

Reduction of Mercury Bio accessibility Using Dietary Strategies

Krushna Yadav, D. K.^{1*} Venkatesh, R.¹ and Shilpa, K.²

¹Department of Food Science and Nutrition, University of Agricultural Sciences,
GKVK, Bengaluru-560065, Karnataka, India

²Department of Food Technology, Davangere University, Davangere-577002, Karnataka, India

*Corresponding Author E-mail: dr.dkky@gmail.com

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ABSTRACT

Inorganic divalent mercury [Hg (II)] and methylmercury (CH₃Hg) are the major forms of mercury (Hg) in the diet. Seafood products, especially large predators, are the main dietary sources of CH₃Hg, although they also contain considerable concentrations of Hg (II). Vegetable products such as mushrooms make an important contribution to intake of Hg (II). The toxic effects of Hg are well known, consisting mainly of neurological, immune, haematological and renal alterations, and are dependent on the dose, chemical form and exposure route. Continuous exposure to Hg takes place mainly as a result of exposure in the workplace, but population groups exposed to Hg through the diet have also been identified, such as subsistence fishing populations and frequent consumers of certain seafood products. It has been stated that the bioavailability of Hg (the quantity absorbed after ingestion, which reached the systemic circulation) depends on the chemical form in which the metal is present and also is influenced by the presence of certain food components. Thus, there are components in the diet that influence the quantity of Hg that reaches the systemic circulation and that accumulates in target organs. This makes it possible to evaluate the possible use of food components as dietary strategies to reduce the quantity of this metal that reaches the bloodstream.

Key words: Mercury, Bio accessibility, Bioavailability, Reduction, Dietary Strategies.

INTRODUCTION

Mercury is a naturally occurring element that is found in air, water and soil. Mercury (Hg) is a highly toxic element effecting the nervous system, heart, kidneys, lung, and immune system of human being. Mercury (Hg) is a persistent pollutant in the environment and is

one of the most highly bio concentrated trace metal in the human food chain. Mercury is widely distributed in aquatic ecosystems as a result of anthropogenic activities. Eating fish contaminated with methylmercury (MeHg) is the major source of human exposure to mercury⁷.

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Mercury in nature

- Mercury vapors are given off during volcanic eruptions.
- Mercury is a by-product of coal-burning power plants. Mercury is

released into the air, then it falls back to the earth⁵.

- Mercury is used by mining operations to separate gold from impurities in ore.

