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# Iron and Tin Content of Canned Fruit Juices and Nectars

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*ABSTRACT*

*A survey of the iron and tin content of twelve different types of canned fruit juices and nectars revealed that, of the 122 cans examined, 23 (or 18·9%) contained iron in excess of 15 mg kg$^{-1}$ and 16 (or 13·1%) contained tin in excess of 250 mg kg$^{-1}$. Apple juice and tomato juice were found to contain particularly high levels of iron, the maximum level recorded being 42·6 mg kg$^{-1}$. Mango juice and orange juice exhibited significant non-compliance with recommended Codex tolerance limits for tin. Statistical analysis showed that, at the 5% probability level, the mean iron contents of products packed in completely unlacquered and end-lacquered cans were not significantly different from each other, but were significantly lower than the mean iron content of products packed in fully lacquered cans. The mean tin content fell in the order unlacquered > end-lacquered > fully lacquered cans.*

## INTRODUCTION

The accumulation of iron and tin in tinplate canned foods during storage arises as a result of internal can corrosion, the rate of which varies with the properties of the tinplate, the processing and storage conditions used and the nature of the contents (Board & Steele, 1975; Britton, 1975; Mannheim & Passy, 1982). Excessive levels of these metals can cause



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unacceptable changes in colour, taste or clarity of the products, thus limiting their shelf-life even before hydrogen swelling is visibly evident (Szarski, 1971; Britton, 1975; Horwitz, 1979; Mannheim & Passy, 1982). Of even greater concern is the possible toxicity of high levels of tin to humans. Ingestion of foods containing relatively high levels of tin has been reported to cause several physiological disorders such as nausea, vomiting and diarrhoea (Benoy *et al.*, 1971). Horwitz (1979) cited the case where high levels of tin in canned peaches, green beans and tomato paste were implicated in several incidents of apparent tin poisoning in Sweden. Anaemia, tumours and other pathological effects have also been noted in animals fed abnormally high levels of tin (De Groot, 1973; De Groot *et al.*, 1973; Fritsch *et al.*, 1977). More recent studies have also indicated that excessive levels of tin in the diet can cause reduced retention of calcium, copper and zinc in tissues of rats (Yamaguchi *et al.*, 1980; Greger & Johnson, 1981).

Many countries have found it prudent to establish maximum limits for certain metals, including iron and tin, in canned foods (Dewdney & King, 1980; Reilly, 1980). The joint FAO/WHO Codex Alimentarius Commission (1978) has established tentative tolerance levels for iron and tin in many canned products. For most canned fruit juices and nectars, the Codex maximum limits recommended for iron and tin are 15 mg $kg^{-1}$ and 250 mg $kg^{-1}$, respectively. Malaysia has yet to promulgate regulations governing maximum permissible levels of metals in canned foods, despite concern expressed by some quarters in the country regarding the sale of canned foods which have exceeded their shelf-life and which might thus contain excessive levels of metal contaminants. This paper presents the results of a survey of the iron and tin contents of twelve different types of canned fruit juices and nectars carried out to determine the incidence of gross iron and tin contamination (i.e. those cans exceeding recommended Codex limits for these metals). Fruit nectars (which are prepared by blending pulpy fruit juices with sugar syrup, acid and other ingredients) cannot, for purposes of identity, be called fruit juices because of the presence of added ingredients.

## MATERIALS AND METHODS

Samples were collected randomly from supermarkets and minimarkets in Penang, Malaysia, over the period from December, 1982 to February,

1983. Most of the canned fruit juices and nectars purchased were imported brands.

After thorough shaking, each can was opened and duplicate 10-g samples, accurately weighed, were withdrawn and wet-digested with 1·0 ml of concentrated sulphuric acid and 10·0 ml of redistilled nitric acid, additional amounts of the latter being added as needed. After digestion, each sample was diluted to the appropriate volume with distilled deionised water and the iron and tin contents determined using an Instrumentation Laboratory (IL) Model 251 double-beam atomic absorption spectrophotometer with automatic background correction. Iron was determined at 248·3 nm using an air–acetylene flame and conditions recommended by the instrument manufacturer. Tin was determined at 235·4 nm using a nitrous oxide–acetylene flame. For each run, standards and blanks were also prepared and analysed, and calibration curves constructed. Standards were prepared from commercial (BDH) atomic absorption standard solutions.

All glassware was washed with detergent, immersed overnight in a nitric acid solution (1:1, conc. $HNO_3:H_2O$), rinsed with distilled deionised water and dried before use. All chemical reagents used were of spectroscopic or analytical grade.

