluminum: The material possesses a thermal conductivity value of 225 W/m°K and a specific weight of 168.48 lb/ft3. The material thickness ranges from 1/8” to 13/64”. Its appearance is that of a lustrous silver hue, however, it may exhibit a brownish colouration on the interior due to the spontaneous oxidation of the metal (Al_2O_3). Although this discoloration can be eliminated with commercially available chemicals, this oxidation produces an inert protective barrier that should not be removed. Notable advantages of this material include its recyclability, excellent heat conductivity, energy-saving properties for heat sources, hygienic safety, compliance with regulations regarding food-contact containers, and the potential for enhanced effectiveness if it possesses sufficient thickness (Guidetti & Simonetti, 2000).

Non-stick Aluminum: The heat conductivity of the material, weight, and thickness are the same as of the aluminum. The coating has a minimum thickness of 1 31/32". Until the material wears out, its appearance does not deteriorate. The advantages of this material include its excellent heat conductivity, resistant to impacts, thermal shock, and corrosion. Additionally, it is highly convenient due to the reputable brand's choice of cutting-edge painting technology, ensuring quality and durability. Furthermore, this material is suitable for induction cooking when combined with a disk made of ferritic steel. It is easy to use, and clean, and ensures safety from a hygiene perspective. It is compliant with relevant laws and regulations. Moreover, it is lightweight, which is particularly beneficial for professionals in the industry (Guidetti & Simonetti, 2000).

Stainless Steel: The material possesses a heat conductivity value of 16 W/m°K and a specific weight of 486.72 lb/ft^3. The material exhibits a thickness range between 1/32” and 15/32” for the body and 15/64” and 9/32” for the base in aluminum. The material has a bright and shiny appearance, but is susceptible to salt-induced damage, resulting in the formation of holes. The distribution of heat is influenced by the aluminum thickness at the bottom, which should be proportionate to the pot's diameter to optimize heat conductivity. This material has several benefits, such as reduced maintenance needs, great resistance to impacts, thermal stress, scratching, corrosion, and compliance with food container laws. On the other hand, the material has a few drawbacks, such as suboptimal energy-saving capabilities due to its high specific weight, the possibility of food splashing onto the sides during cooking as a result of temperature differences, low heat conductivity, poor resistance to aggression by coarse salt, and the presence of significant amounts of nickel and chrome in stainless steel (Guidetti & Simonetti, 2000).

Copper: The substance possesses a heat conductivity of 392 W/m°K and a specific weight of 555.36 lb/ft^3. Its aesthetic is characterized by a sense of nobility and refinement, rendering it suitable for use as an embellishment during table service. To ensure optimal performance, the material must have a minimum thickness of 5/64". Noteworthy advantages include its exceptional heat-conducting properties, resulting in substantial energy savings. Furthermore, it exhibits corrosion, scratching, thermal shock, and resistance to impacts. The tinplating on the interior and a polished exterior ensures the vessel's enduring longevity. Additionally, it offers hygienic safety and complies with relevant regulations. On the other hand, its drawbacks include its high cost, which may limit accessibility for many individuals, as well as its elevated specific weight (Guidetti & Simonetti, 2000).

Cast Iron: The heat conductivity of this material is 55 W/m°K, and its specific weight is 418 lb/ft^3. Its appearance can either be shiny or dull. The material thickness ranges from 1/16" to 3/16". The advantages of using cast iron include its ability to provide a sense of security, traditional nature, and aesthetically pleasing appearance on the table. Any type of heat source, including induction, can be utilized to cook with cast iron. Moreover, it holds cold well and works flawlessly in freezers or refrigerators. Cast iron pots are very unique because they make cooking possible in a variety of situations, including low-temperature caramelization, softly frying vegetables, grilling meat, browning, sautéing, braising, and stewing.