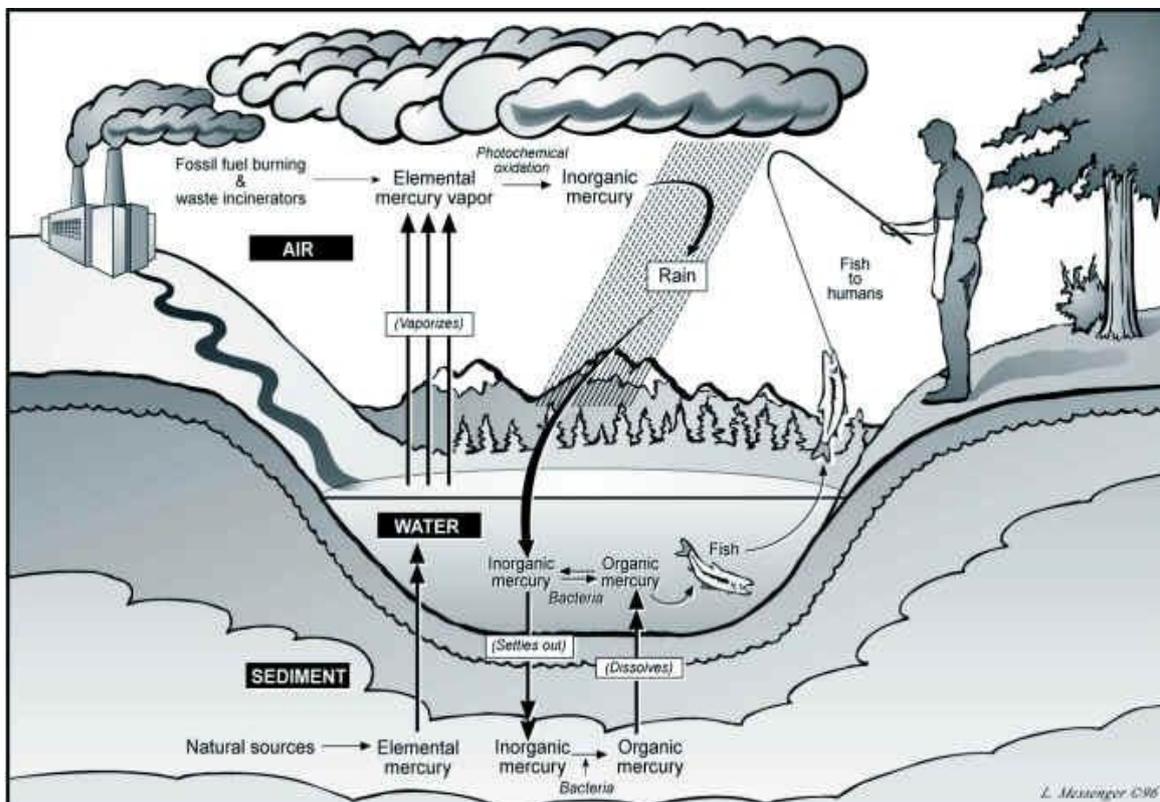


Fig. 1: The mercury cycle: How mercury enters the food chain

Forms of mercury

Mercury exists in various forms and people are exposed to it in different ways. The most common way people are exposed to mercury is by eating fish containing methylmercury.

- **Elemental (Metallic) mercury:** shiny, silver, odorless liquid used in thermometers. It is absorbed by the body through vapors.
- **Organic mercury (Methylmercury):** mercury combined with carbon. Organic mercury is absorbed through the digestive tract.
- **Inorganic mercury:** mercury combined with non-carbon substances.

Exposure to mercury

- Breathe mercury fumes.
- Eat food (especially fish) or drink water that has been contaminated by mercury.

- Absorb mercury through the skin.
- Eat objects that contain mercury. For example, small children may eat batteries that contain mercury.

What is the safe level of exposure to mercury?

- WHO has set a Provisional Tolerable Weekly Intake (PTWI) of 1.6 $\mu\text{g}/\text{kg}$ body weight¹⁵.
- Whole blood mercury levels are usually less than 2 mcg/dL in unexposed individuals¹⁸.

Effect of mercury on nervous system

- Direct effect on ion exchange in a neuron
- Disruption of neurotransmitters
- Destruction of the structural framework of neurons.

Effect of methylmercury in children

Children exposed to methylmercury while they are in the womb can have impacts to their ¹⁰.

1. Cognitive thinking
2. Memory
3. Attention
4. Language
5. Fine motor skills
6. Visual spatial skills

Symptoms of methylmercury poisoning

- Loss of peripheral vision
- "Pins and needles" feelings, usually in the hands, feet, and around the mouth
- Lack of coordination of movements
- Impairment of speech, hearing, walking
- Muscle weakness

Mercury health effects depend upon

- The type of mercury
- Dose of mercury
- The age or developmental stage of the person exposed (the foetus is most susceptible)
- Duration of exposure
- Route of exposure (inhalation, ingestion or dermal contact).

Bioavailability of mercury

Bioavailability is defined as the fraction of an ingested contaminant in a certain matrix that reaches the systemic circulation and three steps can be distinguished:

1. Release of the contaminant from its matrix during digestion in the gastrointestinal tract.
2. Absorption of the bio accessible fraction.
3. Metabolism in the intestine and liver.

