Tin, Inorganic

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Abstract

The form of tin found in canned foods and beverages has gastrointestinal effects that depend on exposure. Food contact conditions and toxicological differences from organotins are covered separately.

This page draws on evidence from EFSA and ATSDR, together with 10 peer-reviewed studies. The complete citation list is at the bottom of the page.

1 | Toxicology

Inorganic tin denotes tin in the +2 (stannous) and +4 (stannic) oxidation states bound to non-carbon ligands such as chloride, sulfate, or oxide. It is toxicologically distinct from organotin compounds (which are systemic immunotoxicants and neurotoxicants at three orders of magnitude lower doses) and from elemental tin; for organotin compounds see organotins. The EFSA ANS Panel re-evaluation of stannous chloride (E 512) found no safety concern at current authorized use levels and adopted the JECFA provisional maximum tolerable daily intake of 2 mg/kg body weight per day (provisional tolerable weekly intake 14 mg/kg bw per week) for inorganic tin as a contaminant as the operative reference value 1.

The principal toxic effect of inorganic tin after ingestion is acute local irritation of the gastrointestinal mucous membrane producing nausea, vomiting, and diarrhea. The threshold for symptomatic effects in controlled human single-dose challenges is approximately 1,000 to 1,400 mg/kg tin in fruit juices 2. Below that concentration, single-dose ingestion is generally well tolerated; above it, gastrointestinal symptoms appear in a fraction of subjects that scales with concentration. Cats are somewhat more sensitive than humans and dogs: 1 of 11 cats vomited at 540 mg/kg, 20 to 30 percent at 1,370 mg/kg, up to 40 percent at 2,000 mg/kg. Systemic absorption of inorganic tin from the gastrointestinal tract is limited: approximately 99 percent of an ingested dose is recovered in feces in rat studies; urinary recovery is essentially zero. ATSDR derived an intermediate-duration oral minimal risk level of 0.3 mg tin per kg per day from a no-observed-adverse-effect level of 32 mg/kg per day in animal studies of stannous chloride, applying an uncertainty factor of 100 3. The chronic effects in the supporting

literature include anemia and reversible liver and kidney effects at sustained doses substantially above realistic dietary intake.

2 | Exposure routes

Ingestion of canned food and canned beverage is the dominant inorganic tin exposure pathway. Acidic foods in tinplated cans dissolve elemental tin from the lining; the dissolution rate is governed by content pH, can lacquering status, oxygen partial pressure, and storage time and temperature. Light-colored fruits and fruit juices are historically packaged in unlacquered tinplate because elemental tin reacts with anthocyanin pigments to maintain product color; this category accounts for the highest-tin canned products in modern markets. More than 90 percent of food cans now use lacquered linings that suppress the food-tin reaction and keep finished-product tin below 25 mg/kg, versus up to 100 mg/kg in unlacquered cans 3. A study of three Indonesian canned beverage categories found tin concentrations between approximately 2.5 and 5.8 mg/kg, well below regulatory caps but with the expected pattern that lower pH and longer storage produce higher tin release 4.

Other ingestion routes are minor: foods not packaged in metal cans contain tin generally below 2 mg/kg. Drinking water tin is typically below 0.003 mg per liter. Stannous fluoride in toothpaste contributes some oral exposure; pewter, bronze, and historic tinware leach inorganic tin into food in some legacy use contexts but are quantitatively minor in modern food systems. Inhalation exposure to tin oxide dust is an occupational concern in tin smelting and electronics manufacturing but is outside dietary scope.

3 | Food sources

Canned acidic fruits and fruit products are the highest-tin food category in multiple independent surveys. The clearest demonstration of the lacquer effect comes from a Slovak retail study of 25 canned fruit and vegetable samples: unlacquered tinplate cans produced tin concentrations of 23.3 to 199.2 mg/kg, with pineapple compote the highest (199.2 mg/kg), while fully lacquered cans of the same product types held 0.44 to 77.2 mg/kg 5. No sample exceeded the EU maximum level of 200 mg/kg, but one approached it. Among unlacquered tinplate products, peach halves in syrup reached 104.9 mg/kg, apricot compote 76.7 to 115.6 mg/kg, and fruit cocktail in light syrup 107.3 to 115.8 mg/kg.