However, there are certain disadvantages to employing cast iron as well. Its capacity to retain heat, one of its common benefits makes it more suited for slow cooking over extended periods. As a result, it is not ideal for hurried or quick cooking. Moreover, enameled cast iron pots are more difficult to handle because of their heavier weights. Another problem with enameled cast iron pots is that the enamel may eventually become dull from repeated washings in a dishwasher using strong detergents. The pots' usage, however, is unaffected by this, nevertheless (Guidetti & Simonetti, 2000).

Carbon Steel: The heat conductivity of this material is measured at 60 W/m°K, while its specific weight is recorded at 486.72 lb/ft^3. To ensure satisfactory performance, the material thickness must be no less than 5/64". The aesthetic appeal of this material is somewhat lacking. The advantages of this material include its low cost of raw materials, which makes it exceptionally affordable, as well as its remarkable resistance to impacts, thermal shock, and scratching. Additionally, it is well-suited for frying purposes. However, this material does have some drawbacks. Firstly, its energy-saving capabilities are suboptimal due to its limited heat conduction capacity. Moreover, it possesses a high specific weight and is prone to rusting, making maintenance a challenging task (Guidetti & Simonetti, 2000).

Terracotta: The material possesses a thermal conductivity of 0.80 W/m°K and a specific weight of 137.28 lb/ft3. To achieve satisfactory performance, the thickness of the material must be at least 5/32". Advantages of this material include its ability to retain heat and low specific weight. On the other hand, there are several drawbacks associated with it. Firstly, its energy-saving capability is suboptimal due to its inadequate heat conduction capacity. Furthermore, it is extremely fragile and lacks resistance to impacts and thermal shock. Additionally, its fragility and relatively high cost make it a less affordable option. The material is highly porous, necessitating constant inspection of its surface to ensure the absence of impurities, cracks, or any signs of compromised integrity, particularly if the glazing has deteriorated. While it is well-suited for oven cooking, it is not suitable for use in professional kitchens; it is only recommended for home use (Guidetti & Simonetti, 2000).

Pyrex: The heat conductivity of this material is measured at 0.95 W/m°K, while its specific weight is determined to be 143.52 lb/ft^3. Its pleasant aesthetic quality is derived from its transparency. However, to ensure optimal performance, the material thickness must be no less than 1/8 of an inch. One of its notable advantages is its low specific weight. However, there are some drawbacks to consider. Firstly, the energy-saving capability is compromised due to its limited heat conduction capacity. Additionally, its extreme fragility makes it highly susceptible to both impacts and thermal shock. Lastly, its exorbitant cost further diminishes its affordability (Guidetti & Simonetti, 2000).

Common toxic metals in cookware

Lead: Lead in cookware can arise from various origins. One potential source is the leaching of lead from artisanal aluminum cookware, which is commonly utilized in nations with low- and middle-income (Abdul et al., 2018). Another possible cause is the utilization of ceramic cookware with lead glaze, which can contaminate food during the preparation process (Weidenhamer et al., 2014). Additionally, lead may be present in materials such as scrap metal and building supplies that are used in the production of cookware (Renee et al., 2020). The contamination of cookware and food can also occur due to environmental pollution resulting from the past usage of lead-based paints, lead gas, and other products (Mario et al., 2009).

Cadmium: A multitude of investigations have been conducted on the exposure of cadmium in cookware. Following the research conducted by Odularu (2011), it has been observed that meals prepared using stainless steel or steel pots possess the potential to release cadmium into the food. It was ascertained that newly manufactured steel pots do not tend to leach cadmium, whereas newly manufactured stainless-steel pots do. However, it was recorded that both steel and stainless-steel pots that have aged considerably are prone to the leaching of cadmium (Preda et al., 1983). Another inquiry focused on the emission of cadmium from plastic materials employed in the production of household items and containers. This investigation unveiled that those specific coatings, composed of cadmium compounds, exhibited the propensity to seep hazardous quantities of the metal, thereby causing alterations in organ histology and enzymology (Jolocam et al., 2011).

