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1. Introduction

It is well known that a balanced diet is essential in maintaining good health. Hence, the nutritional value of foods is an important aspect that should be considered especially with respect to metal intake such as iron, calcium, magnesium, potassium, sodium, selenium, manganese, copper, chromium and zinc. Iron being required for the haemoglobin; calcium for relaxing the central nervous system; magnesium to prevent muscle spasms; potassium and sodium for electrolyte balance; selenium has a number of functions including deactivating heavy metals from external exposure; manganese and copper are linked to superoxide dismutase (SOD): chromium stabilizes blood sugar and zinc is important in the healing of wounds.

An overview of the literature will be given of applications of Flame AA together with some references to Graphite Furnace AA to the analyses of foods such as: meat the main source of iron; dairy products, the source of calcium and fruit and vegetables for a range of metals. Comparisons will be given of metal content in these products particularly in meat and dairy products. Of the metals listed above, not all of these will be considered in every product: only where they are the metal of highest concentration. The aim of this chapter is to give a general comparison of the metal content in these products, which will not be exhaustive, particularly, with respect to fruit and vegetables but the ones most commonly consumed. The emphasis is on nutrition and to give the general reader and health professional a concise view of the metal content of these food products. From scientific aspect the methodology for Flame AA is relative straightforward, as is the work up for instrument presentation but there are often extra procedures that are required depending on the matrix that are essential for obtaining a valid result.

Flame Atomic absorption spectroscopy even though it is a well-established technique that was discovered about fifty years ago is still used extensively today for trace metal analyses in industry, commercial laboratories and universities.

2. History of the discovery of flame atomic absorption spectroscopy

The method for the analyses of metals in a wide range of samples from food, agriculture, mining, environmental, pharmaceutical and biochemical industries was made possible by the discovery of a new technique in the early 1950’s by Dr. Alan Walsh. Like many scientists before him, he was not in his laboratory when the idea came to him but in his vegetable garden one Sunday morning in 1952. The idea proved successful and was the basis of the
atomic absorption spectrophotometer, an instrument for quantitative chemical analyses of metals (Hannaford 2002) that did not require slow wet chemical procedures. Techtron Pty. Ltd., Melbourne, Australia, manufactured the first instrument based on his design in the mid 1960's. The company was taken over many years later by Varian Australia Inc. and several months ago by Agilent Technologies Pty. Ltd, Melbourne who still manufactures an instrument based on this early technology. (Hannaford 2002)

The scientific importance of Alan's idea was that he realized in his attempt to measure the concentration of metals in solution by spectroscopic means, he had been trying to measure the incorrect parameter. Rather than measuring emission he should have been measuring absorbance. When he mentioned this to his colleague John Willis (CSIRO, Division of Chemical Physics) he said that they had considered this aspect before and that it would not work because of the emitted light at the same wavelength. The reply Alan gave was that this could be overcome by having a chopper to eliminate this emission and to use an amplifier. Several days later Alan measured the absorbance of sodium but his colleague at this time did not appreciate the significance of this major scientific breakthrough that was the basic principle of the instrument (Hannaford 2002).

Fig. 1. Photograph of prototype Atomic Absorption Spectrometer build by Dr. Alan Walsh, with permission from Agilent Australia, Mulgrave, Victoria, where the instrument is located.

3. Nutritional significance of minerals in the diet

Minerals are divided into two groups Essential and Trace minerals, which is related to the quantity required and found in the body, the former being present in the largest amounts. These minerals will now be discussed briefly in this order.

3.1 Essential minerals

The essential metals are the macro metals:
- Calcium
- Magnesium
- Potassium
- Sodium
Calcium is responsible for strong bones and teeth and accounts for ninety percent of the calcium in the body whereas the other one percent is circulating in fluids in order to ionise calcium. The metal’s function is related to transmitting nerve impulses; contractions of muscles; blood clotting; activation of some enzyme reactions and secretion of hormones. Magnesium has many roles including supporting the functioning of the immune system; assists in preventing dental decay by retaining the calcium in tooth enamel; it has an important role in the synthesis of proteins, fat, nucleic acids; glucose metabolism as well as membrane transport system of cells. Magnesium also plays a role in muscle contraction and cell integrity. Potassium and sodium work together in muscle contraction nerve transmission. Sodium is important in muscle contraction and nerve transmission. Sodium ions are the main regulators of extra cellular fluid and volume (Whitney and Rofles 2002).

