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INORGANIC TIN
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INORGANIC TIN (addendum)

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1. EXPLANATION

Inorganic tin is found in food in the +2 and +4 oxidation states; it may occur in cationic form (stannous and stannic compounds) or as anions (stannites or stannates). Inorganic tin was evaluated by the Committee at its fourteenth, fifteenth, twenty-second, twenty-sixth, thirty-third and fifty-fifth meetings (Annex 1, references 22, 26, 47, 59, 83 and 149). At its thirty-third meeting, the Committee converted the previously established provisional maximum tolerable daily intake (PMTDI) of 2 mg/kg bw to a provisional tolerable weekly intake (PTWI) of 14 mg/kg bw. At these meetings, the Committee reviewed data from short- and long-term dietary studies and noted that inorganic tin compounds generally have low systemic toxicity in animals because of limited absorption from the gastrointestinal tract, low accumulation in tissues and rapid passage through the gastrointestinal tract. Insoluble tin compounds are less toxic than soluble tin salts.

At its Thirty-first Session, the Codex Committee on Food Additives and Contaminants (CCFAC) asked the Committee to review information on the toxicity of inorganic tin in order to establish an acute reference dose (ARfD) (CAC, 1999). At its fifty-fifth meeting (Annex 1, reference 149), the Committee considered studies of the acute toxic effects seen after consumption of foods containing high concentrations of inorganic compounds of tin. It concluded that the acute toxicity of inorganic tin in animals and humans, however, results from irritation of the mucosa of the gastrointestinal tract, which may lead to vomiting, diarrhoea, anorexia, depression, ataxia and muscular weakness. There was no clear dose–response relationship, and the vehicle in which the tin was administered may have affected its toxicity. The Committee concluded that insufficient data were available to establish an ARfD for inorganic tin. At that meeting, the PTWI previously established for compounds containing inorganic tin was not reconsidered and was retained at its current value. The Committee did not consider studies on organic tin compounds, since it had concluded at its twenty-second meeting (Annex 1, reference 47) that these compounds, which differ considerably from inorganic tin compounds with respect to toxicity, should be considered separately.

At its Thirty-fifth session, CCFAC (CAC, 2003) decided to ask the Committee to evaluate current levels of inorganic tin in "canned food other than beverages" and "canned beverages" and to determine an ARfD, since new data would become available. At its Thirty-sixth session (CAC, 2004), CCFAC asked the Committee, when possible, to take population sensitivity into consideration when considering the new data and to assess the likelihood of the occurrence of effects at the proposed draft maximum levels (MLs) (200 mg/kg in canned beverages and 250 mg/kg in canned foods other than beverages).

At its present meeting, the Committee reconsidered studies of the acute toxic effects seen in humans after consumption of foods containing high concentrations of inorganic compounds of tin and also considered a new study.

2. BIOLOGICAL DATA

2.1 Biochemical aspects

2.1.1 Absorption, distribution and excretion

No new data became available after the fifty-fifth meeting (Annex 1, reference 150).

Inorganic tin is poorly absorbed in humans as well as animals and is excreted mainly in the faeces, with additional slow elimination in the urine. Absorption may differ depending on dose, anion and the presence of other substances.

No new animal data on distribution became available after the fifty-fifth meeting (Annex 1, reference 150). Tin is widely distributed in tissues after parenteral injection, especially in the liver and spleen, where it is deposited in the reticuloendothelial system, most being excreted eventually in the urine and a limited amount in the bile (Barnes & Stoner, 1959).

Tin tends to be retained most in the tongue, liver, kidneys and bones and least in the brain, and rats and rabbits accumulate both inorganic and organic tin in their skin and keratinized appendages. Administration of tin to pregnant rats did not lead to detectable levels of tin in fetuses on day 10 of pregnancy, while on days 20–21, small amounts of tin were detected. Overall, only trace amounts of inorganic tin cross the placental barrier, and this placental transfer is of little toxicological significance (Theuer et al., 1971; Hiles, 1974).

In a human volunteer study (n = 20), the serum inorganic tin concentrations were not elevated after the volunteers drank tomato juice containing <0.5, 161, 264 or 529 mg tin (as tin(II) chloride, or $SnCl_2$) per kg bw (Boogaard et al., 2003) and remained below the detection limit of 10 µg/l serum. The authors concluded that the absorption of tin from the gastrointestinal is minimal in humans.

2.1.2 Biotransformation

No new animal data became available after the fifty-fifth meeting (Annex 1, reference 150). In rats, the half-life of inorganic tin in the femur was estimated to be 34 days for Sn(II) and 40 days for Sn(IV) (Hiles, 1974). Half-lives of 85 and 50 days were reported for tin in liver and spleen, respectively (Marciniak, 1981). A biological half-life of approximately 30 days was estimated for inorganic tin in mice by the whole-body counting method (Brown et al., 1977). A review by Magos (1986) stated that in humans, 20% of absorbed tin was cleared with a half-life of 4 days, 20% with a half-life of 25 days and 60% with a half-life of 400 days.

2.1.3 Effects on enzymes and other biochemical parameters

Tin cations have the ability to influence the biodegradation of cytochrome P450. Some data indicate that Sn(II) may be more potent than Sn(IV). In addition, tin seems to have an inhibitory effect on the activity of several other enzymes, including δ-aminolevulinic acid dehydratase, superoxide dismutase, glutathione peroxidase, glutathione reductase and glucose 6-phosphate dehydrogenase (Westrum & Thomasson, 2002). Thus, tin may alter metabolism. An effect of tin(II) chloride on nerve transmission via altered calcium fluxes is reported (Westrum & Thomasson, 2002).

Tin(II) chloride induced cytotoxicity in several *Escherichia coli* strains. Simultaneous treatment with reactive oxygen species scavengers completely protected the cells against cytotoxic damage (de Silva et al., 2002).

2.2 Toxicological studies

2.2.1 Acute toxicity

As described in the monograph of the fifty-fifth meeting (Annex 1, reference 150), tin metal itself, taken orally, is practically innocuous, but inhaled dust or fumes may cause benign, symptomless pneumoconiosis. The inorganic salts are caustic and of variable toxicity, but some alkyl and aryl derivatives are highly toxic. Inorganic tin compounds and mixed colloidal tin and tin stearate have been used as antistaphylococcal and anthelmintic agents (Kolmer et al., 1931).

Studies in rats provided evidence that the chemical form of inorganic tin is important in determining its toxicity, as concluded by the fifty-fifth meeting (Annex 1, reference 149). Inorganic tin compounds generally have a low systemic toxicity in animals because of limited absorption from the gastrointestinal tract and rapid gastrointestinal passage. The median lethal dose (LD_{50}) of tin(II) chloride varies from 40 to 1200 mg/kg bw in mice and from 700 to 3200 mg/kg bw in rats. Acute toxicity signs include extreme gastrointestinal irritation, anorexia, depression, ataxia and muscular weakness. Mottling, hyperaemia and tubular necrosis in the kidneys of rats have also been described.

Vomiting and diarrhoea were reported in cats given soluble salts of tin, but there was no clear dose–response relationship, and the vehicle in which the tin was administered may have affected its toxicity, as noted by the fifty-fifth meeting (Annex 1, reference 149).

