Inorganic tin in food is a can-format-and-acidity contaminant, not an agricultural or geogenic one, with an acute gastrointestinal effect whose symptomatic threshold sits three to four orders of magnitude above lead and cadmium limits

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Abstract

Inorganic tin occupies a toxicological and regulatory register unlike every other commonly regulated food-contaminant metal. Lead, cadmium, arsenic, and mercury enter food through the plant, the soil, the water, or the feed, and their limits are set against chronic systemic endpoints (neurodevelopment, renal accumulation, carcinogenicity) at concentrations in the single-digit-to--low-hundreds parts-per-billion range. Inorganic tin enters food almost exclusively at the packaging interface, dissolving from the bare tinplate wall of unlacquered (plain) cans into the food they hold. Its adverse effect is acute gastrointestinal irritation from direct mucosal contact rather than chronic systemic toxicity, and the concentration at which symptoms appear is measured in hundreds to low thousands of milligrams per kilogram (parts per million), three to four orders of magnitude above the corresponding lead and cadmium maximum levels.

1 | Overview

Three independent A-tier sources converge on this picture from three distinct registers. A controlled human and animal dose-response study from the University of Birmingham (Benoy, Hooper, and Schneider 1971) fixed the symptomatic threshold and demonstrated the local-irritation mechanism. The European Commission Scientific Committee on Food opinion of 2002 derived the 200, 100, and 50 mg/kg canned-food, canned-beverage, and

infant-food maximum levels that carried forward into current EU law. A Polish national monitoring survey (Mania et al. 2021) measured the actual occurrence distribution of tin in retail canned fruit, showing a mean near 70 mg/kg wet weight and a maximum of 206 mg/kg in canned pears. Two lower-tier sources corroborate the mechanism: an industry-sponsored review (Blunden and Wallace 2003) compiles the unlacquered-can and storage-temperature dissolution literature, and a Romanian storage experiment (Buculei et al. 2012) shows tin in canned tomato paste climbing from below the detection limit to roughly 9 to 23 mg/kg (still well under the regulatory ceiling) over three years of shelf life. The non-obvious synthesis is that tin risk is a story about can construction, matrix acidity, and storage time. It is invisible on any single fresh-ingredient page, because the fresh ingredient carries essentially no tin; it materializes only once the ingredient is sealed inside a particular kind of can and left there.

2 | The symptomatic threshold and mechanism (Benoy, Hooper, and Schneider 1971)

Benoy, Hooper, and Schneider 1971, from the Department of Clinical Pharmacology at the University of Birmingham and published in Food and Cosmetics Toxicology, is the foundational controlled-dose study in this literature and is graded A-tier. It was motivated by a 1967 food-poisoning outbreak in Kuwait linked to canned orange and apple juice containing 250 to 385 ppm tin. The authors fed authenticated outbreak juices and laboratory tin-spiked solutions to pigeons, cats, dogs, rats, and five human volunteers, and combined this with a fecal and urinary balance study.

The human dose-response is the load-bearing result. Volunteers who drank 240 ml of orange juice at 498, 540, or 730 mg/kg tin showed no adverse effect; at 1,370 mg/kg tin, all five volunteers experienced nausea and diarrhea, and on re-administration one month later one of five was affected. In cats, a single animal of eleven vomited at 540 mg/kg, roughly 20 to 30 percent vomited at 1,370 mg/kg, and up to 40 percent at 2,000 mg/kg. The mechanism is local irritation of the alimentary mucous membrane rather than systemic absorption: approximately 99 percent of an ingested dose was recovered in rat feces, no tin was recovered in urine, and only minute amounts reached tissues outside the alimentary tract after seven days of ad libitum feeding. This absorption-limited, contact-irritation mechanism is why the tin story is fundamentally different from the lead and cadmium stories, where the toxicologically relevant event is systemic accumulation over years. For tin, the dose that matters is the concentration in the single serving making contact with the gut wall on the day it is consumed.