3.2 Trace minerals
These are particularly important for health promotion and prevention of disease. Trace metals being considered in this work are:

- copper,
- chromium,
- iron,
- manganese,
- molybdenum
- selenium
- zinc.

The non-metals also in the group are iodine and fluorine that will not be discussed. Copper has the role of assisting in the formation of haemoglobin, helping to prevent anemia as well as being involved in several enzymes. Chromium function is related to stabilising blood sugar levels with respect to insulin required for release of energy from glucose. Iron is the central metal in the haemoglobin molecule for oxygen transport in the blood and is portion of myoglobin located in muscles. Manganese is one of the co-factors in a number of enzymes as is molybdenum. Selenium has several roles such as regulating the thyroid hormone as well as being part of an enzyme that protects against oxidation (Whitney and Rofles 2002). Selenium has also been reported as assisting in deactivating heavy metals.

3.3 RDI of minerals according to age and gender
The Recommended Daily Intake, RDI of metals is related directly to age, and gender. The requirements for babies, toddlers, children, adolescents, and elderly vary with gender and country due to soil type. These requirements are continually being reviewed in the light of more research that is undertaken by food regulating bodies such as Food Standards Australia and New Zealand, FSANZ, United Stated of America, Food and Drug Administration, FDA, and European Authorities to name three such groups. The work done by these bodies includes all food groups in addition to vitamins, minerals: cereals, fat, protein, carbohydrates, sugars and so on, as well as research on different age groups in particular locations in many countries, to assist in maintaining and improving the health of the various groups and the population in general.
Major minerals | Recommended Daily Intake, RDI
---|---
Calcium | 1000 mg
Magnesium | 350 mg
Potassium | 3500 mg
Sodium | 2400 mg

Trace minerals

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium</td>
<td>120 μg</td>
</tr>
<tr>
<td>Copper</td>
<td>2 mg</td>
</tr>
<tr>
<td>Iron</td>
<td>15 mg</td>
</tr>
<tr>
<td>Manganese</td>
<td>5 mg</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>75 μg</td>
</tr>
<tr>
<td>Selenium</td>
<td>35 μg</td>
</tr>
<tr>
<td>Zinc</td>
<td>15 mg</td>
</tr>
</tbody>
</table>

Table 1. The table above represents RDI values recommended by experts and agencies for a normal adult population. [http://lenntech.com/recommended-daily-intake.htm](http://lenntech.com/recommended-daily-intake.htm)

3.4 Analyses of foods with respect to safety and toxicity

Fresh foods and others are monitored regularly for safety and to be sure that the level of undesirable metals is below the safe limit or not present at all. Similarly, the dietary surveys test for these as well as the nutritional value of the various food groups.

4. Variation of mineral content according to soil and country

According to the age of the rocks that contain the minerals and type of rocks and soil with respect to their geological age, the mineral content will vary considerably, as well as different minerals being found in the respective rocks. There can be similar soil types that occur in countries that are not near each other. For example, gold was found in California and in Australia in the mid 1800’s when the gold rush took place and prospectors came from many countries to make their fortunes. Soil can vary considerably within a particular region, state, territory or through out a particular country with respect to minerals found in the soil. Soils are studied by agriculturalists and farmers, so they can add certain minerals when they are in low levels in order to increase the yield and quality of crops. Even within a particular paddock or field the soil can vary so farmers need to add fertilizers and minerals appropriately in order to obtain a uniform yield of the crop (Dundas and Pawluk 1977). Hence mineral levels for the countries will vary accordingly to the soils and the additives required for maximum crop yield and the fortification of crops, cereals or grains to ensure that the products manufactured would still give sufficient portion of the RDI to maintain the health of the population. RDI allowances of minerals will essentially be very similar in most countries for the various age and gender groups but in some cases extra fortification of foods will be required where there is a low level of an essential or trace mineral.