2.2.2 Short-term studies of toxicity

As described in the monograph of the fifty-fifth meeting (Annex 1, reference 150), insoluble tin compounds, such as tin(II) sulfide, had minimal toxic effects in rats when administered for 28 days in the diet at concentrations similar to those at which the soluble tin salts are clearly toxic. In short-term studies with soluble salts in rats, histological changes to the gastrointestinal tract, kidneys, liver and adrenal cortex were observed. Alterations in haematological parameters indicative of anaemia have also been recorded. The toxicity of tin results from irritation of the mucosa of the gastrointestinal tract. In a study (Janssen et al., 1985) not described in the monograph of the fifty-fifth meeting (Annex 1, reference 150), the effects of feeding inorganic tin on the gastrointestinal tract were examined in rats. Three groups of male weanling Wistar rats were fed a diet for 4 weeks to which Sn^{2+} as tin(II) chloride at 0, 250 or 500 mg/kg had been added. A fourth group was subjected to feed restriction by pair feeding with the 500 mg/kg group. Independent of the reduced feed intake, Sn^{2+} affected the haemoglobin concentration in the blood and had several effects on the small intestine: total length as well as absolute and relative weights were increased. An increase was also observed in the migration of epithelial cells along the villus, as revealed by [^{3}H]thymidine incorporation and autoradiography in rats fed Sn^{2+} at 500 mg/kg in the feed for 4 weeks. Stereo-light microscopy and scanning electron microscopy revealed the formation of ridge-like villi due to Sn^{2+} feeding and a decreased number of villi per unit surface. These data suggest that an increase in cell turnover in the small intestine due to Sn^{2+} was responsible for these changes.

2.2.3 Special studies

(a) Interaction of tin with trace elements

No new data became available after the fifty-fifth meeting (Annex 1, reference 150). Limited information is available about the biochemistry of the metabolism of inorganic tin in the body or the exact mechanisms by which this element affects physiological processes. It is known, however, that tin can interact with a number of trace elements, many of which have vital functions in the body. In addition to its effects on copper, zinc and iron metabolism, tin has also been shown to interact with calcium.

(b) Effect on bone strength

No new data became available after the fifty-fifth meeting (Annex 1, reference 150). Tin, when administered in drinking-water as tin(II) chloride for 4 weeks, significantly decreased the compressive mechanical strength of the distal epiphysis of the femur at higher dosages (300 and 600 mg/l; Ogoshi et al., 1981).

2.3 Observations in humans

2.3.1 Episodes of poisoning

No new data became available after the fifty-fifth meeting (Annex 1, reference 150). Episodes of human poisoning have been described to be related to the consumption of tin-contaminated foods and drinks. The common symptoms were abdominal distension and pain, vomiting, diarrhoea and headache. These symptoms start within 0.5–3 h after consumption, and recovery occurs within 48 h. The doses of tin ingested in such episodes of poisoning were not estimated, but the symptoms occurred when canned food or drinks were noticed to contain tin concentrations varying from 250 to 2000 mg/kg.

2.3.2 Studies with volunteers

As described in the monograph of the fifty-fifth meeting (Annex 1, reference 150), in one study (Benoy et al., 1971), five volunteers experienced symptoms when they ingested orange juice derived from tinned containers containing tin at

1370 mg/kg (corresponding to a dose of 4.4–6.7 mg/kg bw). Administration of the same dose of the same juice to these individuals 1 month later resulted in symptoms in only one person. Orange juices containing tin at 498, 540 and 730 mg/kg (corresponding to 1.6–3.6 mg/kg bw) did not provoke symptoms in groups of five volunteers.

After the fifty-fifth meeting (Annex 1, reference 150), one publication describing two separate randomized, single-centre, double-blind, crossover studies became available (Boogaard et al., 2003). In study 1, the tolerability of inorganic tin added as tin(II) chloride at concentrations of <0.5, 161, 264 and 529 mg/kg in 250 ml tomato juice (approximately 0, 0.5, 1 and 2 mg/kg bw, assuming an average weight of 60 kg) was compared in 20 volunteers who had fasted for more than 6 h. In study 2, the effects of inorganic tin that migrated from packaging at concentrations of <0.5, 201 and 267 mg/kg in 250 ml tomato soup were investigated in 24 volunteers who had fasted for 6 h. Carry-over effects were prevented by washing-out periods of 48 h between the different treatments. The distribution of tin in solid matter, supernatant and low-molecular-mass tin complexes in supernatant was measured in both the spiked tomato juice and the tomato soup. Adverse events were classified according to the WHO programme for international monitoring of adverse reactions to drugs. The events were graded as mild, moderate or severe, and the investigator assessed the causal relationship to the ingested tin-containing material in this double-blind study as none, unlikely, possible, probable and highly probable.

The distribution of adverse events related and non-related to tin(II) chloride freshly added to tomato juice is given in Table 1. A clear statistically significant dose–response relationship for related adverse events was observed. Fitting the data points to a linear function with a threshold would suggest a threshold of 150 mg tin/kg juice.

Table 1. Distribution of adverse events related and non-related to tin(II) chloride freshly added to tomato juice

Concentration of tin in juice (mg/kg)	Number of subjects in treatment period	Number of related adverse events		Number of non-related adverse events
		Mild	Moderate	
<0.5	18	0	0	2
161	18	1	0	3
264	18	2	5	2
529	5[a]	5	8	0

[a] Treatment at this dose level was discontinued based on the frequency and the number of adverse events reported.

Table 2 shows the distribution of adverse events related and non-related to tin that migrated from packaging into tomato soup. Related adverse events occurred in 4 out of 23 subjects in the higher dose group (267 mg/kg) versus 3 out of 23 in the controls. At the lower dose (201 mg/kg), no related adverse effects were noticed (Boogaard et al., 2003).

Table 2. Distribution of adverse events related and non-related to inorganic tin that migrated from packaging in tomato soup

Concentration of tin in soup (mg/kg)	Number of subjects in treatment period	Number of related adverse events		Number of non-related adverse events
		Mild	Moderate	
<0.5	23[a]	2	1	0
201	23[a]	0	0	1
267	23[a]	2	2	1

[a] One subject was withdrawn for protocol violation.

The distribution studies on tin showed that elemental tin concentrations in solid and liquid phases differed markedly between tomato juice freshly spiked with tin(II) chloride (study 1) and tomato soup (study 2). One hour after mixing, at the moment of consumption in study 1, solid matter contained 15% of the total tin in study 1 versus 52% in study 2. Correspondingly, supernatant concentrations of tin were 85% and 48% in the materials used in study 1 and 2, respectively. The amount of low-molecular-mass tin (<1000 daltons) in the supernatant was 59% versus 31%, respectively. Examination after 24 h revealed that tin in solid matter had increased from 15% to 35%. The significant differences in occurrence of adverse effects in studies 1 and 2 strongly suggest that these effects and their severity are determined by different speciation of tin and not simply by concentration and are likely a result of differences in the concentration of tin and in the nature of tin complexes formed (Blunden & Wallace, 2003).

2.3.3 Irritation and sensitization

Only a limited number of patch test reports are available. The results showed a positive response with tin, but its relevance to contact dermatitis is unclear (Health Council, 2005).

3. LEVELS AND PATTERNS OF CONTAMINATION OF FOOD COMMODITIES

Extensive information on the tin content of foods was reported in the monograph from the last review of tin by the Committee at its fifty-fifth meeting (Annex 1, reference 150). In summary, concentrations of tin in non-canned foods were very low, with a mean value of <2 mg/kg. Mean concentrations of tin in lacquered canned foods were between 0 and 6.9 mg/kg. Food in unlacquered, partially lacquered or unspecified cans had higher concentrations of tin, with mean values ranging from <1 to 1000 mg/kg.

This assessment is an addendum to the report from the fifty-fifth meeting (Annex 1, reference 150). Therefore, data submitted to the Committee for review at this meeting or that have become available since the last review of tin by the Committee that related to tin concentrations in food have been included in this addendum.