## RESULTS AND DISCUSSION

### Gross contamination

Tables 1 and 2 show the iron and tin contents, respectively, of different brands of canned fruit juices and nectars. Psychological association of quality with certain brands is avoided by omitting brand names. Of a total of 122 cans examined, 23 cans (or 18·9%) were found to contain iron in excess of 15 mg kg$^{-1}$. Forty-two cans, or 34·4% of the cans analysed, would fail to comply with a more stringent standard of 10 mg kg$^{-1}$.

Of the two brands of canned apple juice tested, 10 cans out of 12 (or 83·3%) contained iron in excess of the recommended Codex limit of 10 mg kg$^{-1}$ and 8 cans out of 12 (or 66·7%) contained iron in excess of 15 mg kg$^{-1}$. All 6 cans of one brand had iron contents greater than 15 mg kg$^{-1}$, the average content being three and one-half times the recommended Codex limit. Canned tomato juice was another product found to show significant non-compliance with standards. Of the two

**TABLE 1**
Iron Content of Canned Fruit Juices and Nectars

| *Type of product* | *Brand* | *Can type** | *Number of cans* | *Iron content (mg kg⁻¹)* | | *Codex tolerance limit (mg kg⁻¹)* | *Number of samples exceeding* | |
|---|---|---|---|---|---|---|---|---|
| | | | | *Range* | *Mean ± SD* | | *10 mg kg⁻¹* | *15 mg kg⁻¹* |
| Mango juice | A | P | 6 | 7·9–19·6 | 11·2 ± 4·6 | 15 | 2 | 1 |
| | B | P | 6 | 2·1–3·5 | 2·7 ± 0·5 | 15 | 0 | 0 |
| Pineapple juice | C | P | 6 | 2·8–5·3 | 4·0 ± 1·0 | 15 | 0 | 0 |
| | D | P | 6 | 5·2–26·5 | 12·9 ± 8·7 | 15 | 2 | 2 |
| Grapefruit juice | E | EL | 6 | 2·0–3·7 | 2·7 ± 0·7 | 15 | 0 | 0 |
| | F | EL | 6 | 3·8–10·9 | 6·3 ± 2·6 | 15 | 1 | 0 |
| Guava juice | G | EL | 10 | 3·3–6·0 | 4·6 ± 0·9 | 15 | 0 | 0 |
| Lychee juice | H | EL | 6 | 1·7–6·4 | 3·5 ± 1·6 | 15 | 0 | 0 |
| | I | EL | 6 | 4·0–13·7 | 8·1 ± 4·2 | 15 | 2 | 0 |
| Orange juice | F | EL | 6 | 11·2–18·5 | 14·6 ± 2·5 | 15 | 6 | 2 |
| | J | EL | 6 | 4·1–7·0 | 5·6 ± 0·9 | 15 | 0 | 0 |
| Apple juice | J | L | 6 | 5·5–16·0 | 11·9 ± 4·8 | 10 | 4 | 2 |
| | K | L | 6 | 21·4–42·6 | 35·4 ± 8·1 | 10 | 6 | 6 |
| Grape juice | M | L | 6 | 1·2–13·1 | 7·0 ± 5·0 | 15 | 2 | 0 |
| Tomato juice | M | L | 6 | 16·1–31·0 | 23·8 ± 5·9 | 15 | 6 | 6 |
| | N | L | 6 | 8·8–23·1 | 15·8 ± 4·8 | 15 | 5 | 3 |
| Apricot nectar | M | EL | 10 | 2·8–7·4 | 5·3 ± 1·3 | 15 | 0 | 0 |
| Mango nectar | F | EL | 6 | 4·0–7·8 | 5·7 ± 1·5 | 15 | 0 | 0 |
| Pear and passion fruit nectar | F | EL | 6 | 10·2–15·3 | 13·1 ± 2·1 | 15 | 6 | 1 |
| | | | 122 | | | | 42 | 23 |

* Can type: P = Plain, EL = End-lacquered, L = Fully lacquered.