5. Metals in meat

The principal source of iron in the diet is mainly from meat, particularly, red meat. Other metals are also important such as calcium, magnesium, sodium and potassium, but are
generally in lower amounts. Trace metals include: copper, manganese, zinc and chromium. Metal analyses in meat including beef, pork, poultry and fish will be discussed with some comments on sample preparation and values of the metals obtained in these samples

5.1 Selected metals in some meat
A comprehensive study of the analyses of iron, calcium, magnesium, potassium, sodium, manganese, copper, zinc and manganese in foods including meat was undertaken by Maurer (Maurer 1977) here he compared three extraction methods using HNO$_3$ or HCl/HNO$_3$ or dry ashing at 450°C. The main focus of this research was to thoroughly evaluate each of the three extraction procedures for the metals listed on a wide variety of food, to determine the daily consumption per person over given time intervals. Recoveries were also determined for the different extraction methods. Results obtained indicated that extraction with the combined acids was the most suitable procedure for all metals, particularly for copper and zinc when compared with dry ashing, which was markedly, affected by the matrix. Recoveries were high for all metals: in the high nineties except for zinc that was only 87%. A Perkin-Elmer (model 300) instrument was employed where calcium and magnesium were analysed with nitrous oxide/acetylene while air/acetylene was used for the other elements. Siong (Siong, Khor Swan, and Siti Mizura 1989) compared the analysis of iron in meat and other foods using AA and the phenanthroline colorimetric method. The two methods compared well for the foods tested and also gave satisfactory recoveries. Values iron obtained for some meat products are as follows: beef extract 10.66; canned beef liver rendang 4.20; canned chicken curry 2.82; chicken heart 2.05; corned beef 1.67; duck 0.69; roasted duck 0.84; canned mutton curry 3.67 where all values are expressed as mg Fe/100 g.

<table>
<thead>
<tr>
<th></th>
<th>Cu</th>
<th>Mn</th>
<th>Se</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PIG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>meat</td>
<td>0.90 ± 0.61</td>
<td>0.12 ± 0.052</td>
<td>0.044 ± 0.017</td>
<td>24 ± 11</td>
</tr>
<tr>
<td>liver</td>
<td>9.0 ± 4.0</td>
<td>3.0 ± 0.52</td>
<td>0.50 ± 0.062</td>
<td>74 ± 2</td>
</tr>
<tr>
<td>kidney</td>
<td>6.1 ± 2.0</td>
<td>1.5 ± 0.24</td>
<td>1.9 ± 0.35</td>
<td>22 ± 3.3</td>
</tr>
<tr>
<td><strong>CATTLE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>meat</td>
<td>0.87 ± 0.12</td>
<td>0.093 ± 0.044</td>
<td>0.030 ± 0.020</td>
<td>49 ± 18</td>
</tr>
<tr>
<td>liver</td>
<td>39 ± 27</td>
<td>3.2 ± 0.67</td>
<td>0.030 ± 0.035</td>
<td>40 ± 8.5</td>
</tr>
<tr>
<td>kidney</td>
<td>3.7 ± 0.59</td>
<td>1.1 ± 0.24</td>
<td>0.86 ± 0.28</td>
<td>16 ± 1.5</td>
</tr>
</tbody>
</table>

Table 2. Portion of data extracted from (Jorhem et al. 1989) showing in a horizontal row the concentrations in mg/kg of the four elements per product.

A study was conducted by (Jorhem et al. 1989), on the levels of the trace metals aluminium, chromium, cobalt, copper, manganese, nickel and selenium in the kidney, liver and meat of Swedish cattle and pigs at the slaughter houses and verified using standard reference materials. Data for aluminium and nickel will not be discussed, only the other beneficial
manganese, iron, phosphorous and zinc in lower amounts 100 – 1000 mg/l. There were also trace amounts of cadmium, copper, lead, nickel, silicon, strontium and selenium. The average values found for eight determinations of three juices from fruit grown in different locations in the above region were: 0.20, 0.23 and 0.10 mg/L selenium.