The Inter-Industry Tin Strategy Group submitted information on tin concentrations in foods from a number of sources. The submission included a small number of new data on tin concentrations in foods from recent surveys that have become available since the last review of tin by the Committee. Data submitted to the Committee were from Australia, France, Lithuania and the United Kingdom. A second study from the United Kingdom was also located and reviewed. These data are outlined below.

Two Australian Total Diet Surveys have been conducted since the last tin review: the 19th Australian Total Diet Survey (ANZFA, 2001) and the 20th Australian Total Diet Survey (FSANZ, 2002). These surveys analysed a broad range of food collected randomly at the retail level and were representative of the whole Australian diet. Composites of three individual retail samples were analysed, producing a resulting tin concentration that is the average of the tin concentrations of the individual samples. Concentrations of tin in the foods analysed in the Australian Total Diet Surveys are shown in Table 3. A range of mean values is reported for some foods, whether concentrations below the limit of reporting (LOR) are assumed to be equal to zero or the LOR.

Summary information from a tin monitoring study in France in 2003 was submitted to the Committee for review. The submission reported that 73 samples were taken from 11 areas in France, some samples of which were imported. All samples had a concentration of tin lower than the proposed regulatory limits for France (200 mg/kg, 100 mg/kg or 50 mg/kg, depending on the type of canned food). Samples from lacquered cans had concentrations lower than 3 mg/kg (48 samples). Only two foods had concentrations at levels equal to the proposed regulations (canned olives at 100 mg/kg; lychees at 200 mg/kg).

A study of tin in canned milk products in Lithuania (Ramonaitytė, 2001) was also submitted to the Committee for review. The paper looked specifically at the changes that can occur in tin concentrations during storage. The milk was produced in Lithuania, and the cans used were unlacquered. The products investigated were evaporated sterilized milk, concentrated sterilized milk (solids >28.5%, fat 8.5%) and sweetened condensed milk (solids >28.5%, fat 8.5%). From 1989 to 1992, the products were sampled and analysed at 0, 3, 6, 9, 12, 15, 18, 21 and 24 months. The products were stored at room temperature of 18 °C (±2 °C).

The average contents of tin did not differ greatly over the course of the investigation (see Table 4). Concentrations of tin seemed to increase in the products during sterilization in the cans. This is due to the temperature causing changes in the deeper layers of the tinned plate. Condensed milk has lower concentrations due to the thicker nature of the product, resulting in the concentrations of tin increasing more slowly.

Table 3. Concentrations of tin in composite foods sampled at the retail level from recent Australian Total Diet Surveys

Food	19th ATDS[a]			20th ATDS[b]		
	Number of analyses	Mean[c] (mg/kg)	Maximum (mg/kg)	Number of analyses	Mean[c] (mg/kg)	Maximum (mg/kg)
Alfalfa sprouts	21	0.006–0.022	0.04	–	–	–
Apples, unwashed	21	0.002–0.019	0.02	–	–	–
Apples, washed	21	ND	ND	–	–	–
Baked beans, canned	–	–	–	9	7.0	11.0
Bananas	9	ND	ND	–	–	–
Beef, minced	27	0.014–0.026	0.13	7	0.021–0.015	0.09
Beer, 3.5% alcohol	21	ND	ND	–	–	–
Biscuits, savoury	9	ND	ND	–	–	–
Biscuits, sweet plain	9	ND	ND	–	–	–
Bok choy	21	0.005–0.021	0.04	–	–	–
Bran, wheat processed	9	ND	ND	–	–	–
Bread, white	27	0.007–0.022	0.08	7	0.017–0.014	0.07
Bread, wholemeal	21	0.006–0.02	0.04	–	–	–
Breakfast cereal, mixed grain	9	0.001–0.019	0.01	–	–	–
Capsicum	21	0.004–0.02	0.03	–	–	–
Carrots	9	ND	ND	–	–	–
Cauliflower	21	ND	ND	–	–	–
Cheese, feta, cow's milk	9	ND	ND	–	–	–
Cheese, feta, sheep's milk	9	1.793	7.7	–	–	–

Table 3. (contd)

Food	19th ATDS[a]			20th ATDS[b]		
	Number of analyses	Mean[c] (mg/kg)	Maximum (mg/kg)	Number of analyses	Mean[c] (mg/kg)	Maximum (mg/kg)
Chicken drumsticks	21	0.012–0.027	0.08	–	–	–
Chiko rolls	21	0.003–0.022	0.07	–	–	–
Chocolate cake, iced	9	0.056–0.062	0.16	–	–	–
Cornflakes	9	ND	ND	–	–	–
Crab, canned	9	0.109–0.111	0.34	–	–	–
Crocodile	6	0.002	0.01	–	–	–
Dim Sim	–	–	–	21	0.003–0.012	0.04
Eggs	27	0.018	0.02	7	ND	ND
Fish fillets	21	ND	ND	–	–	–
Grapes, unwashed	18	ND	ND	–	–	–
Grapes, washed	18	ND	ND	–	–	–
Green beans (19th frozen; 20th fresh)	9	ND	ND	9	ND	ND
Ham	21	ND	ND	21	0.005–0.014	0.07
Hamburger	–	–	–	21	0.001–0.011	0.02
Honey	9	0.042	0.07	–	–	–
Infant cereal, mixed	9	0.024–0.04	0.2	–	–	–
Infant custard, chocolate	9	0.114–0.117	0.29	–	–	–
Infant dinner, canned	9	0.082	0.12	–	–	–
Infant formula	9	ND	ND	–	–	–
Lamb loin chops	21	0.011–0.023	0.05	–	–	–

Table 3. (contd)

Food	19th ATDS[a]			20th ATDS[b]		
	Number of analyses	Mean[c] (mg/kg)	Maximum (mg/kg)	Number of analyses	Mean[c] (mg/kg)	Maximum (mg/kg)
Lamb's kidneys	21	0.001–0.02	0.02	–	–	–
Lamb's liver	27	0.004–0.02	0.04	–	–	–
Lettuce	27	0.003–0.021	0.04	–	–	–
Margarine	9	ND	ND	7	0.009–0.011	0.04
Meat pies	21	0.019–0.031	0.18	–	–	–
Milk chocolate	12	0.023–0.033	0.06	–	–	–
Milk, full fat	27	ND	ND	7	ND	ND
Muscatels, dried	9	ND	ND	–	–	–
Mushrooms	21	0.002–0.021	0.04	21	0.001–0.01	0.01
Mussels	21	ND	ND	–	–	–
Oats, rolled	9	ND	ND	–	–	–
Oil, blended vegetable	9	ND	ND	–	–	–
Onions	21	ND	ND	–	–	–
Orange juice	27	0.000–0.02	0.01	7	ND	ND
Pasta, macaroni	9	0.006–0.023	0.05	–	–	–
Peaches	9	0.006–0.023	0.05	–	–	–
Peanut butter	–	–	–	9	0.002–0.01	0.01
Peanuts, roasted, salted	9	0.012–0.023	0.04	–	–	–
Pears, unwashed	21	0.002–0.02	0.02	–	–	–
Pears, washed	21	0.002–0.02	0.03	–	–	–

Table 3. (contd)

Food	19th ATDS[a]			20th ATDS[b]		
	Number of analyses	Mean[c] (mg/kg)	Maximum (mg/kg)	Number of analyses	Mean[c] (mg/kg)	Maximum (mg/kg)
Peas, canned	9	4.578	6.4	–	–	–
Pineapple, canned	9	51.889	81.0	–	–	–
Pork butterfly steaks	20	0.006–0.021	0.03	–	–	–
Potato	27	ND	ND	7	ND	ND
Red kidney beans, canned	9	0.227	0.41	–	–	–
Rice crackers	9	ND	ND	–	–	–
Rice, jasmine	9	ND	ND	–	–	–
Rockmelon	21	ND	ND	–	–	–
Salmon, red, canned	9	0.059	0.12	–	–	–
Sausages	21	0.06–0.062	0.21	–	–	–
Soya sauce	9	ND	ND	–	–	–
Tahina	9	0.003–0.019	0.02	–	–	–
Tea, brewed from tea bags	9	ND	ND	–	–	–
Tomato salsa	9	0.071	0.11	–	–	–
Tomatoes	21	ND	ND	7	ND	ND
Tuna, canned	–	–	–	9	0.196	0.26
Walnuts	9	0.003–0.021	0.03	–	–	–
Yoghurt, strawberry, full fat	9	0.009–0.027	0.08	–	–	–

ATDS, Australian Total Diet Survey; ND, not detected

[a] ANZFA (2001).