The term "bioavailability" has several working definitions, depending on the research area it applies to. From the nutritional point of view, bioavailability refers to the fraction of the nutrient or bioactive compound ingested that is available for use in physiologic functions or to be stored. Bioavailability Is the proportion of a given nutrient in a given food or diet that the body can actually use. Bioavailability is a key concept for nutritional effectiveness, irrespective of the type of food being considered (functional or not) ⁶. Only certain

amounts of all the nutrients and bioactive components in food will be used effectively by the organism. From a pharmacologic point of view, the Food and Drug Administration defines bioavailability as the rate and extent to which the therapeutic moiety is absorbed and becomes available at the site of drug action. The term "bioavailability" includes availability for absorption, absorption, metabolism, tissue distribution, and bioactivity ⁴. However, there are practical and ethical difficulties in the measurement of delivery and bioactivity of food/drug components on specific organ sites of biologic activity, so that the term "bioavailability" is usually defined as the fraction of an oral dose of a parent compound or active metabolite from a particular preparation that reaches the systemic circulation ⁶.

Bio accessibility of mercury

- The quantity or fraction of mercury which is released from the food matrix in the GI tract and becomes available for absorption is called as bio accessibility of mercury ¹⁰.
- Bio accessibility includes digestive transformations of food into material ready for assimilation, the absorption into intestinal epithelium cells, and lastly, the presystemic metabolism (both intestinal and hepatic) ³.
- Bio accessibility indicates the maximum fraction of contaminant that is released from the food matrix into the digestive tract (mouth, stomach, and intestine) ¹¹.
- Determining bio accessibility of mercury contributes to the assessment of the health risk-benefit in human ¹.

Methods to reduce bio accessibility of mercury

1. **In vitro digestion method-** In-vitro digestion models are widely used to study the structural changes, digestibility, and release of food components under simulated gastrointestinal conditions.
2. **Cooking methods-** Boiling, Grilling, Roasting.

3. **Phytochemicals-** e.g., catechin and isoflavone.

Mechanism of *In vitro* digestion method

1. Contaminated sample mixed with 4 mL of artificial saliva at a pH 6.8 for 5 min, then 8 mL of artificial gastric juice (pH 1.3 at 37 °C) was added.
2. The mixing lasted 2 h in a head-over-heels movement (37 rpm at 37 °C).
3. Finally 8 mL of artificial duodenal juice (pH 8.1 at 37 °C), 4 mL of bile

(pH 8.2 at 37 °C), and 1.33 mL of HCO₃ solution (1 M) was added.

4. The pH of the mixture was set at 6.5 and agitation for 2 h was identical to gastric conditions.
5. The mixture generated in the *in vitro* model was subjected to centrifugation at 2750×g for 5 min, thus yielding a non-digested portion and the bio accessible fraction.
6. The bio accessible part was subjected to analysis⁷.