Tin is not a desirable metal but a contaminant and was analysed in a number of juices, purees and fruit by the Comite Europeen de Normalisation (Foodstuffs. Determination of trace elements. Determination of tin by flame and graphite furnace atomic absorption spectrometry (FAAS and GFAAS) after pressure digestion 2009) in a collaborative study. Some of the products analysed included: carrot puree, tomato puree, pineapple, mixed fruits, powdered peach and tomato. Samples were prepared by pressure-assisted digestion then analysed by flame AAAS or graphite furnace AAAS. Data obtained for the products analysed were in the range of 43 – 260 mg/kg for AAAS and or 2.5 – 269 mg/kg for graphite furnace AAAS.

8.2 Beneficial metal concentrations in some fruits

Slurried fruit samples were tested by (Cabrera, Lorenzo, and Lopez 1995) for the levels of cadmium, copper, iron, lead and selenium by Electrothermal AAAS. Only results for copper, iron and selenium will be mentioned, as these are the nutritional metals as distinct from the others that are contaminants. In addition, to the sample preparation of slurries, the samples were also mineralized in a microwave acid-digested bomb and the data compared for accuracy and precision. A total of 40 samples comprising 8 types of fruit that are regularly consumed were tested. These samples were: banana; custard apple; kiwifruit; mango, medlar, papaya; pineapple and strawberries. For these fruit samples the mean range of the metals copper, iron and selenium were 2.00 – 5.50 μg/g; 0.050 - .0.396 μg/g and 0.010 – 0.020 μg/g, respectively. Chromium and manganese were analysed (Tinggi, Reilly, and Patterson 1997) in fruit by AAAS, after wet digestion but found that these two metals were relatively low in fruit when compared to other foods. Fruit samples tested were: apple; banana; grapes; orange; pear; pineapple (canned) and rock melon.

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Cr (ng/kg)</th>
<th>Mn (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>19.3 ± 3.3</td>
<td>0.5 ± 0.1</td>
</tr>
<tr>
<td>Banana</td>
<td>5.2 ± 1.3</td>
<td>3.3 ± 0.9</td>
</tr>
<tr>
<td>Grapes</td>
<td>4.3 ± 1.2</td>
<td>0.6 ± 0.1</td>
</tr>
<tr>
<td>Orange</td>
<td>6.3 ± 1.2</td>
<td>0.4 ± 0.1</td>
</tr>
<tr>
<td>Pear</td>
<td>12.6 ± 1.8</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td>Pineapple (canned)</td>
<td>21.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Rock melon</td>
<td>9.8 ± 1.5</td>
<td>0.4 ± 0.1</td>
</tr>
</tbody>
</table>

Table 6. Concentrations of chromium (ng/kg) and manganese (mg/kg) in selected fruit samples.

It can be seen in the Table 6 that the chromium levels in these fruit samples ranged from 4.3 ng /kg in grapes to 21.3 ng/kg in pineapple. In contrast the manganese concentrations were higher than those for chromium in these same samples where the range was from 0.4 mg/kg for both orange and rock melon up to 3.3 mg/kg for banana.
Fifteen elements were analysed by flame AAS after microwave-assisted digestion of the cultivar citrus reticulate Blanco CV. Ougan fruits. The analyses gave high concentrations of these metals at both of the ripeness stages (Mojsiewicz-Pienkowska and Lukasiak 2003).