[b] FSANZ (2002).

[c] Range of concentrations where ND = 0 to ND = LOR. LOR = 0.01 mg/kg. Where a single value is reported, all samples were detections. Results presented as ND means all of samples analysed were ND.

Table 4. Concentrations of tin over time in canned milk products from Lithuania

Product	Year	Number of samples	Tin concentration (mg/kg)		
			Mean	Minimum	Maximum
Evaporated sterilized milk	1986–1990	12	97	40	124
	1991–1992	27	114	84	146
	1993–1994	28	53	20	87
	1995–1997	24	–	–	–
	Mean	91	85	20	146
Concentrated sterilized milk	Initial level	NS	74	57	104
	1983–1985	24	73	60	104
	1986–1990	35–46	102	33	148
	1991–1992	40	98	53	161
	1993–1994	35	98	3	161
	Mean	126–157	89	44	161
Sweetened condensed milk	Initial level	NS	49.5	21	67
	1983–1985	34–52	28	9	60
	1986–1990	49	60	24	98
	1991–1992	45	38	16	58
	1993–1994	41	37	19	52
	1995–1997	27	39	12	80
	Mean	196–214	40	9	98

From Ramonaitytė (2001)

NS, not specified

For many foods, the Committee has previously outlined that there tend to be increases in tin in canned foods over time. This study did not demonstrate this. This may be due to the food type that was assessed.

In a study in the United Kingdom, samples of canned foods were analysed for tin between December 2000 and August 2001 (UK FSA, 2002). A summary of these data is shown in Table 5. There were over 1200 individual samples taken for this survey, with results from 400 brand/product combinations reported. Each of the 400 samples usually consisted of three individual cans of the food from the same batch number. Of the 400 samples, only two samples (one of spaghetti in tomato sauce and the other of gooseberries) exceeded the maximum permitted level specified in the United Kingdom's *Tin in Food Regulations 1992* of 200 mg/kg.

Table 5. Concentrations of tin in canned foods in the United Kingdom

Product type	Number of samples	Tin concentration (mg/kg as sold)		
		Mean[a]	Minimum	Maximum
Tomatoes (plum and chopped)	54	24	<5	196
Spaghetti and other pasta in tomato sauce	54	61	<5	298
Tomato soups	54	77	<5	199
Other tomato-based soups, e.g. minestrone, vegetable, etc.	30	25	<5	141
Baked beans	42	24	<5	76
Cooking sauces containing tomato	30	<5	<5	6
Pineapples	30	61	26	169
Fruit cocktail	18	78	9	167
Grapefruit	15	80	39	123
Apricots	15	68	<5	135
Fruit fillings	12	<5	<5	<5
Mushrooms	10	9	<5	46
Celery	9	<5	<5	<5
Gooseberries	9	106	<5	237
Rhubarb	9	6	<5	13
Asparagus	9	47	<5	139
All samples	400	44	<5	298

From UK FSA (2002)

[a] Means are calculated by assuming that not detected results are equal to the limit of detection (LOD) of 5 mg/kg.

The 2000 United Kingdom Total Diet Study also included an analysis of tin in foods (UK FSA, 2004). The tin concentrations determined are shown in Table 6. The samples were analysed as composites. Concentrations are reported as a range where there were not detected results for some foods. The lower-bound mean is where not detected results were assigned a concentration of zero, and upper-bound means were where not detected results were assigned a concentration equal to the limit of detection (LOD) (between 0.0001 and 0.0016 mg/kg, depending on the food).

Table 6. Mean tin concentration for food groups in the 2000 United Kingdom Total Diet Study

Food group	Mean tin concentration (mg/kg)
Bread	0.006
Miscellaneous cereals	0.030
Carcass meat	0.008
Offal	0.007
Meat products (including some canned)	0.130
Poultry	0.003
Fish	0.028
Fats and oils	0.004–0.005
Eggs	0.0002–0.0005
Sugar and preserves	0.055
Green vegetables	0.0009
Potatoes	0.001
Other vegetables	0.008
Canned vegetables	25.000
Fresh fruits	0.012
Fruit products (including some canned)	11.000
Beverages	0.001
Milk	0.0008–0.0009
Dairy products	0.034
Nuts	0.022

From UK FSA (2004)

Overall, concentrations from the 2000 United Kingdom Total Diet Study are similar to or lower than those from the previous 1997 United Kingdom Total Diet Study and were lower than those from the United Kingdom survey outlined above (UK FSA, 2002) specifically on canned fruits and vegetables, particularly for non-canned foods.

The recent data on tin concentrations in foods are consistent with the findings of the last review of tin undertaken by the Committee, the new concentrations ranging between <1 and 300 mg/kg.

4. DIETARY INTAKE ASSESSMENT

4.1 Introduction and background to intake estimates

Inorganic tin (hereafter called tin) was last evaluated by the Committee at its fifty-fifth meeting in 2000 (Annex 1, reference 150). The last evaluation included information on concentrations in foods and estimates of chronic intake. Estimates of intake were compared with the PTWI of 14 mg/kg bw maintained by the Committee at its fifty-fifth meeting.

In summary, the previous evaluation of tin intakes showed that the main source of tin in the diet is from canned foods. Water and air were not significant sources of intake of tin for the general population. Natural concentrations of tin in plant and animal foods were low. Tin-containing food additives contributed little to the intake. There were a number of factors influencing the tin concentrations in canned foods, including the pH of the food, whether the can is lacquered, storage conditions, plant pigments and the presence of reducible organic compounds.

Mean dietary intakes of tin reported from seven countries ranged from <1 mg/day to about 14 mg/day, considerably lower than the tolerable daily intake established at the earlier meeting by the Committee.

This current assessment is an addendum to the report from the fifty-fifth meeting (Annex 1, reference 150). While the focus of this evaluation by the Committee was on acute toxicity and therefore short-term dietary intakes, data submitted to the Committee for review at this meeting or that have become available since the last review of tin by the Committee that related to chronic intakes have also been included in this addendum.

The Inter-Industry Tin Strategy Group submission included some estimates of chronic tin intakes for review by the Committee.

Also included in this assessment are short-term intake estimates for tin (i.e. in a period of 24 h or less). Short-term intake estimates for tin have not previously been considered by the Committee. Short-term intake estimates were submitted for Australia and New Zealand.

4.2 Estimated chronic dietary intakes of tin

Some recent estimates of chronic intakes of tin have become available since the last review of tin by the Committee. Chronic intake estimates for tin were submitted from two Australian total diet studies and a United Kingdom total diet study.