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
5, Slovakia	Canned fruit and vegetable, tinplate unlacquered, retail; HG-ICP-OES	total tin (inorganic)	23.3 to 199.2 mg/kg, wet weight	11 tinplate samples	Highest single sample 199.2 mg/kg (pineapple); approaching EU 200 mg/kg limit
5, Slovakia	Canned fruit and vegetable, lacquered, retail; HG-ICP-OES	total tin (inorganic)	0.44 to 77.2 mg/kg, wet weight	8 lacquered samples	Range very wide; below 5 mg/kg most lacquered products except peach compote (69.6) and champignons (77.2)

6, Zhejiang, China	Canned fruits and fruit products; ICP-MS; dry weight basis	total tin	mean 12.67 mg/kg, P50 0.15 mg/kg, P95 80.73 mg/kg, max 134 mg/kg, dry weight	82	High mean driven by right-skewed distribution; dry weight basis requires wet-weight conversion for comparison
6, Zhejiang, China	Canned vegetables and vegetable products; ICP-MS; dry weight	total tin	mean 1.05 mg/kg, P95 5.13 mg/kg, max 19.80 mg/kg, dry weight	57	Lower than canned fruits by an order of magnitude
6, Zhejiang, China	Canned meat and meat products; ICP-MS; dry weight	total tin	mean 0.96 mg/kg, dry weight	71	Low absolute values
6, Zhejiang, China	Fresh vegetables (all categories); ICP-MS; dry weight	total tin	means 0.01 to 0.06 mg/kg, dry weight	673	Two to three orders of magnitude below canned fruit
7, Valencia, Spain	Sauces and mayonnaise composite (within sweeteners and condiments group); ICP-MS	total tin	mean 6.12 mg/kg, max 25.62 mg/kg, wet weight	subset of 50 composites	Highest-tin non-canned-fruit matrix in this TDS; sauce packaging type not specified
7, Valencia, Spain	Canned fish, composite; ICP-MS	total tin	mean 0.22 mg/kg, range 0.10 to 0.35 mg/kg, wet weight	subset of 120 composites	Relatively low; tin not the primary risk in canned fish
8, Lebanon	Canned tuna, 17 brands, center and outer portions; ICP-MS	total tin (inorganic)	mean 3.35 mg/kg, range 0.99 to 8.96 mg/kg, wet weight	102 sub-samples from 51 cans	100% detection; all well below EU 200 mg/kg limit; HRI <0.001 for all scenarios
9, Turkey	Canned tuna, 105 samples, three packing media; ICP-MS	total tin	oil-packed 59.4 plus or minus 20.8 mg/kg (38.2 to 115.9), wet weight	35 per group	Oil-packed substantially higher than water-packed or sauce-packed; all below EU 200 mg/kg

9, Turkey	Canned tuna, water-packed; ICP-MS	total tin	mean 37.1 plus or minus 2.9 mg/kg (32.6 to 43.1), wet weight	35	n/a
9, Turkey	Canned tuna, sauce-packed; ICP-MS	total tin	mean 39.5 plus or minus 3.3 mg/kg (34.0 to 44.8), wet weight	35	n/a
10, Iran	Canned tomato paste, canned olives, pickled cucumbers; ICP-MS	total tin	tomato paste 0.41 mg/kg, olives 0.32 mg/kg, pickled cucumbers 0.11 mg/kg, wet weight	49 total	All below method LOQ of 4.6 mg/kg; qualitative confirmation of presence only
11, Portugal	National total diet study; ICP-MS; fresh weight	total tin	fruit and fruit products highest group; specific values in supplementary only	n/a	Quantitative data in Supplementary Table S1; main text confirms fruit group highest for tin

The canned tuna data from the Turkish study 9 shows substantially higher tin than the Lebanese survey 8 (mean 37 to 59 mg/kg versus 3.35 mg/kg, wet weight). Both studies used ICP-MS on commercially available products; the difference may reflect brand or origin differences in can lining or processing. All samples in both studies were below the EU maximum level of 200 mg/kg.

Historical occurrence data from Biego et al. 1999 (cited in 3 Table 6-2) reported canned vegetable and fruit category means in the high tens of mg/kg from unlacquered cans; non-canned dietary staples (meats, milk, dairy, breads, pasta, mineral water) reported tin at or below 0.003 mg/kg, three orders of magnitude below the canned categories.