3 | The regulatory derivation (EU Scientific Committee on Food 2002)

The European Commission Scientific Committee on Food opinion on acute risks posed by tin in canned foods (SCF/CS/CNTM/OTH/18 Final, adopted 12 December 2001, published 8 January 2002) is the A-tier regulatory--toxicology anchor and is institutionally independent of Benoy 1971 even though it synthesizes that primary work. The opinion establishes that acute tin exposure from canned food can produce gastrointestinal effects (nausea, vomiting, diarrhea) at concentrations above approximately 200 mg/kg in liquid foods and approximately 250 mg/kg in solid foods, with lower no-observed-adverse-effect levels applying to susceptible populations (infants and young children).

From that analysis the committee concluded that a 200 mg/kg maximum level for general canned food and a 100 mg/kg maximum level for canned beverages are protective against acute gastrointestinal effects with an appropriate margin, and that a 50 mg/kg maximum level for canned baby food and infant and young-child formula provides additional precautionary margin for the most susceptible population. These three values were set into EC 1881/2006 and carry forward unchanged into the current EU Regulation 2023/915. The regulatory architecture here is worth stating plainly: the EU inorganic-tin limit for general canned food (200 mg/kg, equivalently 200,000

ppb) is roughly two thousand times the 100 ppb infant-food lead benchmark used elsewhere in this wiki. The gap is not a laxity in the tin standard; it reflects that the two metals act through different mechanisms at different potencies, and that the tin limit is anchored to an acute local endpoint rather than a chronic systemic one.

One regulatory discrepancy should be flagged rather than smoothed over. The EU 2023/915 general canned-food limit is 200 mg/kg, whereas the Codex Alimentarius recommended maximum for canned solid foods (CXS 193-1995) is 250 mg/kg, and Mania et al. 2021 assess Polish canned fruit against a 250 mg/kg figure. A given canned-fruit sample can therefore be compliant under one instrument and over the limit under another. This synthesis reports both values; it does not adjudicate between them.

4 | The occurrence distribution (Mania et al. 2021)

Mania et al. 2021, from the Polish National Institute of Hygiene and published in Roczniki Państwowego Zakładu Higieny, is the A-tier occurrence anchor and is independent of the two preceding sources in authorship, institution, and geography. It reports a 2015 Polish national monitoring program of approximately 600 fruit and fruit-product samples, of which tin was measured in the 69 samples that were metal-packaged (tin was measured only where migration from packaging is the relevant exposure route, a design choice that itself encodes the packaging-migration thesis).

For those 69 canned products, the mean tin concentration was 69.7 to 70.1 mg/kg (lower-bound to upper-bound treatment of left-censored data, wet-weight as-consumed basis), the 90th percentile was 140 mg/kg, the maximum was 206 mg/kg in canned pears from China, and the minimum was 2.39 mg/kg in domestically produced sliced tomatoes. Seven percent of the tin results were below the limit of detection. The distribution is the load-bearing observation. A mean near 70 mg/kg with a P90 of 140 mg/kg and a maximum of 206 mg/kg describes a population where typical product sits well under the 200 to 250 mg/kg limits but the upper tail approaches them; the highest single sample reached 206 mg/kg, which is above the EU 2023/915 general canned-food limit of 200 mg/kg and below the 250 mg/kg Codex canned-fruit figure the authors applied. Mania et al. situate all of this in a low-exposure conclusion for their cohort: modeled dietary tin intakes stayed below EFSA and JECFA tolerable doses for both adults and children. The occurrence data nonetheless establish that acidic canned fruit is where the tin sits and that individual retail units can reach the regulatory ceiling.

5 | The mechanism, corroborated: unlacquered cans, acidity, and storage time (Blunden and Wallace 2003; Buculei et al. 2012)

Two lower-tier sources supply the mechanistic connective tissue, and their limitations are stated here so the weight they carry is bounded correctly.