IN VITRO

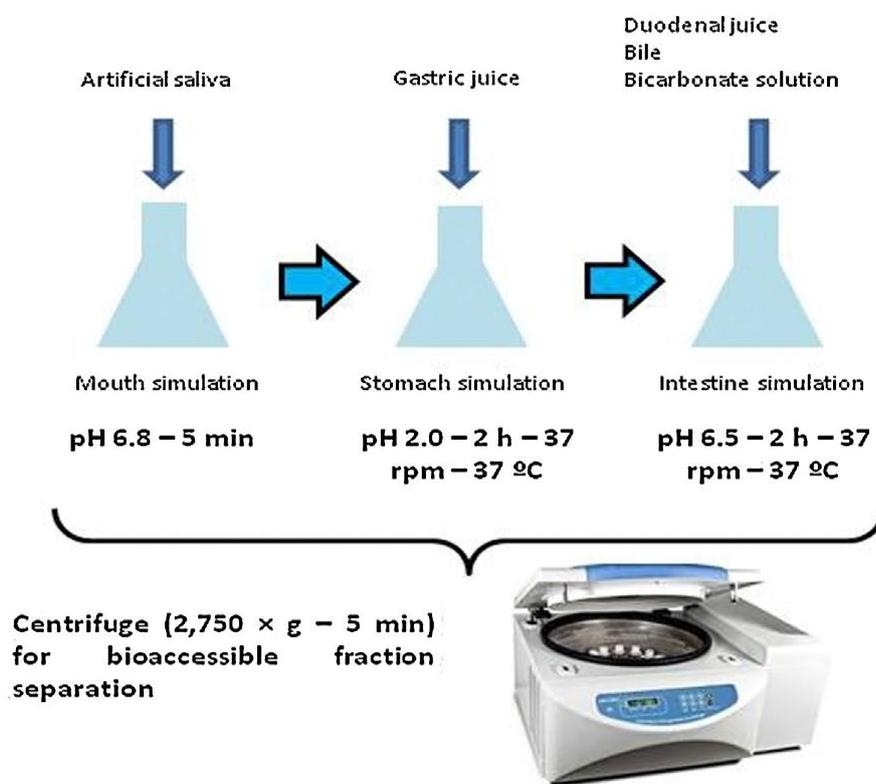


Fig. 2: Mechanism of *In vitro* digestion method

Mechanism of cooking in reduction of mercury bio accessibility

- Hg have a strong chemical propensity to bind to the small amount of aggregated and non-bio accessible protein that forms during cooking.
- The reduction of the bio accessible Hg in cooking methods related with the protein denaturation. The denatured proteins become less accessible to the

protease action and consequently less Hg is released into the digested fraction¹.

Effect of phytochemicals in reduction of mercury bio accessibility

- Phytochemicals/dietary fibres (insoluble fibre) will bind mercury in the gut, making it insoluble and unavailable for absorption by intestinal mucosa¹⁷.

Advantages and disadvantages of *In-vitro* digestion method

Advantages	Disadvantages
1. Screening of numerous samples is possible	1. Homeostatic mechanisms are not present
2. Extrapolation to <i>in vivo</i>	2. Relatively inexpensive and technically simple
3. Focus on small number of components	3. Dynamic conditions of gastrointestinal tract are not fully reproduced with biochemical and cell culture models
4. Specific mechanisms of action can be tested	4. Intestinal bacteria and hepatic metabolism is not always considered
5. Validation with reference material	5. Oral and large intestinal phases are often not included although can readily be added
6. Closed system not responsive to composition and quantity of foods	6. Efficiency of each digestion, absorption or transport

SUMMARY

- ✓ Inorganic divalent mercury [Hg(II)] and methylmercury (CH₃Hg) are the major forms of mercury (Hg) in the diet. Seafood products are the large predators of mercury¹⁶.
- ✓ The toxic effects of Hg are well known, consisting mainly of neurological, immune, haematological and renal alterations and are dependent on the dose, chemical form and exposure route¹⁹.
- ✓ Concentrations of mercury in fish present a food safety problem for many countries.
- ✓ *In vitro* digestion method was an effective method to reduce the bio accessibility of Hg and MeHg in raw and cooked meagre¹.
- ✓ Mercury bio accessibility was found to be dependent on the type of fish analyzed due to different degradation effectiveness of the food matrix².
- ✓ Hg and MeHg bio accessibility was reduced by different cooking methods such as boiling, grilling, roasting¹².
- ✓ The potential of dietary fiber prepared from cassava pulp to decreased Hg bio accessibility¹⁴.
- ✓ The incorporation of cellulose derivatives, tannic acid, lignin or pectin in the diet, either in the form of supplements or else added to foodstuffs, may provide solutions for reducing the oral bioavailability of Hg¹³.
- ✓ Food which is rich in phytochemicals may be as efficient as synthetic

chelating agents (e.g., DMPS) for long-term chronic methylmercury exposure in fish-eating populations by reducing mercury bio accessibility¹⁷.

CONCLUSION

The incorporation of phytochemical-rich foods, dietary fiber and the different types of cooking methods employed in foodstuffs helps in reducing the bio accessibility of Hg and may provide solutions to reduce the oral bioavailability of Hg. Further, before considering their use as dietary strategies for reducing absorption of Hg, it is necessary to verify that their application does not affect the nutritional state by means of tests on laboratory animals.

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