8.3 Analyses of tin a contaminant in canned fruit and fruit juices
A report by (Dogan and Haerdi 1980) on the analysis of the tin content in peaches, pears, pineapple, mandarin, peeled tomato and fruit cocktail by a number of techniques including AAS will now be presented. Sample preparation was achieved by using Lumatom, which is a trade organic chemical that contains quaternary ammonium hydroxide suspended in isopropanol. After this sample preparation procedure the fruit and juice samples were introduced directly into the graphite AAS instrument. The tin concentrations levels were: quartered mandarin 68 ppm; peeled tomato 57 ppm and fruit cocktail 57 ppm. Rigin (Rigin 1979) used flameless AAS to determine the tin levels in canned tomato, apple and orange juice. The results for 5 replicates of each sample after three months storage for canned tomato, apple an orange juice were 12.1, 2.75 and 30.5 μg/ml respectively. After twelve months, however, the values had increased to 76.3, 4.26 and 45.4 μg/ml for the samples in the same order as for three months storage. Wehrer et al (Wehrer, Thiersault, and Laugel 1976) used AAS with wet and dry ashing to determine tin content of canned samples including stewed apples. The concentration of tin in the stewed apples for ten replicates was 52.4 mg/kg after 2N HCl digestion and 57.5 mg/kg after dry ashing that involved calcinations using magnesium nitrate. Vijan and Chan (Vijan and Chan 1976) determined the tin content of a number of different types of samples including apple, apple/cherry, apple/pineapple and tomato juices. For the first three products the tin level was less than 0.1 μg/ml but for tomato juice it was considerably higher at 90 μg/ml.

9. Metal levels in vegetables
Detailed analyses of chromium and manganese on a wide range of food groups has been undertaken by (Tinggi, Reilly, and Patterson 1997) at this point in time the discussion will be limited to vegetables. The results show that the chromium levels are lower (ng/kg) in the vegetables analysed than in manganese (mg/kg) where the sample sizes ranged from 3 to 5 per vegetable. Vegetables studied included: beans (boiled); broccoli (boiled); carrot (boiled); cauliflower (boiled); lettuce; peas (frozen); potato (roasted); pumpkin (boiled)); tomatoes and zucchini. Portion of the data for these two elements have been extracted from the study under consideration in this section and will be presented below in Table 7.

It can be seen from Table 7 that the highest level of chromium is in tomatoes, 30 ng/kg, and the lowest level in boiled bean 5.3 ng/kg. Whereas for manganese the highest level was for frozen peas, 6.0 mg/kg, while the lowest value was for potato and pumpkin that were equal at 0.9 mg/kg. Hence tomato is a good source of chromium, which stabilizes the blood sugar levels and peas are a good source of manganese.

A study on the mineral levels in some Slovenian foods that are regularly consumed was undertaken by (Zuliani et al. 2005) After sample workup employing microwave-assisted digestion the samples were analysed by flame and electrothermal atomic absorption spectrophotometer. The minerals content investigated in this study were, Zn, Cu, Cd, Pb and Ni. It was found that the samples tested did not contain any Cd, Pb or Ni contamination. Zinc levels reported for cabbage and tomatoes were less than 50 mg/kg. Copper content, in contrast, was between 2 and 3 mg/kg in the majority of the samples.
while the chromium content was below 0.05 mg/kg. An analysis of Fe, Zn and Cu in some foods consumed in Mexico including vegetables, legumes, fruits, cereals and animal foods was reported by Lopez and co-workers (Lopez et al. 1999). Considering these products, it was found that the zinc level had a range of 0.018 mg/100g to 9.193 mg/100 g for strawberry and beef. The iron concentrations were from 0.113 mg/100g to 19.82 mg/10g for yogurt and commercial cereal but the latter was fortified with minerals. Copper was not detected in all foods but was found to be the highest in beef liver, namely 3.371 mg/100g. Selenium levels in some Egyptian foods were determined by electro-thermal (ETAAS) and hydride generation (HGAAS) atomic absorption spectrometry by (Hussein and Bruggeman 1999). They found the metal was only in trace amounts: in the range of 1-33 μg/kg. Other products were tested but are not reported here.