**TABLE 2**
Tin Content of Canned Fruit Juices and Nectars

| *Type of product* | *Brand* | *Can type** | *Number of cans* | *Tin content ($mg\ kg^{-1}$)* | | *Codex tolerance limit ($mg\ kg^{-1}$)* | *Number of samples exceeding* | |
|---|---|---|---|---|---|---|---|---|
| | | | | *Range* | *Mean ± SD* | | *150 $mg\ kg^{-1}$* | *250 $mg\ kg^{-1}$* |
| Mango juice | A | P | 6 | 518–722 | 583 ± 74 | 250 | 6 | 6 |
| | B | P | 6 | 111–177 | 137 ± 22 | 250 | 1 | 0 |
| Pineapple juice | C | P | 6 | 54–94 | 72 ± 14 | 250 | 0 | 0 |
| | D | P | 6 | 35–100 | 56 ± 25 | 250 | 0 | 0 |
| Grapefruit juice | E | EL | 6 | 28–94 | 59 ± 25 | 250 | 0 | 0 |
| | F | EL | 6 | 56–139 | 90 ± 28 | 250 | 0 | 0 |
| Guava juice | G | EL | 10 | 53–94 | 71 ± 14 | 250 | 0 | 0 |
| Lychee juice | H | EL | 6 | 171–263 | 214 ± 36 | 250 | 6 | 1 |
| | I | EL | 6 | 43–65 | 54 ± 9 | 250 | 0 | 0 |
| Orange juice | F | EL | 6 | 205–318 | 288 ± 42 | 250 | 6 | 5 |
| | J | EL | 6 | 242–290 | 261 ± 20 | 250 | 6 | 4 |
| Apple juice | J | L | 6 | ← trace → | | 150 | 0 | 0 |
| | K | L | 6 | ← trace → | | 150 | 0 | 0 |
| Grape juice | M | L | 6 | 0–18 | 6 ± 7 | 150 | 0 | 0 |
| Tomato juice | M | L | 6 | ← trace → | | 250 | 0 | 0 |
| | N | L | 6 | 32–51 | 43 ± 7 | 250 | 0 | 0 |
| Apricot nectar | M | EL | 10 | 87–249 | 140 ± 60 | 250 | 2 | 0 |
| Mango nectar | F | EL | 6 | 82–122 | 104 ± 14 | 250 | 0 | 0 |
| Pear and passion fruit nectar | F | EL | 6 | 121–143 | 127 ± 9 | 250 | 0 | 0 |
| | | | 122 | | | | 27 | 16 |

* Can type: P = Plain, EL = End-lacquered, L = Fully lacquered.

brands of this product studied, 9 cans out of 12 (or 75 %) contained iron in excess of the recommended Codex limit of 15 mg $kg^{-1}$, with all 6 cans of one brand exceeding this limit.

Where tin content is concerned, 16 cans out of a total of 122 (or 13·1 %) were found to contain tin in excess of 250 mg $kg^{-1}$. If a more stringent standard of 150 mg $kg^{-1}$ were to be applied, the percentage non-compliance would increase to 22·1 %. In a survey carried out in New Zealand, Page *et al.*, (1974) found that only 3 of 28 cans of fruit juices and beverages (or 10·7 %) exceeded this limit for tin.

Areas of significant non-compliance with Codex tin standards were mainly restricted to mango juice and orange juice. All 6 cans of one brand of canned mango juice tested were above the Codex tolerance level of 250 mg $kg^{-1}$, the average tin content being 583 mg $kg^{-1}$. The Codex limit for tin was also exceeded by 75 % of the canned orange juice analysed.

The results show that there is a relatively high incidence of canned fruit juices containing excessive levels of iron and tin. This is a situation which should be improved upon, especially since such products are likely to be consumed in relatively large amounts by children. Although technical faults cannot be totally discounted, such unusually high levels of these metals in certain products appear more likely to be due to slow corrosion occurring over a prolonged period of time (Szarski, 1971; Britton, 1975). It is interesting to note that most of the products exhibiting a high incidence of non-compliance with standards are those which appear to face stiff competition from alternative products in dehydrated form or juices packed in plastic and glass bottles and Tetra-Paks. It is reasonable to assume that such canned products are more likely to remain on the supermarket shelves for an extended period of time. Improper storage conditions may also accelerate the dissolution of iron and tin from tinplate containers. In any case, products with excessively high levels of these metals may be deemed to have exceeded their shelf-life even though obvious external signs are not evident. An undesirable tinny or metallic taste was clearly evident in grossly contaminated samples of canned mango and orange juices.

Shelf-life dating of canned fruit juices (something which is not legally mandatory in Malaysia at present) could help to reduce the incidence of gross metal contamination in such products. To be effective and of benefit to consumers, however, expiry dating must be coupled with proper handling and storage of the canned products. In particular, exposure to high storage temperatures (a factor which is especially pertinent in a tropical country like Malaysia) should be avoided as tinplate can corrosion is known to be accelerated by an increase in temperature (Hartwell, 1951; Mahadeviah, 1976; Nagy *et al.*, 1980).