4.2.1 Methods

Individual dietary records were used for intake estimates for the Australian Total Diet Surveys, producing a distribution of estimated intakes from which population summary statistics (e.g. mean intakes) were derived. The 2000 United

Kingdom Total Diet Study estimates of tin intakes were based on a model diet of mean population consumption data.

Apart from reviewing the recent chronic intakes submitted to the Committee, a literature review was also conducted to find recent studies of chronic intake of tin. No other recent estimates were found.

4.2.2 Australia

Estimated chronic intakes of tin from two recent Australian Total Diet Surveys have become available since the last review of tin by the Committee: the 19th Australian Total Diet Survey (ANZFA, 2001) and the 20th Australian Total Diet Survey (FSANZ, 2002). Estimated intakes from these two surveys are summarized in Table 7.

Table 7. Estimated mean chronic intakes of tin from recent Australian Total Diet Surveys for all respondents in various age groups

Population group	Estimated tin intake (mg/kg bw per day)	
	19th ATDS[a]	20th ATDS[b]
Adult males 25–34 years	0.0088–0.0094	0.0013–0.0016
Adult females 25–34 years	0.009–0.0096	0.0015–0.0018
Boys 12 years	0.011	0.0017–0.0020
Girls 12 years	0.0091–0.0096	0.00064–0.00093
Toddlers 2 years	0.031–0.032	0.012–0.013
Infants 9 months	0.013–0.015	0.0087–0.0090

ATDS, Australian Total Diet Survey

[a] ANZFA (2001).

[b] FSANZ (2002).

The estimated intakes for the 19th and 20th Australian Total Diet Surveys were calculated using analytical concentrations of tin (see Table 3) and food consumption data from the 1995 Australian National Nutrition Survey (n = 13 858). The survey respondents were 2 years old and above. The survey used a 24-h recall methodology. Foods consumed in the National Nutrition Survey were "mapped" to the foods analysed in the Australian Total Diet Survey before concentrations of tin were assigned. Individual dietary records and body weights from individuals were used for the intake calculations, resulting in a distribution of intakes, from which population summary statistics were derived. Results for all respondents in the age groups assessed are presented. Lower- and upper-bound estimates were derived, the lower-bound estimate where not detected results were assigned a concentration of zero, and an upper-bound estimate where not detected results were assigned a concentration equal to the LOR (0.02 mg/kg, 19th Australian Total Diet Survey; 0.01 mg/kg, 20th Australian Total Diet Survey).

Intakes for infants 9 months of age were based on a model diet with average food consumption data, extrapolated from a 2-year-old's diet.

These intakes are similar to or slightly lower than those estimated from an earlier total diet study from Australia that was considered in the previous review of tin by the Committee. The differences in the intakes could be attributed to differences in methodology used to estimate the intakes.

4.2.3 United Kingdom

When the United Kingdom recently conducted an analytical survey of tin in canned foods (see concentration data in Table 5), intake of tin from the diet was also estimated (UK FSA, 2002). Tin intake from canned foods was estimated, with the additional intake from the rest of the diet added on. The additional intake was the mean intake of tin from the 1997 United Kingdom Total Diet Study. Estimated intakes of tin from this United Kingdom study are shown in Table 8. The estimated intakes are an overestimate; they include a certain amount of double-counting, as canned foods would have been included in the estimation of the mean intake of tin from the 1997 Total Diet Study. Samples less than the LOD were assigned a concentration equal to the LOD.

Table 8. Estimated intakes of tin from United Kingdom survey of tin in canned foods

Intake (mg/person per day)				
From canned fruits and vegetables		From rest of diet (1997 TDS)	Total dietary intake	
Mean	P97.5	Mean	Mean	P97.5
1.7	5.6	1.9	3.6	7.5

From UK FSA (2002)

P97.5, 97.5th percentile; TDS, Total Diet Study

Estimated tin intakes for the United Kingdom from the 2000 Total Diet Study (UK FSA, 2004) were also submitted for consideration by the Committee. Estimated intakes for consumers only are shown in Table 9. The Total Diet Study included 119 foods combined into 20 food groups for analysis. The proportion of each food reflects its relative importance in the United Kingdom diet, based on data from the National Food Survey. The mean concentration of tin for each food was used in the calculations. Concentration data for tin used in the intake estimates were shown previously in Table 6. Food consumption data used for these calculations were from the relevant National Diet and Nutrition Survey. Children had higher intakes on a body weight basis due to their higher food consumption amounts per kilogram of body weight. The foods contributing the most to tin intakes were canned vegetables (61%) and fruit products (37%).

Table 9. Estimated consumer intakes of tin for various population groups from the 2000 United Kingdom Total Diet Study

Population group	Mean intake (mg/kg bw per day)	P97.5 intake (mg/kg bw per day)
Adults	0.020	0.070
Toddlers 1.5–4.5 years	0.070	0.283
Young people 4–18 years	0.038	0.150
Elderly: free-living	0.017	0.076
Elderly: institutionalized	0.017	0.061
Vegetarians[a]	0.026	0.101

From UK FSA (2004)

P97.5, 97.5th percentile

[a] Some of these respondents consumed fish.

Estimated intake of tin on a population basis, reported in the 2000 United Kingdom Total Diet Study report (based on consumption data from the National Food Survey), was 1.4 mg/day. While recognizing the different methodologies used to estimate intakes for the total population from United Kingdom Total Diet Studies since 1976 (i.e. different survey methodology, food consumption survey data and analytical methodology), it appears as though tin intakes of the population have reduced from 4.4 mg/day in 1976 to 1.4 mg/day in 2000 (COT, 2003).

4.3 Estimated short-term dietary intakes of tin

Short-term dietary intakes of contaminants from food are defined as those occurring in a period of 24 h or less.

A limited number of short-term intake estimates were available for the Committee to review. Short-term intake estimates were submitted for Australia and New Zealand. A literature search was also conducted; however, no short-term intake estimates for tin were located. Additional short-term intake estimates were made based on United Kingdom tin concentration data from the recent study on tin in canned foods reported above (UK FSA, 2002). Estimated intakes were also calculated based on proposed Codex MLs for tin in canned foods.

4.3.1 Methods

There is no internationally agreed methodology for estimating short-term dietary intakes of contaminants.

International Estimated Short Term Intakes have been calculated for pesticide residues for a number of years and have been included in the assessments conducted by the Joint FAO/WHO Meeting on Pesticide Residues (JMPR) and also considered at the Codex Committee on Pesticide Resides. Some national agencies also conduct short-term intake assessments for agricultural residues and veterinary chemicals.

Equations for estimating short-term intakes for pesticide residues are defined by JMPR (WHO, 2005). Some of the basic principles of the methodology used for estimating short-term dietary intakes for pesticide residues can be applied to contaminants and were therefore used to develop the method for calculating short-term intakes of tin.

The main data sets required to calculate short-term intakes are information on food consumption and chemical concentrations. Information on body weights is also required.

Estimated short-term dietary intakes of pesticide residues are based on 97.5th-percentile consumption amounts. This was deemed appropriate to use for short-term intake estimates for the tin assessment. Thirty-nine or more consumers of a food are needed to ensure a reliable 97.5th-percentile consumption figure.

In relation to concentration data, the calculations of short-term intake for pesticide residues take account of the high variability in residue levels between individual commodity units (e.g. individual apples) within a composite sample, by the incorporation of a variability factor, where relevant. It is assumed that for commodities where the unit weight is smaller than the total high consumption amount, the first unit consumed has a concentration equal to the highest residue of any composite sample from data from supervised trials for use of the chemical, multiplied by the variability factor. The rest of the consumption is assigned a concentration equal to the highest residue. This is based on the fact that the treatment of crops, from sprayed applications, for example, can result in one unit being sprayed with a lot of the chemical, whereas another unit, which may have been more protected from the spray by leaves or other units, has not had the same level of application of the chemical.