Aluminum: Because of its easy accessibility and reasonable cost, aluminum cookware is extensively utilized in low- and middle-income countries for culinary purposes. Extensive research has indicated that aluminum cookware, particularly those produced from discarded metal, possess the potential to release hazardous substances into cooked food, including heavy metals (Weidenhamer et al., 2014; Weidenhamer et al., 2017; Yogendra et al., 2019; Alabi & Adeoluwa, 2020; Sheth & Shah, 2022). The utilization of metal-based cookware has been definitively linked to the severity of Alzheimer's disease (Hung-Mao et al., 2016). In a study conducted by Weidenhamer et al. (2017) on aluminum cookware sourced from ten developing nations, it was discovered that lead, cadmium, and arsenic were emitted in significant amounts during the cooking process.

Factors responsible for leaching of toxic metals from cookware

Cookware's ability to leach metals into food has been discovered to be influenced by temperature and cooking techniques (Ehsan et al., 2023). The kind of cookware used, the meal's pH, how long it cooks for, and the presence of specific ingredients in the food are all factors that might affect how much metal leaches into the food from cookware. According to a study by Habimaana et al. (2022), lead leached from locally manufactured cookware at 100˚C and substantial quantities of aluminum and cadmium leached at 50˚C. It suggests that there may be a chance of metal exposure even at low temperatures. This risk could be related to manufacturing flaws (Weidenhamer et al., 2017) and scrap metals utilized as raw materials (Alabi et al., 2020). Food in copper pots coated in tin can leach metals; leaching occurs more when boiling than when refrigerated (Ponts'o et al., 2023). Cookware's metal leaching can be accelerated by acidic solutions, like those that contain citric acid (Parvaneh et al., 2020). According to Parvaneh et al. (2020), the leaching of aluminum is strongest in acidic settings and less prevalent in alkaline situations. Furthermore, using outdated or badly made cookware might lead to food contamination (Rim et al., 2009).

Chemical analysis of food/water from cookware

Research on aluminum cooking pots' leaching capacity during food preparation is consistent with the substantial migration of Aluminum ions from these pots (Liang et al., 2010). The majority of aluminum pots are made entirely of aluminum metal, which melts at a high, steady temperature and is soft, porous, and easily soluble (Liang et al., 2010). Al-Mayouf et al. (2008) found that foods reheated and stored in old aluminum cooking pots due to a lack of freezers had a high value of Aluminum (30ppm-45ppm) in their investigation into the potential contribution of aluminum cooking pots to foods recooked at varied times. Positive reports indicate older aluminum cooking pots have higher Aluminum leachate than modern ones, as this study found. Because homeowners typically use abrasive cleaning procedures, aluminum pots eventually leach additional metals. When Aluminum pots are washed with abrasive detergent, the pot develops pits and gains surface area, which increases the amount of metals that can contaminate the food. With reference to the NIS (2007) maximum allowed standard (0.2 mg/L) for Al in water, however, Odularu (2011) found the lower amounts within safe bounds. Less cooking in aluminum pots should be emphasized even while the values are within safe bounds to prevent bioaccumulation and the consequences that follow in the future (Odularu, 2011). Bioaccumulation is possible with aluminum, even though enamel cooking pots are composed of aluminum, they are shielded from aluminum contamination by coatings made of inert materials. This explains why the enamel pot's leachate level was found to be low. The finding of aluminum in the clay cooking pot suggests that the metal may be soluble and highly concentrated in the earth's crust. This suggests that the kind of soil used to produce the clay pots will affect the metal concentration (Odularu, 2011; Stahl et al., 2011).

Health impact of cookware heavy metals on humans

Lead exposure has been connected to several harmful health impacts, including cardiovascular dysfunction, heart failure risk, and toxicological effects (Zihan et al., 2021). Long-term lead exposure has been connected to cardiovascular dysfunction, which includes hypertension, atherosclerosis, and other cardiovascular issues (Liana et al., 2023). Long-term exposure to lead has been linked to high blood pressure, peripheral vascular disease, ischemic coronary heart disease, and cerebrovascular accidents, according to research from epidemiological and clinical studies (Bengt et al, 2015). Experiments on animals have shown a causal relationship between lead exposure and hypertension (Praveen & Purvi, 2014). Nosratola & Harvey (2008) propose that lead-associated hypertension and cardiovascular disease are caused by oxidative stress, inflammation, and altered vascular function.