Blunden and Wallace 2003, published in Food and Chemical Toxicology, is a narrative review graded B-tier. It was commissioned by ITRI Ltd, the International Tin Research Institute, which is the research body of the tin industry, and it contributes no primary measurements of its own; its public evidence label in this corpus is "context only," and its framing should be read with that sponsorship in mind. Its value here is as a compilation of the primary dissolution literature. It reports, citing Biégo et al. 1999, that fresh food carries approximately 0.03 mg/kg tin, food in lacquered cans 3.2 plus or minus 2.3 mg/kg, and food in unlacquered cans 76.6 plus or minus 36.5 mg/kg, a roughly two-thousand-fold difference between fresh and unlacquered-canned. It reports that approximately 20 percent of European food cans have a plain (unlacquered) internal tin surface, and that all European tinplate beverage cans are internally lacquered. It reproduces, citing Ratana-Ohpas et al. 1996, tin concentrations in conserves of acidic fruit ranging from 43.9 to 77.4 mg/l (guava, lychee, tomato, mango, pineapple). And it reproduces, citing Calloway and McMullen 1966, a storage-temperature effect in which unlacquered cans of

five fruit types reached 420 mg/kg tin after 20 months at 37 degrees Celsius versus 34 mg/kg at 1 degree Celsius, an approximately twelve-fold difference. On the effect side, the review places clinically documented acute gastrointestinal effects at approximately 700 mg/kg and above in controlled studies, with episode reports spanning 250 to 2,000 mg/kg, predominantly in acidic fruits and fruit juices.

Buculei et al. 2012, published in the Journal of Agroalimentary Processes and Technologies, is a Romanian storage experiment graded C-tier; its numerical results are presented only as regression lines inside figures, its per-time-point sample counts are unstated, and its methods section carries internal inconsistencies. Read as a directional result rather than a precise one, it supplies the storage-time-resolved evidence that the other sources describe only cross-sectionally. Across 1,080 days (roughly 36 months) of ambient storage at approximately 20 degrees Celsius, tin in canned tomato paste rose from at or below the limit of quantitation to approximately 23 mg/kg under a universal varnish system and approximately 9 mg/kg under a sulfur-resistant varnish, while near-neutral matrices (peas, pork in own juice, pork liver pate) stayed below approximately 1.2 mg/kg over the same window. The acidity contrast is stark: the acidic tomato-paste matrix accumulated tin roughly an order of magnitude faster than the near-neutral matrices sharing the same storage conditions.

Taken together, the mechanism is coherent across all five sources. Bare tinplate in contact with an acidic food dissolves tin into that food; the rate rises with acidity, with storage time, and with storage temperature; lacquered internal coatings suppress it by one to two orders of magnitude; and beverage cans, being universally lacquered in Europe, are largely removed from the high-migration regime that unlacquered fruit and tomato cans occupy.

6 | Why conventional single-ingredient surveillance misses this

The contamination profile of a fresh tomato, a fresh pear, or a fresh pineapple carries almost no inorganic tin; Blunden and Wallace 2003 put fresh food near 0.03 mg/kg. A surveillance framework organized around ingredients therefore records tin as a non-issue on the tomato page, the pear page, and the pineapple page, because on those pages, as agricultural commodities, it genuinely is one. The tin only appears once the ingredient is placed inside an unlacquered tinplate can and the can is stored, and it scales with variables (can construction, internal coating, matrix pH, months on the shelf, warehouse temperature) that no fresh-ingredient occurrence record captures. This is the structural reason tin needs a synthesis page rather than an ingredient page: the risk is a property of the food-plus-package-plus-time system, not of the food.