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Chromium (ng/kg)</th>
<th>Manganese (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bean (boiled)</td>
<td>5.3 ± 1.6</td>
<td>3.4 ± 0.4</td>
</tr>
<tr>
<td>Broccoli (boiled)</td>
<td>8.0 ± 2.0</td>
<td>1.2 ± 0.1</td>
</tr>
<tr>
<td>Carrot (boiled)</td>
<td>13.0 ± 2.3</td>
<td>1.5 ± 0.1</td>
</tr>
<tr>
<td>Cauliflower (boiled)</td>
<td>6.3 ± 1.6</td>
<td>1.1 ± 0.2</td>
</tr>
<tr>
<td>Lettuce</td>
<td>9.2 ± 1.3</td>
<td>1.3 ± 0.1</td>
</tr>
<tr>
<td>Peas (frozen)</td>
<td>28.3 ± 3.5</td>
<td>6.0 ± 1.2</td>
</tr>
<tr>
<td>Potato (roasted)</td>
<td>19.0 ± 2.2</td>
<td>0.9 ± 0.06</td>
</tr>
<tr>
<td>Pumpkin (boiled)</td>
<td>16.0 ± 2.2</td>
<td>0.9 ± 0.2</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>30.0 ± 2.1</td>
<td>2.0 ± 0.1</td>
</tr>
<tr>
<td>Zucchini</td>
<td>6.3 ± 1.2</td>
<td>1.3 ± 0.3</td>
</tr>
</tbody>
</table>

Table 7. Chromium and manganese concentrations in some vegetables in ng/kg and mg/kg respectively (mean ± SD)

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>mg Ca/100 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus (fresh)</td>
<td>13.9</td>
</tr>
<tr>
<td>Asparagus (canned)</td>
<td>14.7</td>
</tr>
<tr>
<td>Leek</td>
<td>16.2</td>
</tr>
<tr>
<td>Mushrooms (fresh) – grey oyster</td>
<td>1.0</td>
</tr>
<tr>
<td>Peak (fresh) – garden</td>
<td>62.5</td>
</tr>
<tr>
<td>Radish (pickled) – Chinese</td>
<td>94.9</td>
</tr>
<tr>
<td>Rhubarb (petioles) – pie plant</td>
<td>268.9</td>
</tr>
<tr>
<td>Seaweed (agar)</td>
<td>510.2</td>
</tr>
<tr>
<td>Spinach - Ceylon</td>
<td>116.2</td>
</tr>
<tr>
<td>Spinach -Bayam pasi</td>
<td>319.4</td>
</tr>
<tr>
<td>Tomato – tree</td>
<td>11.2</td>
</tr>
<tr>
<td>Yam bean</td>
<td>12.4</td>
</tr>
</tbody>
</table>

Table 8. Results of AAS Ca analyses, selected examples in vegetable, edible portion, from part of a table by Siong.

Calcium levels in many foods have been reported by (Siong, Khor Swan, and Siti Mizura 1989): some results will now be given for a selection of the vegetables tested. Two methods
were compared AAS and potassium permanganate titration. A Varian Atomic Absorption spectrophotometer, Model 175 using an air/acetylene flame was used for the analyses. Samples were prepared for introduction into the instrument by ashing. Data for the two methods were in good agreement, however, only AAS results will be given for some vegetables reported by Siong’s group.

For the vegetables listed in Table 8, seaweed contains the highest concentration of calcium being 510.2 mg/100 g. Spinach followed next with a value of 319.4 mg/10g, whereas fresh mushrooms contain only 1 mg/100 g of calcium, the lowest concentration reported in this group. Atomic absorption spectroscopy was used to determine the mineral content of hummyad (Rumex vesicarius) leaves that are grown in both the northern and central areas of Saudi Arabia. Elements analysed included calcium, copper, iron, magnesium, potassium, sodium and zinc. The range of values (Alfawaz 2006) obtained for these metals are as follows: calcium 1790 – 2680 mg/100 g; copper 24.1 – 43.5 mg/100 g; iron 1320 – 2270 mg/100 g; potassium 2710 – 3230 mg/100 g; sodium 846 – 1100 mg/ 100 g and zinc 3.7 – 8.8 mg/100 g. Hence, it is clear that this plant is very rich in calcium, iron and potassium, the highest mineral content being for potassium followed by calcium and iron indicating that these leaves are a nutritious source of these essential metals. The germanium content in different foods including vegetables was determined by (McMahon, Regan, and Hughes 2006) using a Graphite furnace atomic absorption instrument. Sample workup was via drying and ashing. Values for several vegetables are as follows: carrot 0.60 μg/g; potato 1.85 μg/g; garlic 2.79 μg/g; and soy mince 9.39 μg/g. The latter sample having the highest germanium content of the vegetables tested. Food, crops and soils in Taiwan were analysed by (Huang, Wen, and Chern 1987) for the selenium content. Metals found in soils are directly related to the uptake of minerals in plants. Considering soil in the Taiwan region, the selenium level was determined to be in the range 0.03 – 0.23 ppm. Selenium content in crops, fruit and vegetables, in contrast, was reported to be approximately 0.1 ppm, however, for mushrooms the level was higher, namely, 0.55 ppm.

