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Oxidation States of Toxic Metals in Food Toxicology: A Critical Gap

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Abstract

Toxic metals such as chromium (Cr), nickel (Ni), arsenic (As), mercury (Hg), cadmium (Cd), and lead (Pb) are frequently detected in food and are known for their significant health hazards. However, many studies focus solely on total metal concentrations, often neglecting the critical influence of oxidation states on toxicity, mobility, and bioavailability. For example, chromium in the higher oxidation state (Cr^{6+}) and arsenic in the lower oxidation state (As^{3+}) are remarkably more toxic than their respective lower (Cr^{3+}) and higher (As^{5+}) oxidation states, while methylmercury (CH_3Hg^+) poses far greater health risks than elemental mercury. Overlooking these differences can lead to inaccurate health risk assessments. This letter emphasizes the necessity of identifying both concentrations and oxidation states to support a more precise evaluation of food safety. Although advanced spectroscopic techniques such as X-ray absorption spectroscopy (XAS), X-ray photoelectron spectroscopy (XPS), and inductively coupled plasma mass spectrometry (ICP-MS) can provide this insight, their complexity and cost hinder widespread adoption. Addressing this research gap through collaborative, cost-effective strategies and standardized methodologies can substantially improve the accuracy of food toxicology assessments and safeguard public health.

SCAN ME

Dear Editor,

Many studies highlighted the significance of taking into account bio-accessibility and bioavailability when assessing health risks associated with toxic metals in food. The bioavailability, toxicity, and environmental behaviour of a metal can be different across its different oxidation states in food studies [1]. Health assessment of food is incomplete without the determination of the oxidation state of toxic metals. The presence of toxic metals in food, such as chromium (Cr), cadmium (Cd), nickel (Ni), arsenic (As), mercury (Hg), and lead (Pb) is a significant concern in food studies. Determination of concentrations and oxidation states of toxic metals is essential for public health in foods. However, a significant research deficiency remains in the identification and confirmation of the different oxidation states and concentrations of the same metals in food. Traditional risk assessments that focus on total metal concentrations in raw or cooked food may overestimate actual exposure [1].

In this letter, we point out the health issues in food studies to determine the different oxidation states and concentrations of the toxic metals. It was studied that it was ecologically and economically beneficial for intercropping peanuts with plants like lucerne and jute to enhance arsenic removal from contaminated soil [2]. These studies overlooked the oxidation states of arsenic and their presence in biota. It is important to note that As^{+3} is significantly more toxic than As^{+5}[3]. Understanding the various oxidation states of toxic metals is essential; otherwise, the evaluation of the health risk assessment is incomplete. Similarly, mercury (Hg) is also present in various food sources in different oxidation states. Elemental mercury (Hg^0) is rarely found in food. In contrast, mercury with oxidation state $^{+}1$, found as methylmercury (CH_3Hg^+), an organic form of mercury, commonly accumulates in fish and seafood, posing significant health risks. Mercury (Hg^{2+}) is present in crops grown in contaminated soil [4]. The studies on mercury contamination in food often overlook the specificity of its oxidation states, which limits the accuracy of its toxicity assessment. The mercury (Hg^{2+}) is highly toxic because it binds to proteins and enzymes, which leads to disrupting biological functions and causes damage to the kidney and neurological system [5].

In Ethiopia, chromium (Cr) metals in vegetables were found to range from 2.90 to 3.77 mg/kg, exceeding the safety limits set by the WHO and FAO. However, the oxidation state of chromium was not evaluated in this study. Here, the concentration was determined, but oxidation states were not ruled out because Cr^{+6} is highly toxic and carcinogenic, while Cr^{+3} is an essential nutrient in small amounts. Without determining between these two oxidation states, it is impossible to accurately assess the risks associated with chromium contamination in food [6]. Olafisoye et al. reviewed the presence of As, Cd, Pb, Cr, Ni, Hg, Al, Cu, and Zn in palm oil, but oxidation states were not mentioned. The nickel metal bioavailability in various foods varies from 0% to 30% [7].

For determining the oxidation states of metals, advanced analytical techniques such as X-ray absorption spectroscopy (XAS), X-ray photoelectron spectroscopy (XPS), and inductively coupled plasma mass spectrometry (ICP-MS) can be used. However, many studies neglect the significance of oxidation states in assessing toxicity, often due to the complexity of techniques like X-ray absorption near-edge structure (XANES). To address this issue, it is vital to develop cost-effective methods, encourage collaboration among research institutions, and raise awareness about the importance of both oxidation states and metal concentrations. Establishing standardized protocols and adopting multidisciplinary approaches will enhance the accuracy of toxic metal assessment and improve food safety. Regardless of significant research efforts, suitable research is lacking on the oxidation state of toxic metals in foods. I urge researchers and institutions to prioritize oxidation state and concentration analysis in food investigations. Focusing on this gap will lead to more accurate risk assessments and contribute to the safety of food for consumers worldwide. Furthermore, filling this knowledge gap will advance agricultural, environmental, and phytochemical sciences.

Conflict of interest

The authors declare no conflict of interest.

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