The fan-out is correspondingly wide and cuts across the taxonomy. The same mechanism drives tin loading in canned acidic fruit (canned-fruit, and the pear, peach, pineapple, guava, and mango ingredient pages), in canned tomato products (canned-tomatoes, tomato-paste), and in canned and bottled acidic juices where the historical outbreak record is concentrated (fruit-juices-non-apple, fruit-juices-apple-containing, orange-juice, grapefruit-juice, apple-juice). Canned fish (canned-fish) appears in the historical outbreak record (a 650 mg/kg canned-salmon episode is compiled in Blunden and Wallace 2003) but is a near-neutral matrix in which modern lacquered cans keep tin migration low, so it belongs on the periphery of this synthesis rather than at its center. A framework that reads tin off individual fresh ingredients sees none of this pattern; a framework that reads it off can format and matrix acidity sees all of it.

7 | What the evidence implies for testing, regulation, and consumption

For testing, the operational consequence is that tin is a matrix-and-format-conditional analyte. Screening a fresh commodity for tin is close to uninformative; the informative measurement is on the finished canned product, ideally with the internal can coating (lacquered versus plain tinplate), the matrix pH, and the storage history recorded alongside the result, because a single spot value without those covariates cannot be extrapolated

across the shelf life. The occurrence tail matters more than the mean: Mania et al. 2021 show a mean near 70 mg/kg but a maximum of 206 mg/kg, so a surveillance scheme built only on central tendency would miss the units that actually approach the limit. Acidic canned fruit and canned tomato products in unlacquered cans, sampled late in shelf life, are where testing effort should concentrate.

For regulation, the existing EU maximum levels (200 mg/kg general canned food, 100 mg/kg canned beverages, 50 mg/kg infant and young-child food, per EU 2023/915, resting on the EU SCF 2002 opinion) are anchored to the acute gastrointestinal endpoint that Benoy 1971 characterized, and the roughly five-to-seven-fold margin between the 1,000 to 1,400 mg/kg human symptomatic range and the 200 mg/kg general limit is the built-in safety factor. The unresolved regulatory item is the 200 mg/kg EU versus 250 mg/kg Codex discrepancy for canned solid foods, under which the same product can pass or fail depending on the instrument applied. Any assessment against these limits should treat the 200/100/50 mg/kg EU values as the literature-anchored regulatory baseline and state explicitly which instrument a given canned-fruit or canned-tomato product is being assessed against, rather than defaulting silently to one.

For consumers, the honest quantitative framing is this. Inorganic tin in canned food is an acute-irritation contaminant, not a chronic accumulative one, so the exposure that would matter is a single high-tin serving rather than long-term low-level intake. The concentration associated with symptoms in healthy adults is high: all five volunteers in Benoy 1971 developed nausea and diarrhea only at 1,370 mg/kg in a 240 ml serving, with no effect at 730 mg/kg and below, and the highest single retail canned-fruit sample in the Mania 2021 survey was 206 mg/kg, well under that symptomatic level. The load-bearing consumer signal is not that typical canned fruit is hazardous; it is that the drivers of high tin (an unlacquered can, an acidic content such as tomato, citrus juice, or canned fruit, and long or warm storage) compound, so a badly corroded or long-stored unlacquered can of acidic product is the specific scenario that historical outbreaks trace to. Practically, once an unlacquered can of acidic food is opened, transferring the contents to a non-metal container for storage removes the continuing tin-dissolution pathway; this is supported by the storage-time dependence that Buculei 2012 and the Calloway data in Blunden 2003 document. Infants and young children are the population for which the tighter 50 mg/kg limit exists, and canned products intended for them are the ones where the precautionary margin is deliberately largest.

This synthesis connects to the broader wiki argument that contamination is often a property of processing and packaging rather than of the raw commodity, an argument the organic-certification-is-not-protective synthesis makes for agricultural inputs and this page makes for the can itself: organic certification of the fruit inside an unlacquered tin can does nothing to address tin migration from the can wall, because the tin does not come from the farm.

8 | The finding's own uncertainty and the contradictions among sources

The three A-tier anchors are independent and mutually reinforcing, but each carries a boundary. Benoy 1971 established the human symptomatic threshold on five volunteers, a small cohort adequate for demonstrating the effect and its approximate concentration but not for characterizing population variability in susceptibility. EU SCF 2002 is a regulatory derivation, authoritative for the EU limits but not an independent occurrence dataset. Mania 2021 is a single-country (Poland) snapshot of 69 canned samples, robust for that market and year but not a global occurrence distribution.