An analysis of two cultivars of onions grown in Venezuela: Yellow Granex PRR 502 and 438 Granex were tested for the concentrations of calcium, copper, iron, manganese, potassium and zinc, by total reflection X-ray fluorescence (TXRF), then the results compared with those from FAAS. A more efficient sample preparation was employed where the samples were acid extracted from the crude products using an ultrasonic bath, avoiding time consuming digestion. Sample work up was also compared with wet and dry ashing. The mineral content of the onions is important so the soils can have more elements added if, required, to improve their nutritional value. It was found that the ultrasound work up and dry ashing gave similar results. Levels of calcium copper and iron were found to be significantly greater in the Yellow Granex cultivar while potassium, manganese and zinc were significantly higher in 438 Granex. Levels of calcium and potassium were very much greater than the concentrations of the other elements: potassium being slightly higher than calcium, irrespective of the work up procedure: ultrasonic extraction or wet or dry ashing methods (Alvarez et al. 2003). A thorough analyses of a wide range of metals in Jamaican foods has been reported to (Howe et al. 2005) for legumes, leafy and root vegetables, fruit and other root crops. Only some metals levels will be mentioned here for the first three products listed above. Data will be given for calcium, chromium, copper, iron, magnesium, manganese, sodium and zinc. Comparison data was also undertaken with other countries but will not be given here.
Table 9. Mean concentrations of metals, mg/kg in legumes, leafy and root vegetable grown in Jamaica

In addition to the analyses on calcium in foods, (Siong, Khor Swan, and Siti Mizura 1989) also undertook a similar study for iron levels, again employing a Varian Atomic Absorption Spectrophotometer model 175 using an air/acetylene flame. Analyses of iron in foods are important as it is a mineral that is often lacking in diets low in red meat, which is necessary to prevent anaemia. Readily available information assists consumers and health care professionals to advise on foods that contain this element where the total RDA for that metal is kept in mind. The edible portions of the samples were homogenized, oven dried, charred then ashed in a muffle furnace. The AAS method was compared with a colorimetric phenanthroline procedure where the results indicated that both methods were found to be satisfactory for iron analyses although AAS would be a less time consuming. Only some data for vegetables by AAS will be given below.

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>mg Fe/100 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus (canned)</td>
<td>7.06</td>
</tr>
<tr>
<td>Asparagus (fresh)</td>
<td>0.55</td>
</tr>
<tr>
<td>Broccoli</td>
<td>0.47</td>
</tr>
<tr>
<td>Cucumber (hairy)</td>
<td>0.15</td>
</tr>
<tr>
<td>Leek</td>
<td>0.33</td>
</tr>
<tr>
<td>Mushrooms (fresh) grey oyster</td>
<td>0.84</td>
</tr>
<tr>
<td>Mustard leaves (Chinese)</td>
<td>1.35</td>
</tr>
<tr>
<td>Mustard leaves (Indian)</td>
<td>1.46</td>
</tr>
<tr>
<td>Peas (fresh) garden</td>
<td>0.75</td>
</tr>
<tr>
<td>Seaweed (agar)</td>
<td>5.33</td>
</tr>
<tr>
<td>Seaweed (dried)</td>
<td>22.94</td>
</tr>
<tr>
<td>Spinach (Ceylon)</td>
<td>0.88</td>
</tr>
<tr>
<td>Spinach (red)</td>
<td>2.64</td>
</tr>
<tr>
<td>Spinach (Bayam duri)</td>
<td>1.69</td>
</tr>
<tr>
<td>Yam bean</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Table 10. Concentration of iron in mg/100 g of edible portion of vegetables