## Brand differences

In cases where two brands of a particular product were studied, statistical analysis revealed that brand differences in mean iron contents were significant at the 5% probability level. Where tin content is concerned, however, significant differences ($p < 0.05$) were found only for canned mango, lychee and tomato juices. It should be pointed out that such statistical analysis of brand differences may not be altogether valid because of the limited number of cans in each category and also because the storage history and age of the materials tested are not known. Large inter-can variations within each brand apparently exist and can possibly be accounted for in large part by differences in temperature and length of storage.

## Effect of lacquering

Of the 122 cans of fruit juices and nectars collected, it was observed after opening that 24 were completely unlacquered (P), 68 were end-lacquered with plain bodies (EL) and 30 were fully lacquered (L). Table 3 shows the distribution of iron and tin concentrations in the can contents as a function of can type. The overall mean iron and tin contents according to can type are shown in Table 4.

No significant difference ($p < 0.05$) in mean iron content was detected between unlacquered and end-lacquered cans. However, the mean iron content of fully lacquered cans was significantly higher ($p < 0.001$) than that of either unlacquered or end-lacquered cans. Statistical analysis also showed that the mean tin contents for P, EL and L cans were significantly different ($p < 0.05$), one from the other. The mean tin level fell in the order P > EL > L, a result which is consistent with those obtained by Page *et al.*, (1974) and Greger & Baier (1981). The present results are to be expected, being consistent with currently accepted theories of tinplate can corrosion (Board & Steele, 1975; Britton, 1975; Mannheim & Passy, 1982). In plain cans where the ratio of exposed tin to iron areas is large, the tin coating provides cathodic protection to the base steel and very little dissolution of iron occurs until nearly all of the tin has been removed

**TABLE 3**

Distribution of the Concentration of Iron and Tin in the Can Contents as a Function of Can Type

| *Can type* | *Total number of cans* | *Distribution of iron (mg kg$^{-1}$)* | | | | *Distribution of tin (mg kg$^{-1}$)* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *0–5·0* | *5·1–10·0* | *10·1–15·0* | *>15·0* | *0–50* | *51–100* | *101–150* | *151–200* | *201–250* | *>250* |
| Plain | 24 | 11 | 9 | 1 | 3 | 3 | 9 | 5 | 1 | 0 | 6 |
| End-lacquered | 68 | 31 | 22 | 12 | 3 | 5 | 27 | 16 | 3 | 7 | 10 |
| Fully lacquered | 30 | 2 | 5 | 6 | 17 | 29 | 1 | 0 | 0 | 0 | 0 |

**TABLE 4**
Iron and Tin Contents of Fruit Juices and Nectars as a Function of Can Type

| *Can type* | *Number of cans* | *Iron content (mg kg$^{-1}$)* | | *Tin content (mg kg$^{-1}$)* | |
|---|---|---|---|---|---|
| | | *Range* | *Mean* ± SD* | *Range* | *Mean* ± SD* |
| Plain | 24 | 2·1–26·5 | $7{\cdot}7^a \pm 6{\cdot}4$ | 35–722 | $212^a \pm 224$ |
| End-lacquered | 68 | 1·7–18·5 | $6{\cdot}7^a \pm 4{\cdot}0$ | 28–318 | $137^b \pm 83$ |
| Fully lacquered | 30 | 1·2–42·6 | $18{\cdot}8^b \pm 11{\cdot}5$ | 0–51 | $10^c \pm 17$ |

* Means followed by the same letter are not significantly different at $p < 0{\cdot}05$.

from the container walls. Tin dissolution and the electrochemical protection of iron by the tin are reduced in the presence of a lacquer coating. Corrosion is then normally concentrated at discontinuities in the lacquer coating, leading to failure of the can through hydrogen swelling or to perforations of the base steel.

The incidence of cans containing iron in excess of 15 mg kg$^{-1}$ was very much higher for fully lacquered (56·7 %) than for plain (12·5 %) or end-lacquered cans (4·4 %). As expected, gross tin contamination (i.e. in excess of 250 mg kg$^{-1}$) was more prevalent in plain or end-lacquered cans than in fully lacquered cans where the tin content did not exceed 100 mg kg$^{-1}$ No definite relationship between pH of the products and the degree of corrosion could be observed.

All the different types of nectars sampled were packed in end-lacquered cans. Statistical comparison with fruit juices packed in similar type cans revealed no significant differences in overall mean iron or tin contents at the 5 % probability level. Only one can of nectar of the 22 cans collected exceeded the Codex limit for iron of 15 mg kg$^{-1}$, and none exceeded the limit for tin.

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