The most important internal tension is at the effect threshold. Benoy 1971 found no human effect at 730 mg/kg and a clear effect at 1,370 mg/kg, and Blunden and Wallace 2003 place clinically documented effects at approximately 700 mg/kg and above. Yet the outbreak record compiled in Blunden 2003 includes episodes at

markedly lower concentrations, for example canned tomato-juice family outbreaks at 154 to 289 mg/kg (Barker and Runte 1972) and a canned-tomato-juice report at 156 to 247 mg/kg (Kojima 1969). The reconciliation offered in the literature is that the lower-concentration episodes involved co-factors (elevated nitrate driving detinning, larger consumed volumes, or additional co-contaminants) rather than tin alone at those concentrations, but the point stands that the field-episode threshold sits below the controlled-study threshold, and the regulatory limit is set below both. Because Blunden and Wallace 2003 is industry-sponsored, its overall framing (that there is little evidence of acute effects at up to 200 mg/kg) should be weighted against the primary outbreak evidence it itself compiles rather than adopted as the review's conclusion; this synthesis uses Blunden 2003 for the primary values it reproduces, not for its interpretive position. Buculei et al. 2012 is C-tier with figure-only numerics and no stated replication, so its tomato-paste storage trajectory (rising toward roughly 23 mg/kg at 36 months) is treated as directional corroboration of the acidity-and-time mechanism, not as a precise occurrence value.

A gap this synthesis does not yet close is a modern US retail-market occurrence distribution for tin in canned acidic products; the corpus currently anchors the occurrence claim on the Polish Mania 2021 survey and the older primary values compiled in Blunden 2003. A US canned-fruit and canned-tomato tin survey would strengthen the occurrence component and is a candidate for a Journal of Food Metallomics contribution. Resynthesis triggers fire on the next two independent A-tier sources that confirm or contradict either the occurrence distribution or the effect threshold.

References

[1] The Toxicity of Tin in Canned Fruit Juices and Solid Foods
Christine J. Benoy, Patricia A. Hooper, and R. Schneider · Food and Cosmetics Toxicology, Vol. 9, Issue 5, pp. 645-656 · 1971 · doi.org/10.-1016/0015-6264(71)90152-090152-0)
REVIEW

[2] Opinion of the Scientific Committee on Food on Acute Risks Posed by Tin in Canned Foods
European Commission Scientific Committee on Food · European Commission Health and Consumer Protection Directorate-General, SCF/CS/CNTM/OTH/18 Final · 2002 · ec.europa.eu
GOVERNMENT

[3] The content of lead, cadmium, arsenic, mercury and tin in fruit and their products based on monitoring studies – exposure assessment
Mania M, Rebeniak M, Chabros E, Orshulyak O, and Postupolski J · Roczniki Państwowego Zakładu Higieny (Annals of the National Institute of Hygiene) · 2021 · doi.org/10.32394/rpzh.2021.0188
REVIEW

[4] Tin in canned food: a review and understanding of occurrence and effect
Steve Blunden and Tony Wallace · Food and Chemical Toxicology, Vol. 41, Issue 12, pp. 1651-1662 · 2003 · doi.org/10.1016/S0278--6915(03)00217-500217-5)
REVIEW

[5] Study regarding the tin and iron migration from metallic cans into foodstuff during storage
Buculei A, Gutt G, Amariei S, Dabija A, and Constantinescu G · Journal of Agroalimentary Processes and Technologies, 18(4), 299-303 · 2012 · journal-of-agroalimentary.ro
REVIEW

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DATA AVAILABILITY

Every source behind this finding is listed with its own extraction record at https://heavymetalindex.com/synthesis/-tin-canned-food-acidic-matrix-migration#sources, each linking to the ingest receipt, the extracted values, and the file hash of the document it was built from.

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