Tin contamination is generally not expected to result in residues that follow a pattern similar to pesticide residues. Therefore, in the short-term intake estimates for tin, no consideration of serving size or varying concentrations in different proportions of the total consumption have been taken into account.

Mean or median concentrations of contaminants are generally used in calculations of intake estimates for contaminants on a long-term basis; however, different concentration data are needed for conducting short-term intake estimates. Resulting residues from pesticide trials would not be expected to be above a certain concentration if the chemical has been applied and used in the specified way. Contaminants that are naturally occurring generally have a positively skewed distribution of concentration values. Within the naturally occurring distribution, there can be some high concentrations. This may occur in "spikes" for some contaminants such as toxins. Naturally occurring tin concentrations in foods are very low, with none of the high values seen in canned foods. Tin concentrations in canned foods probably vary in distribution, depending on the food.

Based on the general approach for calculating short-term intake estimates for pesticide residues, the following method has been determined and used for the short-term intake estimates for tin:

Short-term intake (mg/kg bw per day)

$$= \frac{\text{P97.5th consumption (kg)} \times \text{representative high tin concentration (mg/kg)}}{\text{Mean body weight (kg)}}$$

Short-term intakes based on 90th-percentile tin concentration data and the maximum concentration of tin for a food group are presented in Tables 11 and 13 below. The 90th percentile is reflective of representative high concentrations of tin in a canned food. The maximum concentrations were, for the majority of samples, below the proposed Codex MLs (200 mg/kg for canned beverages and 250 mg/kg for canned foods other than beverages) and, if not, were not largely exceeding this value. The maximum concentrations for the countries for which short-term intakes were calculated were a lot lower than concentrations reported in the previous review by the Committee (up to 1000 mg/kg); therefore, it was not unreasonable to estimate short-term intakes based on maximum concentrations as well.

Short-term dietary intakes of tin were calculated only for canned foods, as these contribute the most to chronic intakes, and as concentrations in foods from naturally occurring sources are much lower and do not warrant investigation for acute health risks.

Due to the varying nature of tin concentrations in different canned foods, which depends on the food type, there is a need to look at some foods separately. Therefore, short-term intakes were calculated for single foods. Intakes of tin from short-term assessments cannot be summed to obtain a total short-term intake of tin from all foods because they are based on high-level consumption data, and it is unrealistic to assume that people have consumed all foods at a high level of consumption. In addition, high-level food consumption figures are derived for "consumers only" for each food group. There is a different population of consumers for each food, which means that estimated short-term intakes cannot be summed across the whole diet.

Short-term intakes were also calculated for tin based on proposed Codex MLs to determine whether concentrations of tin at the current proposed regulatory limits would pose an undue acute health risk to humans.

Short-term estimates from consumption of water have not been estimated due to the low contribution of water to chronic intakes of tin and low tin concentrations in water (0.01 mg/l quoted previously by the Committee; Annex 1, reference 150).

Short-term intake estimates have been calculated on a "whole population" basis only; no population subgroups were assessed.

Concentration data used for the Australian and New Zealand short-term intake estimates were sourced from a range of Australian and New Zealand national surveys, including the 19th and 20th Australian Total Diet Surveys mentioned above. It was assumed that concentrations of tin in canned foods are the same for Australia and New Zealand. Results from individual and composite samples were pooled for each food to boost sample numbers to derive concentrations for use in estimating short-term intakes. Concentration data are shown in Table 10. Microsoft Excel was used to derive the 90th-percentile figures. Nine samples or more for a food are needed to ensure a reliable 90th-percentile concentration figure. Despite this, estimated intakes based on fewer than nine samples are presented below for completeness, although they have been highlighted as being not as reliable.

Table 10. Tin concentrations used for short-term intake assessments for Australia and New Zealand

Food	Tin concentration (mg/kg)		Number of samples
	90th-percentile tin concentration	Maximum tin concentration	
Pineapple, canned	87.0	270.0	52
Peaches, canned	107.9	130.0	12
Fruit salad, canned	86.4	116.0	9
Asparagus, canned	186.5[a]	230.0	4
Kidney beans, canned	1.1	1.1	9
Baked beans, canned	172.8	230.0	27
Beetroot, canned	5.1	9.0	19
Corn, sweet and creamed, canned	1.4	2.0	11
Mushrooms, canned	197.0	260.0	84
Tomatoes, canned in juice	112.0	190.0	71
Water chestnuts, canned	5.2[a]	5.4	4
Spaghetti in tomato sauce, canned	169.2[a]	190.0	3
Seafood, canned (including crab, salmon, tuna, abalone)	2.0	2.0	38

[a] Not as reliable due to fewer than nine samples.

4.3.2 Australia

Consumption figures for canned foods for Australia at the 97.5th-percentile level are based on food consumption for a 24-h period based on data from the 1995 Australian National Nutrition Survey and include consumption of the food on its own (e.g. a can of diced peaches as a snack) as well as use of the item in a mixed food (e.g. canned peaches in a trifle dessert).

Estimated short-term intakes for Australia for tin from canned foods are presented in Table 11. Intakes ranged from 0.004 to 1.34 mg/kg bw per day when based on 90th-percentile tin concentrations and from 0.005 to 1.53 mg/kg bw per day based on maximum tin concentrations. There was little difference between the estimated intakes based on the different concentration levels, because there was

Table 11. Estimated short-term intakes of tin for Australia based on analytical data

Food	Number of consumers	97.5th-percentile consumption (kg)	Source of concentration data	Short-term intake: 90th-percentile concentrations (mg/kg bw per day)[a]	Short-term intake: maximum concentrations (mg/kg bw per day)[a]
Tropical fruit, canned, including pineapple	331	0.236	Pineapple, canned	0.310	0.950
Peaches, canned	233	0.496	Peaches, canned	0.800	0.960
Stone fruits, except peaches	87	0.275	Peaches, canned	0.440	0.530
Fruit salad, canned	148	0.526	Fruit salad, canned	0.680	0.910
Two fruits, canned	41	0.521	Fruit salad, canned	0.670	0.900
Pome fruits (including apple and pear), canned	83	0.475	Fruit salad, canned	0.610	0.820
Stalk vegetables (including asparagus)	140	0.253	Asparagus, canned	0.700[b]	0.870
Legumes and pulses (including kidney beans, lentils, chickpeas, soya beans)	119	0.310	Kidney beans, canned	0.005	0.005
Baked beans, canned	376	0.446	Baked beans, canned	1.150	1.530
Root vegetables, including beetroot and carrot	963	0.099	Beetroot, canned	0.008	0.013
Corn, sweet and creamed, canned	293	0.192	Corn, sweet and creamed, canned	0.004	0.006
Mushrooms, canned	673	0.192	Mushrooms, canned	0.570	0.750
Tomatoes, canned in juice	80	0.439	Tomatoes, canned	0.730	1.250

Table 11. (contd)

Food	Number of consumers	97.5th-percentile consumption (kg)	Source of concentration data	Short-term intake: 90th-percentile concentrations (mg/kg bw per day)[a]	Short-term intake: maximum concentrations (mg/kg bw per day)[a]
Artichoke/water chestnuts, canned	23	0.094[b]	Water chestnuts, canned	0.007[b]	0.008[b]
Pasta in tomato sauce, canned	151	0.530	Spaghetti, canned	1.340[b]	1.500
Seafood, canned	0.559	0.225	All canned seafood	0.007	0.007

[a] Mean body weight of all respondents, 67 kg.
[b] Not as reliable due to either fewer than 39 consumers for the food or fewer than 9 samples for the analytical data.

often very little difference between the 90th-percentile and maximum tin concentrations for a food.