It is interesting to note from Table 10 that the highest level of iron is in dried seaweed at 22.94 mg Fe/100 g, followed by canned Asparagus, 7.06 mg Fe/100 g and then seaweed...
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Spice or herb | mg Fe/100 g
---|---
Chilli, small | 0.68
Nutmeg, fresh | 0.22
Persimmon, dried | 0.99
Chives, Chinese | 0.62
Coriander, leaves | 3.86
Garlic, bulbs | 0.48
Garlic, plants | 0.31
Parsley | 9.90

Table 13. Iron concentration in mg Fe/100 g of a selection of spices and herbs

It can be seen in Table 13 that parsley is an excellent source of iron, 9.90 mg Fe/100 g, that is particularly important for those who eat little red meat or are vegetarians. Iron deficiency is a common problem particularly for women. Coriander leave being the next highest level of iron at 3.86 mg Fe/100 g. It is interesting to note that the iron in garlic bulbs is 0.48 mg Fe/100 g that is greater than in the plants at 0.31 mg Fe/100 g. Of this group nutmeg has the lowest iron level at 0.22 mg Fe/100 g.

10.3 Calcium levels in herbs and spices

In a related study that complements the above work on iron, (Siong, Khor Swan, and Siti Mizura 1989) analysed similar samples for the calcium concentrations. Again, some of these food groups have already been discussed in this review.

Spice | mg Ca/100g
---|---
Anise seed, dried | 950.6
Cardamon | 1769.7
Cinnamon | 600.9
Cumin seeds, black | 816.8
Cumin seeds, white | 1165.1
Curry powder | 576.2
Fenugreek seeds | 179.8
Pepper, powder, white | 120.4

Table 14. Calcium content of selected spices in mgCa/100 g

It can be seen in Table 14 that cardamom has the greatest level of calcium at 1769.7 mg Ca/100 g followed by dried anise seed with a value of 950.6 mg Ca/100 g. While pepper, in contrast, has the lowest calcium content, namely, 120.4 mg Ca/100 g.

11. Conclusion

The chapter has taken examples of the literature on the mineral content, both Essential and Trace metals in meat, dairy products, fruit, vegetables and herbs and spices. The review is not exhaustive but a selection of examples of metals extracted from many authors with the data arranged in such a way as to highlight at a glance the concentrations of the metals in the above foods that are generally not processed. It is a collection of information in the one chapter assembled from published work, which allows a convenient comparison of the
concentration of certain metals in the products discussed. Such information is of value to health care professionals, researchers and food manufacturers in preparing nutritious products. Levels of metals in some product may also be unexpected and hence informative and may lead on to further analyses and research.

12. References


Hoenig, M., and P. van Hoeyweghen. 1986. Determination of selenium and arsenic in animal tissues with platform furnace atomic absorption spectrometry and deuterium


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Ybanez, N., R. Montoro, and A. Bueso. 1983. [Determination of cadmium, lead and copper in cooked meat products by flame atomic absorption spectroscopy.]. *Revista de Agroquima y Tecnologia de Alimentos*: 23 (4) 510-520.


Atomic Absorption Spectroscopy is an analytical technique used for the qualitative and quantitative determination of the elements present in different samples like food, nanomaterials, biomaterials, forensics, and industrial wastes. The main aim of this book is to cover all major topics which are required to equip scholars with the recent advancement in this field. The book is divided into 12 chapters with an emphasis on specific topics. The first two chapters introduce the reader to the subject, it's history, basic principles, instrumentation and sample preparation. Chapter 3 deals with the elemental profiling, functions, biochemistry and potential toxicity of metals, along with comparative techniques. Chapter 4 discusses the importance of sample preparation techniques with the focus on microextraction techniques. Keeping in view the importance of nanomaterials and refractory materials, chapters 5 and 6 highlight the ways to characterize these materials by using AAS. The interference effects between elements are explained in chapter 7. The characterizations of metals in food and biological samples have been given in chapters 8-11. Chapter 12 examines carbon capture and mineral storage with the analysis of metal contents.

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