4 | Regulatory limits

The EU sets binding maximum levels for inorganic tin under EU 2023/915 1: 200 mg/kg in canned food other than canned beverages; 100 mg/kg in canned beverages; 50 mg/kg in canned infant formula and follow-on formula and canned young-child formula; 50 mg/kg in canned baby food and canned processed cereal-based food; 50 mg/kg in canned infant and young-child medical foods. The infant and baby-food limits are tightened by an order of magnitude relative to general canned beverages.

Stannous chloride (E 512) is authorized as a food additive in the EU only in white asparagus (food category 04.2.3) at a maximum permitted level of 25 mg tin per kg 1. No E 512 labelling was found in EU or Norwegian market searches from 2013 to 2018, suggesting the authorization is rarely exercised.

The U.S. has no equivalent FDA action level or maximum level for tin in food at the federal level; FDA addresses tin primarily through Total Diet Study surveillance and contact-material guidance rather than a numeric food limit. Codex Alimentarius CXS 193-1995 sets a 250 mg/kg general food maximum for inorganic tin in canned

foods other than canned beverages and 150 mg/kg for canned beverages; the Codex limits are looser than EU 2023/915.

5 | Testing

Atomic absorption spectrophotometry at 286.3 nm with air-acetylene flame is the historical workhorse for inorganic tin in food; ICP-MS is now the routine multi-element method and produces total-tin values that, in canned food matrices, are appropriately treated as inorganic tin. Hydride generation ICP-OES (HG-ICP-OES) achieves a sample LOQ of approximately 6.4 µg/kg, substantially lower than the AAS detection threshold of 5 mg/kg, enabling quantification in fully lacquered cans where AAS returns only below-detection results 5.

Speciation methods that separate stannous from stannic forms are uncommon in routine food occurrence work because the toxicological distinction between those two inorganic forms is small relative to the inorganic--versus-organotin distinction. Speciation methods separating inorganic tin from organotin compounds (gas--chromatographic or HPLC separation with ICP-MS detection) are essential for any matrix where organotin loading is suspected, especially seafood and drinking water from PVC distribution. The EFSA ANS Panel noted that all total-tin measurements were of stannous chloride (inorganic, Sn2+) and explicitly excluded organotin compounds from scope 1.

Fecal collection over 24 hours is sufficient to characterize inorganic tin absorption and excretion in animal challenge experiments because urinary excretion is essentially absent 2. This metabolic pattern matters for biomonitoring choices: blood and tissue tin reflect organotin and not inorganic tin in mixed exposures, so urinary or fecal measurement is the appropriate route for ingested inorganic tin assessment 12.

6 | Microbiome effects

The current corpus is essentially silent on inorganic-tin effects on the gut microbiome. The local-irritation mechanism documented in 2 implies real interaction with the small-intestinal and gastric mucosa, but no taxon-level or functional metals-microbiome study with inorganic tin as the primary exposure is loaded on the wiki. This is a candidate gap for WikiBiome crosswalk when source material is identified.

7 | Vulnerable populations

Infants and young children fed canned baby food are the principal inorganic-tin dietary vulnerable group, which is why EU 2023/915 sets the 50 mg/kg infant and baby-food limit at one quarter of the general canned-food limit EU 2023/915. Body-weight-normalized intake of tin from canned baby food can be substantially higher than adult intake of tin from canned beverages, even at lower per-product concentrations, because small infants consume larger fractions of body weight per serving.

People with acidic-food-heavy diets (canned tomato products, citrus juice, fruit cocktails, sauerkraut, pickles) take in more inorganic tin than typical Western mixed diets. The Zhejiang survey found that adults aged 18 to 59 years had the highest dietary tin exposure under high-consumption and high-concentration scenarios, dominated by canned fruits, while children under 6 years had the highest exposure from canned meat 6.

8 | Mitigation

The dominant determinant of tin concentration in canned food is can lining type. Products in fully lacquered cans had concentrations of 0.44 to 77.2 mg/kg, while unlacquered tinplate products of equivalent acidity reached 23.3

to 199.2 mg/kg in the same retail study 5. More than 90 percent of food cans globally now use lacquered linings; selecting products from manufacturers known to use fully lacquered cans for acidic products (tomatoes, citrus, pineapple, peaches) reduces inorganic tin intake. Storage time and temperature matter for unlacquered and partially lacquered cans: lower storage temperatures and shorter storage times reduce tin migration 4. Damaged lacquer on the interior of a can accelerates tin release; discarding cans with internal damage, rust, or unusual odor is prudent. Pouch and glass packaging eliminate the tinplate migration pathway entirely.