Based on the ML of tin in canned foods in Australia, 250 mg/kg, estimated short-term intakes of tin, using the same consumption data as used in previous estimates, are shown in Table 12. Short-term intakes range from 0.35 to 1.98 mg/kg bw per day.

Table 12. Estimated short-term intakes of tin for Australia based on national MLs

Canned food	Short-term intake based on Australian ML, 250 mg/kg (mg/kg bw per day)[a]
Tropical fruit, canned, including pineapple	0.88
Peaches, canned	1.85
Stone fruits, except peaches	1.03
Fruit salad, canned	1.96
Two fruits, canned	1.94
Pome fruits (including apple and pear), canned	1.77
Stalk vegetables (including asparagus)	0.94
Legumes and pulses (including kidney beans, lentils, chickpeas, soybeans)	1.16
Baked beans, canned	1.66
Root vegetables, including beetroot and carrot	0.37
Corn, sweet and creamed, canned	0.72
Mushrooms, canned	0.72
Tomatoes, canned in juice	1.64
Artichoke/water chestnuts, canned	0.35[b]
Pasta in tomato sauce, canned	1.98
Seafood, canned	0.84

[a] Mean body weight of all respondents, 67 kg.

[b] Not as reliable due to fewer than 39 consumers for the food.

4.3.3 New Zealand

Consumption figures for canned foods for New Zealand at the 97.5th-percentile level are based on food consumption for a 24-h period based on data from the 1997 New Zealand National Nutrition Survey and include consumption of the food on its own (e.g. a can of diced peaches as a snack) as well as use of the item in a mixed food (e.g. canned peaches in a trifle dessert).

Estimated short-term intakes for New Zealand for tin from canned foods are presented in Table 13. Intakes ranged from 0.005 to 1.37 mg/kg bw per day when based on 90th-percentile tin concentrations and from 0.005 to 1.55 mg/kg bw per day based on maximum tin concentrations. There was little difference between the estimated intakes based on the different concentration levels because there was often very little difference between the 90th-percentile and maximum tin concentrations for a food.

Based on the ML of tin in canned foods in New Zealand, 250 mg/kg, estimated short-term intakes of tin, using the same consumption data as used in the estimates above, are shown in Table 14. Short-term intakes range from 0.39 to 3.34 mg/kg bw per day.

The same concentration values were used for the Australian and New Zealand estimates; therefore, the similarity in the short-term intake estimates between the two countries can be attributed to similar consumption of canned foods.

4.3.4 United Kingdom

From the 2002 United Kingdom survey of tin in canned fruits and vegetables (UK FSA, 2002), there were over 1200 individual cans of food analysed. The raw data were compiled, and the 90th-percentile and maximum tin concentrations were determined from the 1200 samples for use in the short-term intake estimates. These are shown in Table 15.

In the absence of high-percentile food consumption data for canned foods for the United Kingdom, a single can size was used as a representative high-percentile consumption amount (approximately 440 g). Using this as approximating a 97.5th-percentile consumption does not appear to be unreasonable when comparing it with the 97.5th-percentile consumption figures derived for Australia and New Zealand. It may be an overestimate of the amount of food consumed for some foods that are generally eaten in smaller quantities (e.g. peas compared with peaches); however, this means the short-term intake estimate is likely to be a worst-case scenario.

Estimated short-term intakes for tin for the United Kingdom based on the 90th-percentile tin concentrations range between 0.037 and 1.3 mg/kg bw per day; based on maximum tin concentrations, short-term intakes range between 0.037 and 2.19 mg/kg bw per day.

4.4 General estimates of short-term intakes based on MLs

Various MLs are specified for tin, usually in canned foods, in regulations both internationally, by Codex, and at the national level. Assessments of intake of tin based on Codex-proposed MLs and high-level consumption data have also been made to determine if there are acute health concerns associated with these levels.

Proposed MLs by Codex were 200 mg/kg in canned beverages and 250 mg/kg in canned foods other than beverages.

Table 13. Estimated short-term intakes of tin for New Zealand based on analytical data

Food	Number of consumers	97.5th-percentile consumption (kg)	Source of concentration data	Short-term intake: 90th-percentile concentrations (mg/kg bw per day)[a]	Short-term intake: maximum concentrations (mg/kg bw per day)[a]
Tropical fruit, canned, including pineapple	113	0.234	Pineapple, canned	0.280	0.890
Stone fruits, including peaches, apricots, canned	175	0.416	Peaches, canned	0.630	0.760
Fruit salad, canned	88	0.474	Fruit salad, canned	0.580	0.770
Pome fruits (including apple and pear), canned	31	0.950[b]	Fruit salad, canned	1.160[b]	1.550[b]
Asparagus, canned	15	0.300[b]	Asparagus, canned	0.790[b]	0.970[b]
Beans mix, canned	119	0.310	Kidney beans, canned	0.005	0.005
Baked beans, canned	101	0.425	Baked beans, canned	1.030	1.380
Beetroot, canned	145	0.111	Beetroot, canned	0.008	0.014
Corn, sweet and creamed, canned	56	0.425	Corn, sweet and creamed, canned	0.008	0.012
Mushrooms, canned	13	0.220[b]	Mushrooms, canned	0.610[b]	0.810[b]
Tomatoes, canned in juice	88	0.408	Tomatoes, canned	0.640	1.090
Spaghetti in tomato sauce, canned	102	0.576	Spaghetti, canned	1.370[b]	1.540
Seafood, canned	195	0.289	All canned seafood	0.008	0.008

[a] Mean body weight of all respondents, 71 kg.
[b] Not as reliable due to either fewer than 39 consumers for the food or fewer than 9 samples for the analytical data.

Table 14. Estimated short-term intake of tin for New Zealand based on national MLs

Canned food	Short-term intake based on New Zealand ML, 250 mg/kg (mg/kg bw per day)[a]
Tropical fruit, canned, including pineapple	0.820
Stone fruits, including peaches, apricots	1.470
Fruit salad, canned	1.670
Pome fruits (including apple and pear), canned	3.340[b]
Asparagus, canned	1.060[b]
Beans mix, canned	1.090
Baked beans, canned	1.500
Beetroot, canned	0.390
Corn, sweet and creamed, canned	1.500
Mushrooms, canned	0.780[b]
Tomatoes, canned in juice	1.440
Spaghetti in tomato sauce, canned	2.030
Seafood, canned	1.020

[a] Mean body weight of all respondents, 71 kg.
[b] Not as reliable due to fewer than 39 consumers for the food.

The estimated short-term intake of tin based on consumption of canned foods of a large can size (440 g) and the highest proposed ML of 250 mg/kg would be 1.8 mg/kg bw per day (Table 16).

4.5 Conclusions

The concentrations of tin in foods from recent studies are similar to those previously evaluated by the Committee, with the new data ranging between <1 and 300 mg/kg.

These recent chronic intake estimates of tin from Australia and the United Kingdom were in the same range of reported intakes presented in the previous review of tin by the Committee (which were from <1 to 14 mg/day). All estimated chronic intakes were lower than the tolerable limit that was previously established by the Committee. The major contributor to tin intake is canned foods.