Reactive astrogliosis and microgliosis in the hippocampus are two effects of lead exposure that may add to the pathophysiology of cardiovascular problems linked to long-term lead exposure (Upa et al., 2016). There have also been reports of lead-induced inflammation and oxidative stress, which can raise peripheral vascular resistance and vascular tone. Infants and early children are especially susceptible to the neurotoxic effects of lead, which can have long-term neurological impacts such as reduced cognitive ability, motor dysfunction, and learning difficulties (Michael et al., 2016). The severity of the clinical manifestations of lead toxicity depends on the duration and level of exposure (Garfield, 1982). Among the initial signs of lead poisoning are limb numbness, weakness, exhaustion, and constitutional complaints (Chukwukasi et al., 2021). Lead poisoning should be considered when conventional explanations of stomach pain are ruled out, especially in people with impaired liver function and anaemia (Wei et al., 2023). Leucoerythroblastic blood film, hypochromic microcytic anaemia with sideroblastic erythropoiesis, and hemolytic anaemia are among the conditions that can result from lead poisoning (Saeed et al., 2021).

Cadmium exposure has been linked to several harmful health outcomes, including damage to the kidneys, brain, and other organs (Chwalba et al., 2023); it can also result in oxidative stress, which impairs cellular metabolism, and an imbalance in the redox state of cells (Yong-Xin et al., 2022). Studies have shown that cadmium causes oxidative stress, DNA damage, autophagy, and endoplasmic reticulum stress—all adaptive stress responses that aid in the survival of cells in hostile settings (Saif et al., 2023). Too much stress might cause death or serious tissue damage (Ibha et al., 2021). Furthermore, exposure to cadmium can result in the bioaccumulation of heavy metals in tissues and organs, which can have a detrimental effect on reproductive health (Eric et al., 2022). The cadmium also poses a risk for thyroid cancer as indicated by studies (Zhang et al., 2020). Cadmium exposure causes histological and enzymatic changes in exposed organs (Murtaza et al., 2023). Rats treated with lead and cadmium showed congestion, sinusoidal dilatation, vacuolar degeneration, and MNC infiltration in the liver, along with degenerative changes in the tubules and intertubular haemorrhages in the kidneys (Ramesh et al., 2019). Malgorzata et al. (2018) observed ultrastructural changes in the kidney and liver tissues of chicken embryos exposed to cadmium, including growth of the lysosomal system and disruption of the mitochondrial structure.

Numerous health problems have been connected to aluminum absorption. Studies suggest that aluminum could be involved in neurological and nerve conditions such as autism, Parkinson's disease, Alzheimer's disease, and multiple sclerosis (Habimaana et al., 2022; Henry, 2022). Aluminum accumulation in tissues has been found to induce dysfunction, particularly in patients with chronic renal insufficiency (Qiao, 2018). Aluminum exposure at work has been found to affect the central nervous system, skeletal system, haematological system, urinary tract, and respiratory system (Bartłomiej et al., 2020). Studies have reported potential neurological effects from aluminum exposure, including memory and learning impairment, prevention of long-term potentiation (LTP), and decreased expression of brain-derived neurotrophic factor (BDNF) (Huan et al., 2020). Several studies have revealed a link between aluminum absorption and Alzheimer's disease (AD) (Alkaya et al., 2022). Long-term low-dose aluminum intake has been connected to neurodegenerative diseases including AD (Ivanenko et al., 2021). Atypical aluminum accumulations have been observed in the brains of individuals with Alzheimer's disease, amyotrophic lateral sclerosis, and parkinsonism with dementia, among other conditions (Linping, 2018).