9 | What remains uncertain

What is the current US-market distribution of inorganic tin in canned acidic foods, particularly canned tomato products and canned fruit juices? Surveillance updates since the early 1990s are limited in the loaded corpus; the FDA Total Diet Study and any successor surveys would be useful to ingest.

How does the introduction of plant-derived can-lining lacquers (replacements for BPA-containing epoxy linings) affect tin release in acidic canned foods? Lacquer chemistry has shifted substantially in the past decade, and tin release behavior under newer linings is not characterized in the loaded corpus.

What explains the apparent discrepancy in canned tuna tin concentrations between the Lebanese survey (mean 3.35 mg/kg wet weight) and the Turkish survey (mean 37 to 59 mg/kg wet weight)? Both studies used ICP-MS on commercially available products. Brand differences, can lining types, or geographic sourcing of the canned product are plausible explanations but are not characterized.

What is the dietary tin intake for infants on heavy reliance on canned commercial baby food? The 50 mg/kg EU canned-baby-food limit prevents acute exposures, but chronic body-burden from frequent canned-product feeding is not modeled in the loaded corpus.

10 | Frequently asked questions

Where does the tin in my food actually come from?

The dominant dietary source of inorganic tin is food packaged in tinplated metal cans, where acidic contents dissolve elemental tin from the lining. Light-colored fruits and fruit juices in unlacquered cans are the highest-tin products, though more than 90 percent of cans now use lacquered linings that keep finished-product tin below 25 ppm versus up to 100 ppm in unlacquered cans (ATSDR 2005). Foods not packaged in metal cans generally contain tin below 2 ppm, and drinking water is typically below 0.003 mg per liter.

What are the health effects of swallowing too much inorganic tin?

The main effect is acute local irritation of the gastrointestinal lining, causing nausea, vomiting, and diarrhea. In controlled human single-dose challenges, symptoms appeared at roughly 1,000 to 1,400 ppm tin in fruit juices, and below that level single-dose ingestion is generally well tolerated (Benoy, Hooper, Schneider 1971). Systemic absorption is limited (about 99 percent of an ingested dose leaves in the feces in rat studies), so inorganic tin acts mainly as a local irritant rather than a systemic poison.

Is inorganic tin the same as the tin in seafood I've read about?

No. Inorganic tin (the +2 and +4 forms bound to chloride, sulfate, or oxide) acts as a local gastrointestinal irritant, while organotin compounds are systemic immunotoxicants and neurotoxicants at doses about three orders of magnitude lower. This mechanism difference is described as the central toxicological fact about tin, which is why

honest exposure assessment requires separating the two species. Organotin loading is documented in matrices such as seafood, drinking water from PVC pipes, and food contacting PVC plastics; see organotins.

Are there legal limits on how much tin canned food can contain?

Yes. The EU sets binding maximum levels of 200 mg/kg in canned food other than beverages, 100 mg/kg in canned beverages, and 50 mg/kg in canned infant formula and baby food (EU 2023/915). Codex Alimentarius sets looser limits of 250 mg/kg for canned foods and 150 mg/kg for canned beverages. The U.S. has no equivalent federal FDA action level for tin in food, addressing it instead through Total Diet Study surveillance and contact-material guidance.

Are babies and young children more at risk from tin in canned food?

Infants and young children fed canned baby food are the principal dietary vulnerable group, which is why the EU sets the 50 mg/kg infant and baby-food limit at one quarter of the general canned-food limit (EU 2023/915). Body-weight-normalized tin intake from canned baby food can be substantially higher than adult intake from canned beverages, even at lower per-product concentrations, because small infants consume larger fractions of body weight per serving. People with acidic-food-heavy diets (canned tomato products, citrus juice, pickles, sauerkraut) also take in more inorganic tin than typical mixed diets.

How is tin measured in food, and does testing separate the different forms?

Atomic absorption spectrophotometry has historically been the workhorse, while ICP-MS is now the routine multi-element method, producing total-tin values that in canned food are treated as inorganic tin. Methods that separate stannous (Sn2+) from stannic (Sn4+) forms are uncommon because their toxicological difference is small compared with the inorganic-versus-organotin split. Separating inorganic tin from organotin compounds does require dedicated speciation methods (such as gas chromatography or HPLC with ICP-MS detection), which are essential for matrices like seafood or PVC-contacted water where organotin is suspected.

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Every source behind this reference is listed with its own source record at https://heavymetalindex.com/metals/tin-inorganic#sources.

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