Estimated short-term dietary intakes range between 0.004 and 3.3 mg/kg bw per day. Intakes depend on the concentration in the food, but also the type of food. These short-term intakes can be regarded as preliminary only due to small sample numbers for either the food consumption data or concentration data from which they were derived and the assumptions made for the calculations. They are a

Table 15. Concentrations of tin in canned foods from the United Kingdom and short-term intake estimates

Food	Number of samples	90th percentile		Maximum	
		Tin concentration (mg/kg)	Short-term intake (mg/kg bw per day)[a]	Tin concentration (mg/kg)	Short-term intake (mg/kg bw per day)[a]
Canned tomato products	161	79	0.580	196	1.440
Canned pasta products	162	119	0.870	298	2.190
Canned tomato soup products	162	139	1.020	196	1.440
Canned tomato-based soup products	90	54	0.400	141	1.034
Baked beans	126	46	0.340	76	0.560
Canned cooking sauces	90	5	0.037	6	0.044
Canned pineapple	90	96	0.710	168	1.230
Canned fruit cocktail	54	147	1.080	166	1.220
Canned grapefruit	45	100	0.730	123	0.900
Canned apricot	45	109	0.800	135	0.990
Canned fruit fillings	36	5	0.037	5	0.037
Canned mushrooms	30	9	0.065	46	0.340
Canned celery	27	5	0.037	5	0.037
Canned gooseberries	27	178	1.300	236	1.730
Canned rhubarb	27	9	0.065	12	0.088
Canned asparagus	29	108	0.790	139	1.020

[a] Based on a canned food consumption amount of 440 g and a mean body weight of 60 kg.

Table 16. Short-term intake estimates for tin, based on can size and MLs

Can size (g)	ML (mg/kg)	Body weight (kg)	Short-term intake (mg/kg bw per day)
440	250	60	1.83
	200	60	1.47
220	250	60	0.92
	200	60	0.73

guide to likely short-term dietary intakes only and are not representative of international intakes.

No short-term intakes of tin specifically from beverages, such as canned fruit juices, were available, as submitters had no data on either consumption or concentrations of tin in these foods. Beverages are consumed in larger amounts than non-beverage foods, which may potentially lead to higher short-term intakes of tin from beverages, and even more so if high tin concentrations occur in this food group.

No short-term estimates of tin intake by children were available due to a lack of information on consumption of canned foods for this age group. Children are likely to have higher short-term intakes of tin per kilogram of body weight compared with adults, due to their lower body weights and higher food consumption per kilogram of body weight than adults.

The Committee noted that the data on acute effects available indicated that it is inappropriate to establish an ARfD for inorganic tin, since whether or not acute effects of gastric irritation occur after ingesting a food containing tin depends on the concentration and nature of tin in the product, rather than on the dose ingested on a body weight basis. Therefore, the Committee concluded that the short-term dietary intake estimates were not particularly relevant for the assessment, as they were estimated likely doses of total inorganic tin.

5. COMMENTS

5.1 Observations in humans

Episodes of human poisoning resulting from consumption of food and drink contaminated with inorganic tin have resulted in abdominal distension and pain, vomiting, diarrhoea and headache. Symptoms commonly start within 0.5–3 h, and recovery occurs within 48 h. The doses of inorganic tin ingested in such episodes of poisoning were not estimated, but the symptoms occurred when canned food or beverages were found to contain tin at concentrations varying from 250 to 2000 mg/kg.

In one study, all five volunteers experienced symptoms when they ingested orange juice containing inorganic tin at a concentration of 1370 mg/kg (equal to a dose of 4.4–6.7 mg/kg bw). Orange juice containing inorganic tin at concentrations of 498, 540 or 730 mg/kg (equal to a dose range of 1.6–3.6 mg/kg bw) did not provoke any symptoms in groups of five volunteers. Administration of the same amount of the same juice (containing tin at 1370 mg/kg) to these individuals 1 month later resulted in symptoms in only one person. Although this was explained by the authors as development of tolerance, another possible explanation might be that the longer storage of the juice led to a different speciation.

A newly available study (Boogaard et al., 2003) showed that tomato juice freshly spiked with tin(II) chloride at a concentration of ≥161 mg/kg causes gastrointestinal disorders in humans in a concentration-related manner. The concentration–response relationship indicated a threshold for acute effects caused by inorganic tin at a concentration of about 150 mg/kg of juice. In the second part of this study, volunteers receiving 250 ml of a tomato soup contaminated with inorganic tin that had migrated from packaging at concentrations of <0.5, 201 and 267 mg/kg did not experience an increased incidence of adverse effects compared with controls. The results of distribution studies of tin in the soup and juice consumed supported the view that both complexation and adsorption of tin onto solid matter reduce its irritant effect on the gastrointestinal tract.

Overall, the information available showed that gastrointestinal irritation from inorganic tin in canned foods is more closely related to the concentration and nature of tin in the product than to the dose of tin ingested on a body weight basis. No information was available regarding subpopulations such as children or people with gastrointestinal disorders.

5.2 Prevention and control

The lacquering of tin-plated cans prevents the migration of inorganic tin into food and beverages. Food and beverages should not be stored in opened tin-plated cans.

5.3 Levels and pattern of food contamination

Data on the concentrations of inorganic tin in a range of foods from four countries (Australia, France, Lithuania and the United Kingdom) had become available since the last review of inorganic tin by the Committee and were reviewed at this meeting. The Committee noted that the reported concentrations of inorganic tin were in the same range as those previously assessed by the Committee, the new values ranging from not detected to 300 mg/kg.

5.4 Dietary intake assessment

The major dietary source of inorganic tin is food packaged in unlacquered or partially lacquered tin-plated cans. The migration of inorganic tin from tin plate into foods is greater in highly acidic foods such as pineapples and tomatoes; with increased time and temperature of food storage; and in foods, such as fruit juice, in opened cans. The inorganic tin content of canned foods is variable, and some foods may have concentrations high enough to cause an acute toxic reaction. Information previously evaluated by the Committee and additional data from Australia and the United Kingdom indicated that the mean long-term dietary intakes of inorganic tin by individuals ranged from <1 to about 14 mg/person per day. Population groups with higher intakes of canned foods may have higher intakes of inorganic tin. A small number of estimates of short-term dietary intake (i.e. in a period of 24 h or less) were assessed by the Committee. Based on limited data, preliminary short-term intakes of inorganic tin were estimated to be between 0.004 and 3.3 mg/kg bw per day, depending on the food considered.

6. EVALUATION

The Committee concluded that the data available indicated that it is inappropriate to establish an ARfD for inorganic tin, since whether or not irritation of the gastrointestinal tract occurs after ingestion of a food containing tin depends on the concentration and nature of tin in the product, rather than on the dose ingested on a body weight basis. Therefore, the Committee concluded that the short-term intake estimates were not particularly relevant for the assessment, as they were estimated likely doses of total inorganic tin. The Committee reiterated its opinion, expressed at its thirty-third and fifty-fifth meetings, that the available data for humans indicated that inorganic tin at concentrations of >150 mg/kg in canned beverages or >250 mg/kg in canned foods may produce acute manifestations of gastric irritation in certain individuals. Therefore, ingestion of reasonably sized portions of food containing inorganic tin at concentrations equal to the proposed standard for canned beverages (200 mg/kg) may lead to adverse reactions. No information was available as to whether there are subpopulations that are particularly sensitive for such adverse reactions. The Committee reiterated its advice that consumers should not store food and beverages in opened tin-plated cans.

In addition, the Committee noted that the basis for the PMTDI and PTWI established at its twenty-sixth and thirty-third meetings was unclear and that these values may have been derived from intakes associated with acute effects. The Committee concluded that it was desirable to (re)assess the toxicokinetics and effects of inorganic tin after long-term exposure to dietary doses of inorganic tin at concentrations that did not elicit acute effects.

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