Aluminum can enter the brain through the blood-brain barrier, choroid plexuses, and nasal cavities (Mistry et al., 2013). Aluminum takes time to exit the brain once it is there. Epidemiological studies suggest that aluminum exposure may accelerate brain aging and promote the onset of Alzheimer's disease and other age-related neurological illnesses (Stephen, 2014). Chronic aluminum exposure has been demonstrated to impact rat learning and memory, with higher aluminum intake resulting in more pronounced changes to the histology of the hippocampus (Wei et al., 2022). Aluminum exposure has also been linked to altered behavioural performance, cognitive impairment, and impaired synaptic plasticity (Owen, 2023).

Mitigating toxic metals in cookware

Cookware as source of toxic metals: An overview

The most effective methods for minimizing the presence of toxic metallic substances in cookware encompass the utilization of cookware composed of safe materials like stainless steel or glass, rather than recycled metallic materials; the application of a coating to the cookware, and the utilization of appropriate cleaning techniques (Habimaana et al., 2022). Extensive research has conclusively demonstrated that cookware derived from specific forms of discarded aluminum, such as automobile radiators and mixed metals leach higher levels of lead and other metals into the culinary preparations (Weidenhamer et al., 2017; Alabi & Adeoluwa, 2020). However, it has been found that cookware crafted from engine blocks does not leach any detectable quantities of lead (Habimaana et al., 2022). Employing a protective layer on the cookware substantially diminishes the leaching of metals, including aluminum, lead, cadmium, and arsenic (Pan et al., 2022).

Employing gentle cleansing agents such as steel filaments, sand, or ashes can assist in mitigating harm to the cookware surfaces and curtailing the hazard of metal leaching. It is also imperative to abstain from the use of aggressive cleaning agents, such as steel wire, sand, or ash, which possess the capability to inflict damage upon the surfaces of the cookware, thereby augmenting the migration of metals (Koo et al., 2020; Street et al., 2020). Moreover, the management of heating duration and temperature can play a significant role in minimizing the migration of metals, as a proportional relationship between temperature and the migration of specific metals like aluminum, lead, and cadmium has been observed (Alabi et al., 2020; Habimaana et al., 2022; Ehsan et al., 2023). The regular replacement of aged and impaired cookware is advisable, as the release of heavy metals is exacerbated in older containers due to frequent usage and damage or abrasion (Fatunsin et al., 2022). Moreover, the avoidance of cooking acidic foods in metal pots, unless utilizing glass pots, can contribute to the reduction of the leaching of potentially toxic metals into the food (Weidenhamer et al., 2023).

Conclusion

Careful attention is required to address the complex connection between cookware and human health to mitigate the potential dangers associated with exposure to toxic metals. The discussed findings emphasize the importance of making thoughtful choices when selecting cookware materials, considering not only their functional qualities but also their potential impact on the safety of the food being prepared. The presence of toxic metals such as lead, cadmium, and aluminum in certain cookware necessitates a heightened level of awareness among consumers, prompting them to prioritize materials that have a lower likelihood of leaching. Ultimately, the informed decision-making and responsible cooking practices can emerge as a key strategy in safeguarding public health.

Various factors, including acidity, cooking duration and temperature, affect metal leaching. Acidic foods, such as tomatoes and citrus fruits, may facilitate the release of metals in foods during cooking. Extended cooking times and high temperatures also increase the likelihood that metals migrate from cooking devices to food. Consumers must make well-informed decisions when selecting kitchen appliances to mitigate these risks. Selecting materials with a lower metal release potential, such as stainless steel or cast iron, can significantly reduce exposure.

Educational initiatives targeting consumers, which highlight the risks associated with specific materials and provide guidelines for safe cooking practices, play a pivotal role in this endeavour. By embracing these measures, individuals are empowered to make choices that prioritize both culinary needs and long-term well-being, thereby paving the way toward a healthier and safer culinary environment.

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